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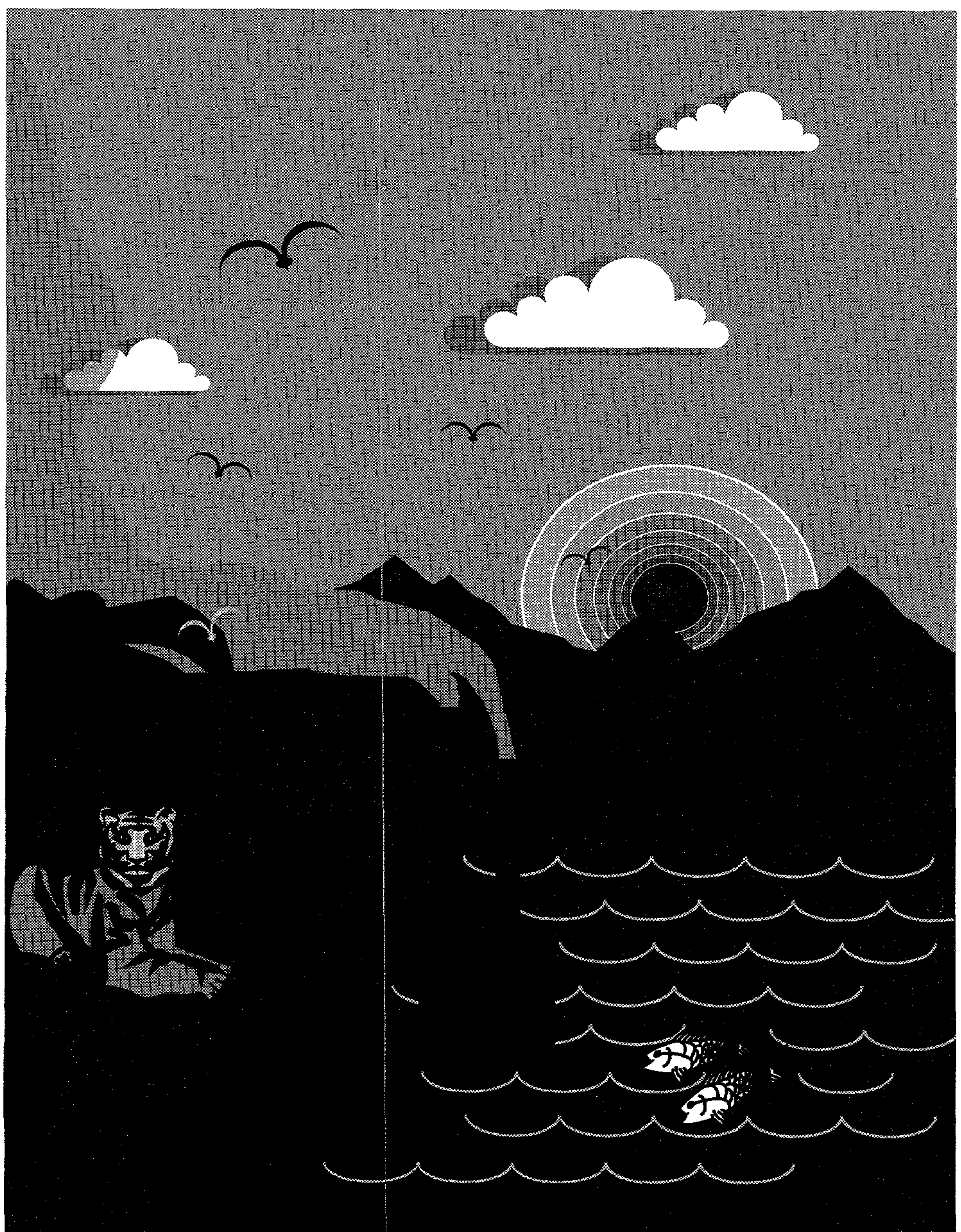
Ernst Lutz, Stefano Pagiola, and Carlos Reiche, editors



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Editors' Note

Support for environmentally sustainable development is broad-based. To define it more precisely and to operationalize it require work at the macro level as well as at the micro level. A closer look at the soil conservation issue was also warranted because it is often suggested that soil erosion and degradation are among the most severe environmental problems in developing countries and that, perhaps, farmers are not sufficiently aware of the problem or are not addressing it properly. This study was conceived by the recognition of the need to specifically analyze the important problem of soil conservation at the farm level, with the expectation of gaining insights into the problem and its solution. On-farm effects are most important; off-site effects are also important in some cases, depending on the watershed in question, but even then an on-farm analysis is a necessary first step before analyzing off-site effects and the costs involved in reducing sedimentation from sources other than agriculture.

The research presented in this volume was motivated by a desire to analyze objectively soil degradation and conservation in Central America and the Caribbean in collaboration with CATIE (Centro Agronomico Tropical de Investigación y Enseñanza) and local soil conservation practitioners. A cost-benefit perspective was used to examine both the extent of the problem and the cost-effectiveness of various proposed solutions. These calculations examine the conditions under which it pays for small farmers to adopt specified soil conservation measures. Moisture conservation as part of soil conservation was recognized as being very important, and increasingly so in dryer areas and/or those with less reliable rainfall patterns. To the extent that good productivity data are available, the added benefits of moisture conservation are captured to a large extent: in dry years, the "with project" scenario would show yields much higher than in the "without project" case. Past and present soil conservation efforts were also examined for any institutional lessons they might contain for the design of future project, institutional, or policy interventions.

The country studies undertaken and presented in this volume suggest that the problem, at least in the countries studied, is less severe than sometimes assumed. Based on our analyses, we would therefore wish to see more caution and caveats applied to statements that are sometimes made and that are based on projections representing extrapolations from sketchy plot information and often incorrectly assume that all soil moved is actually lost to agriculture. Also, when speaking of the sediment load in rivers, the impression is sometimes given that all of it originates in agriculture. But this is only in part so, the rest coming from areas such as wildlands, roads, urban areas.

Generally, farmers appear to act rationally in deciding whether to invest in conservation measures. They are often already using farming practices and low-cost soil conservation techniques that are sensible from a cost-benefit perspective. Cases in which returns to conservation were estimated to be low or negative correlated well with low adoption rates. In that regard, the country studies confirm other findings that cultivation and cropping practices as well as vegetative barriers tend to be superior to mechanical structures that have sometimes been advocated in the past.

Whether specific conservation measures are profitable from the farmers' perspective is an empirical issue that must be examined on a site-specific basis. Returns to conservation depend on the specific agroecological conditions faced, on the technologies used, and on the prices of inputs and outputs. As in many other parts of the world, however, "hard" data on the actual extent of soil degradation and its effects on productivity remain scarce. There is a need for more systematic research on soil degradation and its consequences. Since all countries within Central America include a large number of different agroecological regions, and since many agroecological regions are found in more than one country, there is considerable scope for collaboration on such research.

The results of the case studies carried out in this volume show that conservation is profitable in some cases but not in others. Given the small number of cases studied and the weakness of the data used, broad lessons must be drawn with care. It does appear clear, however, that expensive mechanical structures are unlikely to be profitable from the farmers' perspective. Conservation measures are particularly likely to be profitable when they either are cheap and simple or allow improved practices to be adopted.

Given that farmers generally adopt conservation measures when it is in their interest to do so, unless some constraint prevents them from doing so, the role of government in conservation appears limited to three areas. First, there is considerable room for research efforts, in which government can play a role, aimed at incrementally improving conservation technology. Although it is unrealistic to hope that a "breakthrough technology" will be developed that will magically solve all conservation problems, even marginal improvements to existing practices can often make them much more attractive. The improvements to the *ramp pay* technique used in Haiti are an example of what might be achieved. Similar approaches have proven successful in West Africa. To maximize the chances that such research will prove truly useful, it should be carried out primarily through on-farm research and in close consultation with farmers. Also, government has a role to ensure that constraints such as insecure tenure do not prevent farmers from adopting conservation measures. Lastly, governments already provide, through the extension service, some assistance to farmers who undertake conservation work. But the effectiveness with which such assistance is provided is often poor, however. In many cases, nongovernmental organizations have proven to be more effective at delivering appropriate technical assistance to farmers. This has given rise to the idea of providing a budget to local communities for soil conservation (and other) activities and letting them contract the extension service where they hope to get the best value for the funds. Regarding the provision of subsidies to induce farmers to adopt soil conservation measures, the experiences reviewed were generally not favorable. It is concluded that assistance in adopting soil conservation measures should *not* include subsidies except where off-site considerations are important or to provide seeds or seedlings as subsidies in kind for encouraging farmers to experiment with a new technology.

Foreword

The *World Development Report 1992* on development and environment, in its chapter on rural environmental policy, noted that we still know relatively little about key aspects of resources management. Therefore it concluded that "a common theme in many aspects of natural resource use is the need for better research."

The work presented in this report was motivated by an interest in understanding the extent of soil degradation in Central America and the Caribbean, in knowing how farmers are in general responding to it, and in examining the possibilities that exist to help farmers better respond to the challenges they face. The authors have used a cost-benefit perspective to analyze which practices, under which circumstances, may be beneficial for the farmer to adopt.

It was found that although social and other factors also play a role, the expected economic payoff for adopting a practice, to the extent that it is known in an uncertain environment, is a key determinant for farmers' adoption decisions. In line with this, farmers tend to adopt low-cost methods such as cultural practices and vegetative barriers and seldom adopt structural measures voluntarily. Another important result of the studies is that the economics of adopting certain practices depends very much on site-specific circumstances. Further, the productivity effect for the same practice under the same conditions depends crucially not on the amount of soil lost, but on the soil that remains.

The research was carried out in a collaborative, participatory approach. Thus, the country studies, with the exception of Haiti, were undertaken by local practitioners under the general guidance of staff at the Bank, the Stanford Food Research Institute, and the Tropical Agricultural Research Center in Costa Rica.

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Introduction

1. Lessons from Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean

Ernst Lutz, Stefano Pagiola, and Carlos Reiche

Land degradation is thought to pose a severe threat to the sustainability of agricultural production in Central America and the Caribbean. Since most countries in the region remain heavily dependent on agriculture, efforts to sustain and improve the productivity of agriculture are very important for the process of economic development as well as for the welfare of a significant proportion of the population. Unfortunately, many conservation programs designed to address these problems have fallen far short of expectations. Farmers have often resisted adopting the recommended conservation practices and have frequently abandoned them once projects ended. Despite these long-standing concerns, however, and notwithstanding the dramatic claims of environmental damage that are often heard, very little empirical analysis has been carried out on the causes and severity of land degradation problems in the region and on the best ways to address them.

The research presented in this volume was motivated by a desire to analyze soil degradation and conservation in Central America and the Caribbean objectively. A cost-benefit approach was used to analyze soil degradation problems and the cost-effectiveness of proposed solutions. The main focus is on the profitability of conservation measures and the constraints to their adoption from the farmers' perspective. Because soil degradation problems tend to be very site-specific, a case study approach is employed. Past and present conservation efforts are also examined for institutional lessons they may contain for the design of future project, institutional, or policy interventions.

Soil degradation in Central America and the Caribbean

Soil degradation can be defined as a reduction in the land's actual or potential uses (Blaikie and Brookfield 1987). Many cultivation practices tend to degrade soil over time. For example, cultivation practices can expose soil to water and wind erosion; repeated tillage can weaken soil structure; crop production can remove nutrients; and use of machinery can lead to soil compaction. Central America's often mountainous environment and heavy rainfall make much of the region particularly vulnerable to degradation. Moreover, population pressure has often led to the opening up of new lands that are only marginally suited to agriculture or vulnerable to degradation. Soil degradation, in turn, affects productivity. As soil is degraded, crop yields decline or input levels (and hence costs) rise to restore productivity.

Despite the many years of concern about the problems caused by soil degradation in Central America and the Caribbean, surprisingly little hard evidence exists on its magnitude. The

Table 1-1. Empirical Evidence on Soil Erosion in Central America and the Caribbean

Location and source	*Rainfall (millimeters)*	*Slope (percent)*	*Farming system*	*Average annual rate of erosion per hectare*	
				Metric tons	*Millimeters*
El Salvador					
Metapán					
Flores Zelaya (1979)	1,895	—	Corn	137.0	8.9
CTA (1956)	1,724	30	Corn, beans	230.0	15.3
Haiti					
Cunard (1991)	2,000	30	Hedges	4.0–45.0	—
Papaye					
Grosjean (1987)	1,214	25	Grass hedges	8.3	—
Honduras					
Tatumbla, Morazán					
Welchez (1991)	2,000	45	Corn, beans	42.0	2.7
Sánchez (1991)	900–1,500	15–40	—	18.0–30.0	
Nicaragua					
Cristo Rey					
Proyecto de Control de Erosion de Occidente (1981)	1,700	30–40	Cotton	40.0	—
Panama					
Cuenca del Canal					
Soto (1981)	1,200	35	Rice	153.0	—
Soto (1981)	1,200	35	Corn	136.6	—
Soto (1981)	1,200	35	Rice	118.0	—
Coclé					
Vásquez and Santamaría (1991)	1,937	—	Rice, corn, cassava, beans	34.0	17.0
Chiriquí					
Oster (1981)	1,500–2,800	—	Pasture	35.0	5.0
Oster (1981)	1,500–2,800	—	Coffee	77.0	11.0
Oster (1981)	1,500–2,800	—	None	183.2	27.0
Dominican Republic					
Taveras					
Hartshorn and others (1981)	—	—	—	275.0	—
North Central					
Altieri (1990)	—	36	Various	24.0–69.0	—
South West					
Veloz and Logan (1988)	—	30	Various	2.0–1,254.0	—

— Not available.

degradation figures quoted in the literature are often extrapolated from very limited data and may exaggerate the problem because they often consider "moved soil" as "lost soil," even though much of it may be deposited on other agricultural land.[1] Few efforts have been made to measure erosion rates and the factors that influence them directly, and these have generally been scattered and unsystematic. Even less effort has been devoted to studying other forms of land degradation, such as nutrient depletion, damage to the soil's physical and chemical properties, or reductions in moisture-retention capacity. Table 1-1 presents an overview of estimated erosion rates in Central American countries. Although the figures presented in this table are not always comparable, having been obtained in a variety of ways, they illustrate the great diversity of erosion rates present within the region.

The threat of degradation to agricultural production is often stressed by making catastrophic predictions of its effects on productivity. However, very little evidence is presented on the magnitude of these effects. Indeed, in many cases no evidence whatsoever is presented to support claims of declines in productivity.[2] Leonard (1987), for example, simply asserts that a "pattern of extensive land use leading to soil loss or decline in fertility is apparent" in the Caribbean areas of Central America. Speaking of the highland areas, he points to "increasing reports of localized desertification in areas of western Honduras and Costa Rica." He also mentions that cotton yields are "reportedly declining" where severe erosion has been experienced. But in none of these cases does he provide any indication of the magnitude or rate of fertility loss. More generally, the assumption that fertility must be declining rapidly is usually left implicit from statements about high rates of erosion.

It is possible, however, that erosion rates, even where they are significant, may have very little effect on productivity under certain conditions. The Tierra Blanca area in Costa Rica's Cartago Province is an example of this (chapters 3 and 16). Although erosion rates are extremely high, the consequent effect on productivity is minor because soils in that region are very deep (up to 1 meter in places) and have high organic matter throughout the soil profile. Moreover, the subsoil that underlies these soils is itself productive, although less so than the topsoil. The Chiriquí region in Panama provides another example of this (chapter 8). Conversely, areas with shallow soils or unfavorable subsoils, such as the Turrubares area in Costa Rica, can be very sensitive to even limited rates of erosion. The same is true of other forms of soil degradation. The impact of nutrient loss on productivity, for example, depends on the initial stock of nutrients and on their rate of regeneration.

Given the different impacts of soil degradation on productivity, any specific soil conservation measure—and particularly the more costly ones—may not necessarily be desirable from a farm household's or society's perspective. Degradation can be slowed or arrested by a large range of options, including cultural practices such as contour plowing and minimum tillage, vegetative practices such as grass strips/stripcropping and vegetative barriers, and mechanical measures such as terraces and cut-off drains. The effectiveness of each type of measure differs; some measures are well suited to some conditions and not to others. Adoption of any conservation technique is often costly, however, either directly in investment requirements or indirectly in production forgone. The critical question facing farmers, and society as a whole, is whether the benefits of a given conservation measure or set of measures are sufficient to make these costs worth bearing. This volume examines this question through detailed case studies of soil degradation in Central America and the Caribbean.

Conceptual issues

The problem of soil degradation and conservation can be examined from two perspectives. The first is that of society as a whole. Under this perspective, all the costs and benefits of a given activity must be considered. If agricultural production leads to siltation of reservoirs, for example, this represents a real cost to society that should be considered together with the value of the output obtained and any effects on fertility. In addition, valuation of the resources used and obtained from agricultural production should be adjusted for any distortions resulting from policy interventions or market failures in order to measure their true opportunity cost from a social perspective. The other possible perspective is that of the farmers themselves. Under this perspective, only the costs and benefits that actually accrue to the agent making the decisions about resource use are considered; these costs and benefits are valued at the prices these agents actually face, with no attempt to adjust for distortions.

This volume examines the returns to investment in conservation measures mainly from the perspective of individual farmers. This approach is adopted for two reasons. First, decisions about land use are ultimately made by the farmers themselves and not by social planners or government agencies. Farmers decide how to use their land in light of their own objectives, production possibilities, and constraints and not on the basis of any theory of the social good. Understanding the incentives faced by individual farmers is necessary, therefore, if patterns of resource use are to be understood and appropriate responses to problems formulated. Second, land use problems are generally highly dependent on site-specific biophysical characteristics, which can vary significantly even within small areas (Pagiola 1993). A farm-level approach is the most natural approach to incorporating site-specific effects.

A farm-level approach also places the focus firmly on the effects of degradation on farm productivity. In developing countries, where substantial proportions of the population still depend directly on agricultural production, the effect of degradation on yields is often critical. This is not to belittle the importance, in some situations, of off-farm effects of soil degradation such as siltation of reservoirs and waterways. Even where such off-farm effects are the primary concern, however, a farm-level approach is an appropriate first step since conservation measures would have to be implemented on farms.[3]

In making their land use decisions, farm households need to consider both the agroecological and the economic characteristics of the environment in which they operate. In addition, they often face numerous constraints, such as tenure problems, liquidity constraints, and the need to meet consumption requirements and to compensate for missing or incomplete markets. Moreover, many farm decisions are made in the context of considerable risk and uncertainty. A complete analysis of land use decisions, therefore, requires that a household approach be adopted (Singh, Squire, and Strauss 1986; Reardon and Vosti 1992).

The farm household's problem can be formulated as one of maximizing the utility of consumption over time, subject to a budget constraint imposed by its returns from agriculture over time and any returns from nonfarm activities and subject to any other constraints it might face. Singh, Squire, and Strauss (1986) show that if markets exist for all goods and services, the maximization problem is separable, in the sense that production decisions are made independently of consumption decisions. Even when separability does not hold, however, production decisions can be analyzed independently as long as the "prices" of goods for which markets are missing are interpreted as shadow prices that reflect the farm household's perception of the severity of the constraints it faces (de Janvry, Fafchamps, and Sadoulet 1990).

The farm household's problem, then, can be summarized as one of maximizing the present value of the stream of expected net returns to agricultural production (Pagiola 1993). In practice, data are generally not available to estimate complex maximization models. But for empirical analysis, the model can be reformulated to fit in a cost-benefit analysis framework. The household's choice can be thought of as between two or more alternative cropping systems. For concreteness, one might think of a household deciding whether to replace its traditional cultivation system, in which conservation measures are limited to the use of practices such as contour plowing, with a more conserving cultivation system, which might include, for example, the use of terraces or reduced-tillage techniques. Each system would be characterized by a distinct production function and soil growth function and would, therefore, generate a different optimal path. From the household's perspective, the problem is whether returns under the optimal path of the new, more conserving system are sufficiently greater than returns under the optimal path of the current, more degrading system to justify the cost of switching.

Basically, it would be in the farm household's financial interest to adopt the new, more conserving system if the net present value of the incremental returns from switching was positive (NPV > 0). This formulation is equivalent to a standard cost-benefit analysis formulation. This approach lends itself particularly well to empirical analysis, because data are often available in a suitable form. Observing practices in use allows time paths of yield and input use to be constructed; these are then used to project costs and revenues over time. The method can also be used if the only data available are on total costs and revenues in each period. This method also incorporates lumpy investments and other discontinuities in cropping practices (Walker 1982; Taylor and others 1986).[4]

The discussion so far has assumed that the only constraints on behavior are those imposed by the properties of the biophysical system. Thus, the NPV > 0 criterion is only a necessary and not a sufficient criterion for the adoption of a new production system. Other factors might prevent adoption of a new system even if NPV > 0. In principle, these other constraints could be built into the optimization framework. The effect of tenure insecurity might be included, for example, by limiting the length of the time horizon. In practice, however, it generally proves easier to compute the profitability of a system assuming that no constraints hold and then verifying whether other constraints are binding. The cost-benefit calculations often provide considerable insight into whether particular constraints are likely to prove binding. The length of time it takes for an investment to be repaid, for example, indicates whether tenure problems are likely to pose problems. If the investment is repaid very rapidly, insecurity of tenure is unlikely to affect adoption. Of course, if adoption of a new production system is unprofitable from the farm household's perspective, the question of whether other constraints might prevent its adoption does not arise.

Methodology

Cost-benefit analysis techniques lend themselves well to the evaluation of soil conservation measures, since they provide a coherent framework for integrating information on the biophysical and economic environments faced by farmers. Variants of these techniques have been used to examine a number of soil conservation cases: for example, in the Dominican Republic (Veloz and others 1985), in India (Magrath 1989), and in Kenya (Pagiola 1992). Other simple techniques, such as calculating the value of lost nutrients (Repetto and Cruz 1991), only provide rough indicators of the severity of the problem; they cannot provide guidance in selecting the best response. The methodology used in the country studies is presented in chapter 2.

The basic principles of the analysis are straightforward. First, the effects of continued erosion (or other types of soil degradation) on productivity are estimated for the time horizon of interest. These are then used to estimate returns at each point in time. Second, the calculations are repeated under the conditions that would be experienced if a specific conservation measure were adopted. The returns to the investment in this measure are then obtained by taking the difference between the streams of discounted costs and benefits in the cases with and without conservation. This approach estimates only the returns to the specific conservation measures being examined, not to conservation per se. A finding that specific conservation measures are not profitable does not imply that all conservation measures are not profitable. Indeed, the case without conservation practices often already includes numerous measures designed to reduce degradation.

As was argued in the previous section, when the analysis is carried out at the farm level using prices actually faced by farmers, a positive NPV estimate for a given conservation measure can be interpreted as showing that adoption of that measure is profitable from the farmers' perspective. Farmers should, in principle, be willing to adopt such a measure voluntarily. As with all cost-benefit analysis, however, options can only be considered pairwise; there is no guarantee that other, unexamined options are not preferable. When several options are known to exist, the analysis can be repeated for each in turn and the most profitable among them found.

The study sites chosen for analysis are listed in table 1-2. The study sites were chosen primarily by the availability of data. The case studies do not, therefore, present a comprehensive overview of soil conservation problems and practices in Central America and the Caribbean. They do illustrate the wide diversity of conditions encountered. In particular, they are likely not to be representative for two main reasons. First, research efforts have focused almost exclusively on problems due to erosion, while neglecting other forms of soil degradation. Second, most conservation projects have tended to emphasize mechanical structures. Because of the historical emphasis on erosion and on mechanical conservation structures, most available data are limited to these aspects of the problem.

A collaborative, participatory approach was adopted in undertaking these case studies. The country studies, with the exception of Haiti, were undertaken by local practitioners. In most cases, teams were composed of economists, agronomists, and soil scientists from relevant government agencies. This arrangement proved successful in drawing on local knowledge and expertise while at the same time building local analytical capacity.

In order to carry out the analysis, data were needed on the nature and rate of degradation caused by current practices and on the effects of degradation on future productivity. Similar information was also required on the effects of conservation practices. Unfortunately, such data are very scarce. Several different approaches were used to estimate the required relationships, depending on the nature of the available data. In some cases, the effect on yield of certain observed conditions (such as the presence or absence of certain conservation measures) was estimated econometrically. Although disentangling the impact of soil degradation on productivity is a very difficult task (Capalbo and Antle

Table 1-2. Description of the Study Sites

Country and study site	*Biophysical environment*	*Degradation problem*	*Proposed conservation measure*
Costa Rica			
Barva area, Province of Heredia	Important coffee-producing region; relatively deep soil, but vulnerable to erosion due to topography	Soil loss affects nutrients available to coffee	Diversion ditches
Tierra Blanca–San Juan Chicoá, Province of Cartago	Important vegetable-producing area; deep volcanic soils	Deep soils mean yield decline is not significant, but erosion washes away seed and fertilizer and exposes rocks	Diversion ditches are recommended but interfere with prevalent cultivation practices
Turrubares, Central Pacific Region	Previously used for pasture, now converted to production of cocoa yam for export	Very high rates of erosion; soils are thin and thus vulnerable to erosion	Diversion ditches or terraces
Dominican Republic			
El Naranjal sub-watershed, Peravia Province	Subsistence agriculture; steep slopes; soils of moderate natural fertility	High rates of erosion	Diversion ditches at 10-meter intervals, live barriers, and cropping on the contour
Guatemala			
Patzité, Department of Quiché	Small farmer area; strongly undulating topography; soils of medium depth and fertility	Heavily affected by soil erosion	Terraces with a protected embankment
Haiti			
Maissade watershed, Central Plateau region	Hilly area; generally less degraded and more productive than most other hilly regions of Haiti	Erosion	*Ramp pay* (indigenous technique: crop residue placed along the contour, held in place by stakes); hedgerows along the contour; and contour rock walls
Honduras			
Tatumbla, Department of Francisco Morazán	Predominantly subsistence agriculture; thin topsoil, with low levels of organic material and of many nutrients	Susceptible to water erosion, especially in the high areas	Diversion ditches protected by live barriers
Yorito, Department of Yoro	Small-scale subsistence agriculture, still largely forested; shallow, easily erodible soils of medium to low natural fertility	Cleared plots vulnerable to erosion	Diversion ditches with live barriers
Nicaragua			
Santa Lucía valley, watershed of Malacatoya River	Subtropical foothills; moderately deep soils; one of the most productive areas in the country	High risk of erosion due to steep slopes, scarce vegetation cover, and intense precipitation; deforestation on upper slopes	Manually constructed diversion ditches with stone barriers
Panama			
Coclé	Subsistence agriculture using slash-and-burn techniques, with plots cultivated one year every five; shallow soils, generally low in organic matter and nutrients, on steep slopes	Rapid yield decline on cleared plots; deforestation	Combination of erosion-prevention measures (plantoing on the contour, live and dead barriers, diversion ditches) and improved cultivation practices

Note: Research was also carried out at additional sites in several of the countries listed and at several sites in El Salvador. Data on these sites are insufficient to allow a full analysis of the returns to conservation measures. The lack of reliable data on the yield effects of degradation was the most frequent problem.

1988), for the purposes of the calculations described here, estimating a time trend of yields with and without a given conservation measure was usually sufficient.[5] In other cases, simple models of the physical environment were used, using a mixture of experimental and observational data. The Universal Soil Loss Equation (USLE) was used in a number of cases, while the Soil Changes Under Agroforestry (SCUAF) model was used in the Haiti case study. This modeling approach is more flexible, since it allows parameter values to be drawn from a variety of data sources, but also requires detailed knowledge (both qualitative and quantitative) of the biophysical environment. Building and validating a complete and realistic model are complex endeavors. Even calibrating existing models is far from easy.

Economic data requirements generally posed fewer problems. The main need was for crop production budgets, which were used to estimate returns. Although such data are generally widely available, they are rarely found at the degree of disaggregation needed. Fortunately, preliminary budgets built from available secondary data were easy to confirm, supplement, and correct during fieldwork in the study sites. The most important problem was to ensure that the crop production budgets accurately reflected practices in the area being studied and prices faced by farmers. Inputs provided by the households themselves, such as family labor, were priced at their cost in the nearest market. Output and input prices used in the analysis were meant to represent long-run real price trends for outputs and inputs. The choice of an appropriate discount rate has been the subject of considerable controversy since, given the intertemporal nature of the problem, it has a very significant effect on the results. Since the analysis was meant to examine the profitability of conservation from the farm household's viewpoint, the appropriate discount rate to use was the farmers' cost of borrowing or their rate of time preference. Little empirical evidence exists on either, however (Pender 1992). In light of this, and to facilitate comparability of results across study sites, a common real discount rate of 20 percent was used in each case study. In addition, the internal rate of return (IRR) was computed in each case. If the appropriate discount rate, assuming it was known, was smaller than the IRR, the proposed conservation measures would be profitable.

Effects of degradation on productivity

The estimates of productivity loss vary considerably across the case studies. Table 1-3 presents findings on the productivity losses for some of the crops analyzed by the case studies. In several cases, the data point to very rapid rates of decline in yield. In the Maissade watershed of Haiti, for example, yields of corn and sorghum were estimated to decline as much as 60 percent over a ten-year period (chapter 10). In the Tatumbla region in Honduras, corn yields would decline almost 50 percent in ten years if no conservation measures were used. In other cases, estimated declines in yield would be minor. Coffee yields in the Barva region of Costa Rica, for example, were estimated to decline just over 10 percent in ten years; moreover, this rate of decline in yield may be overestimated. In Costa Rica's Tierra Blanca region, declines in potato yield caused by erosion would be easily compensated by small increments in fertilizer use; indeed, potato production has been steadily increasing despite high rates of erosion. The effects of degradation on yield can also vary significantly across crops, even in the same area, as shown by the data from El Naranjal in the Dominican Republic (chapter 9).

If no conservation measures were adopted, returns to agricultural production would gradually decline in each of the case studies. Eventually, production would become uneconomic and cease. The time at which this would occur varies from case to case, depending on the rate of decline in yield, the cost of production, and the price of the output.[6] The very high rates of decline in yield experienced in Turrubares mean that the production of coco yam would shut down in four years if no conservation measures were adopted; conversely, in Tierra Blanca the production of potatoes would remain profitable more or less indefinitely even in the absence of conservation.

Not all the damage caused by soil degradation takes the form of yield losses. In Costa Rica's Tierra Blanca region, for example, the effects of degradation on agricultural production are reflected primarily in higher costs due to the need to apply higher rates of fertilizer, to the lower efficiency of fertilizer (since some is washed away), and to the need to "harvest" stones that accumulate on fields as soil is eroded. In Panama's Coclé Province, agricultural production could only be sustained for a very short

Table 1-3. Estimates of the Impact of Soil Degradation on Productivity in Central America and the Caribbean, by Crop, for a 50-Year Time Horizon
(yield in year as a percentage of initial yield)

Location and crop	*10*	*20*	*30*	*40*	*50*
Costa Rica					
Heredia					
Coffee	89	78	67	56	46
Turrubares					
Coco yam	0	0	0	0	0
Dominican Republic					
San José de Ocoa					
Pigeon peas	58	16	0	0	0
Peanuts	100	100	100	100	100
Beans	77	53	30	0	0
Haiti					
Maissade					
Corn, sorghum	41	22	10	1	0
Honduras					
Tatumbla					
Corn	53	39	39	39	39
Yorito					
Corn	82	65	47	41	41

period on a given plot if no conservation measures were used (chapter 8). The costs of degradation, therefore, are reflected primarily in the need to clear new plots of land at frequent intervals.

These examples, together with the diversity of yield effects observed, reinforce the need for site-specific information if degradation problems are to be understood and better ways of helping farmers respond to them are to be formulated. It is also important to bear in mind, however, that these case studies do not represent a random sample of degradation conditions in the region. On the contrary, because the case studies were drawn from sites for which data are available, and because data were collected primarily in areas where degradation problems are perceived to be significant, these case studies probably represent high-case scenarios on the degree and rate of degradation in the region.

The effects on yields of the conservation practices examined in the case studies are likewise varied. In some cases, yields were estimated to recover once conservation measures are established. This occurs partly because soil regenerates once the processes of degradation are halted, partly because fertilizers are used more efficiently, and partly because improved cultivation practices are sometimes introduced together with conservation. In the Tatumbla area of Honduras, for example, corn yields were estimated to increase about 145 kilograms annually after diversion ditches are built and improved planting practices are adopted, up to a maximum set by the local agroecological conditions and the technology employed by the farmers (chapter 6). In other cases, conservation measures would slow but not halt the decline in yield. In the Turrubares area of Costa Rica, for example, diversion ditches were estimated to halve the rate of decline in yield; the much more expensive terraces, on the other hand, were estimated to reduce the rate of decline to one-tenth its level without conservation. Again, the diversity of conditions is evident.

Construction of conservation measures often also has an adverse effect on production because the effective area cultivated is reduced since some land is turned over to use as diversion ditches, terraces, or hedges. In particular, physical structures usually reduce the effective area by over 10 percent. Construction of cut-off drains in Tierra Blanca, for example, reduces the effective area cultivated by about 14 percent, while terrace construction in the Patzité region of Guatemala leads to a 15 percent reduction in effective area (chapter 5). Further, constructing terraces often moves the earth in ways that bring unproductive soil to the surface. This, together with the reduction in the area cultivated, and the resulting production forgone, often heavily influence the ultimate profitability of these conservation measures. In Tierra Blanca, construction of diversion ditches also interferes with the prevailing production practices, which rely heavily on mechanical equipment.

In addition to reducing soil loss and hence the rate of decline in yield, conservation measures also affect yields by encouraging the retention of moisture and by stimulating improvements in the soil's physical structure. In Haiti's Maissade area, land treated with conservation structures was found to produce an average of 51 percent more corn and 28 percent more sorghum than plots without conservation structures in 1988, a year of poorly timed rainfall, and an average of 22 percent more corn and 32 percent more sorghum in 1989, a more normal year. In dry areas, therefore, soil conservation often reduces the risk of crop failure by improving moisture retention.

Some of the productivity estimates were based on weak or incomplete data. Therefore, extensive sensitivity analyses were undertaken as part of each of the case studies. In several cases, the results were robust to changes in the estimated effects on yield. In other cases, however, results were affected significantly by changes in assumed rates of decline in yield. In such cases, the premium to additional research would be high. In the Santa Lucía case study in Nicaragua, data were insufficient to estimate the productivity effects of degradation (chapter 7). Simulation analysis was used, therefore, to examine returns to the proposed conservation measures (manually constructed diversion ditches with stone barriers) under a range of assumptions about the effect of degradation and conservation on yield. The results of the simulations show that the proposed conservation measures are likely to be profitable only if the yield benefits of conservation are substantial.

Farm-level returns to soil conservation measures

Considering the decline in yield alone is insufficient to determine whether investments in any given conservation measure are advisable. A cost-benefit analysis of such investments is needed. Table 1-4 summarizes the results of the economic analysis of each of the case studies where data were sufficient to allow the analysis to proceed.

The most profitable conservation measure studied, in terms of rate of return, was found in Maissade, Haiti. The conservation measure used in this area is an indigenous measure known as *ramp pay*, which consists of crop stubble laid out along the contour, supported by stakes, and covered with soil. This measure is cheap to construct and very effective in halting erosion. Moreover, in the absence of conservation measures, yield would decline particularly rapidly in that area. Conservation measures also have high rates of return in Turrubares, Costa Rica, where highly profitable export crop production is threatened by rapid rates of yield decline. Rates of return to the proposed conservation measures are also high in the Tatumbla area of Honduras, where the decline in yield would be very rapid if no conservation measures were taken.

The least profitable conservation measures studied are found in Barva and Tierra Blanca, Costa Rica. The Tierra Blanca case is particularly interesting, since rates of erosion are very high. Because of the region's deep volcanic soils, however, the effects of degradation on productivity are minimal. In fact, production would actually be higher without the proposed conservation measures (diversion ditches) than with them, since construction of the measures would reduce the effective cultivated area. In addition, these measures would interfere with current production practices, thus increasing the costs of production. Under these conditions, the farmers' lack of interest in adopting these conservation measures is not surprising.

The cases of Maissade in Haiti, Turrubares in Costa Rica, and Patzité in Guatemala are of particular interest because data were available to examine the returns to different forms of conservation. In Maissade, the indigenous *ramp pay* conservation technique is clearly superior to rock walls, which are more expensive and lack the agronomic advantages of *ramp pay*. In Turrubares, on the other hand, the choice is less evident. Terraces are substantially more effective than diversion ditches at slowing erosion, but they are also more expensive to construct and entail a greater reduction in effective cultivated area. A tradeoff must be made, therefore, between effectiveness and cost. In this case, the

Table 1-4. Estimated Returns to Investments in Conservation in the Central American and Caribbean Case Studies

Country and area	*Conservation measure*	*Crop*	*Net present value (U.S. dollars)*[a]	*IRR (percent)*	*Number of years to break even*
Costa Rica					
Barva	Diversion ditches	Coffee	-920	< 0	> 100
Tierra Blanca	Diversion ditches	Potatoes	-3,440	< 0	> 100
Turrubares	Diversion ditches	Coco yam	1,110	84.2	2
Turrubares	Terraces	Coco yam	4,140	60.2	3
Dominican Republic					
El Naranjal	Diversion ditches	Pigeon peas, peanuts, beans	-132	16.9	> 100
Guatemala					
Patzité	Terraces	Corn	-156	16.5	> 100
Haiti					
Maissade	*Ramp pay*	Corn, sorghum	1,180	..	0
	Rock walls	Corn, sorghum	956	..	1
Honduras					
Tatumbla	Diversion ditches	Corn	909	56.5	4
Yorito	Diversion ditches	Corn	83	21.9	18
Panamá					
Coclé	Terraces	Rice, corn, yucca, beans	34	27.2	8

.. Undefined.
a. Computed over fifty years using a 20 percent real discount rate.

greater effectiveness of terraces more than compensates for their additional cost, but this will not always be true. In the case of Patzité, for example, a combination of diversion ditches and live barriers appears to be substantially more profitable than terraces, even if their effectiveness is much lower. This case apparently is more representative of conditions encountered in Central America. In analyses of twenty conservation techniques in Mexico, McIntire (chapter 11) also found that cultivation and cropping practices, including vegetative barriers, are superior to structural measures. Only when crop production is very profitable but extremely vulnerable to degradation (as in the case of Turrubares) are expensive conservation measures likely to be justified.

Unfortunately, data are insufficient to examine differences in returns *within* the study areas. Evidence from Kenya (Pagiola 1992) suggests that returns to conservation can vary considerably even within narrowly defined agroecological zones. Farmers on different slopes, for example, experience different rates of erosion. They also face different costs of conservation; the optimal spacing of terraces and diversion ditches, for example, is a function of the slope. Whether these differences are significant in any given instance is an empirical matter.

In each case, adoption rates appear to correlate well with the estimated profitability of conservation. The profitability of *ramp pay* is confirmed by its widespread adoption in Maissade. Adoption rates are also high in the Tatumbla region of Honduras and the Turrubares region of Costa Rica. Not surprisingly, adoption rates are very low in Tierra Blanca. Adoption rates are also low in Yorito, Honduras; although the conservation measures were estimated to be marginally profitable, the estimates were based on particularly weak data and were fairly sensitive to changes in assumptions. These results of the economic analysis suggest that it can be perfectly rational for farmers not to adopt the proposed conservation measures. In some cases—such as in Tierra Blanca—degradation simply is not a significant problem from the perspective of productivity. In others, the costs of the proposed conservation measures are too high relative to their benefits. The case of Patzité in Guatemala illustrates this best: although degradation is relatively rapid and, if left untreated, will result in production becoming uneconomic within a decade, the proposed terraces are very expensive to construct and take a significant portion of the land out of cultivation. Again, this is not to say that *all* conservation measures are unprofitable. Visits to Tierra Blanca show, for example, that although farmers have not adopted diversion ditches, they do plant along contours and, on steeper slopes, construct temporary bunds.[7]

Obstacles to the adoption of conservation measures

Although conservation practices must be profitable for farmers to adopt them, profitability alone may not be sufficient. In addition to cost-benefit considerations, other factors also play a role in whether farmers adopt conservation measures (chapter 12). Some of these factors are reflected in the cost-benefit analysis to the extent that they affect the prices faced by farmers. The effect of imperfect factor markets, for example, would be reflected in higher prices for inputs, which would affect the profitability of production activities. Most often, however, institutional factors must be considered together with the results of the cost-benefit analysis. Although the analysis carried out for these case studies does not always provide conclusive evidence on these factors, it does provide some insight into them.

It has often been argued that insecure property rights dissuade farmers from undertaking long-term investments, such as investments in soil conservation, because they may not be able to reap the benefits of such investments (Ervin 1986; Wachter 1992). This has produced numerous efforts to reduce insecurity of tenure by providing farmers with legal title to their land. The U.S. Agency for International Development (USAID), for example, has funded titling projects in several countries, including El Salvador and Honduras. However, equating land titles with secure tenure and thus with increased investment is too simplistic. Unless numerous improvements are made to the legal system and governmental institutions, land titles often prove to be too costly to obtain or enforce for most farmers. Moreover, unless access to credit is improved for farmers holding titles, the desired investment effect may not materialize.

The length of time required for investments in conservation measures to break even provides an important indicator of the likely severity of tenure insecurity. Farmers with insecure tenure may doubt that they will be able to enjoy the benefits of adopting conservation measures that will accrue in the distant future. Table 1-4 shows that in most of the case studies, profitable conservation measures have relatively short payback periods. Where payback periods were estimated to be long, the measures are either unprofitable or only marginally profitable and thus unlikely to be adopted even in the absence of tenure problems. Moreover, tenure insecurity is not as significant a problem in this region as is sometimes indicated. About 80 percent of the farmers in the Tatumbla area in Honduras own land by occupation—that is, they do not have legal titles—yet most have adopted the recommended conservation measures. In the Patzité region in Guatemala, the proportion of farmers without title is similar; only 10 percent of farmers have title to their land. Although erosion is a significant problem, adoption of conservation measures in this area has been relatively slow. At first sight, this might appear to support the importance of titling. In light of the negative profitability of the recommended conservation measures, however, assigning the blame to tenure insecurity or lack of land titles appears to be misplaced.

The other important obstacle to adoption that is often cited is the lack of capital markets. If credit markets fail, adoption of conservation will be limited by the farmers' ability to self-finance the required investments (Pender 1992). The research carried out for this project did not bring to light any direct evidence on the functioning of capital markets in the region. The estimated rates of return for investments in conservation measures, shown in table 1-4, do indicate the maximum rates that could be supported before the investments become unprofitable. It is encouraging to note that several are relatively high.[8]

Conclusions

Whether conservation measures are profitable from the farmers' perspective is an empirical issue that must be examined on a site-specific basis. Returns to conservation depend on the specific agroecological conditions faced, on the technologies used, and on the prices of inputs used and outputs produced. As in many other parts of the world, however, hard data on the actual extent of soil degradation and its effects on productivity remain extremely scarce despite several decades of soil conservation efforts (Lal 1988). There is a need for more systematic research on soil degradation and its consequences. Since all countries within Central America include a large number of different agroecological regions, and since many agroecological regions are found in more than one country, there is considerable scope for collaboration on such research. Regional organizations such as CATIE have an obvious role to play in coordinating and undertaking it. The payoff to such research is likely to be high, since it would allow a much more targeted approach to be taken to soil conservation and allow efforts to be concentrated where they are needed most.

The results of the case studies carried out in the region show that conservation is profitable in some cases, but not in others. Given the small number of cases studied and the weakness of the data used, broad lessons must be drawn with care. It does appear, however, that except in cases where high-value crops are planted on very fragile soils, as in the case of coco yam in Turrubares, expensive mechanical structures are unlikely to be profitable from the farmers' perspective. Conservation measures are particularly likely to be profitable either when they are cheap and simple or when they allow improved practices to be adopted.

Generally, farmers appear to act rationally in deciding whether to invest in conservation measures. They tend to adopt conservation measures when it is in their interest to do so, unless some constraint is present. Cases in which returns to conservation are low or negative correlate well with low adoption rates.

A full examination of the role of government policy in conservation requires a broader analysis than that undertaken here. In particular, off-site effects of degradation would have to be included explicitly and allowance made for distortions in observed price signals resulting from government policies or market failures. Nevertheless, several important points emerge from the present analysis.

Soil conservation advocates in Central America and the Caribbean, and in much of the rest of the world, often argue that subsidies are indispensable to induce farmers to adopt conservation measures. Such statements are often made, however, on the implicit assumption that conservation is inherently desirable (or at least in the absence of concrete evidence that it is not). The results presented in this volume show that in many cases, specific conservation techniques (such as mechanical structures) are *not* desirable in that their cost is greater than the benefits they bring. Unless there are important off-site effects or the price signals received by farmers are significantly distorted, subsidies to induce adoption do not result in increased economic efficiency.

Off-site effects provide a potent rationale for intervention, since in their presence, the farmers' perceptions of the returns to conservation underestimate the social benefits of conservation, and less conservation is undertaken than would be socially optimal. In the Santa Lucía Milpas Altas watershed in Guatemala, for example, a USAID project uses subsidies (so-called *pago social*) to induce farmers to build terraces and thus reduce flooding in the historic town of Antigua. In the same watershed, farmers who do not receive subsidies generally use less costly conservation methods such as vegetative barriers and live fences. Although these measures are privately profitable from the farmers' perspective, they may not be sufficiently effective to control floods.

The impact of price distortions is more difficult to establish; because of the many factors that affect the profitability of a given conservation measure and the complicated way in which they interact, it is difficult to predict whether any given distortion encourages or discourages conservation. Recent evidence suggests that typical policy distortions in developing countries tend to encourage degradation (Panayotou 1993), but more work is needed on this topic. When policy distortions or market failures are present, the first-best approach to the problem would be to attempt to remove the distortions themselves. Conceivably, in some instances distortions or market failures may be so difficult to eradicate that it is simpler to offset their effect with subsidies to conservation, but such an approach should only be adopted as a last resort.

Whatever their justification, the use of subsidies encounters several difficulties. First, the divergence between social and private returns to conservation must be established, so that intervention can be targeted where it will be most effective. This requirement is not always met. Subsidies are often used in cases where no off-site effects are present. In Costa Rica, for example, the soil conservation service (SENACSA) subsidizes half the cost of establishing conservation measures on small farmers' fields, irrespective of location. But providing subsidies in areas where they are not justified by any social benefits wastes scarce budgetary resources. Subsidies are also provided in cases such as Turrubares, where individual farmers already have sufficient incentive to conserve purely on productivity grounds. Conversely, subsidies are not always provided in cases where off-site effects are present. More commonly, subsidies are provided to construct, but not maintain, the conservation measures, so farmers sometimes allow them to decay. In Nicaragua, for example, terraces were built on fields in the Lake Xolotlán watershed above Managua in an effort to reduce flooding in the city and sedimentation in its reservoirs. Built at no cost to the farmers, these terraces interfered with cultivation practices and did not result in private net benefits to the farmers; most were soon destroyed. Similar experiences have occurred in the Tierra Blanca area of Costa Rica.

The second problem in the use of subsidies, then, is the difficulty of designing appropriate incentive structures so that social objectives are met. The case of the Lake Xolotlán watershed illustrates a situation in which subsidies are insufficient to overcome the divergence between private and social returns to conservation. The El Naranjal watershed in the Dominican Republic provides another example. The USAID-funded Management of Natural Resources Project (MARENA) provided subsidized credit to participating farmers, so adoption rates were initially very high, even though the evidence developed here suggests that these measures were unprofitable from the farmers' perspective. In 1985, over 90 percent of the area's farms practiced soil conservation. Five years later, however, only half of these farms continued to do so. Subsidies can only convince farmers to modify their behavior as long as they continue to be paid. Conversely, MARENA's successor stimulated considerable use of conservation techniques even though no subsidies were offered—in fact, the cost of participation was quite high—by tying conservation to access to irrigation. Although sufficient data are not available to undertake a full analysis, these new practices appear to be highly profitable. Care must also be taken to ensure that subsidies do not create perverse incentives for farmers. In Costa Rica, for example, a reforestation credit system unintentionally encouraged farmers to deforest their land so that they might qualify for the credit. The expectation that subsidies will be forthcoming to fund conservation efforts may also encourage farmers to delay conservation, even when such measures are privately profitable, in the hope that the government will bear part of their cost. Even when they are justified, then, subsidies must be used with great care.

Governments should also ensure that constraints such as insecure tenure do not prevent farmers from adopting conservation measures. But such efforts also require prior research if they are to be effective. Too often the existence of tenure problems and the effectiveness of titling as a solution are simply taken as given.

Governments already undertake some research on soil conservation and provide, through extension services, some assistance to farmers who undertake conservation work. However, research in experiment stations has tended to favor technical efficiency (including structural measures such as terraces) over cost-effectiveness. Further, government extension work is often ineffective. In many cases, nongovernmental organizations, such as Vecinos Mundiales in Central America (chapter 18), have proven to be more effective at presenting the range of options to farmers and delivering related technical assistance. Given the large variety of conditions that farmers face, government extension services should also provide, explain, and demonstrate the existing variety of options to farmers rather than, what has often happened in the past, pushing broadly for adoption of specific techniques. Also, it may be innovative as well as effective for governments to decentralize decisionmaking and channel budgetary resources for soil conservation to the local level. This would allow communities to participate and contract assistance from agencies that could make the greatest contributions.

It is unrealistic to hope that research will produce a "breakthrough technology" that will solve all conservation problems. Improvements will usually be more "marginal." Such improvements, alone or in combination with others, can, however, have a significant impact on productivity. The *ramp pay* technique used in Haiti is one example of what might be achieved. The traditional practice of gathering crop stubble along the contour was improved by more exact placement and by covering the structure with upslope soil, thus discouraging rat infestations and encouraging surface flow infiltration. These changes made the practice much more effective in halting degradation and more acceptable to farmers. Similar approaches have been successful in West Africa (Reij 1992).

Since the conflict between conservation and production that was noted in many of the case studies often affects the returns to conservation significantly, attempts to develop practices that reduce this conflict or serve both conservation and production needs simultaneously—"overlap technologies," in the terminology of Reardon and Vosti (1992)—should be especially encouraged. To maximize the chances that such research will be truly useful, it should be carried out primarily as on-farm research and in close consultation with farmers.

Notes

1. In a recent assessment of the extent of human-induced soil degradation, the International Soil References and Information Centre estimated that 56 percent of the land in Central America has experienced moderate degradation, implying that productivity has been substantially reduced, and that 41 percent has experienced strong degradation, implying that agricultural use has become impossible (Oldeman, Hakkeling, and Sombroek 1990). Aggregate measures such as these, however, often have a weak empirical basis.
2. Biot, Lambert, and Perkin (1992) have pointed this out in an African context.
3. In addition to off-site effects, the inappropriate use of common-property lands is the other important category of land degradation that is not addressed in this research (Bromley 1992).
4. Village- or watershed-level investments are sometimes required for effective management of land degradation problems. Such interactions are outside the scope of this chapter. For an example of the analysis of such problems in the same area as the Haiti case study, see White and Runge (1992).
5. Even this more limited objective encounters numerous difficulties, including the likelihood of sample selection bias problems when fields with and without conservation are compared. In addition, many of the case studies had to rely on farmer recall data and were able to control for other sources of variation in yield, such as weather, only to a limited extent.
6. Because farmers are likely to adjust their production practices as yields decline, the time before production becomes unprofitable is likely to be overestimated.
7. The effects of these measures are implicit in the estimates of degradation and productivity effects for the case without conservation.
8. Even when rates of return to investment in conservation are high, however, conservation might not be undertaken if even higher rates of return can be obtained by investing in off-farm income opportunities. Schneider and others (1993) argue that perceptions of limitless land resources in the Amazon prompt farmers to "mine" their soils and then move on.

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Country Studies

2. Cost-Benefit Analysis of Soil Conservation

Stefano Pagiola

Despite the high level of concern over soil degradation problems in developing countries, very little empirical analysis has been carried out on the causes and severity of these problems and on the best ways to address them. Work in this field has been largely theoretical, with little emphasis placed on practical methodologies to examine the economics of soil conservation under specific, practical conditions. This chapter develops the practical methodology—an application of cost-benefit analysis to soil conservation problems—used in the country studies executed in this volume.

The basic principle of the methodology, as in all cost-benefit analysis, is to compare the flows of costs and benefits with and without the proposed intervention—in this case some kind of soil conservation activity. The approach taken here is to consider the proposed interventions from the standpoint of the farmers themselves. Although the primary result of the analysis concerns the profitability of the specific conservation measures, this approach also allows detailed examination of the alternatives open to farmers, the constraints they face in undertaking soil conservation, and numerous policy issues.

The most difficult problems in the analysis of soil conservation arise because of the issue's specific data requirements. Two basic sets of information are required: (a) biophysical data on the effect of farming activities on soil and the effect of degradation on yield and (b) economic data on costs and prices. Although economic data are often easily available, biophysical data pose considerable—sometimes insuperable—problems. Since much of the theoretical work comes to the conclusion that whether conservation pays under specific conditions depends on those conditions (Pagiola 1993), addressing the data problems is fundamental to applied analysis. Many of the principles developed in this chapter are broadly applicable to numerous other natural resource problems; some, however, are relatively specific to soil conservation problems.

This chapter begins with an overview of the principal aspects of soil degradation problems, bringing out their salient features from an economic viewpoint. As with all resource problems, the characteristics of the natural system play a critical role in soil conservation problems. The biophysical characteristics of the setting must be known in detail if these problems are to be understood and addressed. This chapter discusses how a cost-benefit analysis of these problems might be structured. The following section examines different approaches to obtaining the necessary data on the biophysical aspects of them. A final section examines some possible extensions of the methodology.

Biophysical setting

Soil provides the environment in which plants grow. It can supply all of the environmental factors needed to produce crops except light.[1] Soil differs from other resources in that it is not an end product, but an input into a production process; there are no markets for soil per se—only for products produced from the soil.[2] Soil degradation is of interest, therefore, because of what it might mean for productivity on the farm and for possible damages off the farm.

Soil characteristics and, therefore, the specific combination of services that soil can provide to crops vary widely from place to place, depending on climate, parent material, topography, biotic activity, and the length of time that soil formation has been under way. Soils that develop on steep slopes tend to be shallow, for example, and soils that form under grassland usually have higher organic matter content than soils that form under forests. Site-specific variations in the conditions under which given soils were created can lead to significant differences in properties even within small geographical areas and similar soil series.

Depending on their characteristics, soils are naturally better suited for some agricultural activities than for others. Farmers can, to some extent, manipulate the soil to improve conditions for the specific crops they are growing, by using appropriate tillage, fertilization, and irrigation practices. Crop yields depend on the level of the services provided by the natural environment and the inputs used by the farmers.

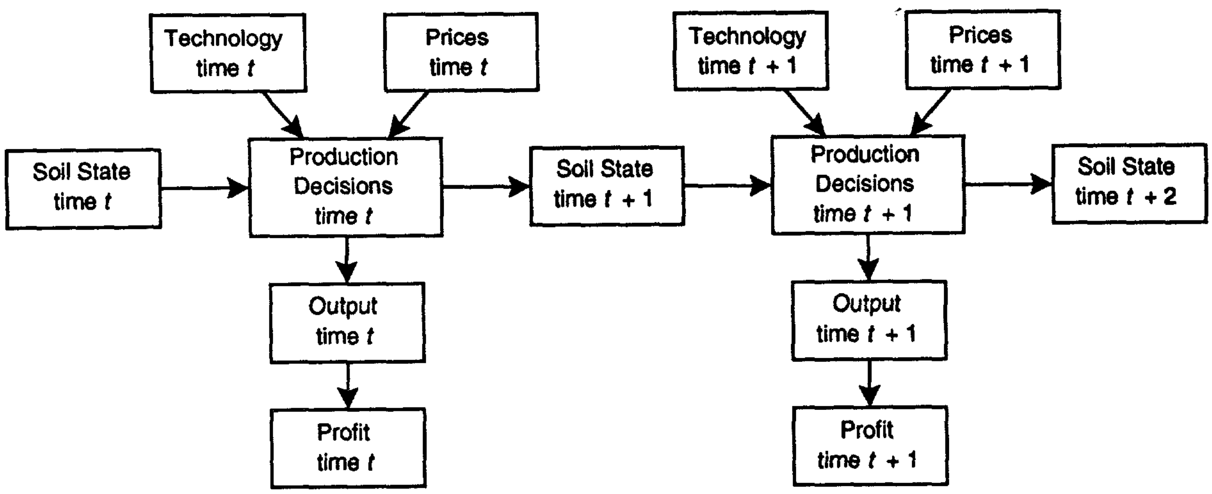
Lal (1989) defines degradation as "a deterioration in quality and capacity of the life-supporting processes of the land." From the point of view of farmers, however, defining degradation more narrowly as relating to a reduction in the land's actual or potential uses is more appropriate (Blaikie and Brookfield 1987). Unfortunately, crop production itself often leads to soil degradation. For example, cultivation practices can expose soil to water and wind erosion; repeated tillage can weaken soil structure; crop production can remove nutrients; and use of machinery can lead to soil compaction. Reductions in soil depth through erosion are the best-known form of degradation, but far from the only one. In many cases, different forms of degradation are correlated. For example, soil compaction can result in increased runoff and higher rates of erosion; conversely, erosion can carry away nutrients and weaken the soil's physical structure. An important characteristic of such damage is that it is usually cumulative; its effects in any one year can be minor or insignificant but become important as they accumulate over time (Lal 1987).[3] Whatever its form, soil degradation is usually reflected in lower yields or, if compensating measures are taken, in higher costs for a given yield. In the limit, the ability to grow crops (technically, economically, or both) might be lost completely.

A soil's vulnerability to degradation depends on how easily it is damaged and on how significant that damage is for crop production. The erodibility of soils varies, for example, according to their structure and to their chemical and physical composition (Hudson 1981). The effects of environmental conditions must also be considered. The predominant soils in the humid tropics (oxisols, ultisols, and alfisols), for example, tend to be less erodible, under equivalent conditions, than temperate region soils (Lal 1982). However, erosivity is generally much higher in these regions.

In turn, the effects of degradation on productivity depend on complex soil characteristics and on crop requirements. The impact of erosion, for example, depends on the distribution of plant nutrients in the soil profile, on the crop's rooting depth, on plant-available water resources, and on physical and chemical properties of subsoil horizons (Lal 1987). Where soils are deep and subsoil characteristics are favorable, even substantial rates of soil loss may have little effect on productivity. In semiarid regions, the loss of moisture storage capacity resulting from erosion can often be more important than the loss of soil per se.

In addition to affecting the productivity of the soil (on-farm effects), some forms of degradation may also cause damage off the farm. In particular, erosion often causes economic damage to reservoirs and waterways and to aquatic life within them.[4] Degradation on one farm can also induce or worsen degradation on neighboring farms. Conversely, some farms might benefit from degradation elsewhere; this might occur, for example, if fertile topsoil eroded from one plot is deposited on another.[5] In the United States, changes in soil productivity have been estimated to be relatively minor compared with the off-site costs (Crosson and Stout 1983; Clark, Haverkamp, and Chapman 1985). In developing countries, on the other hand, productivity concerns are generally dominant. Magrath and Arens (1989), for example, estimate that productivity effects account for 95 percent of the costs of soil erosion in Java (although several categories of off-site costs could not be quantified). Repetto and Cruz (1991) obtain similar results in Costa Rica.

Figure 2-1. Intemporal Linkages in Farm Decisions



Economic setting

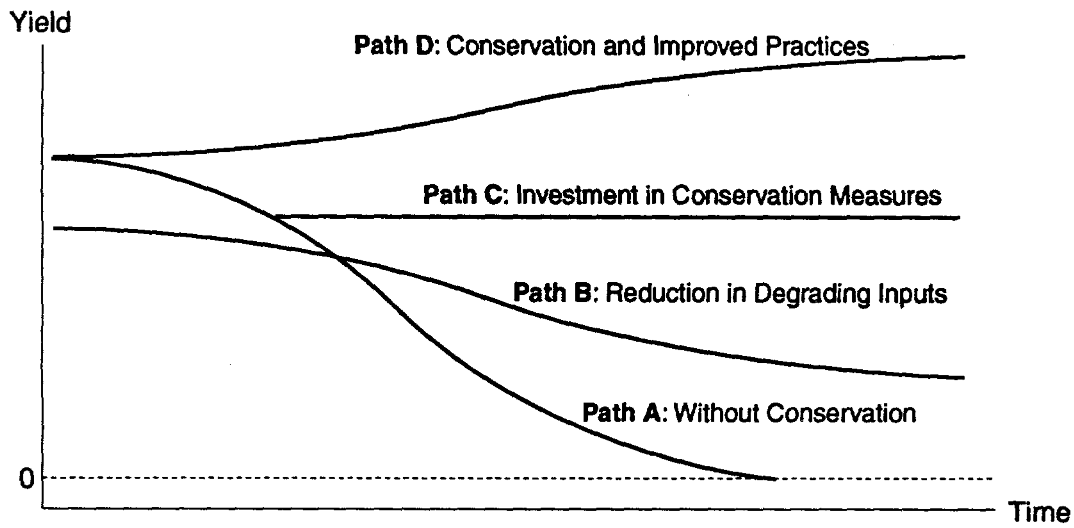
Cultivation practices can lead to soil degradation, but they also produce food and fiber. Actions to slow or arrest soil degradation, such as changes in crop and management practices or the adoption of soil conservation techniques, are likely to be costly. The critical question is whether the long-term benefits of reduced degradation make these costs worth bearing. The need to ask this question is shown by considering an extreme position sometimes found in the soil conservation literature, which suggests that certain fields should not be cultivated at all. If such a practice were adopted, soil erosion might be stopped (natural vegetation generally provides very good protection against erosion), thus preventing future declines in yields. But all benefits from the land would also be forgone. There is little to be gained from maintaining soil productivity if that soil is then left idle.

Consider the production decisions made by farmers in a given year. Their output depends on their technology, their use of inputs, and the condition of their soil. In a standard single-period profit-maximizing problem, they would treat the status of their soil as a given and choose their level of production and input use as a function of input and output prices. If cultivation also affects their soil stock, however, the production decisions they make today will also affect their production possibilities in the future. This linkage is illustrated in figure 2-1.

In effect, farmers face a choice of following various paths for their future yields. If cultivation practices degrade the soil, yields will gradually decline, as shown by path A in figure 2-2. The rate and magnitude of this decline will depend on site-specific conditions. If farmers reduce their use of the inputs that cause the degradation (by, for example, adopting some kind of minimum tillage practice), they might slow their rate of degradation substantially, although they might have to accept a lower level of yield initially (path B).[6] If farmers were to invest in a soil conservation practice (for example, terracing), they might be able to maintain their current yield indefinitely, thus shifting to path C. In some cases, they might even have options that would not only conserve soil but also increase yield (path D).

In order to make decisions in such a context, farmers need to be able to evaluate the relative benefits of being on each path. Each would involve its own distinct flow of costs and benefits over time. How much does soil degradation cost farmers in lost productivity or extra costs? How much would the alternative practices cost in higher costs or lower output? Are highly effective but expensive conservation practices more cost-effective than less effective but cheaper conservation practices? Even major degrada-

Figure 2-2. Alternative Yield Paths



tion problems may not be worth addressing if doing so is very costly.

The evaluation of alternative practices is complicated substantially by the intertemporal nature of the problem. The costs of soil conservation investments generally need to be borne early on, while most of the benefits (such as avoided damage from degradation) may not accrue until far in the future. In addition to the cost-effectiveness tradeoffs between practices, therefore, intertemporal tradeoffs also exist between practices with short- or long-term benefits.

Cost-benefit analysis of soil conservation

Efforts to examine the economics of soil conservation have often been crude at best. In many cases, rates of soil loss are simply compared against soil loss tolerance values (T values). These T values purport to give the maximum rate of soil erosion that would allow a high level of crop productivity to be sustained "economically and indefinitely" (Wischmeier and Smith 1978). In practice they are set at levels that approximate what is thought to be the rate of soil regeneration and have practically no economic content.[7] Although the magnitude of costs and benefits resulting from conservation will clearly affect how much conservation is optimal, T values are generally treated as constants. Moreover, they give no guidance as to the most cost-effective method of reaching this or any other objective.

Another common approach consists of calculating the amount of nutrients lost from the soil as a result of erosion or other forms of degradation. These losses are then frequently valued by estimating the cost of replacing them (typically using fertilizer prices). Repetto and Cruz (1991), for example, adopt this approach to value soil losses in Costa Rica. Although this approach can provide an index of damage to the soil, it has numerous weaknesses. First, the impact of a given amount of nutrient loss on productivity varies across soils and crops. A rich soil might be only minimally affected by nutrient loss, while a poor soil might be dramatically affected. Second, this approach does not provide any way of assessing the costs and benefits of remedial practices.

At the other end of the spectrum, there have been several applications of dynamic optimization techniques, such as optimal control theory, to soil conservation problems (Burt 1981; McConnell 1983; LaFrance 1990; Pagiola 1993). Although such techniques have lead to numerous insights concerning optimal soil use, they have been applied almost solely in abstract, stylized settings. Indeed, in many cases, no numerical data are used to illustrate the results, which remain at a purely theoretical level. Moreover, these results are often ambiguous unless specific assumptions are made about the properties of the biophysical system; they cannot, therefore, be applied directly to any arbitrary setting.

Cost-benefit analysis techniques offer a simple and relatively easily implemented, yet powerful, approach to the analysis of soil conservation problems. The method is particularly well suited to applied analysis of specific practical situations. Cost-benefit analysis was originally developed as a tool to examine the economics of projects involving the development of water resources. Although its application to resource issues was thereafter neglected for some time, it has once again come into widespread use for this purpose (Krutilla and Fisher 1975; Hufschmidt and others 1983). Variants of this method have been used to examine a number of soil conservation cases: for example, in India (Magrath 1989), in the Dominican Republic (Veloz and others 1985), in Mali (Bishop and Allen 1989), and in several locations in Kenya (Hedfors 1981; Holmberg 1985; Lindgren 1988; Pagiola 1992b).

Level of analysis

Although cost-benefit analysis is usually associated with analysis at a fairly aggregated project level, it is not limited to this level of analysis. Indeed, the approach developed here is primarily intended for use at the farm level. This level of analysis is chosen for several reasons. First, soil conservation problems are highly site-specific, and aggregating over different biophysical conditions could produce misleading results. Second, many soil conservation programs founder because they are not accepted by farmers. Decisions about land use are ultimately made by the farmers themselves in light of their own objectives, production possibilities, and constraints and not by social planners or government agencies. Understanding the incentives faced by individual farmers is necessary, therefore, if patterns of resource use are to be understood and appropriate responses to problems formulated. Carrying out the analysis at the farm level increases the likelihood that appropriate programs will be devised and that the constraints faced by farmers will be understood and taken into account. Project-level analysis can then be carried out by aggregating the results of different farm-level analyses.

A farm-level approach also places the focus firmly on the effects of degradation on farm productivity. In developing countries, where substantial proportions of the population still depend directly on agricultural production, the effect of degradation on yields is usually critical. This is not to belittle the importance, in some situations, of off-farm effects of soil degradation such as siltation of reservoirs and waterways. Even where such off-farm effects are the primary concern, a farm-level approach is an appropriate first step since conservation measures, possibly along with other measures, may have to be implemented on farms.

Cost-benefit analysis can be carried out from either a private or a social perspective.[8] Under a private perspective, only the costs and benefits that actually accrue to the agent making the decisions about resource use are considered; and these costs and benefits are valued at the prices that these agents actually face, with no attempt to adjust for distortions that might result from government policies or market failures. This approach is most appropriate when the question concerns the incentives farmers face to adopt any given conservation practice. Since farmers would generally not bear the off-site costs resulting from a given practice, it is appropriate to omit them from the analysis. Under a social perspective, on the other hand, all the costs and benefits of a given activity need to be considered. If agricultural production leads to siltation of reservoirs, for example, this represents a real cost to society that should be included together with consideration of the value of the output obtained and any fertility effects. In addition, valuation of the resources used and obtained from agricultural production should be adjusted for any distortions resulting from policy interventions or market failures, in order to measure their true opportunity cost from a social perspective. In keeping with the farm-level focus of the analysis, this chapter, and the research in this volume, examines the private returns to conservation.

Constructing the analysis

The principle of the analysis is simple: it involves calculating the differences in the flows of costs and benefits between what would happen if current practices continued and what would happen if a specified conservation practice was adopted. This is *not* the same as a before and after analysis, and the results estimate the return to the *specific* conservation measures being examined, not to conservation per se. A finding that specific conservation measures are not profitable does not imply that all conservation measures are unprofitable. Indeed, the case of practices without conservation often includes numerous measures designed to reduce degradation rates.

If one defines y^D_t as the yield in year t under the degrading practice and $c^D(y^D_t)$ as the corresponding annual cost of production, then the returns obtained in year t under the degrading practice are given by $\pi^D_t = p_t y^D_t - c^D(y^D_t)$. Similarly, if y^C_t is the yield in year t under the specified conservation practice, the returns in year t would be $\pi^C_t = p_t y^C_t - c^C(y^C_t) - c^C_t$, where $c^C(y^C_t)$ is the cost of production and c^C_t isthe cost of constructing and maintaining the conservation measures. The net benefit obtained from adoption of the conservation practice in any given period would thus be $\pi^C_t - \pi^D_t$, $t = 1,2,...T$. Losses and gains in different periods are discounted back to the current period and summed. Taking r as the discount rate, the net benefit, in present value terms, to investing in the soil conservation technique is given by

$$\text{NPV} = \sum_{t=0}^{T} \frac{(\pi^C_t - \pi^D_t)}{(1+r)^t}$$

Adoption of the given soil conservation practices is profitable if NPV > 0, since this indicates that cumulative returns are greater if the conservation practices are adopted than if current practices are continued. For terracing and other measures with relatively high costs, the net benefits are usually negative in the period in which investment is made. It may then take several years before the conservation practice is more profitable than the degrading practice, depending on how fast yields decline under the degrading practice. Additional time is then required before the cumulative benefits from the conservation practice become high enough to pay back the initial investment. For some measures, this may never occur, indicating that adoption of these measures would not be economically profitable for farmers.

It is instructive to expand the formula, giving

$$\text{NPV} = \sum_{t=0}^{T} \frac{p_t(y^C_t - y^D_t) - [c^C(y^C_t) - c^D(y_t)] - c^C_t}{(1+r)^t}$$

This expression clearly indicates that the net benefit to be obtained from soil conservation depends not only on the difference in yields between practices but also on the price of output (and hence the *value* of the additional yield), on relative costs of production, on the cost of adopting the conservation practice, and on the discount rate used to weight the returns in different periods.

The NPV is the criterion most commonly used to judge the profitability of the investment, but other criteria also provide useful insights. The internal rate of return (IRR) is the discount rate under which the net present value is exactly zero—in other words, the discount rate i such that

$$\sum_{t=0}^{T} \frac{(\pi^C_t - \pi^D_t)}{(1+i)^t} = 0$$

This measure is most useful when—as is commonly the case—the discount rate that should be used is uncertain or in dispute. The number of years before the initial investment is repaid is also often useful; that is, the smallest number of years τ such that

$$\sum_{t=0}^{\tau} \frac{(\pi^C_t - \pi^D_t)}{(1+r)^t} \geq 0$$

This measure is particularly useful when the planning horizon of farmers is restricted or uncertain.

As with all cost-benefit analysis, the method developed here gives no pretense of optimization. Options are considered pairwise, and there is no guarantee that other, unexamined, options would not be preferable to both. However, the method does allow numerous alternative practices to be compared, which, in turn, allows the most profitable to be selected.

The calculations required can be easily carried out using an electronic spreadsheet. A spreadsheet also provides a convenient way of carrying out sensitivity analysis. Because they build on widely used techniques of cost-benefit analysis, the results of the calculations are easy to communicate to policymakers.

Biophysical data requirements

Understanding the biophysical framework is critical to evaluating the flow of costs and benefits. The initial step should be to obtain a solid *qualitative* understanding of the problems being experienced, so as to guide the analysis and the choice of appropriate conservation measures. The assistance of experienced soil scientists and agronomists is often invaluable, as is that of the farmers themselves. The teams that carried out the case studies in this volume were each composed of an economist, a soil scientist, and an agronomist.

For the analysis to proceed, the effect of specified activities on yields over time must be quantified. This might be achieved either directly or by quantifying separately the relation between the activities and the level of degradation of the soil and the relation between the soil's level of degradation and its productivity. Unfortunately, our understanding of these relationships is often limited. And even when our understanding is adequate, our ability to quantify them is minimal.[9]

Quantifying degradation rates and yield losses

In general, there are two ways to estimate the relationships required for the analysis: by directly estimating the effect on yield of certain observed conditions and by modeling the biophysical environment using (most likely) experimental data. Both approaches have advantages and disadvantages. The statistical approach is generally simpler, because it requires less detailed scientific knowledge of the analyst. However, in addition to the difficulty of finding appropriate data and the pitfalls of estimation, the method is highly inflexible: results can only be applied to the specific case from which the data were drawn. The modeling approach is more flexible and allows parameter values to be drawn from a variety of data sources. It also requires detailed qualitative and quantitative knowledge of the biophysical environment, which makes building and validating a complete and realistic model, or even calibrating an existing model, a complex endeavor. In practice, the approach (or combination of approaches) followed is likely to be driven by the availability of data.

Statistical method. Disentangling the impact of soil degradation on productivity is a very difficult task. An examination of the econometric methods required to undertake such an analysis properly is outside the scope of this chapter (interested readers are referred to Capalbo and Antle 1988 for an excellent introduction to this field). Unfortunately, although considerable work has been done on estimating the causes of changes in agricultural productivity, little of it has focused on understanding the role of natural resources such as soil. Much remains to be done in this regard.

For the purposes of the calculations described here, the more modest objective of estimating a time trend of yields is often sufficient. Moreover, the availability of data often precludes more sophisticated analysis. This is true in many of the case studies in the following chapters. This approach requires a time series of yield for the practices of interest both with and without conservation. In addition, it also requires information on changes of any other variables that might affect yield over the same period. The idea is to estimate the impact of cumulative degradation by running a regression of yield against time and other variables. For this to work, it is important to ensure that the data are drawn from a relatively homogenous area and that, except for changes captured in the included independent variables, practices and conditions remain essentially unchanged during the period of analysis. Panel data are particularly useful for this task, as they allow some of these conditions to be controlled for.

The effects of the conservation measure on yields could be estimated either independently or together with the effects of degradation, using dummy variables, if the practices are similar enough. This latter approach economizes on degrees of freedom by pooling the available data and allows for a formal statistical test of the hypothesis that the yield trend varies between land with and without conservation.

Once the relationship has been estimated, the yield path for the practice can be predicted by substituting average values for the variables describing weather conditions and other factors and using a time index. If the estimated relationship shows a significant effect of the variables reflecting variations in physical conditions, it is often useful to estimate separate paths for a range of such conditions, repeating the economic calculations for each case.

This approach has several problems, including difficulties of estimation, unreliable data, and restrictions on the use of results. Because the decision to conserve is not exogenous, serious problems of bias often arise in the selection of the sample. If farmers tend to conserve their more productive land, estimates of yield trends under the conservation practice will be biased upward; if farmers tend to conserve their more fragile land, yield trends without the conservation practice will be biased upward. Capturing the effect of a weak signal, such as that of cumulative degradation, in an environment that is usually very noisy can be exceedingly difficult. Differences in initial conditions and in management levels or weather variability can all swamp the signal from degradation. In order to detect such a signal, observations are required for numerous years, the more so the slower the process of decline in yield. But practices may not remain the same over a long enough period. Some analysts have tried to sidestep these differences by using data from paired fields on the same farm, one with and one without the conservation measures being studied (Holmberg 1985; Lindgren 1988). Even if a signal can be detected, the trend must often be extrapolated well beyond the observed sample; given the nonlinearity of most degradation processes, extrapolation poses particular dangers. Analysis is also limited to the specific conditions under which the measurements were made.

Modeling the biophysical environment. In this approach, a detailed parametric model of the biophysical environment is developed. The idea is to develop a model that captures the principal biological and physical relationships at work and to predict yields and the effects of degradation on the basis of a number of physical parameters and values for farmer input levels. Ideally, such models predict yield effects for a variety of conditions, if the appropriate parameter values are entered. Such models range from the relatively simple, such as those based on the Universal Soil Loss Equation (USLE), to the very sophisticated.

When the problem to be examined is primarily due to erosion, models based on the USLE are often attractive, because this equation is flexible and considerable work has already been carried out on it. The USLE relates soil loss from a field to the climate, type of soil, topography, and management variables as follows:

$$A = RKLSCP$$

Where A is the soil loss (metric tons per hectare), R is the erosivity of rainfall (MJ.cm/ha.hr), K is the erodibility of the soil (mt.hr/MJ.cm), L and S are factors for the length and slope of the field, C is a crop cover and management factor, and P is a conservation practices factor.[10] The core of the USLE gives soil loss as a function of the erosivity of rainfall (R) and the erodibility of soil (K) on a "standard" plot (slope length 22.6 meters on a slope of 9 percent when land use practice is cultivated fallow with plowing up and down the slope). On such a plot, A = RK. Differences in erosion rates due to variations from this standard plot are then obtained from the basic relationship, A = RK, by using proportionality factors. For example, a steeper slope will experience a higher rate of erosion than a more gradual one. The slope factor, S, reflects the ratio of soil loss on a steeper slope to that on the reference slope and is used to modify the soil loss predicted from the reference plot to obtain that on the plot under investigation. Similarly, the L, C, and P factors allow for differences in erosion rates due to slope length, crop and management effects, and adoption of specific conservation practices. All factors are set to 1.0 under standard conditions. Using data from a large number of experimental plots, the U.S. Department of Agriculture has developed K factors for several hundred different soil types and LS, C, and P factors for a large variety of topographies and land use practices. A complete and authoritative exposition of the derivation and use of the USLE can be found in Wischmeier and Smith (1978).

The universality of the USLE refers not to the specific parameters used in it but to its structure, which allows the many factors that affect soil erosion to be incorporated into a single equation. As has been argued by Hudson (1981), this structure makes the USLE relatively easy to modify for local conditions. Indeed, the USLE has been successfully adapted for use in several countries.[11] The principal task is to obtain estimates for its factors that are suitable to the case of interest, since the parameter values supplied by the U.S. Department of Agriculture for the USLE are calibrated to U.S. midwest conditions and cannot, therefore, be used directly in other settings. This is particularly true of rainfall erosivity (R), soil erodibility (K), and crop and management (C) factors, which depend on local agroclimatic conditions.[12] Slope (LS) and conservation (P) factors can be used directly from U.S. Department of Agriculture data (Hudson 1981).[13]

The USLE is an advantageous means of expressing available information on erosion because once appropriate values for the factors have been obtained, they can be used in any combination to provide estimates of expected mean soil loss for any given situation. Aside from the difficulty of obtaining values for the various factors that are appropriate to the case being investigated, however, other difficulties arise. In particular, although the USLE predicts soil loss from a given plot, it says nothing about what happens to the soil washed away from that plot. Some of this soil may be lost to agriculture, but some is likely to be redeposited on lower plots. USLE estimates, therefore, generally overestimate the *net* soil loss from any given plot. The yield loss predictions are, therefore, also overestimates.[14]

Unfortunately, the USLE's simplicity has often led to its being applied in inappropriate conditions (Wischmeier and Smith 1978). The most common mistake has been to use U.S. Department of Agriculture parameter values derived under U.S. midwest conditions in completely different environments such as the humid tropics. Locally derived values for the various parameters are indispensable for the USLE's application. Moreover, the USLE is designed to predict *mean annual* soil loss over a long time period. Actual soil loss in a given field can differ substantially over time because of variations in antecedent conditions. The U.S. Department of Agriculture's estimates for soil erodibility (K) values are based on over twenty years of measurements. In many developing countries, however, local measurement of USLE parameters—where any has been undertaken at all—is often based on short periods of observation—sometimes as short as single storm events. Use of such data to produce USLE estimates can then give an illusion of precision that is wholly unjustified. The USLE's ease of use has also often led researchers to pay excessive attention to erosion problems and to neglect problems caused by other forms of degradation, such as nutrient depletion.

The second step in the process requires an estimate of the relationship between cumulative erosion and yield. This is generally a much more difficult step, primarily because suitable data are rarely available. No simple relationship exists between erosion and yield. One cannot assume, for example, that loss of 50 percent of the topsoil will reduce yields 50 percent; nor is it necessarily true that if a loss of 1 centimeter of soil reduces yields, say, 5 percent, that a further 1 centimeter of soil loss would lead to an identical reduction in yield. Nor are these factors independent of the practices employed. Practices that do not use commercial fertilizer or manure, for example, may be more vulnerable to the effects of degradation since they depend more heavily on the natural fertility of the soil. Generally, the required relationships can be obtained only from work at experiment stations, such as desurfacing experiments.[15] Data generally come in the form of a discrete set of observations of yield on fields with a set amount of (natural or artificial) soil loss. Regression analysis is then used to obtain a relationship between soil loss and yield. Such experiments typically repeat the trials with a number of alternative practices. If the objective is to evaluate the impact of erosion on farmers' fields, the results from the experimental practices that most closely approximate farmer practices should be used.

Several more sophisticated biophysical models have been developed that provide a better representation of the effect of various forms of soil degradation and of other biophysical variables on productivity. EPIC (Williams, Renard, and Dyke 1983) is an example of such a model. Many of these models, including EPIC, retain the USLE as their core method of estimating erosion rates. Although such models clearly provide a more accurate simulation of the likely effects of erosion, they generally require very detailed soil information—the values of numerous variables disaggregated by soil horizon, for example. By and large, these models are not operational in developing countries.

Consistency checks. Whatever the method, or combination of methods, adopted to estimate the biophysical relationships, it is important to check the results for consistency with known information. The form that such consistency checks might take differs from case to case. Seckler (1987) cites a study carried out in the upper Solo basin of Central Java that estimated annual soil erosion at between 1,800 and 4,800 tons per hectare. A simple calculation shows, as Seckler notes, that this implies an average reduction of soil depth of 14–38 centimeters annually. This is an area in which a good qualitative understanding of the problem could help avoid some of the difficulties encountered in the quantitative analysis.

Inappropriate approaches

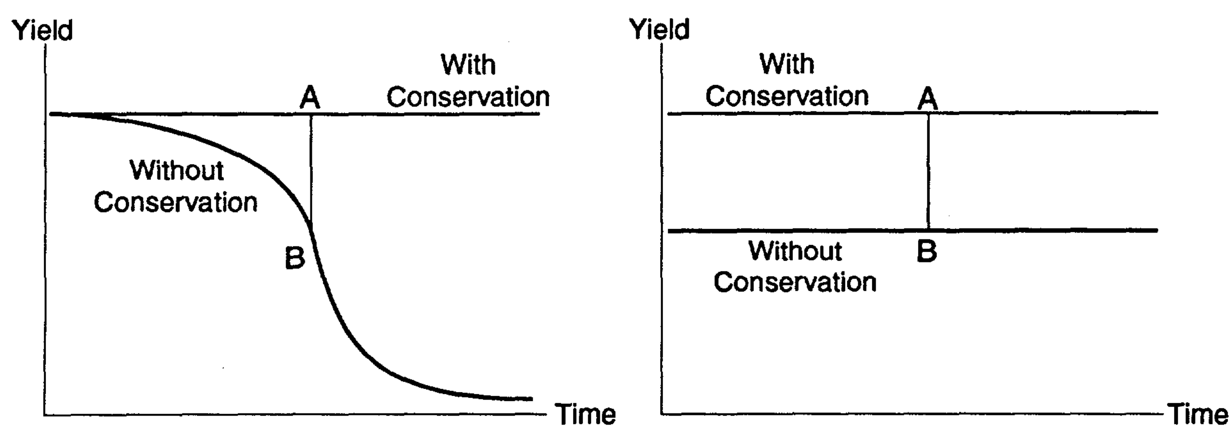
The availability of suitable data for soil conservation analysis has proved to be a significant stumbling block. In many cases, analysts have been forced to adopt approximations or incomplete data for any calculations to be carried out. All such approximations introduce possible errors in the measures of productivity effects and consequently reduce the confidence level of the estimates of profitability. In addition to reducing precision, however, some approximations also significantly bias the results of the analysis.

One such approximation that is common consists of using a fixed measure of the difference in yield between the alternative practices, which is assumed to remain constant throughout the period of analysis. This fixed measure might be an average of the difference in yield over a time period or an observed difference in yield at a particular time. Use of this measure is appealing because the data requirements are modest and, perhaps most important, the required data can be gathered quickly when the need arises, simply by measuring yields on samples of plots with and without the conservation measure. The use of a fixed difference in yield in the analysis of the returns to soil conservation can be challenged on many grounds, however. It is at best only a snapshot of the degradation process and might hide considerable variation in outcomes. Despite the apparent ease with which data can be collected, significant measurement problems are likely to be encountered, particularly in finding comparable plots. Most important, however, use of a fixed difference in yield can severely distort both the numerical and the qualitative results of the cost-benefit analysis (for a full discussion, see Pagiola 1992a).

The reason for the distortion can be seen in figure 2-3. Panel A shows the true time path of yield. Without conservation, degradation leads to a gradual decline in yield. At some point, cumulative degradation might drive yields to zero; long before such a point is reached, however, production will have become uneconomic. Conservation could prevent such degradation, leading to little or no change in yields over time, but at some cost. Use of a fixed difference in yield, however, is equivalent to assuming that the biophysical system behaves as in panel B. Unlike panel A, the yield effect of degradation does not build up gradually but rather occurs immediately. And unlike panel A, yield does not eventually decline to zero but rather remains at a constant level indefinitely. These two critical differences mean that analysis based on these two different models of the yield-degradation relationship leads to very different results.

Consider first the effect of an immediate rather than a gradual decline in yield. A gradual decline means that returns to soil conservation, which depend on the difference in yield between land with and without conservation, build up gradually. Conversely, an immediate decline in

Figure 2-3. Implicit Effect of Assuming a Fixed Yield Decline



A. True Time Path of Yield

B. Implicit Time Path of Yield Under a Fixed Yield Decline Assumption yield leads to an immediate jump in the returns to conservation. Since returns that occur later in the period of analysis are weighted less, because of discounting, than returns that occur earlier, the distribution of benefits affects the ultimate estimate of the returns to conservation. Specifically, the returns to soil conservation appear to be higher if an immediate rather than a gradual yield effect is assumed, since losses without conservation are brought forward to the heavily weighted initial period. The effect of shutdown on estimated returns to conservation is slightly different. Cumulative degradation, if left untreated, eventually causes production to become uneconomic as yields continue to decline, causing the stream of returns without conservation practices to drop to zero. If a fixed difference in yield between conservation and no conservation is used, however, and if production is profitable at the lower level of yield, it is undertaken and continues indefinitely. This tends to make the returns to conservation appear to be lower under the latter assumption, since returns to no conservation remain positive throughout the period of analysis.

Sources of data

Because agroecological conditions are very site-specific, the data required are also very site-specific. Possible data sources include experiment stations, Ministry of Agriculture records, various projects, local universities, and surveys; sometimes ad hoc surveys can collect suitable data. Often much of the data available is too aggregated: it does not distinguish between different conditions and practices. It is impossible to overemphasize the need to ensure that the data used are applicable to the case of interest; as the old saying goes, "garbage in, garbage out."

Economic data requirements

The economic data requirements generally pose significantly fewer problems. The main need is for crop production budgets, which are used to estimate returns. Although the kind of data required is generally widely available, however, it is rarely available at the degree of disaggregation needed. Fortunately, preliminary budgets built from available secondary data can usually be confirmed, supplemented, or corrected relatively easily with some additional fieldwork. Several of the points raised here apply to any kind of project for which cost-benefit analysis is being used; more extensive discussions can be found in numerous sources (Gittinger 1982 is probably the most widely available). Applying cost-benefit analysis to soil conservation issues does raise some distinct issues, however.

Input levels

The first step in constructing appropriate crop production budgets involves estimating the level of use of the various inputs. The most important problem here is to ensure that input levels accurately reflect practices in the area being studied. Even seemingly minor variations in practices can, at times, have significant effects on the profitability of agriculture and of conservation measures. Although often available from the Ministry of Agriculture, budgets should be verified in the field.

In cases where the conservation activity being investigated has yet to be implemented in the study area, input levels for this activity must be estimated. The problems involved in doing so vary according to the type of measure being considered. Where the measure consists of constructing a physical conservation work without otherwise changing farming practices, the input levels for the degrading activity can be used and any additional inputs required for conservation added. Modifications of current budgets might also be adequate for cases involving minor changes to existing practices. As changes to existing practices become more significant, however, entirely new budgets might be required. Basic parameters for such budgets might be obtained from experiment stations or from other regions where similar practices have been implemented. Care is required in using such estimates, however, since actual practice often differs—sometimes substantially—from experiment station practice, and differences in agroecological and economic conditions across areas might induce differences even in seemingly identical practices.

One difficulty involved in estimating input levels in such an intertemporal analysis is that they are unlikely to remain constant over the entire period of analysis. On the contrary, the level of various inputs can be expected to adjust as yields change in response to degradation or to conservation measures: use of complementary inputs will decline, while use of inputs that substitute for soil (such as fertilizers) will increase. At some point, returns under the degrading practice might become so low that cultivation would cease entirely, and the land would either be abandoned or be converted to a different use. If farmers can be identified who have already experienced different degrees of degradation, their use of inputs can be compared directly. Otherwise, the specific form that such changes might take could perhaps be obtained by consulting farmers as to their likely responses. Where such fieldwork is not possible, the most common approach is to adjust some inputs, particularly labor, in proportion to changes in yield and to leave all other inputs constant. Such crude approximations are not terribly satisfactory from a formal viewpoint but generally do not affect results tremendously. One likely result of omitting such adjustments in input levels is that net revenues under the degrading practice appear to decline faster than they would in reality; the returns to conservation, therefore, are slightly overestimated. Provision should also be made in the model for production to either cease or convert to an alternative activity when returns fall beyond a certain point.

Where the conservation practice takes the form of physical structures, engineering calculations are commonly used to estimate the amount of materials and other inputs required. If possible, these should be checked against actual field practice, which sometimes deviates from recommended practice. Deviations from recommended practice might also affect the efficiency of the measure, of course, so this should also be taken into account in estimating the productivity effects of the measures. Comparing estimates of returns to conservation with impeccably (and expensively) constructed physical works to those obtained with more cheaply constructed (and hence less effective) works often reveals interesting tradeoffs.

Prices

As in the case of input levels, the most important need is to ensure that the costs and prices used accurately represent the situation in the study area. This generally requires some fieldwork, since the prices found in published budgets are often out of date; moreover, official prices often differ from prices actually faced by farmers. Selecting appropriate prices involves selecting an appropriate base year for the analysis, since prices in any given year might be distorted from their "normal" levels for various reasons. Where prices often vary substantially from year to year, or follow a cycle, as occurs with crops such as coffee, it might be desirable to use an average price over the last five or so years; the analysis could also be repeated with high and low prices to determine the effects of such fluctuations on returns. Once prices are estimated for a base period, they are usually treated as real prices and kept fixed for the entire period of analysis, unless there is a specific reason to expect relative prices to change.

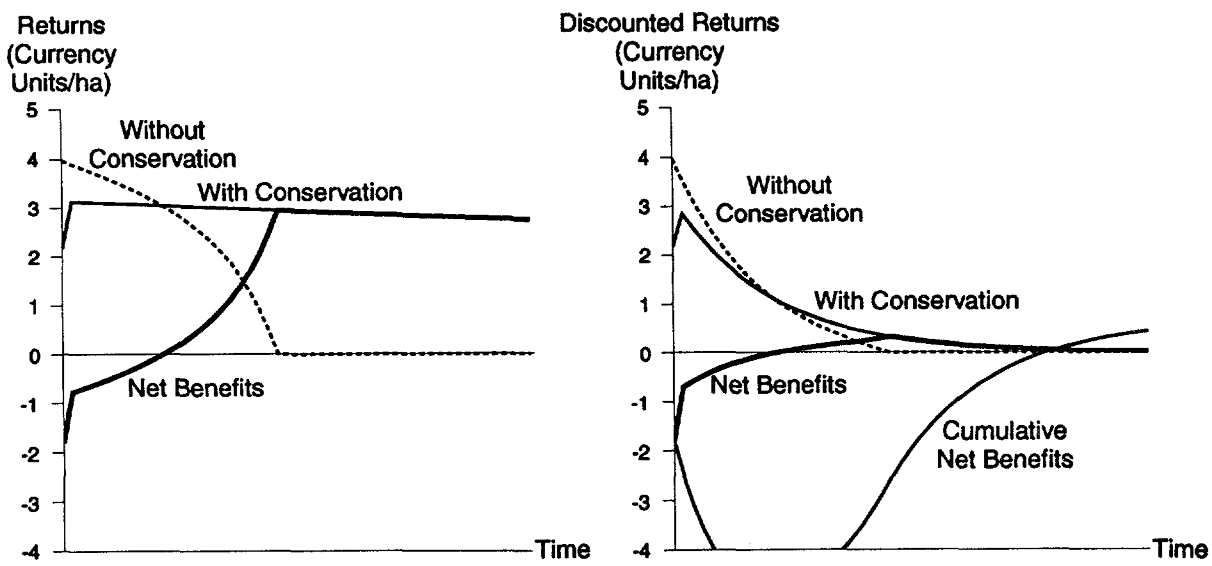
Choosing an appropriate wage rate often poses one of the most difficult problems, since much farming and conservation work is carried out with family labor. Costing this labor often requires analysis of the local labor market. Where labor markets are active and opportunities for work off the farm are reasonably easily available, using the going market wage rate to value family labor is justified, since that wage represents the opportunity cost to the household of time spent on conservation activities. In many instances, however, labor markets are imperfect or conservation work is carried out in the off-season, when the opportunity cost of labor is low. Since assumptions made about the wage rate often drive results, given the large share of labor in both production and conservation costs, considerable care needs to be taken in choosing an appropriate wage.

Another price whose choice is critical for the results is that of capital—the discount rate. The choice of an appropriate discount rate has been the subject of considerable controversy since, given the intertemporal nature of the problem, it will have a very significant effect on the results. At high discount rates, few measures that require heavy initial investments in order to obtain future benefits appear to be profitable. This is not the place to plunge anew into the polemic over discount rates, which has been discussed extensively in numerous other places (see, among others, Pierce, Barbier, and Markandya 1990). For the purpose of the discussion here, the most important point is that the discount rate used depends on the purpose of the analysis. If the analysis is centered on examining the profitability of conservation from the farmers' viewpoint, then the discount rate actually faced by farmers is the appropriate one to use. This is not as simple as it might sound, since farmers generally face highly imperfect capital markets. Here too, detailed knowledge of local capital markets is needed for accurate estimates. In practice, however, analysts often assume an arbitrary but plausible rate and then carry out sensitivity analysis. Where the purpose of the analysis is to calculate social profitability, then the best estimate of the social opportunity cost of capital is the appropriate discount rate to use; in this case, however, all other prices should also be adjusted to reflect social rather than private opportunity costs. In either case, the rate to use is the *real*, not the nominal, discount rate. The internal rate of return provides a useful statistic in cases where the discount rate is particularly uncertain or controversial.

Interpretation of results and sensitivity analysis

Figure 2-4 illustrates a typical returns profile for investments in soil conservation, in both current value (undiscounted) and present value (discounted) terms. For concreteness, this might be thought of as the return to an investment in terracing. As degradation gradually reduces yield, returns under the practice without conservation gradually decline. Eventually, the damage grows to the point that production becomes unprofitable. The specified conservation measure (terracing) is assumed to slow the rate of degradation substantially, but not to halt it. Thus returns under this practice also decline, but at a much slower rate than if the conservation practice had not been adopted. Returns to the practice with conservation are affected by two additional factors, however. First, there is an initial investment cost resulting from the need to build the terraces. This is shown by the downward spike in the first year of the analysis. In addition, yields might initially actually be lower than they would be if the conservation measure had not been adopted, because of, for example, loss of land to terrace edges resulting in a smaller effective area being cultivated. Farmers adopting the conservation practice must also bear recurring maintenance costs. Returns under conservation, therefore, are often initially lower—sometimes substantially so—than they would be if the conservation measure had not been adopted. As time passes, however, yield declines under the practice without conservation accumulate to the point where the conservation measure is more profitable despite

Figure 2-4. Typical Returns Profile for a Soil Conservation Problem



its higher costs. An additional period is then necessary, however, before the accumulated gains from adoption of the conservation measure are sufficient to offset its high initial costs. In some cases, this might never happen. As discussed earlier, a number of factors play a role in determining whether a given conservation measure is profitable.

The interpretation of a positive net present value for the investment is that farmers in the study area *facing conditions such as those specified in the example* would *personally* benefit from adopting the given conservation measure, even if they have to pay the entire cost of conservation themselves. This gain arises from the prevention of future yield losses due to cumulative degradation. This interpretation is only possible if all goods and resources are valued at their actual opportunity cost from the farmers' viewpoint, and all construction and maintenance costs are included in the calculations.

Sensitivity analysis can be used in two ways. First, sensitivity analysis can be used to examine whether certain assumptions or particularly suspect data have a significant impact on the results. Given the weakness of much of the available data, such tests are particularly important. Second, sensitivity analysis can be used in a more positive sense to study the effect of changes in parameter values on the results. It was stressed earlier that the results only apply to the specific conditions assumed in the example. Even if the conditions assumed in the base case are representative of conditions in a region, they are likely to represent only one point on a spectrum of conditions experienced in the region. Variations in slope, soil type, crops grown, and other biophysical variables all affect the precise rate of degradation experienced on a given plot of land. Variations in prices due to transport costs and other factors also affect the profitability of adopting conservation measures at a given location.

Extensions

The basic approach presented here provides a flexible tool to examine soil conservation problems and, with appropriate modifications, other resource problems. The chapters in the first part of this volume provide numerous examples of the application of these tools to soil degradation problems. In addition to providing estimates of the profitability or otherwise of specific conservation activities, the calculations required for the analysis can be used directly or with minor alterations to examine a number of issues.

Farm-level analysis

Cost-benefit analysis ignores the nonfinancial preferences of farmers (see chapter 16 in this volume) as well as constraints on access to resources. It simply states whether it would be in farmers' financial interest to adopt a particular soil conservation technology under specified circumstances. Only if farmers were operating under perfect markets with the sole objective of maximizing profits would such an analysis be sufficient to indicate whether soil conservation would be adopted. Imperfect credit markets, for example, might prevent adoption of costly soil conservation technology even if it were profitable. Although cost-benefit analysis does not directly address these issues, the calculations involved provide important insights into many of them.

Credit constraints. Soil conservation often imposes immediate costs (in terms of actual expenses and, in many cases, of forgone earnings) and brings benefits in the future. Suppose that, according to the cost-benefit analysis, investment in a particular conservation practice would be profitable. If the required absolute investment is too high in the initial periods, farmers might not be able to undertake it no matter how profitable it is. As a first cut to this issue, the analysis permits the magnitude of the initial investment and the cash flow generated by the activity to be calculated; this allows analysts to judge whether the sums involved are within the capacity of farmers, either through formal or informal credit markets or through self-financing. Alternatively, the practice could be modified to ease the constraint. For example, conservation might be undertaken gradually over several years. Such an approach might be less profitable—since land without conservation continues to degrade in the meantime—but more likely to be implemented.

Tenure problems. It has often been argued that conservation practices are not adopted because insecurity of tenure implies that farmers are not sure they will be able to draw the long-term benefits of their investments (see chapters 12, 14, and 15 in this volume). Calculating the returns to the activity of interest in terms of the number of years needed to repay the investment can be illuminating, since it permits a comparison between the payback period and the length of tenure. Unless tenure lasts at least as long as the minimum time for the investment to be repaid, farmers are unlikely to undertake it.

Social cost-benefit analysis

The analysis thus far has been carried out in private terms. That is, it provides estimates of the cost and returns to conservation activities *as perceived directly by farmers*. But private costs and benefits might diverge from the social costs and benefits of soil conservation for two main reasons. First, market failures or policy-induced distortions might distort signals received by farmers. Under such conditions, individual profit-maximizing behavior does not lead to a social optimum. Second, degradation might impose costs on society in addition to the decline in productivity on the fields where degradation occurs. If such costs are present, standard economic theory tells us that too little conservation is undertaken, since farmers do not take those costs into account in calculating how much they would be willing to pay to avoid a given amount of degradation.

Probably the most important potential divergence in the case of soil conservation concerns the discount rate, which plays a critical role in the profitability of conservation measures. Yet credit markets are frequently among the worst functioning markets. Policies that affect the relative profitability of various crops (such as taxes or subsidies) also affect the returns to soil conservation, since all crops are not equally damaging to the soil. In general, such problems can be studied by calculating the returns to soil conservation under both private and social prices and then comparing the two. There is an ample literature on procedures to correct observed market prices for distortions (see, among others, Gittinger 1982; Monke and Pearson 1989).

Externalities pose slightly different problems. Examples of externalities caused by erosion might include the siltation of reservoirs and increased erosion downslope. Such costs were ignored in the preceding discussion but may well be important in particular instances. Quantifying such external damages raises difficult problems that are not dealt with here. This method does allow, however, estimates to be made of the cost of reducing such damage by changing the activities that cause it. If the downstream damage due to erosion can be reduced by terracing farmers' fields, for example, the method allows the cost of such an investment to be calculated. Part of this cost is assigned to preventing declines in productivity. If productivity gains alone are not sufficient to justify the investment, then the negative NPV that will be calculated is an estimate of the minimum subsidy required to induce farmers to adopt the measure anyway.[16] Since there may be alternative measures of reducing the externality by any given amount, the least-cost way of achieving this objective (among the proposed methods) can be identified by comparing their profitabilities. Alternatively, the costs resulting from achieving different levels of reduction in the externality might be compared to determine the most cost-effective level of abatement.

Considerable concern has been expressed about the sustainability of agricultural production in situations characterized by rapid degradation. Definitions of sustainability vary but are usually couched in terms of maintaining the volume of output over time or of preserving a particular level of the resource stock. The activity identified as most profitable by the method presented here would not necessarily result in sustainability in that sense (although it may). In cases where the most profitable activity is not sustainable, the methodology presented here can answer two types of questions: Does an alternative practice exist that is both sustainable and profitable? How much worse off would farmers (at least in the short term) be if they were to adopt the most profitable sustainable practice rather than the absolutely most profitable practice?

Regional analysis

The procedure can also be used as a point of departure in estimating the effects of degradation at a more macro level, such as a region. For example, the method used here could generate expected patterns of degradation and the consequent productivity effects for various representative farms. A survey of the area of interest could then be used to find out how prevalent each system is; each model is then weighted appropriately to obtain estimates of trends for the entire area. If calculations are based on a parametric model of the biophysical environment, a detailed survey could be undertaken in which information on land use and all the relevant parameters for the model are recorded at each point on the survey grid. Calculations can then be made for each such point and the results aggregated to obtain estimates of erosion rates and likely productivity effects for the area as a whole. (If estimates are based on statistical relationships between activities and yield, such an approach would only be valid for regions where conditions are very homogenous.)

Such macro analysis would probably have to take into account endogeneity issues; that is to say, the effects of degradation might change some of the parameter values that describe the situation facing farmers and therefore the future path they will follow. For example, if all farmers experience degradation, production will decline and prices will rise. This will be very likely to change the relative returns of erosive and conservation practices.

Conclusions

The application of cost-benefit analysis to soil conservation problems described in this paper demonstrates that analysis of resource issues in developing countries is possible using even relatively limited data. Even so, the data requirements may be difficult to meet in many circumstances, especially in light of the high degree of site-specificity of the problems involved. In such cases, attempting to carry out a coherent, consistent analysis such as that described here will allow gaps and weaknesses in the available data to be identified. The case studies in the first part of this volume provide numerous examples of the application of the techniques described in this chapter to a variety of agroecological and institutional settings. They illustrate how a variety of data sources can be used in the analysis and bring out many limitations in the current data base.

Notes

1. For a standard text on soil properties, which places considerable emphasis on soil's *edaphological* properties (that is, its properties in relation to plant production), see Brady (1984).
2. If efficient markets for land exist, it can be argued that they provide an implicit market for soil per se through soil's effect on land values (McConnell 1983). However, since land values in such markets are themselves determined by the future productive potential of the land, the ultimate market remains one for the products of the soil rather than for the soil itself. Whether land markets do in fact reflect soil quality has been the subject of controversy.
3. In some cases, however, the same-year damage to the crop may be significant. For example, soil erosion might wash away seed and fertilizer, causing significant reductions in yield even though the inherent productivity of the soil has changed little.
4. Soil degradation might also damage the functioning of ecological systems. This issue does not arise very often, however, in the analysis of soil conservation, because agricultural environments are already modified from their natural environments. For better or worse, a decision has already been made to use these areas for agricultural purposes, and the issue then becomes how best to use them for this end. Ecological concerns are likely to arise, however, when land is newly converted to agriculture. In addition, some types of land use are more ecologically benign than others; conversion to or from these uses would, therefore, raise ecological issues in addition to economic ones.
5. Although deposition of soil onto plots can be beneficial in the long run, the initial deposition often damages standing crops. Deposition can also be harmful if productive low-lying land is buried under less-productive, nutrient-poor sediment from upland erosion.
6. In general, we assume that the proposed change is less degrading than current practices, but the opposite case is also possible. For example, a higher-yielding but more degrading practice might be proposed to replace a lower-yielding but more conserving traditional practice. In this case, path B would represent the current practice and path A the alternative. The proposed methodology would be equally applicable in determining which path is economically preferable.
7. In fact, considerable uncertainty exists regarding rates of soil generation. For an interesting discussion of the concept and (mis)measurement of T values, see Johnson (1987).

8. As used here, the terms "private" and "social" are equivalent to Gittinger's terms "financial" and "economic" (1982).
9. Recent reviews by Lal (1987) and Stocking (1984) provide an overview of the state of knowledge in this field, with specific attention to soil erosion.
10. The USLE is generally expressed in Customary English Units (CEU); the units indicated here are for the SI metric version. See Wischmeier and Smith (1978) for conversion factors.
11. Numerous examples of applications of the USLE to areas outside the United States can be found in El-Swaify, Moldenhauer, and Lo (1985). For a more detailed example of an application to Ethiopia, see Hurni (1985).
12. The rainfall erosivity (R) factor is usually measured using the EI_{30} index. Some researchers, among them Hudson (1981), have suggested that other indexes might be more appropriate for tropical conditions. The experimental evidence on this matter is mixed. A nomograph has been developed by the U.S. Department of Agriculture to estimate the soil erodibility (K) factor from various physical properties (Wischmeier and Smith 1978), but its applicability to conditions outside the United States is in dispute. If an index other than EI_{30} is used for R, the K factor must be modified accordingly.
13. However, the U.S. Department of Agriculture formula to calculate the slope (S) factor is only valid on slopes up to 18 percent. Although the formula is frequently used on steeper slopes, some results suggest that the resulting S factor is too high (Hurni 1982).
14. This is a problem that the statistical approach avoids, since it measures the net effects of all the factors at play. In doing so, however, the statistical approach also conceals these factors in a "black box," thus preventing their use in the design of appropriate conservation measures.
15. Data from a desurfacing experiment are generally thought to underestimate the severity of productivity decline due to erosion (because nutrients are preferentially carried away under natural erosion conditions), so they should be used with care. Conversely, it has also been suggested (Thomas, personal communication) that such data overestimate the impact because desurfacing removes all the organic matter from the soil, whereas under natural erosion conditions organic matter continues to regenerate in the upper layers of the remaining soil.
16. Judging whether this per farm cost of avoiding erosion is worth bearing from a social viewpoint is difficult because considerable uncertainty exists about the impact of any one farm on the total external damage. Estimates of the delivery ratio (the proportion of total soil eroded that is delivered to the waterway) in any given catchment often differ by orders of magnitude.

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3. Economic Analysis of Soil Conservation Projects in Costa Rica

Mauricio D. Cuesta

The agricultural sector contributes about 20 percent of Costa Rica's gross national product and generates about 70 percent of its foreign exchange. Sustaining and improving the productivity of agriculture is very important, therefore, for the process of economic development in Costa Rica as well as for the welfare of the significant proportion of the population employed in the sector (28 percent in 1988).

Agricultural expansion is likely to have produced some inadequate use of ecologically fragile areas, thus creating soil degradation. In 1984, 42 percent of the agricultural area was thought to have been affected by soil erosion (Dercksen 1991a), although such global estimates are weak.

Soil conservation in Costa Rica

As early as 1942, an agricultural extension service project was undertaken that had a strong soil and water conservation component (anonymous 1948). The project promoted methodologies and equipment that are still being used by some farmers (Dercksen 1991a). The service lasted until December 1955 and became part of the Ministry of Agriculture and Industry in January of 1956 (Alvarado and others 1983). Aware that the sustained increase of agricultural productivity could only be achieved through the application of modern techniques of soil management and conservation, the government promulgated the Law of Natural Resource Conservation in 1953, with the purpose of promoting conservation and improving and restoring water and soils (Bonilla 1985). The law also required farmers and others to observe measures dictated by the Ministry of Agriculture and Industry for preventing and controlling erosion and for maintaining and increasing fertility of the land.

The government neglected soil conservation activities during the 1970s. Renewed interest arose in the 1980s, with the implementation of the Natural Resource Conservation Project (CORENA) in the zone of Puriscal and the Parrita and the Hojancha rivers in the Nicoya Peninsula. In 1984, the Food and Agriculture Organization of the United Nations (FAO) began a project with the objective of introducing a series of conservation measures. A follow-up project, initiated in 1991 in cooperation with the National Soil and Water Conservation Service (SENACSA), promotes soil conservation on small farms. Soil conservation activities in recent years have included the elaboration by SENACSA, with the institutional support of the FAO, of a manual for use in all soil conservation activities; a joint FAO-Holland-SENACSA program of technical assistance in soil conservation; and training of personnel from the Ministry of Agriculture and Livestock, through both short courses and continued and permanent training, in conservation and soil use. Projects have also been undertaken with assistance from the European Economic Community, German Agency for Technical Cooperation, Proyecto Desarrollo Agrícola Forestal, and Instituto Interamericano de Cooperación para la Agricultura. Universities have incorporated conservationist subjects in their programs of study. SENACSA and the Universidad Nacional Autónoma, through the Schools of Geographical Sciences, are collaborating closely on research into the dimensions of the soil erosion problem in various parts of the country. Considerable conservation work has also been carried out by nongovernmental organizations, such as Vecinos Mundiales, and by farmer cooperatives and unions.

The National Development Plan for 1986–90 promoted an integrated effort to manage and use the country's renewable natural resources, employing the concept of sustainable development. Among the actions included in the plan were the creation of SENACSA; the preparation of a new soil conservation law aimed at carrying out, modifying, and improving the 1953 Natural Resource Law; and passage of numerous other laws aimed at discouraging degradation of the resource stock and promoting conservation. Presently, Costa Rica has a series of projects on environmental conservation and protection that include soil conservation components. They are directed, financed, and executed by donors, through local and international nongovernmental organizations and educational research institutions.

The natural resource protection effort falls under the direction of the Ministry of Energy, Mining, and Natural Resources, which is responsible for setting conservation policy and for directing the management of watersheds through the Executive Secretariat for Watersheds, the coordinating body integrated by various institutions of the state. The Ministry of Agriculture and Livestock is responsible for managing and directing agricultural resources through SENACSA, which issues rules and criteria at the national level. The guidelines for planning in the agricultural sector are developed by the Executive Secretariat for Sectoral Planning in Agriculture, which concentrates and coordinates the efforts of agricultural institutions. In addition, the National Commission on Research and Extension of Agricultural Technology, created in 1989, is in charge of coordinating technically the development and execution of the National Agricultural Sector Plan and of research and technology transfer, in which soil conservation programs are a priority.

Soil conservation projects are undertaken by SENACSA, which provides counterpart personnel in each of the eight regional management units of the Ministry of Agriculture and Livestock. These soil conservation professionals provide training services to agricultural extension agents, coordinate soil conservation efforts, promote and establish regional land use committees, and supervise and advise extension agents. Funds derived from the FAO-SENACSA projects have provided the service with vehicles, machinery, and equipment for constructing the physical works of conservation. The project is structured so that the maintenance of basic equipment (tractors, implements, vehicles, and so forth) is self-financed with funds derived from payments received for construction services and the management of funds. The Ministry of Agriculture and Livestock establishes the salary and per diem of SENACSA personnel following general public sector guidelines. These rates are significantly lower than those in the private sector, and few financial incentives and little motivation exist for carrying out work in the field.

The cost of building conservation works is subsidized for small farmers (farmers with less than 5 hectares): SENACSA bears half of the costs of conservation. Moreover, farmers whose land is used as a model farm for the demonstration of conservation measures do not pay for the services that SENACSA carries out in the field.

Despite its many activities, SENACSA is not reaching most farmers. According to Jiménez and Quirós (1991), "the agricultural and forestry extension system has barely achieved a coverage of 15–20 percent of the population dedicated to these activities." Numerous agencies do not take conservation into consideration in their activities. The Institute for Agricultural Development (IDA), for example, distributes land without considering its capacity for use (Proyecto Forestal IDA-FAO-Holanda 1990). In some cases, perverse incentive structures are created: the reforestation credit system, for example, could actually be encouraging deforestation since farmers might deforest in order to qualify for credit to reforest.

Data

Despite the considerable amount of work on soil conservation that has been carried out in Costa Rica, data on the problem are scarce. In addition to using field data collected in each of the study areas, the analysis relies on an adaptation of the

Universal Soil Loss Equation (USLE) to Costa Rican conditions (Wischmeier and Smith 1978).

Harden (1991) and El-Swaify (1989) have argued that the USLE is not appropriate for conditions in tropical countries. Thanks to work by Jeffery, Dercksen, and Sonneveld (1989), these limitations have been partially overcome for Costa Rica. Using this methodology, SENACSA has developed a 1:200,000 erosion map. The rainfall erosivity factor, R, was calculated using the formula developed for Puerto Rico, where climatic conditions are similar to those of Costa Rica (Woodward 1975; Vahrson and Fallas 1988). The soil erodibility factor, K, was calculated using the original formula and data available from the analysis of soil samples.[1] Average K factors were calculated for physiographic mapping units, based on a 1:200,000 scale soil map (Vásquez 1988) and the interpretation of aerial photographs. Average slope and length factors, LS, were calculated for various topographic classes. Crop and management factors, C, and conservation practice factors, P, were taken from Jeffery, Dercksen, and Sonneveld (1989).

This adaptation of the USLE was designed primarily to identify areas subject to severe erosion. For this purpose, the estimates obtained were adequate (Jeffery, Dercksen, and Sonneveld 1989). Comparisons of calculated erosion values with measurements made on runoff plots show, however, that the coefficients proposed by Jeffery, Dercksen, and Sonneveld (1989) tend to overestimate erosion rates. Cortés and Oconitrillo (1987), for example, report annual soil losses on strongly undulating slopes in the Tierra Blanca area in the range of 0.01–30.8 metric tons per hectare. Even the maximum value in that range is far below the value calculated for the same region: 184.5 metric tons per hectare a year. Forsythe (1991) cites a case in which the USLE overestimated soil loss by 152 times and suggests that the extrapolation of the USLE may not be valid on slopes above 39 percent. These limitations should be borne in mind when considering the results below.

The costs of crop production in each area were obtained from the Banco Nacional de Costa Rica (1991). This information consists of production costs and yields for each crop in 1991. The percentages of the components of costs of production correspond to the cost structure of 1988. The information is reviewed and adjusted annually by an inter-institutional commission. The costs of the soil conservation work are based on the prices and tariffs that SENACSA charges, which are set by government decree. These data were supplemented where necessary by farmer surveys carried out in the study areas.

Economic analysis of three conservation projects

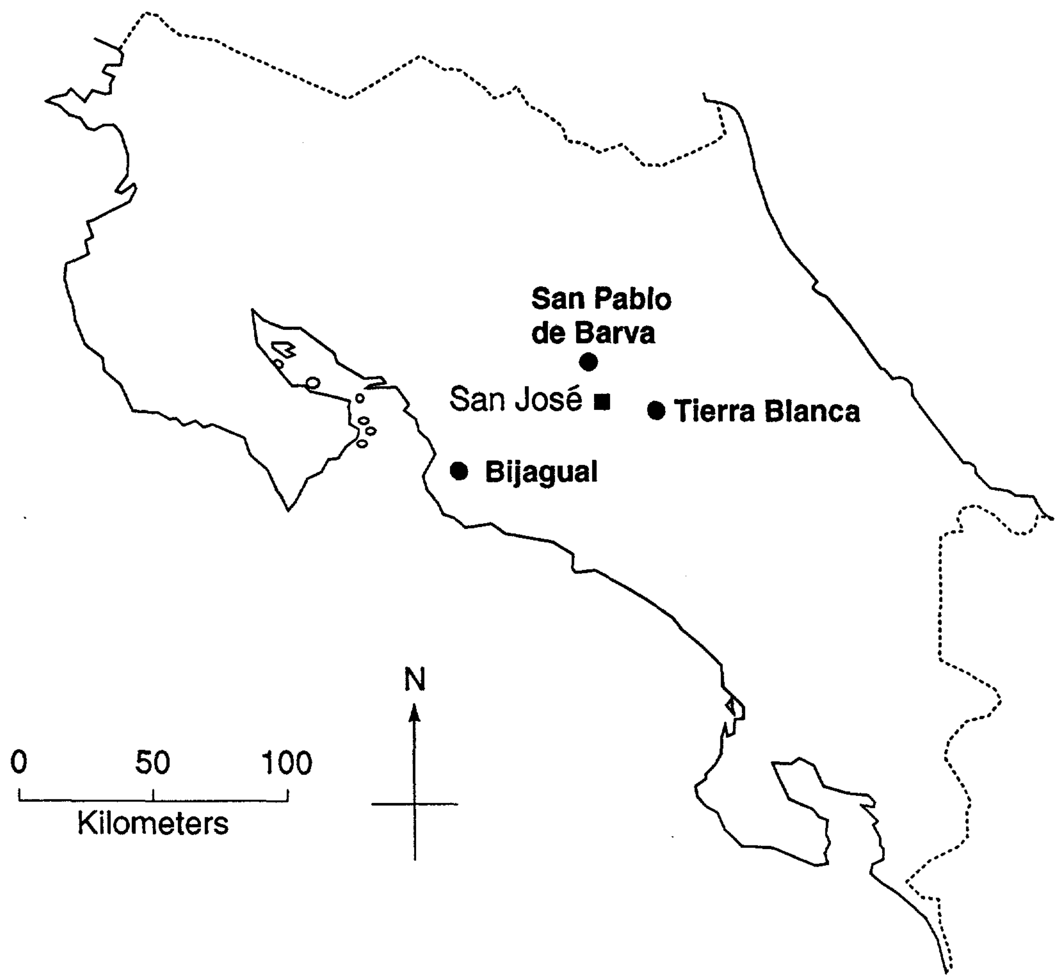
This section describes an economic analysis of conservation efforts in three areas (see figure 3-1). The first case study is of the San Pablo de Barva area of the province of Heredia, in the western central region of the watershed of the Río Grande de Tárcoles, one of the primary coffee-producing regions in the country. The second case study is of the potato-producing area of Tierra Blanca–San Juan Chicoá, in the province of Cartago in the eastern central region of the watershed of Río Reventazón-Parismina. The third is of the area of Turrubares, located in the watershed of the Río Grande of Tárcoles in the central Pacific region.

Heredia

Heredia lies at an altitude of 1,054 to 1,530 meters above sea level; the topography is softly undulating, with slopes of 5 to 30 percent. The climate is hot and humid, with a moderate water deficit; average annual precipitation is 2,200 to 2,800 millimeters, with a dry season that lasts from late December to the end of April. The average annual temperature is 21°C to 25°C. Land use capacity is classified as classes II, III, and IV, indicating slight to strong topographic limitations and the need for conservation measures if cropping is undertaken. Class IV lands should, in principle, only be used for semipermanent and permanent vegetation. Soils in the area are inceptisols and relatively deep, with the A horizon extending to a depth of 45 centimeters and the B horizon extending another 1.5 meters. The topmost (A_p) horizon contains 8.3 percent organic matter; the organic matter content declines with depth, falling to 3.2 percent in the top (B_{w1}) layer of the B horizon and about 2 percent below that.

Cultivation of coffee predominates in Heredia. Research in coffee technology has resulted in the development of high-yield coffee hybrids. Coffee plantations are being renewed with improved varieties that can tolerate complete exposure to the sun (no shade). The system without shade has achieved a 16 percent increase in

Figure 3-1. Costa Rica: Location of the Study Sites



production over the system that requires shade but has increased the soil's vulnerability to erosion. The analysis below attempts to evaluate the benefits of constructing diversion ditches, which are common conservation works in the coffee plantations in the zone.

Soil loss with and without conservation was estimated using the USLE. The following coefficients, taken from Jeffery, Dercksen, and Sonneveld (1989) are assumed:

Rainfall erosivity (R): 425
Soil erodibility (K): 0.19 for inceptisols
Slope and length (LS): 2.11 on a 3–15 percent slope
Crop management (C): 0.086 for a perennial crop
Conservation practice without conservation (P_{UNCONS}): 0.58 for contour planting
Conservation practice with conservation (P_{CONS}): 0.29 for diversion ditches

With these coefficients, the average predicted soil losses are as follows:

With conservation:

A_{CONS} = R K LS C P_{CONS}
= 4.2 metric tons per hectare a year
= 0.4 millimeter a year

Without conservation:

A_{UNCONS} = R K LS C P_{UNCONS}
= 8.5 metric tons per hectare a year
= 0.8 millimeter a year

Note that construction of the conservation measure slows erosion but does not halt it.

Yield loss as a result of soil loss was estimated using the results of a study carried out by the Programa Cooperativo del Café that shows the crop's response to increasing doses of nitrogen fertilizer (ICAFE 1990). The study assumed that nitrogen is the only element that influences or limits the yield of the crop and that lost nitrogen is not recovered or substituted. If 5 percent of the organic matter in the soil corresponds to total nitrogen and 5–15 percent of this is assimilable by the plant (Fassbender 1984), and since soils in Heredia are 8.3 percent organic matter and have an apparent density of 1.05 grams per cubic centimeter, then on average 4.32 kilograms of nitrogen are lost per millimeter of soil loss. Average yield obtained in the area is 11,348 kilograms per hectare (ICAFE 1988). At this level of yield, the efficiency of nitrogen fertilizer is about 35.9 kilograms of coffee per kilogram of nitrogen (ICAFE 1990). Thus, if 4.32 kilograms of nitrogen were lost due to erosion, for example, coffee production would decrease 155 kilograms.

In the case without conservation, therefore, annual yield loss would be 124 kilograms, given the estimated soil loss of 0.8 millimeter a year. With conservation, the rate of soil loss is lower, so the rate of yield loss is correspondingly lower. However, the effective area planted is reduced 8.4 percent since some land is lost to the ditches. Annual yield loss in this case is 57 kilograms.

With the determination of soil loss and its effect on production, in combination with the information on prices, costs of production, and conservation costs, it was possible to estimate the profitability of investment in the conservation measure. The results are shown in table 3-1.

If the assumed relationship between soil loss and yield loss is correct, it does not, under current conditions, pay for coffee farmers to invest in ditches for conserving soil in Heredia. The net present value shown in table 3-1 is calculated using a discount rate of 20 percent, but the result holds true at any positive rate of interest, as shown by the negative internal rate of return. In this case, returns to farming without conservation are consistently greater than returns to farming with conservation. Although yield loss is lower when conservation is adopted, the reduction in the effective area under cultivation more than offsets this benefit. Even with the long-term gain in productivity, therefore, investment in this type of conservation work is not justified.

This result would hold even if the specified conservation measures completely halted erosion on conserved plots.[2] This type of conservation measure would only begin to pay if the rate at which yield declined under the case without conservation were substantially higher. For example, if conservation stopped erosion entirely and erosion rates (or, equivalently, the rate at which yield declined in response to erosion) tripled, then conservation would pay, with an internal rate of return of about 21 percent. Even so, it would take seventeen years for the investment to be repaid. Since, in fact, the rate of erosion is likely to be overestimated, the result that conservation does not pay in this area is likely to be quite robust. The result that conservation does not pay is also robust when considering changes in the price of coffee.

CARTAGO

Physical characteristics, favorable climate, and proximity to metropolitan markets make the Cartago area strategically important for vegetable production. On average, the area supplies 80 percent of the national consumption of potatoes. Production is predominantly on small landholdings, with vegetables planted in a continual succession of crops. The crop sequence follows market demand rather than agricultural or conservationist criteria (Bronzoni and Villalobos 1989). Agriculture is highly intensive, and farmers use plowing techniques that break up the soil, thus promoting soil degradation through water erosion. The effects of this erosion are felt in the sedimentation of the Cachí reservoir, reducing its useful life and its capacity to generate hydroelectricity (SENACSA 1986). Large accumulations of soil are often found on the highway that borders the Irazú volcano.

The Tierra Blanca–San Juan Chicoá area in Cartago lies at an altitude of about 1,800 to 3,000 meters above sea level and has slopes of 5 to 60 percent. The region has a temperate, rainy climate, with a moderate water deficit; average annual precipitation is 1,300 to 1,700 millimeters, with a dry season that lasts from December to April. The soils of the zone are inceptisols characterized by a very deep A horizon (up to 90 centimeters in places), with consistently high organic matter content throughout the soil profile. The underlying B horizon is also fertile, although less so than the A horizon.

Given the fertility and depth of the region's volcanic soils, little productivity loss seems to have occurred as a result of soil loss. However, the use of inputs has increased gradually and

Table 3-1. Analysis of Returns to the Construction of Diversion Ditches on Farms Planted to Coffee in San Pablo de Barva, Heredia Province, Costa Rica, for a 100-Year Time Horizon
(colones per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Soil loss (millimeters)	0.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Cumulative soil loss (millimeters)	0.0	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	15.2	15.2	15.2	15.2	15.2
Yield (kilograms per hectare)	11,384	11,260	11,136	11,012	10,888	10,764	10,640	10,516	10,392	10,268	10,144	0	0	0	0	0
Revenues	234,397	231,844	229,292	226,739	224,187	221,634	219,082	216,529	213,977	211,424	208,872	0	0	0	0	0
Crop production costs	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	0	0	0	0	0
Returns	49,475	46,922	44,370	41,817	39,265	36,712	34,160	31,607	29,055	26,502	23,950	0	0	0	0	0
Present value returns	49,475	39,102	30,812	24,200	18,936	14,754	11,440	8,821	6,757	5,136	3,868	0	0	0	0	0
Number of years before shutdown	20															
With conservation																
Soil loss (millimeters)	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Cumulative soil loss (millimeters)	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	7.6	7.6	7.6	7.6	7.6
Yield (kilograms per hectare)	10,428	10,371	10,314	10,257	10,201	10,144	10,087	10,030	9,974	9,917	9,860	0	0	0	0	0
Revenues	214,707	213,538	212,369	211,200	210,031	208,862	207,693	206,524	205,355	204,186	203,017	0	0	0	0	0
Crop production costs	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	184,922	0	0	0	0	0
Conservation costs	9,063	5,112	5,112	5,112	5,112	5,112	5,112	5,112	5,112	5,112	5,112	0	0	0	0	0
Returns	20,722	23,504	22,335	21,166	19,997	18,828	17,659	16,490	15,321	14,152	12,983	0	0	0	0	0
Present value returns	20,722	19,587	15,511	12,249	9,644	7,567	5,914	4,602	3,563	2,743	2,097	0	0	0	0	0
Number of years before shutdown	19															
Returns to conservation																
Net benefits	-28,752	-23,418	-22,034	-20,651	-19,268	-17,884	-16,501	-15,117	-13,734	-12,350	-10,967	0	0	0	0	0
Present value net benefits	-28,752	-19,515	-15,302	-11,951	-9,292	-7,187	-5,526	-4,219	-3,194	-2,394	-1,771	0	0	0	0	0
Cumulative present value net benefits	-28,752	-48,267	-63,569	-75,520	-84,812	-91,999	-97,525	-101,744	-104,938	-107,331	-109,103	-112,787	-112,787	-112,787	-112,787	-112,787
Net present value																
50 years	-112,787															
100 years	-112,787															
Internal rate of return (percent)	< 0															
Number of years to break even	Never															

Source: Author's calculations.

steadily in the area; according to farmers, the quantity of fertilizer used has increased 50 percent in the past fifteen years. At least some of this increase is thought to result from the gradual exposure of less fertile subsoils; an estimated 10–15 percent of the region has outcroppings of the B horizon, which is evident on the ground by areas of land with a yellowish-brown color. This soil condition reduces production, but due to the relatively high fertility of the B horizon, this reduction can be compensated for by applying fertilizer, which does, however, increase the cost of production. Erosion also reduces productivity, not so much because it decreases the depth of the soil but because it washes away the soil covering planted potatoes. This exposes the seed, producing green potatoes, destroying seed beds, and forming ditches down the slope. Fertilizer also tends to be washed away and is, therefore, less efficient. Erosion also affects the costs of production because of the resulting outcropping of rocks. The region is characterized by a volcanic loess with many hard, heavy rocks that average 10–30 centimeters in size, and these remain on the field as soil loss proceeds. These rocks must be regularly "harvested" to allow production to continue.

An attempt was made to evaluate the impact that the construction of diversion ditches has on the production of potatoes. The main effect of erosion is, as discussed above, not on yield but on the costs of production. These costs increase as erosion proceeds due to the need to harvest exposed rocks and to the increasing cost of fertilizers, which occurs partly because less fertile subsoils are exposed and partly because efficiency decreases.

Estimates of cost increases were based on a questionnaire completed by a small sample of six farmers and on observations of their farms. The annual cost of harvesting rocks is estimated to be ¢15,500 in the case without conservation.[3] With conservation, this cost is reduced in proportion to the reduction in erosion. It is assumed that the entire increase in fertilizer use is due to the need both to offset efficiency losses and to boost fertility. A 50 percent increase in fertilizer use over fifteen years represents an annual rate of increase of 2.74 percent; since fertilizer accounts for 13.76 percent of total costs, costs are estimated to increase 0.38 percent annually in the case without conservation. Decreases in erosion, which occur as a result of conservation, reduce this rate proportionally.

The results of the analysis are shown in table 3-2. In this case as well, adoption of conservation ditches is found not to pay off for farmers; the rate of return is negative. Conditions in the area are such that soil can be "mined" with little apparent detriment to production. In general, conservation works are not acceptable because, besides paying the costs of construction, farmers lose the potential income from the area that is not planted. These results are quite robust to changes in parameter values. Moreover, they are likely to overestimate returns to conservation for two reasons. First, the cost of conservation used in the calculations includes an implicit subsidy by SENACSA, which would construct the measures at less than full cost. Second, the adoption of conservation measures would also increase the costs of land preparation, given the long and narrow shape of fields in the area. These higher costs are not included in the calculations; if they were, the estimated returns to conservation would be even lower.

Turrubares

The Turrubares area was for many years used as pasture for producing beef and cultivating crops such as coffee, tomatoes, sweet peppers, corn, beans, and rice. At the present time, the land is being distributed among farmers. A project of the European Economic Community has promoted the production of cocoa yam for export. This activity has been successful compared with the negative experience with achiote, which was also cultivated for export. However, since cocoa yam is an annual crop cultivated on bare soil, the potential for degradation is high, especially on the steep slopes (30 percent or more) found in the region.

The study area lies at about 400 to 500 meters above sea level. The climate is hot and humid, with a large water deficit. Average annual precipitation is 2,400 to 2,740 millimeters, with a dry season that lasts from December to April. The soils of the area are ultisols. The A horizon extends only to a depth of 8 centimeters. Despite having rough textures throughout the profile, these soils have a good structure. This characteristic allows for good ventilation and infiltration and appropriate effective depth. Although morphologically good, these soils present characteristics of old soils and have a low Cation Exchange Capacity (Cubero and Coghi 1989). Since most of the organic material is located in

Table 3-2. Analysis of Returns to the Construction of Diversion Ditches on Farms Planted to Potatoes in Tierra Blanca, Cartago Province, Costa Rica, for a 100-Year Time Horizon

(colones per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772	20,772
Revenues	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554	574,554
Crop production costs	388,315	389,732	391,148	392,565	393,982	395,398	396,815	398,232	399,649	401,065	402,482	416,649	430,816	444,983	459,150	529,985
Returns	186,239	184,822	183,405	181,988	180,572	179,155	177,738	176,322	174,905	173,488	172,072	157,905	143,738	129,571	115,404	44,569
Present value returns	186,239	154,018	127,365	105,317	87,081	71,998	59,524	49,208	40,677	33,623	27,791	4,119	606	88	13	0
Number of years before shutdown	101															
With conservation																
Yield (kilograms per hectare)	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030	18,030
Revenues	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712	498,712
Crop production costs	379,341	379,938	380,534	381,131	381,727	382,324	382,920	383,517	384,113	384,710	385,306	391,271	397,236	403,201	409,167	438,992
Conservation costs	22,956	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200
Returns	96,415	114,575	113,978	113,382	112,785	112,189	111,592	110,996	110,399	109,803	109,206	103,241	97,276	91,311	85,346	55,521
Present value returns	96,415	95,479	79,151	65,614	54,391	45,086	37,372	30,977	25,675	21,280	17,637	2,693	410	62	9	0
Number of years before shutdown	101															
Returns to conservation																
Net benefits	-89,823	-70,247	-69,427	-68,607	-67,787	-66,966	-66,146	-65,326	-64,506	-63,686	-62,865	-54,664	-46,462	-38,260	-30,058	10,952
Present value net benefits	-89,823	-58,539	-48,213	-39,703	-32,690	-26,912	-22,152	-18,231	-15,002	-12,343	-10,153	-1,426	-196	-26	-3	0
Cumulative present value net benefits	-89,823	-148,363	-196,576	-236,279	-268,969	-295,882	-318,034	-336,265	-351,267	-363,610	-373,763	-414,067	-419,680	-420,441	-420,541	-420,554
Net present value																
50 years	-420,541															
100 years	-420,554															
Internal rate of return (percent)	< 0															
Number of years to break even	Never															

Source: Author's calculations.

Table 3-3. Analysis of Returns to the Construction of Diversion Ditches on Farms Planted to Coco Yams in Turrubares, Costa Rica, for a 100-Year Time Horizon
(colones per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	12,856	8,614	5,771	3,867	0	0	0	0	0	0	0	0	0	0	0	0
Revenues	462,816	310,087	207,758	139,198	0	0	0	0	0	0	0	0	0	0	0	0
Crop production costs	114,870	114,870	114,870	114,870	0	0	0	0	0	0	0	0	0	0	0	0
Returns	347,946	195,217	92,888	24,328	0	0	0	0	0	0	0	0	0	0	0	0
Present value returns	347,946	162,681	64,506	14,079	0	0	0	0	0	0	0	0	0	0	0	0
Number of years before shutdown	4															
With conservation																
Yield (kilograms per hectare)	11,468	9,575	7,995	6,676	5,575	4,655	3,887	0	0	0	0	0	0	0	0	0
Revenues	412,832	344,715	287,837	240,344	200,687	167,574	139,924	0	0	0	0	0	0	0	0	0
Crop production costs	114,870	114,870	114,870	114,870	114,870	114,870	114,870	0	0	0	0	0	0	0	0	0
Conservation costs	14,644	3,900	3,900	3,900	3,900	3,900	3,900	0	0	0	0	0	0	0	0	0
Returns	283,318	225,945	169,067	121,574	81,917	48,804	21,154	0	0	0	0	0	0	0	0	0
Present value returns	283,318	188,287	117,407	70,355	39,505	19,613	7,084	0	0	0	0	0	0	0	0	0
Number of years before shutdown	7															
Returns to conservation																
Net benefits	-64,628	30,728	76,179	97,246	81,917	48,804	21,154	0	0	0	0	0	0	0	0	0
Present value net benefits	-64,628	25,607	52,902	56,276	39,505	19,613	7,084	0	0	0	0	0	0	0	0	0
Cumulative present value net benefits	-64,628	-39,022	13,880	70,157	109,661	129,274	136,359	136,359	136,359	136,359	136,359	136,359	136,359	136,359	136,359	136,359
Net present value																
50 years	136,359															
100 years	136,359															
Internal rate of return (percent)	84.2															
Number of years to break even	2															

Source: Author's calculations.

Table 3-4. Analysis of Returns to the Construction of Terraces on Farms Planted to Cocoa Yams in Turrubares, Costa Rica, for a 100-Year Time Horizon

(colones per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	12,856	8,614	5,771	3,867	0	0	0	0	0	0	0	0	0	0	0	0
Revenues	462,816	310,087	207,758	139,198	0	0	0	0	0	0	0	0	0	0	0	0
Crop production costs	114,870	114,870	114,870	114,870	0	0	0	0	0	0	0	0	0	0	0	0
Returns	347,946	195,217	92,888	24,328	0	0	0	0	0	0	0	0	0	0	0	0
Present value returns	347,946	162,681	64,506	14,079	0	0	0	0	0	0	0	0	0	0	0	0
Number of years before shutdown	4															
With conservation																
Yield (kilograms per hectare)	9,385	9,191	9,002	8,816	8,634	8,456	8,282	8,111	7,944	7,780	7,619	6,186	5,022	4,077	3,310	0
Revenues	337,856	330,887	324,063	317,379	310,833	304,422	298,143	291,994	285,972	280,074	274,297	222,696	180,801	146,788	119,174	0
Crop production costs	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	114,870	0
Conservation costs	51,841	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Returns	171,145	216,017	209,193	202,509	195,963	189,552	183,273	177,124	171,102	165,204	159,427	107,826	65,931	31,918	4,304	0
Present value returns	171,145	180,015	145,273	117,193	94,504	76,177	61,378	49,432	39,793	32,018	25,748	2,813	278	22	0	0
Number of years before shutdown	52															
Returns to conservation																
Net benefits	-176,801	20,801	116,305	178,181	195,963	189,552	183,273	177,124	171,102	165,204	159,427	107,826	65,931	31,918	4,304	0
Present value net benefits	-176,801	17,334	80,767	103,114	94,504	76,177	61,378	49,432	39,793	32,018	25,748	2,813	278	22	0	0
Cumulative present value net benefits	-176,801	-159,467	-78,700	24,414	118,918	195,094	256,472	305,904	345,697	377,715	403,463	496,552	506,395	507,304	507,362	507,362
Net present value																
50 years	507,362															
100 years	507,362															
Internal rate of return (percent)	60.2															
Number of years to break even	3															

Source: Author's calculations.

the first 8 centimeters of the surface layer, it is easily erodible.

The effects of erosion in this area were estimated from information provided by farmers. The farmers feel that in the absence of conservation measures, yield would decline very rapidly, by as much as one-third annually. The farmers' estimation was assumed to be correct because it reflects the fragility of the area's soils and their shallow A horizon. In the case with conservation, the rate of decline in yield was assumed to fall in proportion to the diminution of erosion. The initial yield used in the calculations was the average yield observed in the 1989 harvest. The cost of production was estimated by the Banco Nacional, and the output price was the minimum price guaranteed by the exporters.

The results of the analysis of returns to diversion ditches are shown in table 3-3. In the case without conservation, rapid yield decline would force farmers to abandon production by the fourth year. With diversion ditches, the production period almost doubles to seven years, after which production ceases. Even though degradation is so great that production would have to be abandoned rapidly even if diversion ditches were built, the extra years of production obtained are sufficient, given the high value of the crop, to make adopting the conservation measure profitable. Indeed, investment in the construction of diversion ditches would be repaid in only two years.

Given the fragility of the region's soils, more effective conservation measures are needed. Table 3-4 shows the results of an analysis of the returns to terracing. Bench terraces are assumed to reduce soil loss much more substantially than diversion ditches (to 12.5 metric tons per hectare a year instead of 100). However, the investment cost is more than three times greater (₡51,480 per hectare instead of ₡14,644), and the reduction in effective area is much greater (27 percent instead of 11 percent). Despite its relatively high costs, adoption of this measure is profitable from the farmers' perspective. Compared with diversion ditches, terracing allows production to be maintained for a much longer period (fifty-two years instead of seven) and has higher overall returns (₡507,000 per hectare instead of ₡136,000).

The estimated yield loss used in the calculations is apparently very elevated. Nevertheless, sensitivity analysis shows that the results are quite robust. Even if the annual rate of yield loss is only 15 percent, for example (half of that assumed in the analysis), both diversion ditches and terraces remain profitable. Terraces remain profitable as long as yield loss without conservation is at least 10 percent a year, while the cheaper diversion ditches are profitable as long as yield loss without conservation is at least 7 percent a year. Both measures would be profitable if output prices fall 25 percent. The profitability of conservation in the area is also confirmed by the fact that farmers do use conservation measures.

Conclusions

The results of the analysis show that the adoption of conservation measures is not always profitable for farmers. If the sacrifice of investment in anti-erosive practices is greater than the future benefits, it is rational for farmers to counter erosion with less costly measures that may also be less effective.

In each of the case studies, the estimated returns to conservation depend on very inadequate information about the relations at work between soil loss and yield loss. Therefore, the results should be treated with care, even though sensitivity analysis shows that they are probably quite robust. It would be desirable for these results to be verified with more detailed studies of both the agricultural data (soil studies, production, and so forth) and the economic data (costs, prices, yields, the relation between inputs and product, and so forth) in the areas considered in this study. If the USLE is to be used as a tool for planning, the values of the coefficients for Costa Rica should also be validated. This is especially important in light of its apparent tendency to overestimate significantly the rates of soil loss. The most important task is to carry out applied research at the field level to determine the relation between soil loss and yield loss for each crop and area. It is also important to do field research on the relative effectiveness of conservation measures such as live barriers and windbreaks.

Strategies and plans for different projects should be revised and adapted to the conditions faced by farmers. It is important to take into account the participation of the farmer (planning from bottom to top) in all stages of planning the conservation practices. Farmers must be the starting point and the ending point for plans to be applied in any area. It is necessary to promote activities, to support the farmers with training and advice in techniques, and to provide continuing periodic monitoring and technical assistance for the works.

Adequate resources must also be assigned to support technical and professional personnel in their fieldwork. To do this, it is especially important to provide vehicles, equipment, and per diem, for example, and to maintain a permanent program of training and formation of efficient and motivated human resources in the conservation task. Furthermore, an incentive of salary must be created on the basis of research, publications, and professional initiatives for the purpose of stimulating the work and creating a commitment to conservation.

The effects of erosion at the farm level in the areas studied are not worrisome in the short term, except in the case of Turrubares. The analysis should be amplified, however, by examining the effects of erosion outside the farm on, for example, the quality of water, the frequency of floods, the sedimentation of reservoirs, and the generation of electricity.

Notes

1. However, the value for very fine sand fraction required by the formula could not be used, since it was not determined in the soil analysis. Nevertheless, correlations indicate that there were no significant differences between the calculation of the K factor with and without this fraction.
2. This also implies that terraces, which are more effective than conservation ditches but are also more costly and reduce the effective area even more, would not be profitable.
3. The Costa Rican currency is the colón.

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4. Soil Conservation Projects in El Salvador

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Agriculture is one of the most important sectors of El Salvador's economy, contributing 25 percent of the country's gross national product in 1990. As in other Central American countries, the agricultural sector consists of two distinct groups of producers. On the one hand, modern industrial plantations use large areas of land to produce export products such as coffee, sugarcane, cotton, and livestock. On the other hand, large numbers of small landowners produce subsistence crops using traditional methods on plots of less than 5 hectares. These differences persist despite the agrarian reform that was implemented in the 1980s. This social dichotomy is one of the principal causes of the instability that has had severe repercussions, directly and indirectly, for the country's agricultural sector and economy in general.

Land degradation in El Salvador

El Salvador's dense population (252 inhabitants per square kilometer) and unequal landholdings have resulted in large areas of marginal lands being used for agricultural production. An estimated 50 percent of the forest cover was lost between 1960 and 1980 as a result of the expansion of agricultural and livestock activities. Deforestation continues as forests are converted to agriculture or harvested for fuelwood. Substantial areas that produce annual permanent crops are located on steep slopes or in areas classified as being inadequate for intensive cultivation. Considerable soil degradation is experienced in these areas, and annual soil loss varies from 50 to more than 180 metric tons per hectare in critical conditions. Soil degradation has also led to sedimentation problems in the reservoirs of the three hydroelectric dams in the watershed of the Lempa River, which covers 49 percent of the national territory (10,255 square kilometers).

Flores Zelaya (1976–81) measured erosion rates and yield on runoff plots at Metapán over the period 1975–80. The treatments studied include a traditional practice and two conservation measures: live barriers and bench terraces (a control with bare soil was also studied). The live barriers consisted of rows of perennial and densely growing plants planted along the contour. Each treatment was replicated three times on 1,200 square meter plots with an average slope of 30 percent. Soils at the site are latosols, reddish-clayey, yellowish-red, and gray forest podzol. They are about 75 centimeters deep and have a pH level of 5.7 to 6.7, with low nitrogen and phosphorus content and a medium level of potassium and organic material. Drainage is rapid, causing a high susceptibility to erosion.

Table 4-1 presents the mean soil loss and yield measurements for each of the practices in Metapán. The average values for runoff are presented for the erosion occurring in the traditional crops planted with live barriers. Unfortunately, no clear link among practices, erosion rates, and yields can be drawn from these data. Although the experiment measured soil loss and yields over five years, it only included a few replications of each practice, a problem that was exacerbated when measurement problems meant that data from one of the blocks had to be discarded. Moreover, weather conditions varied considerably during the study period, and exogenous factors such as pest attacks on bean crops occurred as well.

One tentative conclusion that might be drawn from these data is that bench terracing is unlikely to be a cost-effective conservation measure. Under bench terracing, bean yields were lower than under either of the other two practices, while corn yields were lower than under the live barriers practice. This occurred most likely because terracing reduces the area cultivated. The reduction of soil loss also did not appear to be significantly higher than with live barriers. When combined with its high cost, terracing is not likely to be an attractive conservation practice under the conditions found in Metapán. Live barriers appeared to be more promising, at least with regard to corn yields, which were higher under this than under the other practices. The results for bean yields were, however, erratic. More research is clearly needed to establish the effects of different conservation practices on conservation.

National experiences in the execution of soil conservation activities

Since 1955, the government, through the Ministry of Agriculture and Livestock, has undertaken a variety of conservation projects. The Agricultural Land Improvement Program, for example, provided machinery to help farmers prepare lands for cotton production. In 1969, the Watershed Management and Soil Conservation Service was created within the General Directorate of Renewable Natural Resources (DGRNR) and assigned responsibility for regulating land use, designing stream control projects, and establishing farm-level experiments to measure erosion and demonstrate the feasibility of soil and water recovery through anti-erosive treatments.[2]

Programs and projects aimed at conserving and improving soil and water resources have been carried out by different national institutions such as the Center for Natural Resources (CENREN), the Hydroelectric Commission for the Lempa River, and the National Agricultural Technology Center. Unfortunately, the public agricultural sector has traditionally been weakened by a lack of communication among the institutions that form it, a problem that a series of management reforms during the 1980s did not solve. The latest restructuring of the Ministry of Agriculture and Livestock took place in 1989. The private sector, local communities, and international organizations have also made efforts in this field.

Most of the recent conservation works have been developed in the watersheds of the Lempa River and its tributaries, including the Acelhuate, Tamulasco, and Las Cañas rivers. Hands-on training in reforestation techniques has been offered to farmers in the departments of Cabañas, Usulután, and Morazán.

A wide variety of conservation practices are used in El Salvador, depending on the crop being cultivated, the local agroecological conditions, and farmers' resources. Contour cropping is the most widely used cultural practice, being used, to varying degrees, with all crops grown in

Table 4-1. Measurements of Soil Loss and Yield on Runoff Plots in Metapán, El Salvador, 1975–80
(tons per hectare unless otherwise noted)

		Traditional practice			*Live barriers*			*Terraces*		
	Rainfall	*Soil*	*Yield*		*Soil*	*Yield*		*Soil*	*Yield*	
Year	*(millimeters)*	*loss*	*Corn*	*Beans*	*loss*	*Corn*	*Beans*	*loss*	*Corn*	*Beans*
1975	1,895	137.01	1.88	1.15	129.04	2.65	1.35	58.11	2.62	0.71
1976	1,397	72.17	1.50	1.20	5.10	2.45	0.89	5.95	1.88	0.40
1977	1,192	12.68	3.40	1.33	..	4.37	1.50	..	2.62	0.92
1978	1,928	4.50	2.12	1.20	6.89	4.51	0.60	3.25	2.81	0.23
1979	1,716	18.51	2.62	1.33	19.95	3.10	1.51	6.89	2.01	0.07
1980	—	—	2.11	0.48	—	3.15	0.45	—	1.91	0.17

— Not available.
.. Negligible.
Notes: 1978 and 1980 beans yields were affected by severe infestations of slugs (*Vaginulus sp.*). Block III plots were omitted due to measurement problems.
Source: Fifth and sixth reports on research and runoff plots at Metapán.

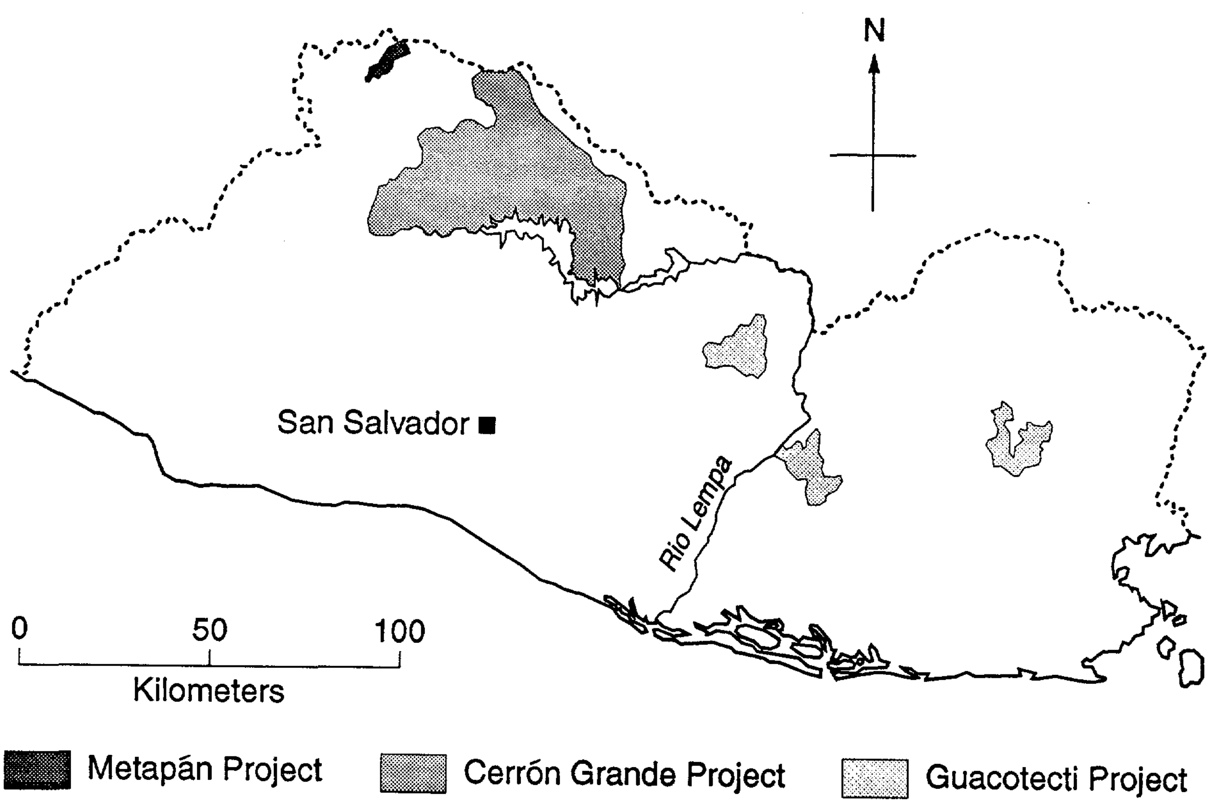
El Salvador. Various other cultural conservation measures, including the use of mulch and crop residues, windbreaks, and live barriers, are sometimes found on cereals and coffee fields. The most commonly used mechanical practices on cultivated land are bunds and drainage and diversion canals. Both are common on large-scale crops such as cotton and sugarcane but are also found in conjunction with cereals.

The Metapán and Cerrón Grande projects are two of the most important soil conservation projects in El Salvador. Both were motivated primarily by the need to prevent flooding and siltation downstream. The soil conservation work in Metapán sought to prevent flooding and other adverse effects in the lower parts of the watershed of the Río San José, while the Cerrón Grande Reservoir Project sought to prolong the useful life of the hydroelectric dam, which is of national importance.

The two projects were very similar, and the experiences and results obtained in Metapán were used to design and execute the Cerrón Grande Project. The execution of the projects was managed by the DGRNR, and later by CENREN, through the Watershed and Soil Conservation Service. In general, the same technical capacity was available for the execution of both projects. The larger Cerrón Grande Project had a more formal organizational structure, with a principal technical adviser, a national director, and a technical team. In addition, executive zonal offices or delegates were located in Nueva Concepción, Chalatenango, and San Ignacio.

The forest district of Metapán is situated in the northern part of the department of Santa Ana (see figure 4-1). The project covered an area of 1,773 hectares, of which 80 percent is forested, 6 percent is used for infrastructure, and 14 percent is planted with annual and permanent crops. Over 70 percent of the area is found in land use classes VI–VIII, which are considered to be inadequate for intensive cultivation. The Metapán Project was carried out on a large hacienda, the San José Ingenio farm, which was acquired by the government in 1971. Gabions and reforestation were used to reduce the threat of downstream flooding.

Figure 4-1. El Salvador: Area of Operation of the Principal Soil Conservation Projects



The Cerrón Grande Project covered a much larger area (140,500 hectares) in which land in agricultural classes V and VII predominate. Unlike Metapán, only about 15 percent of the area is forested, while 28 percent is used for cereal production and 49 percent for pasture and perennial crops. Demonstration plots were established, one with diversion ditches and one with stone barriers. Diversion ditches appeared to be more profitable, but the available data are too limited for definitive conclusions to be reached. To conserve soil, the Cerrón Grande Project promoted stone and vegetative barriers, bench terraces and individual terraces, diversion ditches (bench-type and trenches), earth ridges, drainage canals, and ditches. Farmers adopting conservation measures received a package of incentives, including agricultural inputs (seeds, plants, fertilizer, and insecticides), tools, materials for constructing soil conservation works, and technical assistance.

The Agroforestry Support to Rural Communities with Scarce Resources Project (usually referred to as the Guacotecti Project), which began in 1987, is the third important soil conservation project implemented in recent years. The Guacotecti Project, initially undertaken in the department of Cabañas and later extended to the departments of Usulután and Morazán, covered 35,000 hectares. Land use classes VII and VIII predominate, except at lower elevations, where soils belong to classes II and VI. The ecology is similar to that in the Cerrón Grande area, with undulating to mountainous topography and very broken hills. Because of intense rainfall and average slopes exceeding 20 percent, high rates of erosion are often experienced in this area. The conservation practices promoted in this project were similar to those used in the Cerrón Grande Project. Stone barriers were the most commonly used measure, accounting for 60 percent of total treatments, followed by diversion ditches, individual terraces, and alley cropping. Madrecacao, eucalyptus, and fruit tree orchards were also established. Participating farmers received a set of incentives similar to those used in the Cerrón Grande Project. Credit on generous terms was also provided and has proven very popular among farmers.

At the initial stages of the Metapán Project, no incentives were provided to project personnel. Later, with the continuation of soil conservation activities in the Cerrón Grande Project, some incentives were given. Extra pay was awarded, which initially was applied only to rural assistants in their first three years with the project and later was extended to the director of the project and the technical team. However, the incentive payments did not take into consideration the efficiency and responsibility of the technicians, thus weakening their effectiveness. These incentives were also applied in the agroforestry project, but in a more systematic form, which included training inside and outside the country.

Efforts to stimulate adoption of soil conservation measures in these and other projects have not always been successful. Initial resistance to the proposed conservation measures was often high. At the beginning of the Cerrón Grande Project, for example, the initial reaction was negative among many farmers, who waited to see the results obtained on demonstration plots before committing themselves. Some were ultimately persuaded by the results and by the offer of incentives. Whether the conservation measures will be maintained once the incentives are withdrawn remains to be seen. There has been some limited adoption of conservation measures in areas outside those served by the projects themselves, but no studies have been carried out that might allow their impact to be measured.

Several possible explanations have been proposed for the failure of farmers to adopt conservation measures. Farmers are often constrained by a lack of productive resources and by problems related to landownership. Technical assistance in the construction and maintenance of conservation measures has often been sporadic; it has been estimated that only 6 percent of the demand for extension services has been satisfied in the past few years. Trials of nontraditional cropping practices have often been limited to short experiments in insignificant areas; the cost-effectiveness of new techniques has rarely been demonstrated. The farmers themselves have often pointed to the effective loss of productive area following the construction of conservation measures and to the need for additional labor for construction as important constraints to carrying out soil conservation activities.

Conclusions and recommendations

The scarcity of reliable data on the extent of land degradation and its impact on productivity as well as on the effectiveness of different conservation measures clearly makes data collection a top priority. Plots for measuring runoff, erosion, and effects on yield under different practices should be established. Past projects have provided support to university researchers, but these efforts have often been too short-lived and on too small a scale to yield reliable and conclusive results. Without such information, economic evaluation of conservation measures is impossible.

The limited information that is available suggests that vegetative measures such as live barriers may be more profitable from the farmers' perspective than the mechanical measures that have often been promoted.

Notes

1. This work is the result of efforts carried out by the many professionals, technicians, and support personnel who contributed directly or indirectly to this study. The authors are thankful to the personnel of the project selected for the study and especially to the farmers in those projects, whose sincere and practical support based on their experiences gives more relevance and truthfulness to the results obtained. Special thanks go to a colleague and friend, Ing. Carlos Aguilar Molina, technician for the Watershed Management and Soil Conservation Service of CENREN for his contribution to managing and advice on preparing this document.
2. The DGRNR became the Salvadoran Institute of Natural Resources (ISREN) in 1982, when the Ministry of Agriculture and Livestock implemented a policy of regionalizing institutional services. ISREN, in turn, became the Center for Natural Resources in 1986.

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5. Soil Erosion Control Efforts in Guatemala

Pedro Rosado P., Luis E. Barrientos C., and Saúl A. Lima L.

This chapter analyzes efforts to control soil erosion in Guatemala. Adequate protection and management of soil resources are essential to avoid flooding and to protect the productive potential of the agricultural sector, which contributes one-fourth of Guatemala's gross national product, employs about 60 percent of the work force, and generates, through exports, two-thirds of the country's foreign currency earnings.

Guatemala's agricultural sector is very diverse, varying from subsistence agriculture to highly mechanized export production. Landownership has the most polarized distribution in Central America. According to the 1979 census, 81 percent of farms are smaller than 3.5 hectares and hold only 10 percent of all agricultural land, while 2 percent of farms have more than 44.5 hectares and hold 67 percent of all land. Small farms (less than 3.5 hectares) are dedicated to the production of basic crops, while large farms produce mainly export crops (Devé 1989). Large farms also tend to be concentrated in the better-quality lands. Growing population and low productivity on subsistence farms have encouraged expansion of the agricultural frontier. Between the 1964 and 1979 censuses of agriculture, the number of farms increased almost 50 percent (from 420,000 to 600,000) and the area cultivated increased 20 percent (from 3.4 million hectares to 4.1 million hectares).

Topographic and climatic factors make much of Guatemala's land area vulnerable to degradation: 65 percent of the land is classified as being highly or very highly susceptible to erosion. Based on the U.S. Department of Agriculture classification system, 72 percent of the land is classified as having strong limitations for cultivating crops and as being primarily suitable for forestry. Most of the lands suitable for agriculture are found in the southern part of the country, on the coastal plains of the Pacific. Currently, 37 percent of the national territory is dedicated to agricultural activity, 40 percent is forested, and 22 percent is used for pasture.

Soil conservation efforts in Guatemala

Until the 1980s, soil conservation work was carried out by different agricultural extension agencies as part of the technical assistance provided to farmers. No projects were specifically dedicated, technically or financially, to undertaking soil conservation work. A national soil conservation program was initiated in the 1980s, as a component of the Agricultural Development Project, which was financed by the U.S. Agency for International Development (USAID). The technical part of the project is executed by the General Agricultural Services Directorate (DIGESA), which is a branch of the Ministry of Agriculture, Livestock, and Food (MAGA). The objectives of the project are to help reduce the deterioration of the soil, to increase the retention of nutrients and humidity in the soil, to incorporate more areas into agricultural production with greater capacity but without deteriorating the soil, and to train farmers to practice soil conservation. The conservation works promoted by the project vary according to the characteristics of each community. In general, they consist of the construction of mechanical structures, such as terraces, ditches, contour furrows, stone barriers, and dams, and of vegetative practices, such as live barriers, crop rotation, strip-cropping, and use of green fertilizers.

The project covers each of the agricultural regions except the department of El Petén. Each region has a group of specialized soil conservation technicians. Meetings, presentations, trips, demonstration plots, and training (on an individual and group basis) are used to promote soil conservation in areas affected by soil erosion. Together with technical training in the establishment of conservation measures, monetary incentives for their adoption have often been provided to small farmers. These incentives apparently stimulated the adoption of conservation measures, but farmers often stopped using conservation practices when the incentive payments ceased.

Various nongovernmental institutions also undertake soil conservation work as part of more general projects. The main nongovernmental organizations working with soil conservation are the following: World Vision, Young Christian Association, the Foster Plan, the German-Guatemalan Cooperation on Food for Work, the World Food Program, and CARE-General Forestry Directorate (DIGEBOS).

Returns to soil conservation in Patzité

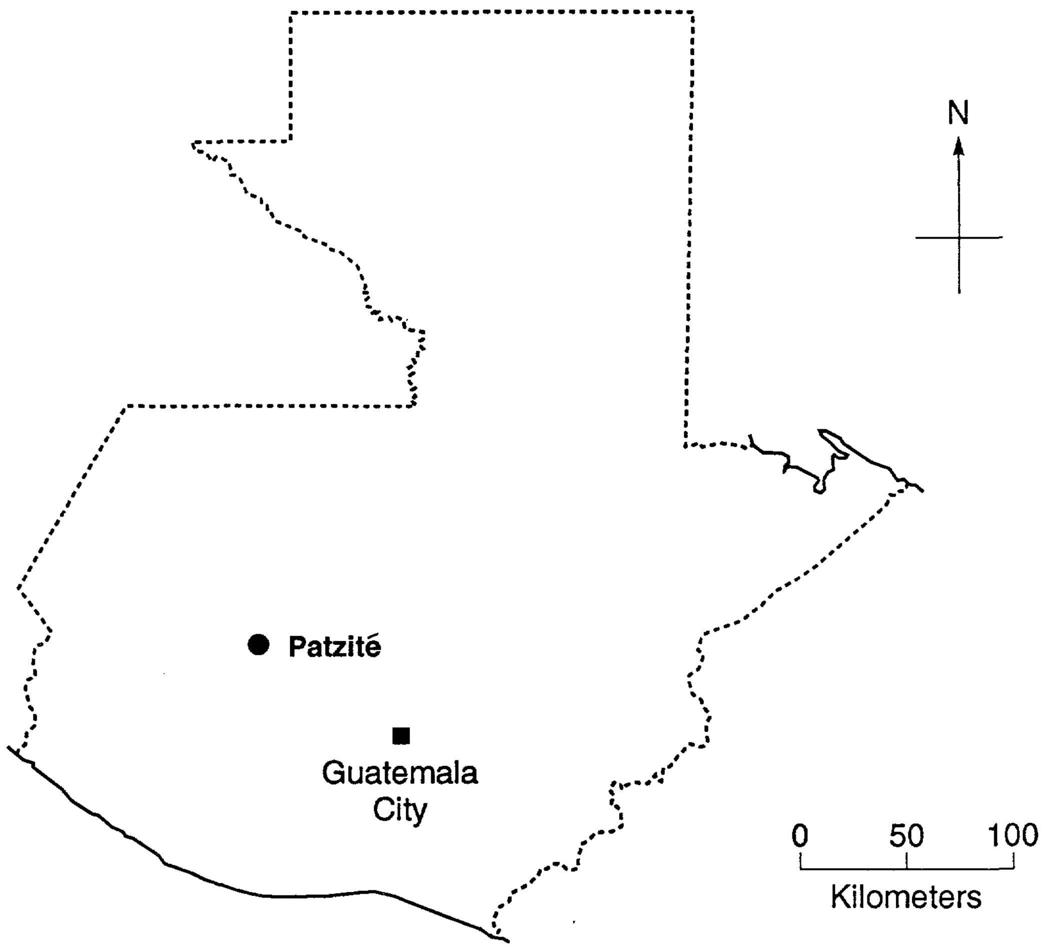
The specific conditions faced in different parts of the country vary substantially. The municipality of Patzité, in the department of Quiché, was selected for detailed analysis (see figure 5-1). Located in the western highlands of Guatemala, Patzité is typical of conditions found in this region. The area has been heavily affected by soil erosion; in some places ravines and ditches cover more than 40 percent of the area. Conservation efforts have also been considerable: Patzité contains 60 percent of the area protected by soil conservation practices within the department. The topography is strongly undulating, with slopes ranging from 15 to 25 percent. The area's soils have developed on volcanic, pomaceous ash. The topsoil is about 20 centimeters deep, while the subsoil is about 50 centimeters deep. This soil is of medium natural fertility. The life zone of Patzité is considered to be low montane, very humid forest. The average annual precipitation is 1,357 millimeters. Patzité has a population of 4,425 inhabitants, 80 percent of whom are employed in agriculture. Among farmers in the area, 10 percent are owners with land titles, 10 percent are tenants, and 80 percent are owners without titles. The main crops are corn, wheat, vegetables, and apples. The predominant crop system is corn alone. Some intercropping is also practiced; corn-bean is the most popular intercrop system, but vegetable-wheat and corn-vegetables can also be found. Of the total area, 30 percent is covered with forest.

Data for the analysis were obtained from a number of sources. Some preliminary estimates of yield were obtained from small surveys carried out among the farmers, but these data are preliminary and need to be confirmed by more accurate measurements. The production costs for the corn crop were also obtained through the survey and represent average costs faced in the community. The market price used is the price received at the farm level.

An average corn yield of 1.40 metric tons per hectare is obtained in the area. Under current practices, yields are thought to be declining gradually as the topsoil erodes. On a 20 percent slope, for example, the USLE predicts an average annual soil loss of about 140 metric tons per hectare, or a decline in topsoil depth of 12 millimeters. The recommended conservation practice on such slopes consists of terraces with a protected embankment. The results of the farmer survey indicate that under this measure, corn yields would gradually recover as soil is regenerated, eventually stabilizing at about 1.55 metric tons per hectare after about seven years. However, when terraces are constructed, the planted area is reduced between 10 and 15 percent.

Because of their high cost of construction (about Q2,500 per hectare) and the decline in effective area, terraces are unlikely to be profitable from the farmers' perspective.[1] Table 5-1 shows some preliminary estimates of the returns to constructing terraces in Patzité, using the estimated annual decline in yield under current practices of 90 kilograms per hectare. Terrace construction is estimated to incur a loss of Q782 per hectare, using a 20 percent discount rate and a 100-year time horizon. The estimated internal rate of return in this case would be 16.5 percent. The rate of decline in yield without terracing would have to be at least 160 kilograms a year before terracing would break even under these conditions, a rate far in excess of all avail-

Figure 5-1. Guatemala: Location of the Patzité Study Site



able estimates. More realistically, if the rate of decline in yield is about 70 kilograms per hectare, which is only slightly lower than the estimated rate, losses from the construction of terraces would be as high as Q1,150 per hectare, and the internal rate of return as low as 15 percent.

Two alternatives for the farmers in Patzité can be inferred from this analysis. First, if more profitable crops were adopted in the areas with conservation, the construction of terraces might be profitable. Improved cropping practices often cannot be adopted on fields without terraces because seed and fertilizer are washed away. Second, use of less expensive soil conservation structures might be profitable, even if the same corn crops are grown. Diversion ditches with live barriers, for example, cost only Q1,000 per hectare to establish. Since such measures might be less effective than terraces at halting erosion, however, their effects on productivity must be estimated before this conclusion can be reached. The analysis allows estimates to be made of the minimum effect on productivity required for the adoption of diversion ditches to be profitable. If the annual decline in yield under current practices is 90 kilograms per hectare, farmers would break even if diversion ditches with live barriers increase yield only one-third as rapidly as occurs with terracing. If the annual rate of decline in yield is as low as 70 kilograms per hectare, diversion ditches with live barriers would be profitable as long as yields after adoption increase at least 30 kilograms per hectare (or about two-thirds the annual rate of increase likely to be obtained with terraces).

Institutional analysis

Soil conservation activities have been included in agricultural extension since the beginning. In

Table 5-1. Analysis of Returns to the Construction of Terraces with a Protected Embankment on Farms with 20 Percent Slope Planted to Corn in Patzité, Quiché, Guatemala, for a 100-Year Time Horizon

(quetzales per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	1,400	1,310	1,220	1,130	1,040	950	860	770	680	590	0	0	0	0	0	0
Revenues	1,540	1,441	1,342	1,243	1,144	1,045	946	847	748	649	0	0	0	0	0	0
Crop production costs	644	644	644	644	644	644	644	644	644	644	0	0	0	0	0	0
Returns	896	797	698	599	500	401	302	203	104	5	0	0	0	0	0	0
Present value returns	896	664	485	347	241	161	101	57	24	1	0	0	0	0	0	0
Number of years before shutdown	10															
With conservation																
Yield (kilograms per hectare)	1,190	1,240	1,290	1,340	1,390	1,440	1,490	1,540	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
Revenues	1,309	1,364	1,419	1,474	1,529	1,584	1,639	1,694	1,705	1,705	1,705	1,705	1,705	1,705	1,705	1,705
Crop production costs	644	644	644	644	644	644	644	644	644	644	644	644	644	644	644	644
Conservation costs	2,500	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Returns	-1,835	620	675	730	785	840	895	950	961	961	961	961	961	961	961	961
Present value returns	-1,835	517	469	422	379	338	300	265	223	186	155	25	4	1	0	0
Number of years before shutdown	Never															
Returns to conservation																
Net benefits	-2,731	-177	-23	131	285	439	593	747	857	956	961	961	961	961	961	961
Present value net benefits	-2,731	-148	-16	76	137	176	199	208	199	185	155	25	4	1	0	0
Cumulative present value net benefits	-2,731	-2,879	-2,894	-2,819	-2,681	-2,505	-2,306	-2,098	-1,898	-1,713	-1,558	-907	-802	-785	-782	-782
Net present value																
50 years	-782															
100 years	-782															
Internal rate of return (percent)	16.5															
Number of years to break even	Never															

Source: Authors' calculations.

1971, the General Agricultural Services Directorate (DIGESA) was created, absorbing a large part of the responsibilities of agricultural extension. The first projects dedicated specifically to soil conservation were initiated in the western and central highland regions at the end of the 1970s. These projects were small-scale, given the lack of institutional experience, and served as a "school" for a generation of extensionists in the field of soil conservation. With the emergence of projects devoted specifically to soil conservation, technical teams were formed in each region to define soil conservation strategies and methodology, to aid in the transfer of soil conservation technology to farmers, and to train agricultural extensionists, field assistants, and farmers. Such teams exist in seven of the eight regions in the country.

The soil conservation technicians in each region carry out their work through teams from the extension agency. Soil conservation technicians show farmers the benefits of using different conservation structures through meetings, personal visits, talks, training courses, day trips to farms that practice soil conservation, demonstrations of methods, and so on. Farmers sometimes receive monetary and nonmonetary incentives for building conservation structures, depending on their socioeconomic condition. Monetary incentives have been funded primarily by external financial assistance, especially from USAID, while food-for-work has been provided by the Guatemalan-German Cooperation on Food for Work and the World Food Program. CARE/DIGEBOS has provided participants in its agroforestry and soil conservation projects with agricultural inputs and tools.

Although it has been suggested that incentives should not be used to encourage soil conservation (MAGA/DIGESA 1991), the success of soil conservation in Guatemala has often been attributed to monetary and nonmonetary incentives. Monetary incentives have had particularly high levels of acceptance by farmers. Monetary incentives are thought to have contributed significantly to expanding the area conserved through different structures (bench terraces, dead barriers, live barriers, ditches, and absorption wells). In particular, monetary incentives are thought to have been very important in allowing poor farmers who practice subsistence agriculture to adopt conservation measures. Monetary incentives, when adequately used, are believed to be an effective way to overcome farmers' initial resistance to soil conservation. However, incentives also have disadvantages. Farmers have often resisted collaborating with projects unless some type of incentive is given; this has led to friction with organizations, such as the World Food Program, CARE, and DIGEBOS, that promote soil conservation with other types of incentives.

Conclusions and recommendations

Soil conservation works that have been executed in different areas of the country must be subjected to a rigorous, economic analysis so that efforts can concentrate on the most cost-effective measures. Much work remains to be done in this regard. In particular, more and better data are needed. Since the effects of soil degradation and conservation can only be observed in the long run, data should be collected on a long-term basis. Collaboration between FAUSAC and DIGESA on this task would enable better estimates to be obtained in the future. National surveys of soil degradation problems should also be carried out, so that scarce soil conservation resources can be targeted to the areas that need them the most.

The preliminary analysis of conservation measures in Patzité suggests that low-cost soil conservation structures such as hillside ditches with live barriers are more likely to be profitable from the farmers' perspective than more expensive measures such as bench terraces.

Note

1. Guatemala's currency is the quetzal.

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6. Economic Analysis of Soil Conservation in Honduras

Antonio Valdés P.[1]

Honduras has experienced a steady and accelerating increase in population, with a growth rate in 1991 of 3 percent. Together with an inadequate distribution of land, this has resulted in an expansion of the agricultural frontier. Since Honduras's topography is predominantly mountainous, with most slopes greater than 15 percent, this expansion has occurred primarily on vulnerable hillsides.

Agricultural activity is of great importance as a source of employment and income for a majority of the population. The agricultural sector employs approximately 53 percent of the economically active population and contributes 25 percent of the country's gross national product. Within the agricultural sector, more than 68 percent of the population is engaged in crop cultivation, 19 percent in livestock production, and the rest (13 percent) in forestry and other activities (CIAH 1983).

Pressure on the land threatens the sustainability of agricultural production. Already, yields are low in the production of basic grains. At the national level, average yields have barely increased in the past thirty years; in the case of beans, average yields have actually declined by 0.176 metric tons per hectare (SRN/CONSUPLANE 1986). The continued pressure on cultivated land and the expansion of cultivation into marginal areas threaten to reduce this even further.

A number of soil conservation projects have been implemented in an effort to counteract this threat, yet there has been little analysis of their economic benefits. This study is a pioneering effort in the economic analysis of returns to soil conservation projects in Honduras. As such, it attempts to generate basic information for evaluating similar projects in the future and to give guidelines for improving the action of programs in the areas of Tatumbla and Yorito.

Soil conservation in Honduras

Soil conservation refers to the use of measures to protect the soil, with the aim of maintaining or improving its natural fertility. Many different soil conservation practices have been used in Honduras, including agricultural and cultural practices such as contour planting and vegetative covering, mechanical practices such as diversion ditches and terraces, and fertilization practices such as manuring and mulching.

Honduras initiated its first soil conservation programs in the 1970s. Early programs focused mainly on stimulating the individual farmer's awareness of the problem. Later programs attempted to develop integrated support activities directed toward farmers in hilly areas. The Secretaría de Recursos Naturales (SRN) has been one of the principal agencies implementing soil conservation programs, but some have also been executed by the forestry development agency—Corporación Hondureña de Desarrollo Forestal (COHDEFOR)—and by nongovernmental organizations such as Vecinos Mundiales. Support for these programs has been received from a number of bilateral and multilateral donors. Current soil conservation projects in Honduras are the product of the experience of these diverse programs, especially those carried out by Vecinos Mundiales.

The SRN has been gradually decreasing its scope of action and has created numerous autonomous public organizations to continue its work. These operate independently, both from one another and from SRN, and the consequent lack of inter-institutional coordination limits the country's institutional ability to address agricultural problems. The multitude of special conditions that each donor requires for administering and executing the programs it finances also weakens the structure of the public sector agencies concerned with agriculture. In response to these problems, efforts are under way to create a decentralized coordinating agency with strong technical skills and an agile administrative management. This new institution, the Dirección de Ciencia y Tecnología Agrícola (DICTA), initiated operations in 1992, and supporting legislation is being prepared.

Initially, programs for the management and conservation of soils did not provide any direct incentives to farmers, either as money or as food-for-work exchanges, except to the owners of demonstration plots, who received inputs and tools.[2] As the soil conservation program developed, however, incentives to encourage the adoption of conservation practices were frequently added. There was no specific national approach on the issue, and each regional management unit of the SRN, in addition to giving its own orientation to conservation activities, chose whether to provide direct incentives, such as subsidies, food-for-work exchanges, or donations of tools.

The type of incentives used and their effectiveness have varied considerably. The Integrated Watershed Management Project implemented by COHDEFOR initially provided monetary incentives for conservation work and later provided food-for-work incentives. Eventually, however, the system became uncontrollable (Ing. Omar Oyuela, personal communication). The Integrated Rural Development Program Marcala-Goascorán (MARGOAS) provided participating farmers with credit to purchase inputs. In some cases, it also provided monetary incentives for each linear meter of bench terraces constructed, up to a maximum (SRN/MARGOAS 1991). The LUPE project offers farmers tools on loan and pasture grasses to establish live barriers. It also distributes trees for use in live barriers or windbreaks and provides fruit seedlings, at nominal prices, for setting up fruit orchards.

Incentives, if well managed, have often been useful instruments for inducing the adoption of soil conservation practices. The MARGOAS project concluded that without the use of incentives, farmers would not have been able to undertake conservation work (SRN/MARGOAS 1991). The widespread use of incentives has, however, created an expectation among farmers that they should be paid for conservation work. Vecinos Mundiales (see chapter 18 in this volume) does not use any incentives and has sometimes had negative experiences as a result (Lagos 1988). Some communities do not like working with this program because they had previously received incentives from other programs.

Data

No up-to-date data on erosion or on the effect of soil loss on yields exist in Honduras, nor are data available to calibrate the Universal Soil Loss Equation (USLE) or similar models to Honduran conditions. Given these problems, and limitations of time and resources, this analysis was based on information collected from small samples of farmers. In each study site, groups of farmers with similar characteristics who had and had not adopted conservation practices were selected, and information on yields and practices was obtained through interviews. The farms selected have slopes between 15 and 35 percent and are representative of the study sites.

The steps for obtaining information and for preparing the study were the following: (a) selection of the study sites; (b) preparation of a questionnaire; (c) interviews of farmers with and without soil conservation practices; (d) analysis of the information; and (e) collection of complementary information. Yield trends were estimated from the data using linear regression analysis (using the Microstat statistical package). These trends were then projected over a 100-year horizon and used to examine the returns to conservation. In carrying out the projections, limits set by the biological potential of the crop, soil fertility, and the technology being used were taken into consideration. Information on maximum yields was obtained from the research department at SRN.

Crop production costs were estimated using information collected by the farmer questionnaires. The costs of constructing and maintaining soil conservation works were estimated using information from Proyecto Manejo de Recursos Naturales (PMRN) and data from Zonas de Omoa and Lago de Yojoa that were verified by technicians at the study sites.

Some of the data used in the analysis are very weak. The limitations of this approach are that it uses data that depend on the accuracy of farmer recall and that time constraints limited the sample size. The results, therefore, must be considered only as a first approximation to be improved and strengthened in the future. Also, the information presented corresponds specifically to the study sites; results should not be extrapolated to other regions.

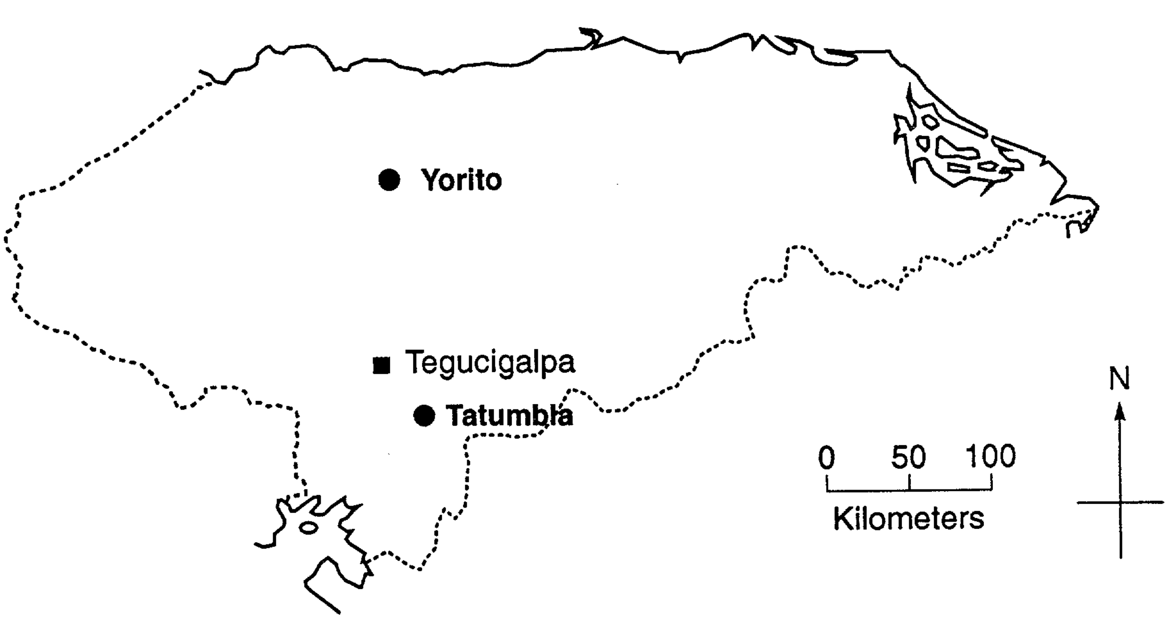
Technical-economic analysis of the Tatumbla site

The municipality of Tatumbla is located in the department of Francisco Morazán, covers an area of 75 square kilometers, and has an estimated population of 2,100 inhabitants, with a density of 28.2 persons per square kilometer (see figure 6-1; Fiallos 1989). In the lowlands (from 500 to 1,000 meters above sea level), the area has a lower humid montane microclimate, while in the highlands (from 1,500 to 2,000 meters above sea level), the microclimate is subtropical humid forest. Annual precipitation is usually between 885 and 1,560 millimeters, with an average of 1,182 millimeters.

The vast majority (90 percent) of the surface soils belong to the Ojojona series of the order of entisols. These soils are shallow and well drained. The topsoil, with a depth of 10 centimeters, is very fine sandy loam to silt loam (Simmons 1969). With an average pH of 5.08, the soils of Tatumbla are very acidic. There are no problems with toxicity of aluminum (Al) or manganese (Mn), but deficiencies in zinc (Zn) may exist. More than half (57 percent) of the soils have low levels of organic material, and 40 percent have a low level of phosphorus (P). On the other hand, 94 percent have high levels of potassium (K). The soils of Tatumbla are susceptible to water erosion, especially in the high areas. Because of their nutrient deficiencies, the application of fertilizers (NKP and NP formulas) is indispensable to achieving increased and sustained yields.

Approximately 67 percent of the area is covered with forest and 33 percent is used for agriculture. The predominant activity is subsistence agriculture, and the principal crops are corn and beans, with cabbage as a cash crop. Potatoes,

Figure 6-1. Honduras: Location of the Study Sites



onions, carrots, and manzanilla are also cultivated on a minor scale. Farms are small in size: 70 percent have less than 2 hectares, 20 percent have from 2 to 10 hectares, and only 10 percent have more than 10 hectares. Most farmers (80 percent) own land by occupation, that is to say, they do not have legal documents that qualify them as landowners; another 10 percent do not have land.

Thanks to its proximity to the capital, Tatumbla has a good communication system with maintenance throughout the year. Five access routes link Tegucigalpa and Tatumbla. Institutional presence in the area is also high.

Soil erosion and conservation in Tatumbla

Before 1978, Tatumbla was characterized by low yields in corn, beans, vegetables, and potatoes. Those yields were caused by two principal factors: (a) poor crop production practices, especially in relation to planting distances; and (b) inadequate soil management that favored erosion. At the beginning of the first conservation program in the area, potato cultivation was promoted and the advantage of reducing planting distances for corn was demonstrated to farmers. Increases in yields resulting from the adoption of conservation practices and inputs were also demonstrated.

Soil erosion has never been measured in the area, but data from Wouters (1980) for the Ojojona soil series estimate that average annual erosion is between 9 and 50 metric tons per hectare on slopes between 15 and 40 percent. In the nearby locality of Brea, municipality of Lepaterique, whose soils also belong to the Ojojona series, annual soil loss of 42 metric tons per hectare has been estimated for a rotation of corn and beans on a 45 percent slope, with annual precipitation of 2,000 millimeters (LUPE-SRN technicians, personal communication).

In addition to the effects on productivity, erosion also causes problems off the farm. Sediment is deposited in the Tatumbla and Sabacuante rivers, which are important sources of water for the southeastern part of the capital. In 1991, those rivers produced only half their normal daily flow (*El Heraldo*, 28 August 1991).[3]

The first soil conservation program in Tatumbla was initiated in 1977, under the SRN's Soil and Water Conservation and Management Program.[4] Two model farms were established in the locality of Linaca, located 1 kilometer from Tatumbla. Diversion ditches protected with live barriers of king grass were constructed on these farms, with the aim of demonstrating the advantages of their use. The diversion ditches consisted of narrow canals, laid across the slope at predetermined intervals, which intercepted runoff water. The live barriers, in addition to protecting the canal, prevented soils from being carried away. Initially, the area was attended by only one technician, and this, together with the farmers' general ignorance of the new technology, contributed to the slow process of technology transfer and adoption in the initial stages. As farmers began to experience the benefits of conservation practices for their yield and the quality of their soil, however, others were motivated to become beneficiaries of this program, and adoption increased rapidly. By 1991, use of soil conservation practices was widespread and visible. Stone barriers were also introduced, especially on rocky lands, as were live barriers without ditches in soils with the highest capacity for natural drainage. Although these measures also gave good results, 95 percent of the conservation measures constructed were diversion ditches protected by live barriers. This is considered the most useful conservation practice for superficial soils as well as for deep soils on slopes up to 50 percent. The analysis that follows refers to the construction of diversion ditches protected by live barriers. Although no systematic research was undertaken to determine their ability to reduce erosion, it has been observed that over the years erosion has been reduced to a high degree and that slopes have been stabilized.

Technical analysis of soil conservation

Table 6-1 shows data on the average yields of creole corn on fields with and without conservation. This information was obtained from the farmer questionnaire carried out in June of 1991 and is consistent with the data available at the national level for the period 1985–89. This information on yield was used to estimate a time trend of yields for farmers with and without conservation measures. The results of the regression analysis are shown in table 6-2. The negative coefficient in the case without soil conservation practices shows that yield deteriorates on fields where conservation is not employed. This decline is likely to continue until a minimum yield is reached of about 0.57 metric ton per hectare, representing achievable yields on the subsoils (unless production becomes unprofitable earlier). In the case with soil conservation practices, yields increase over time, reflecting the gradual improvement of soils. This process will continue until a maximum sustainable yield, given agroecological conditions and the technology used, of about 3.40 metric tons per hectare is reached.

Economic analysis of soil conservation

These estimated relationships were used to project yields with and without conservation over a 100-year time period and to estimate the returns to adopting the conservation practices. The results are shown in table 6-3. Without conservation, yield will decline to a point at which production is no longer profitable in the eighth year. With conservation, yields will gradually climb to their maximum level. Under the conditions assumed here, conservation is very profitable for farmers. This can be seen both from the net present value of L4,910 per hectare (discounted at 20 percent) and from the internal rate of return of over 50 percent.[5] The investment in soil conservation is recovered in the fourth year. Only in year zero are the net returns for the case with soil conservation practices negative due to the initial investment in the construction of works.

Due to limitations of the data, sensitivity analysis was carried out. A number of the key parameters were varied by as much as 50 percent, and the economic analysis was repeated. The results are shown in table 6-4. As can be seen, the conservation measures remain quite profitable even under much more unfavorable assumptions. In fact, adoption of conservation measures would be profitable even if conservation did not lead to any improvement in yield but simply halted the

Table 6-1. Average Yields of Corn with and without the Construction of Diversion Ditches Protected with Live Barriers in Tatumbla and Yorito, Honduras, 1985–90
(metric tons per hectare)

Group	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
Tatumbla, department of Francisco Morazán						
With soil conservation	—	1.771	1.651	1.923	2.180	2.232
Without soil conservation	—	1.356	1.356	1.185	1.242	1.070
Yorito, department of Yoro						
With soil conservation	1.61	2.01	2.33	2.18	2.20	2.31
Without soil conservation	0.95	0.90	1.00	0.91	0.95	0.81

— Not available.
Source: Farmer questionnaire.

Table 6-2. Regression Models for Estimating the Time Trend of Corn Yield in Tatumbla and Yorito, Honduras

Group	*Fitted line (t-statistics)*	*Adjusted R^2*
Tatumbla, department of Francisco Morazán		
With conservation	Yield = 1.5161 + 0.1451 YEAR (11.93) (3.79)	0.769
Without conservation	Yield = 1.4476 – 0.0686 YEAR (22.04) (–3.46)	0.733
Yorito, department of Yoro		
With conservation	Yield = 1.7147 + 0.1120 YEAR (9.78) (2.49)	0.509
Without conservation	Yield = 0.9840 – 0.01828 YEAR (17.290) (–1.25)	0.101

Source: Author's calculations.

Table 6-3. Analysis of Returns to the Construction of Diversion Ditches Protected with Live Barriers on Farms with 20 Percent Slope Planted to Corn in Tatumbla, Department of Francisco Morazán, Honduras, for a 100-Year Time Horizon
(lempiras per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	1,450	1,381	1,313	1,244	1,176	1,107	1,038	970	0	0	0	0	0	0	0	0
Revenues	1,624	1,547	1,470	1,394	1,317	1,240	1,163	1,086	0	0	0	0	0	0	0	0
Crop production costs	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	0	0	0	0	0	0	0	0
Returns	592	515	438	361	285	208	131	54	0	0	0	0	0	0	0	0
Present value returns	592	429	304	209	137	83	44	15	0	0	0	0	0	0	0	0
Number of years before shutdown	8															
With conservation																
Yield (kilograms per hectare)	1,450	1,595	1,740	1,885	2,030	2,176	2,321	2,466	2,611	2,756	2,901	4,000	4,000	4,000	4,000	4,000
Revenues	1,624	1,787	1,949	2,112	2,274	2,437	2,599	2,762	2,924	3,087	3,249	4,480	4,480	4,480	4,480	4,480
Crop production costs	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032
Conservation costs	972	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106
Returns	-380	648	811	973	1,136	1,298	1,461	1,623	1,786	1,948	2,111	3,342	3,342	3,342	3,342	3,342
Present value returns	-380	540	563	563	548	522	489	453	415	378	341	87	14	2	0	0
Number of years before shutdown	Never															
Returns to conservation																
Net benefits	-972	133	372	612	851	1,090	1,330	1,569	1,786	1,948	2,111	3,342	3,342	3,342	3,342	3,342
Present value net benefits	-972	111	259	354	410	438	445	438	415	378	341	87	14	2	0	0
Cumulative present value net benefits	-972	-861	-603	-249	162	600	1,045	1,483	1,899	2,276	2,617	4,474	4,840	4,899	4,908	4,910
Net present value																
50 years	4,908															
100 years	4,910															
Internal rate of return (percent)	56.5															
Number of years to break even	4															

Source: Author's calculations.

continued decline in yield (in this case, the net present value would be L234 per hectare, and the internal rate of return would be 22.8 percent).

These high estimated returns are consistent with the high rates of adoption of conservation that have been observed in the area. Almost all farmers in Tatumbla have adopted soil conservation practices. The fact that the majority of the area's farmers are owners (by occupation) of the small plots of land they farm and that the conservation measures promoted in the region are simple, relatively low cost, and easy to maintain also contributes to the high rates of adoption.

Technical-economic analysis of the Yorito case

The Yorito nucleus is located in the municipality of Yorito, department of Yoro, includes the communities of El Guaco and Río Arriba, and covers an area of 213 square kilometers (figure 6-1). Yorito has an estimated 41.4 inhabitants per square kilometer and a population growth rate of 3.33 percent. The area is located at an altitude of 760 meters above sea level. The mean annual precipitation is 1,287 millimeters; the climate is categorized as semihumid mesothermic (SRN/DRI-Yoro 1987).

Soils in Yorito are well drained and shallow. They are grouped in the Chimbo soil series. Topsoils are about 15 to 25 centimeters deep; they are very fine silt loam or sandy silt soils, dark-red and friable dun-colored. The reaction is slightly acidic: pH 6.0 to 6.5. Their natural fertility is medium to low. They are easily erodible. Underneath these soils lies a fractured, meteorized, and calcareous shale to a depth of 1 meter or less.

A large part of the area is forested or used for pasture. Yorito farmers generally have small plots of land, which they occupy without title (owners by possession). Most of the economically active population is engaged in agriculture and, on a lesser scale, in livestock raising and forestry.

Yorito is traversed by a highway that remains transitable during the entire year; villages are connected with feeder roads, but many are only passable during the summer. Problems of access and the lack of infrastructure for storage are important obstacles to agricultural development in the area.

Soil erosion and conservation in Yorito

The region's vulnerability to erosion and low fertility make soil conservation measures important to the sustenance of agricultural activities. Soil conservation activities in Yorito began in 1985 under the Rural Technology Program (PTR), which offered technical assistance to farmers. Later, Yorito became part of the Integrated Rural Development Project, DRI-Yoro, which initiated maintenance works. This project concentrates on integrated efforts and attempts to coordinate the work of all public institutions

Table 6-4. Sensitivity Analysis of Returns to Conservation to Percentage Changes in Parameter Values in Tatumbla, Department of Francisco Morazán, Honduras

Indicator	*–50*	*–25*	*–10*	*Base*	*+10*	*+25*	*+50*
Change in yield with conservation							
Base = 145.1 kilograms per hectare a year							
Net present value at 100 years (lempiras)	2,667	3,839	4,496	4,910	5,305	5,858	6,680
Internal rate of return (percent)	42.1	49.6	53.8	56.5	59.2	63.0	69.2
Change in yield without conservation							
Base = –68.6 kilograms per hectare a year							
Net present value at 100 years (lempiras)	4,256	4,635	4,810	4,910	5,001	5,116	5,272
Internal rate of return (percent)	50.6	53.7	55.4	56.5	57.6	59.1	61.4
Cost of conservation (construction and maintenance)							
Base = L972 per hectare for construction + L106 per hectare for maintenance							
Net present value at 100 years (lempiras)	5,662	5,286	5,061	4,910	4,760	4,534	4,158
Internal rate of return (percent)	91.7	69.0	60.8	56.5	52.9	48.4	42.7

Source: Author's calculations.

dealing with agriculture. It includes components dealing with the improvement of agricultural, forestry, and livestock activities, grain storage, research, and the development of off-farm employment as well as conservation. The project was still continuing at the time this study was conducted.

The DRI-Yoro project employs a variety of soil conservation measures, which is logical because many factors influence erosion. Soil conservation measures used in Yorito include agronomic and cultural measures such as contour planting and live barriers, fertility measures such as appropriate use of fertilizer and manure, and mechanical measures such as stone barriers and diversion ditches. Diversion ditches are generally constructed on slopes greater than 12 percent and are protected with live barriers of pasture grass. They are constructed on the contour, thus facilitating both the interception and the storage of water. Diversion ditches with live barriers are the principal conservation practice adopted by farmers of Guaco and Río Arriba. Stone barriers have also been constructed, taking advantage, on a lesser scale, of the large quantity of rocks in the superficial soils.

Again, no specific measurements have been made of erosion rates with and without the conservation measures. In general, however, reductions of erosion have been observed through increases in soil depth in the higher part of the structures, greater retention of water, and improvements in soil structure (SRN/DRI-Yoro 1987).

Technical analysis of soil conservation

The conservation measure analyzed in the Yorito case consists of diversion ditches with live barriers, which is the most widely adopted measure in the area. In general, hillside farmers who do not practice soil conservation obtain average yields between 0.7 and 1.1 metric tons per hectare of corn, although in some areas yields barely reach 0.4 metric ton per hectare. Table 6-1 shows data obtained from the farmer questionnaire carried out in June of 1991 on the average yields of corn on fields with and without conservation. As in the case of Tatumbla, this information on yield was used to estimate a time trend of yields for farmers with and without conservation measures.

The results of the regression analysis are shown in table 6-2. In this case, the results are somewhat inconclusive. The negative coefficient in the case with no soil conservation practices seems to indicate that there is deterioration in fields on which soil conservation practices are not employed, but the coefficient is not significantly different from zero. Moreover, the explanatory power of the equation is very low (R^2=0.1). This could be due either to faulty data (since the data depend on farmer recall) or, more likely, to the failure to account for the many other factors that are also influencing yields (for example, weather variations, differences in agroecological conditions within the sample, and changes in practices). This is a problem that can only be resolved by collecting additional data. For the moment, we use the estimates given in table 6-2, but with a very strong word of caution for readers interpreting the results.

The results for the farmers who are employing soil conservation measures are statistically much better; the coefficients are significant and the R^2 is relatively high. These results show both a higher initial level of yield and an increasing trend. Here again, however, caution must be exercised. It is quite possible that the farmers who adopted conservation practices first are the better, more progressive farmers. Such farmers would have achieved higher yields than other farmers even if they had not used conservation practices. If they are adopting improved practices in addition to conservation practices, their improvements in yield might be the result of those practices rather than of conservation alone. It is also possible that farmers would conserve their best, most valuable land first. Again, yields on such land would be better than yields on other land even without conservation. For these reasons, the substantial improvements in yield should not be credited solely to conservation. The estimates given in table 6-2 are used here as a first approximation, but much research is clearly needed to obtain more reliable results.

Economic analysis of soil conservation

The results of the economic analysis are shown in table 6-5. As in the case of Tatumbla, the estimated relationships are used to project yields over a 100-year time horizon. The current average yield on farms without conservation is taken as the initial yield. Information on costs of production and conservation obtained from farmers and project personnel are used to estimate costs and benefits for farmers with and without conservation. Crop production costs for farmers not using conservation measures are assumed to be only 75 percent of crop production costs for those who are. This adjustment is made to allow partially for any improved practices used by farmers employing conservation measures.

In the case of farmers not using conservation, yield is estimated to decline gradually until production becomes unprofitable in the eleventh year. In the case of farmers using conservation, yields gradually increase, as a result of soil damage being repaired and of the improved practices, until the maximum feasible yield under the given conditions is achieved. This is accomplished beginning in the eighteenth year. The returns to the investment in conservation, discounted at 20 percent, are L448 per hectare, which indicates a profitable investment with a 22 percent rate of return that takes eighteen years to be repaid.

Because the data are so weak, simulation analysis was used to determine how robust the results are to changes in assumptions. The results are shown in table 6-6. The yield trends with and without conservation are particularly uncertain. As can be seen, the estimates of returns to conservation are quite sensitive to the assumed change in yield under conservation; if the true effect of conservation on yield is in fact less than the base case assumption, the investment in conservation may not be profitable. If conservation simply stops the decline in yield but does not produce an increase in yield, then conservation will definitely not be profitable. On the other hand, results for the case without conservation are not very sensitive to changes in the assumed rate of decline in yield. Results are also fairly sensitive to assumptions about the cost of conservation.

These mixed results are consistent with observed patterns of adoption. To date, it is estimated that only 20 percent of the farmers in El Guaco and 30 percent in the municipality of Yorito have adopted soil conservation practices. The estimated coverage of conservation measures for the area served by the DRI-Yoro program as a whole is also very low. No doubt logistical problems, the failure to provide adequate technical assistance, and the short life of the project to date all contribute to the low rate of adoption thus far. Yet some farmers who have not adopted conservation practices have adopted other practices promoted by the project. Perhaps the most important example is that farmers no longer burn vegetation to clear their fields.

Conclusions

The results show that the soil conservation practices evaluated (diversion ditches protected with live barriers) are financially profitable for small farmers in the areas studied. These results are preliminary and specific to the areas studied. The estimated returns to conservation in Yorito should be treated with particular caution, but both study sites suffer from a lack of basic information on rates of degradation and their effect on yields. To allow better estimates to be obtained, SRN should implement, at a national level, a continuing program of basic research for determining rates of degradation and the resulting loss of yield. This research should be conducted in a larger number of samples representative of the different agroecological conditions found in the country; variations within regions (for example, the effect of slope) should also be studied.

Notes

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2. Other beneficiaries sometimes received similar supplies but had to repay them with produce from the harvest.
3. Low water flows in 1991 were partially due

Table 6-5. Analysis of Returns to Construction of Diversion Ditches Protected with Live Barriers on Farms with 20 Percent Slope Planted to Corn in Yorito, Department of Yoro, Honduras, for a 100-Year Time Horizon
(lempiras per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	980	963	945	928	911	894	876	859	842	824	807	0	0	0	0	0
Revenues	1,176	1,155	1,134	1,114	1,093	1,072	1,051	1,031	1,010	989	968	0	0	0	0	0
Crop production costs	948	948	948	948	948	948	948	948	948	948	948	0	0	0	0	0
Returns	228	207	186	166	145	124	103	83	62	41	20	0	0	0	0	0
Present value returns	228	173	130	96	70	50	35	23	14	8	3	0	0	0	0	0
Number of years before shutdown	11															
With conservation																
Yield (kilograms per hectare)	980	1,092	1,204	1,316	1,428	1,540	1,652	1,764	1,876	1,988	2,100	2,980	2,980	2,980	2,980	2,980
Revenues	1,176	1,310	1,445	1,579	1,714	1,848	1,982	2,117	2,251	2,386	2,520	3,576	3,576	3,576	3,576	3,576
Crop production costs	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264	1,264
Conservation costs	1,436	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Returns	-1,523	-81	54	188	322	457	591	726	860	994	1,129	2,185	2,185	2,185	2,185	2,185
Present value returns	-1,523	-67	37	109	156	184	198	203	200	193	182	57	9	1	0	0
Number of years before shutdown	Never															
Returns to conservation																
Net benefits	-1,751	-288	-133	22	178	333	488	643	798	953	1,108	2,185	2,185	2,185	2,185	2,185
Present value net benefits	-1,751	-240	-92	13	86	134	163	179	186	185	179	57	9	1	0	0
Cumulative present value net benefits	-1,751	-1,991	-2,083	-2,071	-1,985	-1,851	-1,688	-1,508	-1,323	-1,138	-959	163	402	441	447	448
Net present value																
50 years	447															
100 years	448															
Internal rate of return (percent)	21.9															
Number of years to break even	18															

Source: Author's calculations.

Table 6-6. Sensitivity Analysis of Returns to Conservation and Changes in Parameter Values in Yorito, Department of Yoro, Honduras

Table 6-6. Sensitivity Analysis of Returns to Conservation to Percentage Changes in Parameter Values in Yorito, Department of Yoro, Honduras

Indicator	*–50*	*–25*	*–10*	*Base*	*+10*	*+25*	*+50*
Change in yield with conservation							
Base = 112 kilograms per hectare a year							
Net present value at 100 years (lempiras per hectare)	–1,415	–444	103	448	776	1,238	1,929
Internal rate of return (percent)	13.7	18.1	20.4	21.9	23.4	25.5	28.7
Change in yield without conservation							
Base = -17.3 kilograms per hectare a year							
Net present value at 100 years (lempiras per hectare)	215	344	409	448	483	531	597
Internal rate of return (percent)	20.9	21.5	21.8	21.9	22.1	22.3	22.6
Cost of conservation (construction and maintenance)							
Base = L1,435 kilograms per hectare for construction + L127 per hectare for maintenance							
Net present value at 100 years (lempiras per hectare)	1,485	966	655	448	241	–70	–589
Internal rate of return (percent)	29.0	24.9	23.0	21.9	21.0	19.7	18.0

— Not available.
Source: Author's calculations.

to a general drought in the country.
4. Beginning in 1982, soil conservation efforts in the area were carried out by PARM; beginning in 1990, they were taken over by LUPE.
5. Honduras's currency is the lempira.

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7. Technical and Economic Analysis of a Soil Conservation Project in Nicaragua

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Nicaragua is a predominantly agricultural country. At the end of the 1980s, agriculture accounted for 80 percent of exports and 30 percent of the economically active population. Concern over the deterioration of natural resources grew in the 1980s and suggested the need for establishing a sustainable agricultural system that would satisfy the basic needs of the population while preserving the environment. Despite the sociopolitical crisis in the country during the 1980s, several conservation efforts were launched.

Very few efforts have been made so far to examine the technical, economic, and institutional problems facing soil conservation efforts in Nicaragua. As an initial effort to carry out such an analysis, this paper examines the case of soil conservation in the Santa Lucía Valley. Unfortunately, almost no data are available for use in the analysis, so hypothetical cases had to be constructed to examine the possible returns to conservation under a variety of conditions. The results show that conservation in this area will be profitable from an individual farmer's perspective if crop yields decline rapidly without conservation or crop yields increase rapidly with conservation. If crop yields decline only slowly without conservation or do not increase substantially with it, conservation probably will not be profitable from an individual farmer's perspective.

Soil conservation efforts in Nicaragua

The history of soil conservation in Nicaragua is related to the development of cotton cultivation in the western region of the country in the 1950s, which transformed a diversified agricultural system into a monocultural system. At its peak, the area planted to cotton reached 200,000 hectares. Terracing on contour lines was used throughout most of this area to reduce the danger of soil erosion, which is a serious threat on the loamy volcanic soils that predominate in the region. Promotion of conservation measures in the cotton-producing areas was a joint effort of the Ministry of Agriculture and Livestock, the National Development Bank, and the National Cotton Commission. In general, these initial soil conservation efforts were positive. In the 1970s, however, wind erosion produced enormous dust clouds, and the resulting problems were particularly intense in the area of León. The Soil Conservation and Environmental Project, executed between 1980 and 1983, sought to address this problem by establishing 1,160 kilometers of windbreaks and 800 hectares of forest plantations in hilly and in cultivated areas. Changes in the plowing system were also introduced to avoid excessive pulverization of the soil. Although many of these measures were later abandoned, the project lessened the severity of the "dust cloud."

Several soil conservation projects were initiated in the second half of the 1980s, and many other projects had soil conservation components. Among the most important of these was the Farmer-to-Farmer Program, launched in 1987 by the National Union of Farmers and Cattle Raisers to promote soil conservation and improve crop productivity. By 1990, it covered almost all administrative regions of the country. The Los Maribios is another significant project. Initiated in 1988, it covers 1,200 square kilometers in the mountain ranges of Los Maribios and the Pacific Ocean coastal plain. Its objective is to help restore the ecological potential and productivity of the Los Maribios range through rational use of the soil-water-vegetation system. It also includes a soil conservation component specifically aimed at restoring fertility and crop production. CARE (Cooperative for American Relief Everywhere) has financed and assisted projects in a number of areas, including the watershed of the El Pital River, the community of Escalera in the area of El Tuma-Matagalpa, and the municipality of San Ramón. Considerable conservation activity has also been carried out, beginning in 1983, in the watershed south of Lake Xolotlán, with the primary objective of protecting the city of Managua from flooding.

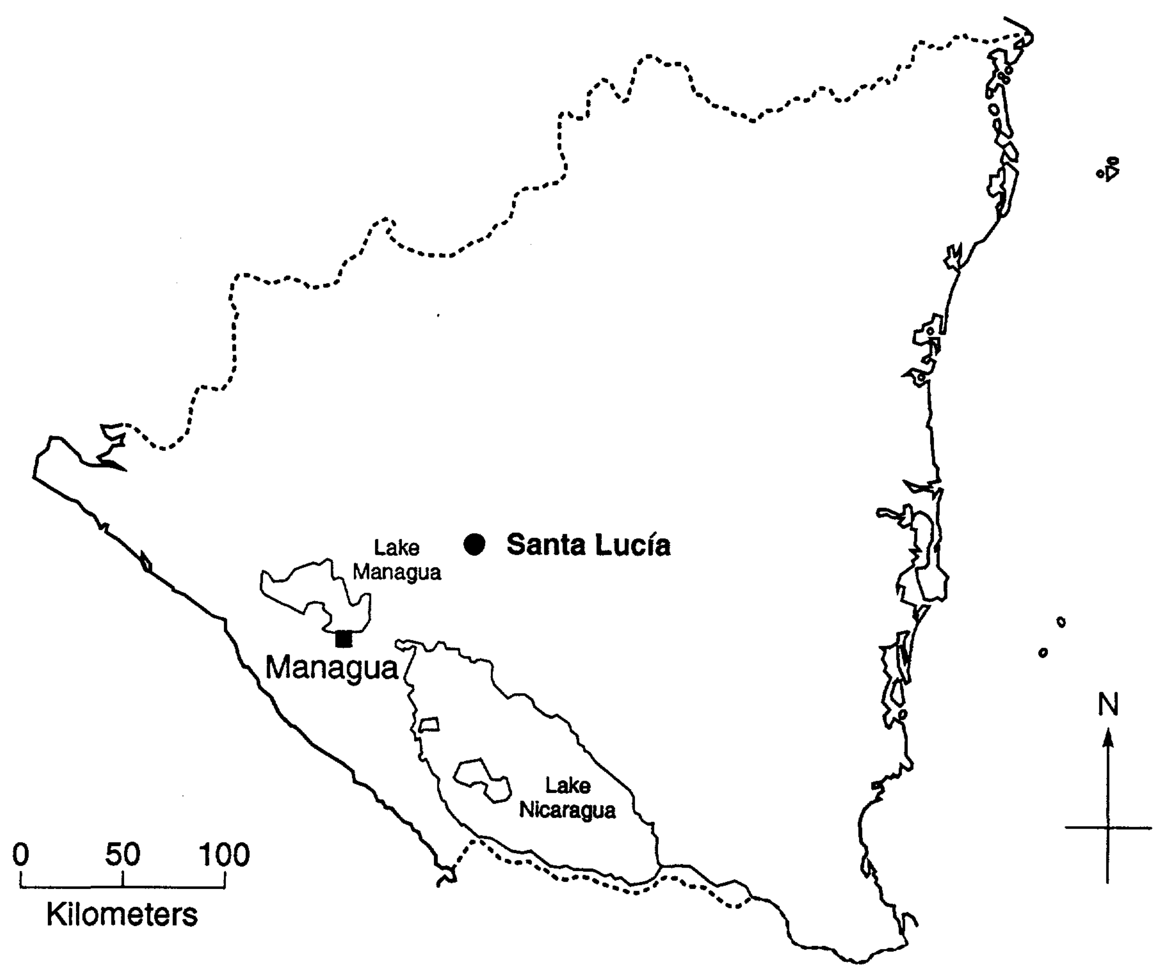
Analysis of soil conservation in Santa Lucía

This section provides a detailed analysis of soil conservation efforts in the Santa Lucía area (see figure 7-1). The conservation measures examined consist of manually constructed diversion ditches with stone barriers.

Characteristics of the study area

The Santa Lucía Valley, located in the highland watershed of the Malacatoya River, is one of the most productive areas in the country. The most productive part of the watershed is the middle area, known as the foothills. This area, which covers about half of the watershed, is located between 300 and 500 meters above sea level and has moderate to steep relief (slopes between 15 and 50 percent). The climate is subtropical semihumid forest, with an average precipita-

Figure 7-1. Nicaragua: Location of the Study Site



tion of about 1,200–1,300 millimeters. Soils are shallow to moderately deep, with a stony surface layer.

More than half of the area is occupied by privately owned small and medium-size farms, and about 5 percent is farmed cooperatively or collectively. The remainder is used for large-scale production.

Agriculture and livestock are the main activities in the foothills, and several crop production systems are in use. Among the dominant ones are beans alone, intercropped corn and beans, and tomatoes alone. Cultivation practices vary, even within a given system. Fertilizer use on food crop systems, for example, varies between 64 and 325 kilograms of the complete formula per hectare. The traditional cultivation practice consists of planting in furrows with an ox plow and a handspike; furrows are generally laid out without considering the direction of the slope. Stubbles are burned on harvested land. Some farmers have adopted improved practices promoted by the conservation project, including plowing on the contour, reducing tillage, and using organic and green fertilizers. Crop stubbles are converted into compost rather than burned.

Deforestation is a severe problem in the higher part of the watershed. In the foothills, the main cause of degradation is soil loss through water erosion. The risk of erosion is high in this area because of steep slopes, scarce vegetation cover, intense precipitation (85 percent of the rain falls during the period from May to October), and other factors. Soil loss threatens both the productivity of the region's agriculture and the downstream reservoirs.

The Farmer-to-Farmer Program has been active in Santa Lucía since 1987; in fact, the area was part of the project's pilot plan. The objectives of soil conservation work here are to protect the Las Canoas dam downstream and to achieve sustainable agricultural and forestry practices. Conservation work carried out by the project primarily involves efforts to control water erosion through mechanical practices in conservation and to improve production through improved crop management practices.

Technical analysis

Manually constructed diversion ditches with stone barriers are one of the most important conservation measures used in Santa Lucía. This section and the following examine the technical and economic benefits of adopting such practices on fields with 20 percent slope planted to beans.

Unfortunately, data are insufficient to allow a full analysis of the returns to soil conservation measures in Santa Lucía. A survey of twenty-six farmers was carried out, but since few had used conservation measures for more than a few years, it was not possible to identify the effect of conservation on yields and compare it with yield trends for farmers who had not used conservation. Anecdotal information obtained from farmers indicates that the combined use of conservation practices and improved agricultural practices produces higher yields than previous practices. However, this effect could not be confirmed through statistical analysis of the data, which did reveal, however, that both rainfall and slope significantly affect yields. A 1 percent increase in slope, for example, appears to reduce average yields by about 80 kilograms per hectare. Fertilizer use was found not to have a significant effect on yields. This probably indicates that fertilizer is being used to compensate for variations in the soil's fertility. These findings are important because they indicate that any analysis of the effects of conservation must allow for variations in conditions on each individual plot.

Soil samples were collected in an attempt to determine whether the use of conservation practices improves the quality of the soil. The effect of soil conservation on the physicochemical characteristics of the soil had not previously been studied in Nicaragua. Results show that plots with conservation have higher cation and organic matter content, indicating that using conservation and improved practices together improves chemical characteristics. The analysis of changes in physical characteristics was inconclusive, however. Impressions obtained from farmers indicated that conservation practices improve soil depth and its capacity to retain moisture, but these subjective impressions could not be confirmed.

Because of the lack of concrete data on the effects that degradation and conservation have on yields, hypothetical yield trends had to be used in the analysis. The effect of a range of possible yield trends was tested. The base case involves no changes in yield under either the conservation or the traditional practice. This case is the most unfavorable for conservation. Case A assumes that yields without conserva-

Table 7-1. Results of Technical-Economic Analysis of Investment in Soil Conservation on Fields Planted to Beans on 20 Percent Slope in the Foothills of the Santa Lucía Watershed, Nicaragua

Case	*Yield decline without conservation (percent)*	*Yield increase with conservation (percent)*	*Net present value (córdobas per hectare)*	*Rate of return (percent)*	*Number of years to repay the investment*
Base	0	0	-2,798	< 0	Never
A	1	0	-2,108	5.5	Never
B	5	0	51	20.4	26
C	0	1	-2,112	6.6	Never
D	0	5	928	25.2	13
E	1	1	-1,423	11.2	Never
F	5	5	3,776	40.2	6

Note: The net present value is discounted at 20 percent.

tion decline 1 percent annually, while yields with conservation remain unchanged. Case B is the same except that an annual decline in yield of 5 percent is assumed. Case C assumes that yields do not decline in the case with no conservation, but that yields increase 1 percent annually if conservation measures are adopted. Yields obtained cannot increase indefinitely, however, because a natural limit is set by the production potential of the plant. In the case of beans, the maximum yield that can be reached with the variety used by the area's farmers employing good management practices is about 2,500 kilograms per hectare. Case D is the same except that yield increases 5 percent annually, up to the same maximum. Finally, cases E and F combine the four previous cases: in case E, yields without conservation fall 1 percent annually and yields with conservation increase 1 percent annually, while in case F yields without conservation fall 5 percent annually and yields with conservation increase 5 percent annually. Case F is the most favorable to conservation. In each case, the initial yield was set at an average of current yields in the area. With conservation, the area planted is decreased 10 percent because some land is used for the diversion ditches.

Economic analysis

Data on production costs were obtained from the farmer questionnaire and from the crop budgets maintained by the National Development Bank. Farmers were asked about their rates of input use, including their use of fertilizer, labor, seed, and other inputs. Labor costs were priced at the prevailing rate of C$10 a day, rather than the officially reported price of C$5 a day, which no one in the study area paid.[2] The output price used in the analysis (C$1.76 per kilogram) is the price paid to farmers at the farm gate. The costs of crop production were assumed to remain constant during the period of analysis. The cost of investment in conservation works was obtained from the questionnaire and from an on-site evaluation carried out by technicians of the Ministry of Agriculture and Livestock.

Table 7-1 shows the results of the analysis of the returns to investment in conservation under each of the hypothetical cases assumed. In the base case, conservation would not pay from the perspective of individual farmers. This is as expected, since in this case conservation would add costs but have no benefits. Likewise, conservation also would not pay if the yield benefits were minor. Cases A, C, and E assume that annual changes in yield with and without conservation are 1 percent or less. In all of these cases, investments in conservation do not pay for individual farmers. Expressed another way, the rate of return for investments in conservation is low under these conditions because the benefits of conservation are too small to pay for the high costs of conservation, including the costs of both investment and maintenance and of the reduction in cultivated area.

Table 7-2 shows the analysis in detail for case E. Even though yields are falling (1 percent annually) without conservation and increasing

Table 7-2. Analysis of Returns to Soil Conservation on Fields Planted to Beans on 20 Percent Slope in the Foothills of the Santa Lucía Watershed, Nicaragua, Assuming an Annual Decline in Yield without Conservation of 1 percent and an Annual Increase in Yield with Conservation of 1 Percent (Case E), for a 100-Year Time Horizon

(córdobas per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)	1,371	1,357	1,344	1,330	1,317	1,304	1,291	1,278	1,265	1,252	1,240	1,121	1,014	917	829	0
Revenues	2,413	2,389	2,365	2,341	2,318	2,295	2,272	2,249	2,227	2,204	2,182	1,974	1,785	1,614	1,460	0
Crop production costs	976	976	976	976	976	976	976	976	976	976	976	976	976	976	976	0
Returns	1,437	1,413	1,389	1,365	1,342	1,319	1,296	1,273	1,251	1,228	1,206	998	809	638	484	0
Present value returns	1,437	1,177	965	790	647	530	434	355	291	238	195	26	3	0	0	0
Number of years before shutdown	91															
With conservation																
Yield (kilograms per hectare)	1,234	1,246	1,259	1,271	1,284	1,297	1,310	1,323	1,336	1,349	1,363	1,506	1,663	1,837	2,029	2,519
Revenues	2,172	2,193	2,215	2,237	2,260	2,282	2,305	2,328	2,352	2,375	2,399	2,650	2,927	3,233	3,572	4,433
Crop production costs	976	976	976	976	976	976	976	976	976	976	976	976	976	976	976	976
Conservation costs	950	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Returns	246	1,137	1,159	1,181	1,204	1,226	1,249	1,272	1,296	1,319	1,343	1,594	1,871	2,177	2,516	3,377
Present value returns	246	948	805	684	581	493	418	355	301	256	217	42	8	1	0	0
Number of years before shutdown	Never															
Returns to conservation																
Net benefits	-1,191	-275	-230	-184	-138	-92	-46	-1	45	91	137	596	1,062	1,539	2,032	3,377
Present value net benefits	-1,191	-230	-159	-106	-67	-37	-16	0	10	18	22	16	4	1	0	0
Cumulative present value net benefits	-1,191	-1,421	-1,580	-1,687	-1,753	-1,790	-1,806	-1,806	-1,796	-1,778	-1,756	-1,537	-1,451	-1,429	-1,424	-1,423
Net present value																
50 years	-1,424															
100 years	-1,423															
Internal rate of return (percent)	11.2															
Number of years to break even	Never															

Source: Authors' calculations.

(also 1 percent annually) with conservation, it would take six years for yields with conservation to exceed yields without conservation, because a smaller area is planted in the case with conservation. Even then, returns to the practices without conservation remain higher for another few years because costs are higher with conservation. Only in the eighth year do returns with conservation exceed returns without it. But the difference remains small for quite some time because yield changes at a slow rate. These small benefits mean that it is very difficult to compensate for the initial investment cost and the relative losses in the early period of the project. In this case, the investment does not pay, as shown by the negative net present value of returns.

Conservation would be profitable if the yield benefits of conservation are substantial. In case B, the decline in yield without conservation is 5 percent a year. If the decline in yield were this rapid, investments in conservation would be profitable for individual farmers despite the high costs of investment and the decline in planted area. The same would be true if yields remain unchanged without conservation but increase 5 percent annually, up to a maximum, if conservation measures are adopted (case D). If both the decline in yield without conservation and the increase in yield with conservation are high (case F), the investment in conservation would be very profitable.

More research is required to determine which of these cases best represents the situation in Santa Lucía. These results show that accurate information on the rate of decline in yield experienced by farmers if they do not adopt conservation measures, and the rate of increase in yield if they do, is necessary to determine the profitability of conservation measures. Without such accurate information, it is impossible to say whether conservation is profitable or not from the individual farmer's perspective. Given that yields were observed to vary with slope, it is also possible that detailed information would show that conservation measures pay for some farmers and not for others.

INSTITUTIONAL ANALYSIS

Soil conservation activities were implemented by the National Union of Farmers and Cattle Raisers as part of the pilot project for the Farmer-to-Farmer Program, with the support from CEDECAP, a Mexican nongovernmental organization. Soil conservation work began in 1987 when fifteen farmers received training from CEDECAP. Seven of these farmers, who showed interest not only in carrying out conservation works but also in providing training to other farmers, became soil conservation promoters in the area. These farmers received C$100 each day that they spent on tasks designed to promote conservation (such as giving talks to farmer groups or organizing field visits). The Institute of Natural Resources and Environment has also been active in the region with, for example, a reforestation project designed to protect the Las Canoas dam.

Adoption of conservation measures by farmers in the area has been limited for several reasons. First, the cost of constructing the conservation structures is high for small farmers. As shown by the economic analysis, this cost would only be justified if the benefits of conservation were also high. Second, farmers who use only their own resources might not be able to undertake the investment required even if that investment would be profitable. Third, the lack of sustained popularization of conservation technology and the lack of continuity and technical assistance might also discourage some farmers.

Nevertheless, results were more encouraging than those experienced in the watershed to the south of Lake Xolotlán. In that area, conservation measures were constructed with machinery in order to protect the city of Managua from flooding. Even though the conservation measures were built at no cost to farmers, they generally interfered with common cultivation practices in the area. Many of the measures built by the project were either abandoned or undermined by farmers returning to their traditional practices.

Conclusions and recommendations

The primary need is for more and better information on the effects of soil degradation and conservation. In the absence of such information, it will be very difficult to develop conservation programs that are appropriate and likely to be adopted by farmers. The results of the simulations carried out in this study show that conservation can be profitable under certain conditions. But developing appropriate conservation programs is not sufficient; information about them and assistance must also be effectively provided to farmers.

Notes

1. The authors are grateful for the cooperation of Ing. Reynaldo Román and Ing. Alfonso Whitford, who are specialists in irrigation and soil, respectively, and to the Management of Mechanization and Irrigation of Dirección General Técnica de Agricultura (DGTA) for its participation in the survey of farmers and its contribution to the characterization of soils in the study areas. The authors are also thankful to the technical team of the Agrometeorology Division of the Ministry of Agriculture for providing climatological information for the cases selected. A special thanks goes to the following persons in the Ministry of Agriculture: Damary Meléndez S., Management of Planning, for her secretarial service in writing up the report; and Lic. Ramiro Saborío, director general of the DGTA; Lic. Roger Montiel, director of planning; and especially Ing. Roberto Rondón, senior minister, for making this study possible. Finally, the authors express their thanks to all others who directly and indirectly contributed to this study.
2. Nicaragua's currency is the córdoba.

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8. Economic and Institutional Analysis of Soil Conservation at the Farm Level in Coclé, Panama

Tomás Vásquez and Julio Santamaría

Panama has, according to reports by national and foreign specialists, one of the most acute erosion problems in Latin America (MIDA/FAO 1975). Soil losses as high as 200 tons a year have been estimated for the highlands of Chiriquí (Oster 1981) and as high as 90 tons a year for the watershed of the Canal (Isaza 1984). At the high rates of soil loss seen in Chiriquí, the area's deep, highly fertile volcanic soils will be lost within twenty-five years. Numerous efforts have been made to halt and reverse these high rates of degradation, with mixed results.

Despite the importance of the problem, soil management and conservation projects have not been analyzed technically, institutionally, or economically to understand their implications for individual farms and for the environment. The principal objective of this chapter is to carry out economic and institutional analysis at the farm level of the Agroforestry Project for Community Development, a soil conservation project that operated in the central province of Coclé. This study is a preliminary exploration and should be complemented with other, more detailed studies.

General aspects of soil conservation efforts in Panama

Several studies suggest that less than 10 percent of Panama's land is potentially useful for intensive agriculture, with another 10 percent being appropriate for improved pastures (Organization of American States 1978; Plath 1979; Tosi 1971). Approximately 65 percent of the country is characterized as being marginal for agriculture. Intensive rains, which are frequent in the isthmus, hilly topography, and lack of aggregation in soils used for agriculture all serve to make Panama's soils very vulnerable to erosion.

Nevertheless, large areas have lost their once-extensive forest areas and been converted to agriculture, thus exposing them to the danger of degradation. An environmental profile of Panama prepared by the U.S. Agency for International Development (1981) for the Ministry of Planning and Economic Policy estimates that soil degradation affects 1.2 million hectares in Panama. Examples of soil damage are not hard to find. Rill and furrow erosion is especially visible in areas used for slash and burn agriculture, whereas gullies are frequent and visible on lands used for extensive livestock production. Gullies are common, for example, in Coclé and Los Santos. Rill erosion is severe in Herrera and Los Santos. In the highlands of Chiriquí, fertile volcanic soils are being washed away by furrow and rill erosion, resulting in the loss of fertility and organic material. Oster (1981) measured soil loss rates of 35 tons per hectare on planted pasture land and of 77 tons per hectare on coffee land in Chiriquí during 1979 and 1980.

Despite high rates of soil loss, few farmers use conservation practices. Agricultural management in most of the country often has the characteristic of extraction. In some cases, a conservationist attitude is missing because soil loss does not have a direct impact on productivity. In the highlands of Chiriquí, for example, high soil fertility, even in secondary horizons, means that erosion has little direct impact on yields. To the extent that an impact exists, farmers find it cheaper to increase their use of fertilizer than to implement conservation. In horticulture, for example, up to a ton of complete fertilizer is used per hectare, together with substantial amounts of *gallinaza*.

In addition to damage on farms, soil erosion also causes significant damage through sedimentation downstream. Most serious for the country's economy is the threat of sedimentation to the Panama Canal.

Despite the dimensions of the problem, Panama lacks clear policies or a national program for dealing with soil management and conservation. Specialists on the subject are scarce, and relatively little research has been done. Although numerous soil surveys have been carried out, beginning in 1955, in many parts of the country, they have not addressed the problems of degradation directly. The first problem encountered in any analysis of erosion is that the available information is not used.

Soil conservation activities were initiated in the 1950s by Panama's Ministry of Agriculture, but their experiences and accomplishments were modest and lost over time. Until the middle of the 1970s, no specific soil conservation projects were carried out. Likewise, although some institutional and legal bases were created for natural resource conservation, no specific laws were passed to regulate soil management. The agricultural code, although it contains isolated measures related to proper use of the land, is oriented primarily toward achieving agrarian reform rather than toward encouraging preservation.

More recently (1979–81), research activities and technical assistance in soil conservation were developed in the highlands of the Chiriquí Province (Boquete and Cerro Punta) with help from the French Mission for Technical Cooperation. Technicians from the National Directorate of Renewable Natural Resources (today an autonomous institution of the Ministry of Agricultural Development), together with a specialist from the French government, carried out applied research on soil conservation.

Additional soil conservation experiences were generated by the Canal Watershed Management Project (AID/RENARE), which sought to reduce erosion by improving pasture, reclaiming gullies, and managing overflow using diversion canals and vegetation as a factor of protection. Nevertheless, farmers and livestock breeders were not incorporated satisfactorily in soil conservation work because the project concentrated almost all its resources on reforesting and on strengthening institutions and had a very short-run planning horizon (five years).

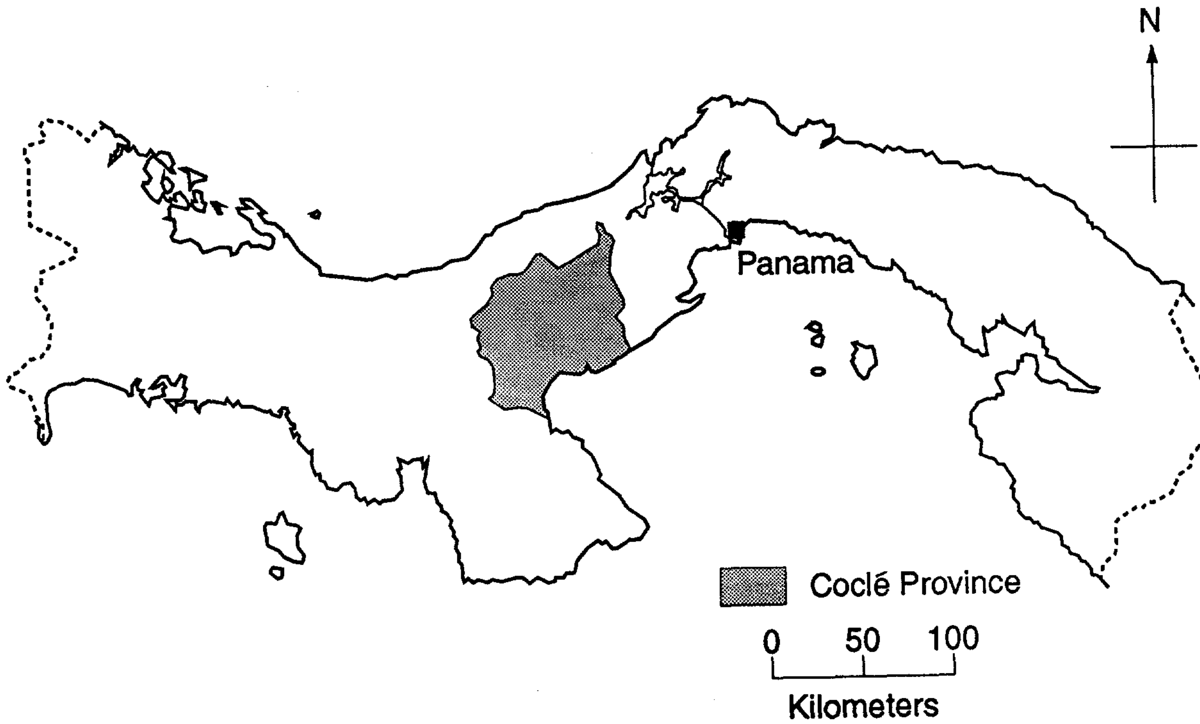
In 1986, CARE International, a nonprofit aid and grass-roots development organization, expressed to the government of Panama its desire to help the country confront the problems of deforestation, low soil productivity, and low income levels in marginal rural areas. Its proposal included combining the use of agroforestry practices with soil conservation techniques. As a result of this proposal, the National Institute on Renewable Natural Resources and CARE (Cooperative for American Relief Everywhere) designed a collaborative project for marginal rural communities, named Agroforestry Project for Community Development, INRENARE/CARE/COMUNIDAD. Its final objective was "to improve the well-being of the small farmer on the basis of land use practices which ensure the sustainable productivity of soil, water, and forest resources." Unfortunately, rising political tensions between Panama and the United States caused CARE's departure in 1988, thus hampering the execution of the second phase of the project.

Analysis of soil conservation practices in Coclé

The Agroforestry Project for Community Development operated in the central province of Coclé, Santa Cruz, San Pedro (see figure 8-1). The climate in the project area is primarily humid tropical forest, except for El Llano, which has a montane humid forest climate. Soils in the project area belong to the Copé series. They are generally low in organic material, nitrogen, and phosphorus. Available potassium and calcium do not present problems. Slopes are often steep, averaging 28 percent.

In general, there are no large cultivated areas. Agricultural activity consists mainly of small areas (which usually do not exceed 0.5 hectare) cultivated to subsistence crops using slash and burn practices. The traditional practice consists of clearing and burning the vegetation of a new plot every year and abandoning plots after a year of cultivation. Farmers return

Figure 8-1. Panama: Location of the Coclé Study Site



to a plot that has remained fallow for five years and the soil's natural fertility has been restored. Crops grown include rice, corn, beans, yucca, sweet potatoes, and horticultural plants. Crop yields are very low compared with the national average, due to the effects of erosion, dry conditions (the region is in a rain shadow), and low soil fertility.

Technical analysis of soil degradation and conservation

Basic research is lacking in the area covered by the CARE/INRENARE (Coclé) Project. The methodology employed for this study combined an analysis of existing secondary documentation with information obtained from project personnel and other key informants and from a sample survey of farmers in the project area. For the sample survey, five of the fourteen communities in the area were visited, and eighteen farmers who use conservation practices were interviewed.

Although information is weak on appropriate coefficients for applying the Universal Soil Loss Equation (USLE) in Panama, a rough estimate of soil loss can be calculated. Alexis (1987) reports a value of R=1,013 for the rainfall erosivity factor, based on analysis of ten years (1980–90) of records at the Antón and Toabre meteorological station, whose radius of influence includes the project area. An average value of K = 0.26 was calculated for the soil erodibility factor for the soils of the Copé series, based on measurements of soil graininess reported by Matthews and Guzmán (1955). Given the average slope length of 30 meters and the average slope of 28 percent, an average value of LS = 6.7 was calculated for the topographic factor, using Wischmeier and Smith's (1978) nomogram, adapted to the metric system by Koolhaas (1977). Finally, values for the crop management factor, C, estimated by Holdridge (1972; cited in Tosi 1971) were used. The results are shown in table 8-1.

Holdridge (1972; cited in Tosi 1971) cites tolerable annual soil loss for these soils of between 26 and 39 tons per hectare a year. Except when conservation practices are employed, estimated levels of soil loss for the project area are well above this range.[1] Considering that the average depth of cultivable soil is 50 centimeters (Matthews and Guzmán 1955), the cultivable soil will be lost within thirty years at these high rates of erosion.

The CARE/INRENARE Agroforestry Project attempted to introduce a package combining simple soil conservation techniques with improved practices such as the use of organic fertilizers. The conservation techniques promoted by the project included planting on the contour and use of live and dead barriers and diversion ditches. Use of these techniques also involves ceasing the pattern of migratory cultivation.

Eighteen farmers who had adopted conservation practices were interviewed about the effect of such practices on their yields. They indicated that use of the conservation practices seemed to allow them to employ continuous cultivation on the plot and maintain practically the same yields over the years. In contrast, under traditional practices, their yields would have fallen rapidly after the first year of production, and they would have been forced to move onto new plots. It is thought that the combination of conservation and improved practices being promoted by the project will enable farmers to remain on the same plot for at least twenty years.

Economic analysis of soil conservation practices

The choices open to farmers in Coclé consist, therefore, either of continuing the traditional pattern of migratory agriculture and thus changing plots every year or of adopting the project package and moving only once every twenty years.

Table 8-2 presents the results of an economic analysis of this choice. The analysis is expressed in terms of returns to the household. In the case without conservation, this is the return to clearing a new 1-hectare plot every year and then moving on the following year. In the case with conservation, it is the return to cultivating a single 1-hectare plot for a twenty-year period before moving to another such plot.

Production costs in the case without conservation include, in addition to the costs of cultivation, the annual cost of clearing new land. In the case with conservation, this cost is borne only once every twenty years. However, use of conservation practices also requires an investment in the construction of the measures used. This investment must be repeated when plots are changed (every twenty years). Cultivation costs are also slightly different; weeding costs are lower under the conservation practice, but this savings is offset by the slightly higher labor requirements of the improved practices being adopted with the conservation measures. Since most tasks are performed by family labor and output is destined almost entirely for home consumption, all values are imputed.[2] Costs were estimated from information obtained in the farmer interviews.

Returns with conservation are higher in each year except that in which the plot is moved and the conservation measures must be established again. The investment in soil conservation takes eight years to break even. The net present value

Table 8-1. Estimated Average Annual Soil Loss under Diverse Conditions of Crop Cover and Soil Management in the Province of Coclé, Panama

Crop and management practice	*C factor*	*Average annual loss:* *Soil (metric tons per hectare)*	*Depth (millimeters)*
Continuous clean cultivation except fallow during dry season	0.65	1,147	55.4
Yucca	0.20	352	17.0
Rice	0.10	176	8.5
Corn	0.30	529	25.6
Clean cultivation with intensive practices, including crop rotation and green cover	0.065	1,286	5.5
Permanent crops without soil conservation practices	0.014	25	1.2
Permanent crops with maximum and intensive soil conservation practices	0.004[a]	7	0.3
Natural and planted pastures without erosion control or pasture control	0.105	185	8.9
Well-managed pastures with rotations and without overgrazing	0.034[a]	60	2.9

Note: R = 1,013; K = 0.26; LS = 2.6; P = 1 (unless otherwise noted).
a. Includes the effect of P.
Source: Authors' calculations.

Table 8-2. Economic Analysis of Returns to Soil Conservation and Improved Agricultural Practices on Farms in Coclé, Panama, for a 100-Year Time Horizon
(balboas per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Yield (kilograms per hectare)																
Rice	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130
Corn	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660
Yucca	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Beans	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Revenues	855	855	855	855	855	855	855	855	855	855	855	855	855	855	855	855
Land clearing costs	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
Crop production costs	465	465	465	465	465	465	465	465	465	465	465	465	465	465	465	465
Returns	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333
Present value returns	333	277	231	193	160	134	111	93	77	64	54	9	1	0	0	0
With conservation																
Yield (kilograms per hectare)																
Rice	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130
Corn	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660
Yucca	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Beans	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Revenues	855	855	855	855	855	855	855	855	855	855	855	855	855	855	855	855
Land clearing costs	58	0	0	0	0	0	0	0	0	0	0	58	0	58	0	58
Crop production costs	465	465	465	465	465	465	465	465	465	465	465	465	465	465	465	465
Conservation costs	100	30	30	30	30	30	30	30	30	30	30	100	30	100	30	100
Returns	233	360	360	360	360	360	360	360	360	360	360	233	360	233	360	233
Present value returns	233	300	250	208	174	145	121	101	84	70	58	6	2	0	0	0
Returns to conservation																
Net benefits	-100	28	28	28	28	28	28	28	28	28	28	-100	28	-100	28	-100
Present value net benefits	-100	23	19	16	13	11	9	8	6	5	4	-3	0	0	0	0
Cumulative present value net benefits	-100	-77	-58	-42	-29	-18	-9	-1	6	11	15	31	34	34	34	34
Net present value																
50 years	34															
100 years	34															
Internal rate of return (percent)	27.2															
Number of years to break even	8															

Source: Authors' calculations.

of returns to conservation, discounted at 20 percent, is B34 per hectare.[3] The internal rate of return for the investment is 27 percent. Although these returns are not very high, they are equivalent to an 8 percent increase in annual income per hectare, which is not negligible. Moreover, returns are positive even in years in which the investment in soil conservation must be carried out.

These results depend on several parameters whose value is uncertain. Table 8-3 shows the results of sensitivity analysis of the effects of changes in these parameters. First, the effect is examined of changes in the length of time in which plots with conservation can be cultivated. Although farmers indicate that yields on plots with conservation have so far remained unchanged after several years of cultivation, how long these yields can be sustained is unclear. In the base case, it was assumed that the plots with conservation must be moved every twenty years. Sensitivity analysis shows that results are sensitive to substantial decreases in this length of time, but not very sensitive to increases. The more often the plot must be moved, the worse are the returns to conservation. Nevertheless, returns remain positive even if the plot must be moved every ten years. The cost of clearing the land is a critical parameter, since it must be borne much more often in the case without conservation. The lower this cost is, the less attractive conservation becomes. The results in table 8-3 show that any significant change in this cost will have a substantial effect on the returns to conservation. Finally, the sensitivity analysis also shows that results are sensitive to changes in the cost of conservation; the higher this cost is, the less profitable is the investment in conservation.

It should be remembered that these results are expressed on a household basis. For the practice of no conservation to be viable, at least 5 hectares of land are required, so that farmers may cultivate a new 1-hectare plot every year and then leave it fallow long enough for fertility to recover. The case with conservation only requires 2 hectares per household. If conservation was widely adopted, therefore, total pressure on the land would be substantially reduced. In addition to the private benefits of increased income, therefore, a social benefit would result from the environmental and ecological benefits associated with the decline in deforestation. More land would remain in undisturbed forest cover. More work is required to quantify such benefits.

INSTITUTIONAL ANALYSIS

The Agroforestry Project for Community Development was executed between November 1986 and June 1989 by personnel of the National Institute of Renewable Natural Resources (INRENARE). This project is considered to be a

Table 8-3. Sensitivity Analysis of Returns to Soil Conservation and Improved Agricultural Practices to Percentage Changes in Parameter Values on Farms in Coclé, Panama

Indicator	*–50*	*–25*	*–10*	*Base*	*+10*	*+25*	*+50*
Years of cultivation with conservation							
Base = 20 years							
Net present value at 100 years (balboas)	13	29	33	34	35	36	37
Internal rate of return (percent)	23.3	26.5	27.0	27.2	27.3	27.4	27.5
Cost of clearing new plots							
Base = B57.5 per hectare							
Net present value at 100 years (balboas)	–109	–37	5	34	63	106	177
Internal rate of return (percent)	< 0	11.5	21.2	27.2	33.1	41.8	56.3
Cost of conservation (construction and maintenance)							
Base = B100 per hectare for construction + B30 per hectare for maintenance							
Net present value at 100 years (balboas)	160	97	59	34	9	–29	–92
Internal rate of return (percent)	85.0	46.6	33.8	27.2	21.7	14.8	5.0

Source: Authors' calculations.

success because of its acceptance by farmers and impact on subsistence farm production. The project trained a large number of farmers to use soil conservation practices and improved agricultural techniques. The farmers most often used barriers and planted on contours, because these practices have low labor costs and require relatively little time to construct. Initially, the project was to operate in both the province of Coclé and the Canal watershed, but due to a lack of resources, only the Coclé portion was implemented.

The project was coordinated by INRENARE's National Directorate of Forestry Development. A forester and a counterpart from CARE coordinated the execution and periodic evaluation of the project in the field. The field team consisted of three INRENARE extensionists. Execution relied heavily on farmer-promoters—community leaders equipped to transmit knowledge to other members of the community. Ten community working groups were also organized. Community nurseries were established, as well as a depository for materials and tools for training participants on site. Training focused on soil conservation works, such as terraces, planting on contours, live barriers, diversion ditches, agroforestry practices, and improved agricultural production techniques. With the participation of farmers during execution of the project, more training and additional activities in agriculture, such as fish culture and nurseries for the sale of plants, were added. The project did not offer any incentives to participating farmers, although it did provide agricultural inputs and tools for communal demonstrations. Farmer-promoters did not receive a salary but did receive food when they worked for the project.

The abrupt departure of CARE in 1988 had negative repercussions on the execution of the project. The first phase of activities, which focused on the selection of promoters and training, was substantially completed, but the second phase, which would have focused on extension and the development of conservation works, met few of its objectives.

The success of the training phase reflected the level of basic knowledge of soil conservation demonstrated by the farmers interviewed. Adoption rates for the practices promoted by the project were relatively high, especially considering the problems experienced in implementing the second phase. For example, 43 percent of the beneficiaries adopted the agroforestry techniques in combination with soil conservation practices, 14 percent integrated agroforestry techniques in the production of horticultural crops, and 11 percent began producing fish in tanks, along with horticultural production.

Despite their low level of schooling and economics, the farmers benefiting from the project demonstrated their capacity for assimilation, manual dexterity, and innovative spirit. The adoption rates and field observations indicated that farmers easily accept the use of simple and cheap conservation practices. The incorporation of trees mixed with crops requires, however, greater demonstration efforts.

Unfortunately, the project did not undertake research nor any analysis of the recommended practices and techniques. It simply assumed an effective result based on the experience of the technicians. Nor was there any system for keeping records or examining the results achieved by the measures being promoted. Thus, neither the farmers nor the technicians of the project were able to measure the economic effects of the practices promoted.

Conclusions

The analysis carried out in this chapter shows that investments in simple, easily implemented conservation measures are profitable for small subsistence farmers in Coclé. Farmers recover the cost of the soil conservation practices in the higher incomes they realize when yields are maintained and new plots do not have to be cleared every year. This result is consistent with the observed rates of adoption achieved by the project despite the problems it experienced in its second phase. However, these results are still preliminary, since they depend on information that is incomplete in qualitative as well as quantitative terms. For more accurate and reliable results, experimental plots would have to be established and results would have to be measured on farms that adopt the proposed conservation measures as well as on a control group of farms that do not. In addition, the current results only apply to the specific area of the study site and should be extrapolated to other lands only with extreme caution.

The results also show that farmers are receptive to new technologies and practices whose benefits can be demonstrated and whose cost is acceptable. The degree to which farmers adopt soil conservation practices might be improved, therefore, by conducting better research to determine which measures are profitable from the farmers' perspective.

Notes

1. For comparison, Soto (1981) reports soil loss rates of 153 tons per hectare in the Canal's watershed on 35 percent slopes planted to traditional rice. Soils in this region—red ultisols—are moderately more resistant to erosion than soils in Coclé, and rainfall is slightly more intense. Under corn, soil loss reached 137 tons per hectare and under beans, 118 tons per hectare. However, these results are based on a single year of measurements.
2. In the most critical periods—cleaning and harvesting—neighbors also exchange labor.
3. Panama's currency is the balboa.

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9. Economic and Institutional Analysis of Soil Conservation Practices in the Dominican Republic

José Abel Hernández[1]

This chapter attempts to examine the farm-level economic profitability of conservation practices in the Dominican Republic. The measures studied were promoted by the Natural Resource Management Project (MARENA), which was executed during 1982–88 in the watershed of the Ocoa River in the municipality of San José de Ocoa (see figure 9-1).

Soil conservation efforts in the Dominican Republic

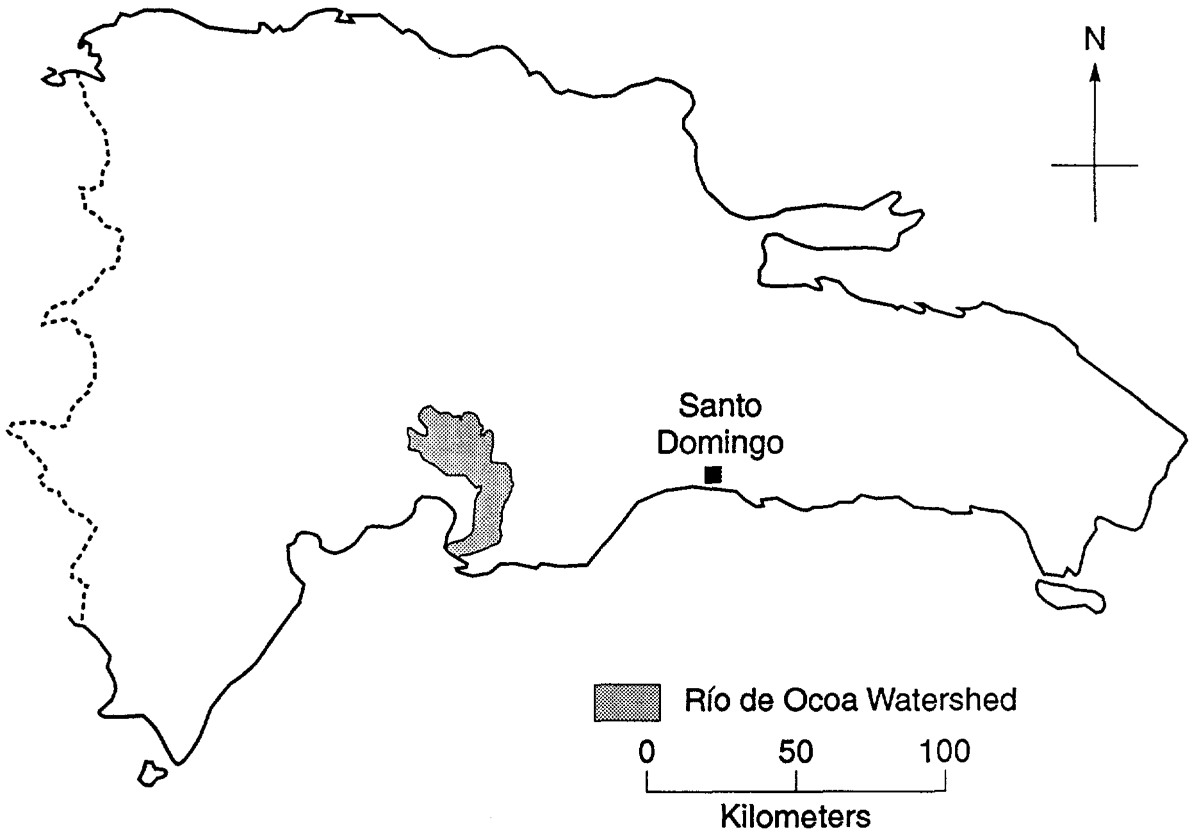
The first formal soil conservation effort in the Dominican Republic, the Bao Project, was initiated in 1978, prompted by concern over sedimentation of the Taveras dam reservoir on the north Yaque River. Erosion rates as high as 275 metric tons per hectare a year were estimated for the Taveras watershed (Hartshorn and others 1981). The Land and Water Department and the Soil Conservation Service, similar to that of the U.S. Department of Agriculture, were also created in that year as departments of the Subsecretariat of Natural Resources (SURENA). Also in 1978, an effort to inventory and evaluate the dominant soil subgroups—the System of Inventory and Evaluation of Agricultural Resources Project—was begun, with financing from the U.S. Agency for International Development (USAID) and assistance from Michigan State University and the U.S. Department of Agriculture. This effort produced an environmental profile of the country (Hartshorn and others 1981).

The Bao Project was executed in the subwatershed of the Bao River. Its results were not very positive, partly because it did not take into account community participation in any stage of its design and execution. Few farmers participated in the project, and even when they allowed technicians to construct conservation practices on their plots, they continued using inappropriate agricultural practices. Soon after the Bao Project began to be implemented, a second office of the Soil Conservation Service was established in the watershed of the Las Cuevas River, with the objective of reducing the rate of sedimentation of the Sabana Yegua dam. As in the case of Bao, this project was designed under the assumption that the primary source of sediment was erosion on agricultural areas located on the hillsides. In fact, local geological conditions and inadequate construction of access roads within the watersheds were both major sources of sediment.

MARENA

These early efforts served as the basis for formulating MARENA. This project was designed to address erosion problems in the watershed of the Ocoa River, which was estimated to be 507 metric tons per hectare a year (Hartshorn and others 1981), and to establish a model for soil and water conservation that could be replicated in other parts of the country. A second component aimed to strengthen the technical capacity of government institutions for managing the

Figure 9-1. Dominican Republic: Location of the Study Site



natural resource base. The project was executed by the State Agriculture Secretariat (SEA), through SURENA, with the participation of the Agricultural Bank, the National Institute of Water Resources, and the State Secretariat of Public Works. An effort was made to include community participation, through the Watershed Development Committee, which included representatives of the Catholic Church, the Association for the Development of San José de Ocoa (known as the Junta), and organizations of women farmers and through the training of community leaders to serve as paratechnicians.

The focus in the soil and water conservation component consisted of developing conservation plans for individual farms. These were laid out by a multidisciplinary technical team and included recommendations for resource management tailored to local agroecological conditions. The most frequently used conservation practices were diversion ditches—canals constructed across the slope so as to intercept and conduct the flow of water toward protected drainage, thus facilitating the infiltration of water and reducing erosion—and live barriers—rows of perennial plants and dense growth planted along the contour so as to reduce the velocity and energy of runoff water and capture sediments suspended in it. Participating farmers received production and conservation credit as well as subsidies covering up to half the cost of the conservation practices.

Adoption rates by farmers were high: in 1985, 90 percent of the farmers practiced soil conservation on their plots. Once the project ended, however, some farmers allowed the conservation measures to lapse. In 1991, five years after the project terminated, only 53 percent of the farmers who had adopted soil conservation practices still employed them (Carrasco and Witter 1991).

FIRENA AND PLAN SIERRA

The trend toward privatization, the performance of the Junta during the execution of MARENA, and problems with SURENA's management led USAID to terminate financing for MARENA in 1988 and transfer funding to the Investment Fund in Natural Resources (FIRENA), which was to be executed by the Junta in common agreement with SEA in essentially the same area, with the addition of the Nizao River watershed. Unlike MARENA, however, FIRENA combined soil conservation measures with financing for irrigation projects.

FIRENA promotes soil conservation practices in places where water resources and land are appropriate for irrigation. Irrigation enables farmers to grow high-value vegetable crops that cannot be grown under rain-fed conditions. In order to qualify for financing for irrigation and conservation projects, owners of irrigable, level lands must contribute between one-third to half of their land to "voluntary agrarian reform." Conversely, landless farmers and hillside farmers who benefit from the voluntary agrarian reform must participate in reforestation programs in the upper watershed. Irrigation and conservation investments are financed through a rotating fund. Participating farmers can borrow funds to construct irrigation works at a nominal rate of 22 percent (compared with the normal 32 percent nominal rate for loans from the Agricultural Bank). Farmers are also eligible to receive credit to produce the recommended crops at a rate of 11 percent and to receive food-for-work in the first crop cycle.

Soil conservation was also a component of the Integrated Rural Development Plan executed by Plan Sierra (a nongovernmental organization) in the mountainous region of La Sierra in Cibao. As in all projects under the plan, social, health, and educational components are the dominant activities. Nevertheless, the project contemplates activities in soil conservation, agroforestry, and forest management. This last activity in particular is considered to be very successful because it incorporates farmers of the hillsides in the management of forest plantations, making it the first forest management project in the country.

LESSONS FOR CONSERVATION PROJECTS

The experience of the Bao, MARENA, FIRENA, and Plan Sierra projects reaffirms the need for effective management and community participation (Kemph and Hernández 1987). Giving the executing unit control over project resources minimizes the danger of diverting funds through the bureaucratic process. There is also a need for close coordination between the various public and private institutions participating in the project. Community participation in planning and execution helps set appropriate priorities and increases the likelihood that farmers will cooperate. Using trained community leaders as paratechnicians to support the activities of project technicians facilitates direct contact with farmers, thus giving the project more credibility and a more informal character.

Experience shows that conservation projects should be initiated in small and manageable areas. As experience grows, new areas may then be incorporated into the project. The availability of permanent (resident) technical assistance is important, particularly in countries where institutional capacity is weak, as in the Dominican Republic. Technicians should receive continuous logistic and moral support, thus providing them with the means and motivation to accomplish their tasks.

Description of the study area

MARENA and its successor, FIRENA, were executed in the watershed of the Ocoa River in the municipality of San José de Ocoa, province of Peravia. The Ocoa watershed covers an area of 700 square kilometers and has a population of 48,600 inhabitants, of whom 71 percent live in rural areas (Oficina Nacional de Estadísticas 1989). The altitude ranges from sea level to 2,200 meters above sea level at the headwaters. More than 60 percent of the area has slopes greater than 20 percent (Witter and others 1985). In the lower and middle watershed areas, the vegetation is characteristic of subtropical dry forests, while in the upper watershed the vegetation is characteristic of humid subtropical forests.

Because the range of agroecological conditions within the project area affects the returns to conservation, a subwatershed was selected for detailed study of the practices promoted by MARENA. The subwatershed selected is that of El Naranjal, in the microwatershed of Arroyo Parra. Slopes in this area reach up to 30 percent. Average annual rainfall is between 1,000 and 1,200 millimeters. Soils are Typic Troporthent with a profile 20 centimeters deep and moderate natural fertility (SEA 1987).

The area is characterized largely by subsistence agriculture. The most important crops are corn, beans (*habichuela*), pigeon peas (*guandul*), and peanuts. Beans and pigeon peas form part of the Dominican diet, corn is used as animal feed, and peanuts are sold to producers of cooking oil. The typical or conventional cultivation practices involve cleaning fallow, plowing and harrowing with animals, seeding by hand, and cleaning with a hoe. The crop cycles begin with peanuts, corn, and pigeon peas, which are planted from March through July, followed by beans, corn, and pigeon peas, which are planted from September through December. Little or no commercial fertilizers are used.

Farms are generally small or medium size: 52 percent have approximately 3 hectares or less, 36 percent have less than 12 hectares, and 12 percent have more than 12 hectares (SEA 1982). Although the majority of farmers have no legal documentation, they are considered landowners because they have gained usufruct rights over time.

Technical analysis

As in most other countries, available data for the analysis of soil degradation problems are very weak. This limitation should be borne in mind when interpreting the results of the analysis presented here. In addition, the measurements are specific to the study area and should not be applied to other areas unless agroecological conditions are very similar.

Soil loss

The Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) is used to estimate rates of soil loss at each study site. Most of the data needed to apply the USLE was generated at the field level in the Dominican Republic. Values for the soil erosivity factor, R, are based on the watershed's climatic conditions (Paulet and others 1978). The value for the soil erodibility factor, K, was obtained from measurements on runoff plots (Veloz 1984; SEA 1989). Values for the topographical factor, LS, were calculated for representative topographical conditions in the study sites using Wischmeier and Smith's (1978) nomogram. Values for the crop management factor, C, and the protective practice factor, P, were also obtained using the procedure outlined by Wischmeier and Smith, using information on rainfall distribution and patterns of crop cover in the watershed.

The results of the estimation for a variety of crop management practices are shown in table 9-1. Estimated soil loss rates range from 8 to almost 200 metric tons per hectare a year, with the high figure being the result of leaving the soil entirely bare. Under the typical practice of intercropped pigeon peas, peanuts, and beans, estimated erosion was slightly less than 50 metric tons per hectare a year. These figures are more plausible than the 507 metric tons per hectare a year estimated by Hartshorn and others (1981). The traditional food crop system (consisting of intercropped pigeon peas, peanuts, and beans) causes less erosion if it is planted in April rather than May, when rainfall is typically very high; crops planted at the beginning of April have developed enough cover by May to protect the soil from some of the rain's erosive effect.

Adoption of conservation practices reduces the estimated rate of erosion. Table 9-1 also shows the estimated rates of soil loss when the typical conservation practices promoted by MARENA are adopted. These measures consist of diversion ditches at intervals of 10 meters, live barriers, and cropping on the contour. Under typical farming practices, soil loss can be reduced to less than 10 metric tons per hectare a year with these practices.

Yield effect

Quantifying the effects of soil erosion on crop yield is complex because it involves complicated interactions among soil properties, crop characteristics, climate, and cultivation practices. Moreover, the effect is generally cumulative and, therefore, hard to observe over short periods (Lal 1988; Stocking 1984).

The impact of soil erosion on crop yields was estimated with data from runoff plot measurements carried out by MARENA. A set of ten runoff plots was installed in 1983 on a model farm located in El Naranjal, and soil loss and yields were measured under a variety of conditions (Veloz 1984). Of the ten trial plots, two approximated the practices observed in the area with and without conservation measures. Plot number two was planted with the traditional food crop system of peanuts, pigeon peas, and beans

Table 9-1. Estimated Annual Rates of Soil Loss under Different Crop Management and Conservation Practices in El Naranjal, San José de Ocoa, Dominican Republic

Crop system and management practice	*Rain erosivity (R)*	*Soil erodibility (K)*	*Slope length (LS)*	*Crop management (C)*	*Conservation practice (P)*	*Soil loss (A)*
Without conservation						
Bare soil	600	0.03	10.92	1.000	1.000	196.56
Onions, potatoes, cabbage	600	0.03	10.92	0.447	1.000	87.86
Pigeon peas alone, planted in May	600	0.03	10.92	0.391	1.000	76.86
Pigeon peas alone, planted in April	600	0.03	10.92	0.352	1.000	69.19
Pigeon peas, peanuts, and beans, planted in May	600	0.03	10.92	0.241	1.000	47.37
Pigeon peas, peanuts, and beans, planted in April	600	0.03	10.92	0.211	1.000	41.47
With conservation (diversion ditches at 10-meter intervals, live barriers, and cropping on the contour)						
Bare soil	600	0.03	4.88	1.000	0.769	67.55
Onions, potatoes, and cabbage	600	0.03	4.88	0.447	0.769	30.19
Pigeon peas alone, planted in May	600	0.03	4.88	0.391	0.769	15.64
Pigeon peas alone, planted in April	600	0.03	4.88	0.352	0.769	14.08
Pigeon peas, peanuts, and beans, planted in May	600	0.03	4.88	0.241	0.769	9.64
Pigeon peas, peanuts, and beans, planted in April	600	0.03	4.88	0.211	0.769	8.44

Note: On plots without conservation, the slope is 30 percent and the length is 50 meters; on those with conservation, the slope is 30 percent and the length is 10 meters. Rain erosivity and soil erodibility are measured using values for parameters appropriate for the condition of the plots; slope length, crop management, and conservation practice are proportionality factors; and soil loss is measured in metric tons per hectare.
Source: Author's calculations.

without any conservation practice, while plot number ten was planted with a similar crop system but with conservation practices consisting of diversion ditches with live barriers (Veloz and Logan 1988). The results of these measurements are given in table 9-2. The erosion measurements on the runoff plots were compared with soil loss rates estimated with the USLE by using values for parameters appropriate for the condition of the plots; the results were very similar.

Nevertheless, these data are a very weak basis from which to estimate the effects of erosion on yield. In addition to measurement problems and differences between the experimental plots and actual farmer practices, the most important weakness is that the available data provide only a single observation of soil loss and yield for each year. Moreover, the very small number of data points makes it impossible to allow for the other factors that also influence yields, such as variations in weather. For example, a dry period occurred during the period in which the data were collected. Nevertheless, these data are used for lack of any other information on the relation between yields and degradation. Finally, as in all statistical analysis, there is considerable danger in extrapolating relationships outside the range of observation.

Linear regression analysis was used to estimate a relationship between the yield of each crop and the loss of topsoil. Given the problems noted above, the results were quite poor. All the estimated equations had low explanatory power, and the significance of the coefficients was very low. Both beans and pigeon peas showed evidence of a negative relationship between yield and soil loss, albeit a weak one. Results indicate that, for each ton of soil loss, bean yields fall 0.26 kilogram per hectare, while pigeon pea yields fall 2.1 kilograms per hectare. In the case of peanuts, an implausible, positive relationship was found between soil loss and yield, although the hypothesis that the relationship was negative could not be rejected. The weakness of this relationship is consistent, however, with farmers' indications that the productivity of peanuts does not decrease as fast as that of other crops in response to erosion. For the purposes of this analysis, no relationship was assumed to exist

Table 9-2. Observed Soil Loss and Crop Yields on Runoff Plots in El Naranjal, San José de Ocoa, Dominican Republic, 1985–89
(metric tons per hectare unless otherwise noted)

Crop management practice	*1985*	*1986*	*1987*	*1988*	*1989*
Without conservation					
Soil loss	17.3	100.4	86.2	—	—
Cumulative soil loss	17.3	117.6	293.8	—	—
Crop yields (kilograms per hectare)					
Peanuts	889	944	1,000	1,444	—
Beans	578	—	578	500	51
Pigeon peas	—	2,056	—	889	3,611
With conservation					
Soil loss	37.2	44.8	43.5	—	—
Cumulative soil loss	37.1	81.9	125.4	—	—
Crop yields (kilograms per hectare)					
Peanuts	777	667	1,278	778	875
Beans	711	—	669	520	76
Pigeon peas	—	2,222	—	1,889	1,780

— Not available.
Source: SEA 1989.

between soil loss and yield in the case of peanuts. For the other crops, estimated relationships were used in the absence of other data. Clearly much more research needs to be done in this area if the economics of conservation are to be discussed meaningfully.

Economic analysis

The estimated relationships between soil loss and yield were used together with the predicted rates of soil loss to project yield trends over the course of the period of analysis. In addition, use of diversion ditches, live barriers, and drainage canals reduced the farm area 10 percent. Data on production costs for pigeon peas, peanuts, and beans planted in the traditional food crop system and average prices at the farm level were obtained through farmer interviews in the Ocoa area (Fortuna & Asociados 1991). They represent the price level observed in the spring of 1991. The costs of constructing and maintaining the conservation practices were obtained from the MARENA project.

The results of the analysis are shown in table 9-3. Net income for the crop system is initially lower under the conservation practice than under the erosive practice, reflecting the investment in conservation and the reduction in cultivated area. Because erosion rates are higher when conservation measures are not used, yields and, therefore, revenues decline much more rapidly in the case without conservation. Beginning in the fourth year, revenues are higher under the conservation practice. Nevertheless, the initial losses are such that the net present value for the investment in conservation practices is negative, indicating that the investment is not profitable, when returns are discounted at 20 percent, from the farmers' perspective. The internal rate of return of 17 percent shows that the investment would be unprofitable at any real discount rate greater than 17 percent.

This result may be a consequence of the poor quality of the data used in the linear regression analysis to estimate the relationship between soil loss and yield. To examine the potential consequences of using incorrect rates of decline in yield, sensitivity analysis was carried out. The results, which are shown in table 9-4, indicate that investment would only be profitable if the actual decline in yield was at least 25 percent greater than that assumed in the base case. Sensitivity analysis also shows that soil loss under the erosive practice would have to be about 20 percent greater than the rate assumed in the base case for investments in conservation to be profitable. Finally, the estimated returns to conservation are not very sensitive to changes in the cost of conservation. Conservation would only become profitable if the cost of implementing and maintaining the conservation measures was about 50 percent lower than the cost assumed for the base case.

Table 9-3. Analysis of Returns to the Construction of Diversion Ditches and Live Barrierson Farms with 30 Percent Slope Planted to Pigeon Peas, Peanuts, and Beans in El Naranjal, San José de Ocoa, Dominican Republic, for a 100-Year Time Horizon

(pesos per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*	*100*
Without conservation																
Soil loss (tons per hectare)	47	47	47	47	47	47	47	47	47	47	47	0	0	0	0	0
Cumulative soil loss (tons per hectare)	47	95	142	189	237	284	332	379	426	474	521	758	758	758	758	758
Yield (kilograms per hectare)																
Pigeon peas	2,359	2,259	2,160	2,060	1,961	1,861	1,762	1,662	1,563	1,463	1,364	0	0	0	0	0
Peanuts	862	862	862	862	862	862	862	862	862	862	862	0	0	0	0	0
Beans	526	513	501	489	476	464	452	439	427	415	403	0	0	0	0	0
Revenues	14,886	14,455	14,023	13,592	13,161	12,730	12,299	11,868	11,436	11,005	10,574	0	0	0	0	0
Crop production costs	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	0	0	0	0	0
Returns	6,724	6,293	5,862	5,431	4,999	4,568	4,137	3,706	3,275	2,843	2,412	0	0	0	0	0
Present value returns	6,724	5,244	4,071	3,143	2,411	1,836	1,385	1,034	762	551	390	0	0	0	0	0
Number of years before shutdown	16															
With conservation																
Soil loss (tons per hectare)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	0
Cumulative soil loss (tons per hectare)	10	19	29	39	48	58	67	77	87	96	106	202	299	395	492	646
Yield (kilograms per hectare)																
Pigeon peas	2,194	2,176	2,158	2,139	2,121	2,103	2,085	2,066	2,048	2,030	2,012	1,830	1,647	1,465	1,283	0
Peanuts	776	776	776	776	776	776	776	776	776	776	776	776	776	776	776	0
Beans	482	480	477	475	473	471	468	466	464	462	459	437	414	392	369	0
Revenues	13,706	13,627	13,548	13,469	13,390	13,312	13,233	13,154	13,075	12,996	12,917	12,127	11,337	10,547	9,758	0
Crop production costs	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162	8,162
Conservation costs	2,937	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294
Returns	2,608	5,172	5,093	5,014	4,935	4,856	4,777	4,698	4,619	4,540	4,461	3,671	2,882	2,092	1,302	-8,455
Present value returns	2,608	4,310	3,537	2,902	2,380	1,952	1,600	1,311	1,074	880	721	96	12	1	0	0
Number of years before shutdown	67															
Returns to conservation																
Net benefits	-4,116	-1,121	-769	-417	-64	288	640	992	1,345	1,697	2,049	3,671	2,882	2,092	1,302	-8,455
Present value net benefits	-4,116	-934	-534	-241	-31	116	214	277	313	329	331	96	12	1	0	0
Cumulative present value net benefits	-4,116	5,050	-5,584	-5,825	-5,856	-5,741	-5,526	-5,249	-4,937	-4,608	-4,277	-2,089	-1,723	-1,678	-1,673	-1,672
Net present value																
50 years	-1,673															
100 years	-1,672															
Internal rate of return (percent)	16.9															
Number of years to break even	Never															

Source: Author's calculations.

Table 9-4. Sensitivity Analysis of Returns to Soil Conservation and Improved Agricultural Practices to Percentage Changes in Parameter Values on Farms with 30 Percent Slope in El Naranjal, San José de Ocoa, Dominican Republic

Indicator	*–50*	*–25*	*–10*	*Base*	*+10*	*+25*	*+50*
Change in yield with conservation							
Base = 2 kilograms per ton for pigeon peas; 0 kilograms per ton for peanuts; –0.3 kilogram per ton for beans							
Net present value at 100 years (pesos per hectare)	–7,274	–4,292	–2,670	–1,672	–741	521	2,308
Internal rate of return (percent)	8.7	12.8	15.3	16.9	18.6	21.1	25.2
Change in yield without conservation							
Base = 47 tons per hectare a year							
Net present value at 100 years (pesos per hectare)	–8,696	–5,003	–2,955	–1,672	–456	1,235	3,745
Internal rate of return (percent)	< 0	11.4	14.7	16.9	19.1	22.4	28.0
Cost of conservation (construction and maintenance)							
Base = RD$2,937 per hectare for construction + RD$294 per hectare for maintenance							
Net present value at 100 years (pesos per hectare)	530	–571	–1,232	–1,672	–2,113	–2,774	–3,875
Internal rate of return (percent)	21.2	18.8	17.7	16.9	16.3	15.4	14.1

Source: Author's calculations.

Conclusions

Improving the problem of soil erosion is a complicated task since it involves complex relationships among ecological, agricultural, economic, and institutional systems. Cropping systems with conservation must be agroecologically and economically feasible if they are to be adopted by farmers. Based on the production and soil loss data used in the analysis, it was determined that although the combination of diversion ditches, live barriers, and drainage canals reduces soil erosion, investment in conservation measures is not profitable from the farmers' perspective if a 20 percent discount rate is assumed. The low returns from conservation are due to the high initial investment required to execute the practices and the resulting 10 percent reduction in the area farmed. Although conservation reduces the rate of decline in yield that farmers would experience if they employed any conservation measure, this benefit is not sufficient to repay the high costs of adopting the specific measures studied. If the costs of conservation were lower or the benefits were higher, this conclusion might be different.

It would have been extremely interesting to compare the returns to the conservation measures promoted by MARENA with those promoted by FIRENA. Although the actual physical measures were similar in both cases, FIRENA combines these measures with investments in irrigation, which allows farmers to cultivate very high-value vegetable crops. The investment required is greater, but the returns are also greater. It is quite possible, therefore, that investment in conservation and irrigation together would be profitable from the farmers' perspective when conservation alone is not. Unfortunately, no data were available on the effects that the combination of conservation and irrigation practices has on yield, so the returns to this project could not be analyzed. Anecdotal information suggests that the measures promoted by FIRENA are indeed much more profitable. This can be deduced from the enthusiasm with which farmers participate in a project that requires them to surrender part of their land and does not provide subsidies. In comparison, farmers were fairly reluctant to participate in MARENA, which did provide subsidies.

This study has revealed the weakness of the available data on soil conservation and degradation. Although it was possible to obtain approximate results, better data are required to increase the reliability and accuracy of the analysis. Future research must also consider variables that were not considered here, such as the effect of different farm sizes, type of land tenancy, variations in agroecological conditions, and different technologies on crop productivity and erosion.

Note

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10. An Economic and Institutional Analysis of Soil Conservation in Haiti

Thomas A. White and Jon L. Jickling[1]

Soil erosion has been a problem in Haiti since the colonial period, when mountain forests were cleared for coffee production and plantation crops such as cotton, indigo, and tobacco were clean-cultivated. Some reports state that coffee plantations were difficult to reestablish after the first generation due to excessive erosion and that indigo crops were only productive for three years (Paskett and Philocete 1990). After the revolution, the slaves and peasants combined remembered African horticultural practices with learned Haitian agriculture and plantation cultivation methods. The result is a mixed system in which farmers clean-cultivate agricultural crops, burn crop stubble prior to tilling, periodically leave annually cropped parcels fallow for an extended period, and establish tree gardens around family compounds. With increasing populations, and resulting pressure on the limited arable lands, fallow has increasingly been precluded, tree gardens have diminished in size, and peasants have steadily moved to less desirable mountain lands for cultivating annual crops. Although only 32 percent of all lands are deemed to be arable, some 61 percent are in current agricultural use. Plantation agriculture and clean-cultivation, two erosive and resistant remnants of the colonial period, have been carried from the plains to the mountain slopes by the new generations.

As a result of this pattern of intensive and inappropriate land use, soil erosion has become the dominant environmental problem in Haiti, causing agricultural yields to decline, damaging downstream lands and water development projects, and destroying coastal marine resources (USAID 1985). Most hillsides are highly eroded; in one representative study area, 60 percent of soils are truncated to the B horizon and 20 percent are truncated to the C horizon. Approximately one-third of all lands are in an extremely degraded state; a study by the Food and Agriculture Organization of the United Nations estimated that the equivalent of 6,000 hectares of arable land are lost annually due to erosion (USAID 1985). Many irrigation systems have been destroyed by sediment or increasingly high water flows, and most of those operating do so below their potential efficiency (Ewell 1977). The summer storms of 1986 caused an estimated $5 million worth of damage to irrigation systems in the Les Cayes plain (Pierce 1988). The Peligre reservoir, which generates 48 megawatts of hydroelectric power (99 percent of the national total), has to date lost half of its capacity to sediment deposits. At current sedimentation rates of 12 million square meters a year, electricity generation will cease by the year 2018 (Louis-Jeune 1991).

Soil conservation efforts in Haiti

Soil conservation has been undertaken at various levels in Haiti: by peasants using indigenous techniques, by governments using laws and national commissions and agencies, and by multilateral and bilateral donors offering support to large projects.

Indigenous responses

When faced with new, sloping cultivation conditions (a phenomenon that did not become widespread until the mid-twentieth century), some peasants adjusted the techniques developed on, and appropriate for, the plains in ways that conserve soil moisture, require limited amounts of labor and nonfinancial inputs, and can be implemented with common tools such as hoes and machetes. These techniques are also predominant in ravines and in association with higher-value crops such as rice, bananas, and taro. With limited exceptions, they are not commonly found in extensively managed gardens planted to cereal crops.

Indigenous innovations associated with annual cropping that conserve soil and water include *zare* (soil and stubble scraped up into a mound to retain water for rice cultivation), *sakle en woulo* (weeds hoed into small mounds along the contour at one-step intervals), *ramp pay* (stubble gathered along the contour and supported with stakes), *dig ravin* (assorted plant and soil material placed in ravines to retain soil and water for banana, taro, or yam cultivation), and *bit* (soil heaped into mounds for sweet potato cultivation). These techniques, when practiced in the traditional manner, must be reconstructed on an annual basis. They are frequently inexactly constructed and, compared with bench terraces, control soil erosion relatively inefficiently.

Several of these indigenous techniques have been refined. *Tram*, a peasant innovation, is a combination of *bit* and a contour seed bed. Since the 1950s, *tram* has become standard practice in the vegetable-producing areas of Furcy (Murray 1979). More recently, *ramp pay* has been improved by placing contours exactly and by covering the structure with upslope soil to discourage rat infestations and encourage surface flow infiltration. Several nongovernmental organizations have recently begun promoting this improved technique, and it has been widely and rapidly adopted in several areas of the country. *Dig ravin* has been recently improved by combining it with wattling (woven plant material, *kleonaj* in Creole) and planting live barriers downslope for support. This technique is also being widely promoted by several development agents and has reportedly been widely adopted.

In analyzing the evolution of *tram*, anthropologist G. Murray concluded that peasants were interested not in saving their soil per se, but in saving the fertilizer sown for vegetable production. In essence, "erosion control has occurred as the secondary result of an innovation whose primary function, from the peasants' viewpoint, is the immediate enhancement of their cash profits" (Murray 1979). This finding is consistent with the authors' finding that the indigenous *dig, woulo, ramp pay,* and *zare* are constructed to retain moisture and enhance crop productivity and only indirectly to retain soil.

Government and donor responses

The government of Haiti has generally taken a legislative approach to resource conservation. Rather than providing incentives for alternative land use, laws have been coercive and repressive, generally taking the form of prohibitions and penalties. They have attempted to eliminate the symptoms of rural decline (such as deforestation, charcoal production, and erosion) rather than the causes of that decline (Alexis and Janvier 1991). The government has also initiated a number of national commissions or agencies to address environmental degradation or its causes, such as the Division de l'Amenagement du Territoire, the Conseil National de l'Environnement et de Lutte contre l'Erosion, and SONAMAR, a national reforestation and soil conservation campaign. However, few, if any, laws and policies have been effectively enforced for lack of political will, financing, and organizational capability (Buteau, personal communication).

The Ministry of Agriculture, Natural Resources, and Rural Development (MARNDR), which is nominally responsible for implementing national soil conservation efforts, has historically been weak, underfunded, and largely ineffective in carrying out substantive field activities. The agricultural extension service, once viable and active in promoting soil conservation, has largely been gutted due to a lack of financial support, leadership, and training (Cassagnol 1990). The Watershed Management Service, which is directly responsible for soil conservation activities, had less than ten professional staff in 1990 (Buteau, personal communication).

Despite its long involvement in soil conservation efforts, MARNDR has not devised a coherent strategy to address the problem, following, instead, donor choices concerning the type, location, and scale of interventions. This has led the government to adopt a project approach to conservation efforts, which have, as a result, been scattered, uncoordinated, short term, and by most reports ineffective (USAID 1985; Bureau 1986; Murray 1979).

Many multilateral and bilateral donors have supported soil conservation efforts in Haiti since the late 1950s. Most of these efforts have been in the form of relatively large projects implemented jointly with the government. Until recently, these projects used the *équipement du territoire* approach, paying laborers with food or currency to treat fragile uplands irrespective of land tenure or owner preferences. Average project-level costs for treating land tended to be high, and most projects reported only limited adoption and maintenance of recommended practices (Pierce 1988). Today, little evidence exists of most of these projects. Use of conventional conservation techniques, such as rock walls and contour canals, which do not result in short-term financial benefits for farmers, was a root cause of the limited and unsustained impact of many projects. Poor project design resulted from the need to work through government agencies in the name of institution building (which resulted in administrative inefficiency and limited program flexibility), the desire to facilitate output monitoring (which led to a bias toward conventional techniques installed with paid labor), and the need to respond to multiple objectives (which meant that, in many cases, soil conservation was a means rather than an end). Bilateral donor support has also often been highly variable, depending on the state of relations between Haiti and the donor country.

In the 1980s, many bilateral donors began to sidestep MARNDR and to fund soil conservation efforts undertaken directly by national or international nongovernmental organizations. Many nongovernmental organizations of diverse backgrounds, levels of finance, program quality, and religious orientation have been involved in soil conservation efforts in Haiti since the 1950s, both independently and as conduits for programs or funds provided by donors. They are generally characterized by a long-term commitment to a specific area and to a specific population, a trait not always evident in government or donor efforts. Many are involved in a wide range of development activities, frequently lack regular and adequate levels of financing, have weak administrative systems, and have limited access to qualified technical assistance. Many have developed a phobia of cooperating with the government or MARNDR. Although the impact of projects has improved, high overhead and expatriate support costs mean that turning to nongovernmental organizations may not have improved their efficiency.

Several important shifts in opinion and institutional innovations took place in the 1980s. Influential agronomists have come to admit that nongovernmental organizations have played a positive role in rural development, substantial in-house opposition has developed against the application of the *équipement du territoire* approach to soil conservation, and incentives are no longer seen as necessary for adopting soil conservation (Pierre-Jean, personal communication). Settling these long-standing debates has resulted in a general consensus concerning soil conservation strategies and techniques. The creation, with USAID assistance, of a Technical Secretariat for Watershed Management (STABV) to coordinate, evaluate, and advise watershed management projects was an interesting and positive experience. This organization, for the first time, surveyed and cataloged watershed management projects, synthesized experiences, and generated guidelines for operation. It also proved important in forging trust and stronger linkages and in negotiating conflicts between nongovernmental organizations and MARNDR (Pierce 1988). An example of significant shifts in MARNDR thinking is found in the 1990 acceptance of a World Bank proposal to fund the field activities of nongovernmental organizations through MARNDR.

Approaches used in soil conservation

Most projects have used the *équipement du territoire* approach, in which soil erosion is considered a technical problem to be solved with engineering responses. This approach has been characterized by prescriptions of large-scale treatments, mechanical rather than biological measures, and monetary and commodity incentives to encourage its adoption (Lilin and Koohafkan 1987). Highly degraded and steep lands upstream from important water development projects have often been the target for intervention. Contour rock walls, canals, and bench terraces have been the primary techniques promoted. Extension has been viewed largely as a process of marketing new technologies generated by technicians (Agarwal 1983). From this viewpoint, conservation techniques are considered inherently good, appropriate for all targeted farmers, and easy to adopt; the adoption and diffusion of technique are thought of as a challenge of communication and persuasion. Farmers who do not adopt are considered irrational. Projects have often been preoccupied, therefore, with how best to persuade, coerce, or bribe farmers into adopting conservation techniques.

Since the late 1970s, this conventional approach and these techniques have been criticized by many development workers for failing to achieve the sustained adoption and maintenance of the technologies promoted. An agricultural parcel approach to soil conservation was developed in the early 1980s in response to the weaknesses of the conventional soil conservation approach. This approach is based on the premises that peasants have a natural incentive to conserve soil in order to increase agricultural production, that remuneration is not necessary for farmers to adopt techniques and might even deter the maintenance and diffusion of techniques, and that indigenous conservation techniques exist and could be improved. This approach views erosion from a farmer's rather than an engineer's perspective and considers it primarily an agricultural problem rather than a watershed sedimentation problem. Projects adopting this approach target individual parcels and do not disburse external incentives to encourage adoption. Increasing agricultural production by retaining moisture and soil is the primary incentive for farmers to adopt soil conservation techniques.

Although successful for the treatment of individual parcels, the agricultural parcel approach is not well suited to the treatment of erosion that crosses private property boundaries or occurs on public lands. A consensus is currently emerging in which the agricultural parcel approach should be used on private land and the *équipement du territoire* approach subsequently employed to treat public areas. STABV has recommended this basic strategy. Remuneration would be used only in cases of collective effort for collective good.

Current extension modes can be separated into three broadly defined categories (adapted from Murray 1990). The mode usually associated with projects that use the *équipement du territoire* approach might be termed the comandante or peasant persuasion mode. In this mode, adoption occurs because of either compulsion or direct payments. This mode can result in rapid construction of treatments, but long-term results have often been disappointing. Some projects have used a technique by task mode in which an extension network is used solely to promote selected techniques. The agroforestry hedgerow campaign of the Pan American Development Foundation, which has since 1988 paid extension agents for each meter of structures established on private land, is an example. This approach has generally proven to be administratively efficient and has produced a large number of treated parcels. The third mode is an integrated and participatory promotion mode in which soil conservation techniques are developed and extended along with other interventions in the agricultural system. Techniques are frequently based on indigenous practices. Projects employing this mode usually focus on select communities and also encourage peasant organization. The Mennonite Central Committee's Bois de Lawrence Project and Save the Children Federation's Maissade Project are examples of this approach.

Various soil conservation techniques have been promoted in Haiti with varying degrees of success. Early projects primarily prescribed mechanical, internationally standard techniques such as bench terraces, contour rock walls, contour canals, and rock check-dams. Although generally efficient in retaining soil, these techniques are expensive and labor intensive. In the case of bench terraces and contour canals, infertile subsoil is brought to the surface during construction, which decreases crop production. Vegetative hill and ravine treatments began to be promoted by a majority of projects during the 1980s. These included hedges of *Leucaena* and elephant grass, *ramp pay*, and wattling in ravines. These techniques generally require low labor inputs and retain soil less efficiently than mechanical structures. They can, however, be altered or combined to meet the specific conditions of the landowner's site and the objectives of management to a greater degree.

The adoption of conservation techniques has varied widely. Mechanical conservation techniques have generally not been adopted unless wages were paid as an incentive and, once adopted, have often been neglected and allowed to decay. Many kilometers of contour rock walls were constructed on infertile lands in food-for-work projects, for example, but maintenance has been extremely limited. Conversely, vegetative techniques have been widely adopted, even though farmers have rarely received wage or food incentives. Factors that appear to influence the decision to adopt conservation techniques include the level of land security felt by the farmer, the productive and economic value of the soil, and the farmer's ability to invest time and labor to learn and install the technique (Pierre-Jean, personal communication). Techniques that have been widely adopted without external incentives generally combine components familiar to peasants, are compatible with other agricultural and social activities, are simple and require low and nonfinancial installment costs, provide short-term economic returns, are adaptable to specific site conditions, and can be adopted sequentially as farmer experience grows.

Analysis of the Maissade Watershed Management Project

This case study explores economic and institutional issues surrounding a soil conservation project in Haiti. The Maissade Watershed Management Project, which was financed by the U.S. Agency for International Development (USAID) and implemented by Save the Children Federation, was chosen for this survey because of the substantial amount of data available on erosion, yield, and project administration. The Maissade Project represents an integrated and participatory approach to soil conservation.

Description of the project area

The Maissade Commune is located in the Central Plateau region and is generally less degraded and more productive than most other hilly regions of Haiti. The climate is humid subtropical with average annual precipitation of 1,732 millimeters. Rains are seasonal with a bimodal distribution. The topography in the project area is dominated by dissected uplands and alluvial plains derived from calcareous sandstones and conglomerates. Soils are predominantly alfisols and vertisols with medium to high levels of nitrogen, medium to low levels of phosphorus, and high levels of potassium. These soils are usually neutral to alkaline and have an organic matter content of about 1 percent (Tabor 1988). The area is physically isolated and has historically received few development services.

The Maissade area has been actively cultivated for over 100 years. Farmers own an average of three noncontiguous agricultural parcels; the average parcel size is 0.7 hectare (Clerisme 1989). About 70 percent of the area is intensively cropped, some 25 percent in mixed pasture and light tree cover (Erlich 1986). Sugarcane was widely cultivated until five years ago, when local stocks were decimated by an anthracnose fungus. A mixture of corn and sorghum is currently the predominant cropping system in the area. Field beans are cultivated extensively at higher elevations, and yams, plantains, taro, and rice are planted in sites richer in moisture. Hoes are used for cultivation, and few agricultural inputs are used.

Description of the project

The Maissade area was selected as a project site for several reasons. Area watersheds are the principal contributors of sediment to the Artibonite River, Haiti's most economically important watercourse. This sediment jeopardizes downstream infrastructure such as the Lake Peligre hydroelectric production facilities and extensive irrigation systems on the lower Artibonite plain (Erlich 1986).

The Maissade Project was initiated in January 1986. Initially scheduled to run three years, it was later extended for two more. It was one of the first integrated watershed management projects in the country. Project planners combined two embryonic yet promising extension strategies: the formation of cooperative peasant groups (*groupement*) based on traditional social linkages for peasant mobilization and the planting of economically beneficial trees. The *groupement* were the basic units through which the project functioned; they were promoted not as ends in themselves, but as the organizational means by which social, economic, and ecological problems would be addressed (Save the Children Federation 1985). The project components included hillside treatment (including agriculture, agroforestry, and soil conservation practices), ravine treatment (soil conservation techniques), forestry (boundary tree plantings), animal husbandry, and small-scale infrastructure development. The analysis in this chapter focuses on hillside and ravine treatments.

Three principal soil conservation techniques were promoted: *ramp pay*, hedgerows, and rock walls. All three structures are established on the contour, reduce erosion, and increase water infiltration. They are frequently established in combination. *Ramp pay* literally translated means straw barrier. It consists of a rough assemblage of crop residue (usually corn and sorghum stalks) placed along the contour of slopes, held in place by stakes, and covered with upslope soil to discourage rodent nesting and facilitate upslope infiltration. Because the structure is composed of decaying vegetative matter, it must be rebuilt annually. Hedgerows are live vegetative strips planted along the contour in shallow trenches just downslope of the *ramp pay*. Once the hedge is established, crop stubble is piled directly against hedge stems instead of repairing the *ramp pay*. Hedgerows were initially planted primarily with *Leucaena leucocephala*, a nitrogen-fixing tree, but other perennial plants (such as elephant grass, sugarcane, and cotton) have increasingly been included. Contour rock walls are piles of rock gathered from the field and set into a shallow contour trench. The wall is repaired and enlarged each season. Ravine treatments used by the project include woven barriers (wattling) supported by stakes capable of reproducing vegetatively; hedgerows of *Leucaena leucocephala*, sugarcane, or elephant grass, and rock check-dams. These treatments are often used in combination.

Economic analysis

Despite substantial investments in soil conservation and a widely recognized erosion problem, little hard data on soil erosion have been collected in Haiti. In the absence of data on erosion rates or locally calibrated USLE parameters, the authors conducted a rapid field assessment of erosion rates on representative agricultural parcels in Maissade. This assessment measured the amount of sediment deposition behind soil conservation structures relative to their sediment production area or catchment area. These results compared favorably with soil loss estimates made with a predictive model, Soil Changes Under Agroforestry (SCUAF), developed at the International Council for Research in Agroforestry by Young and Muraya (1990). Using this methodology, the estimated annual rates of soil loss from six representative fields (22 percent average slope) ranged from 69 to 392 tons per hectare, with an average of 186 tons per hectare, or 101 tons per hectare if outliers are excluded. The on-site erosion results were coupled with estimates of sediment retention in thirteen small watersheds treated with new gully plugs (Toussaint 1990). This yielded approximate sediment delivery ratios to streams for the area. Using on-site erosion rates of 186 and 101 tons per hectare, estimated sediment delivery ratios were 21 and 36 percent, respectively. These estimates support the hypothesis that not all soil lost from a given parcel actually leaves the farm and enters the course of streams.

Changes in crop yields with and without soil conservation were estimated using the SCUAF predictive model. With an erosion rate of 186 tons per hectare, the model predicted an annual decline in yield of 6 percent in the first ten years on plots without conservation, followed by smaller annual declines in subsequent years. Sensitivity analysis of the results showed that a 50 percent increase in estimated erosion rates increased the estimated rate of decline in yield; a 50 percent decrease in estimated erosion, on the other hand, reduced estimated decline in yield by a little less than half (3 percent annually instead of 6 percent).

In addition to reducing soil loss and hence the rate of decline in yield, conservation measures affect yields by encouraging the retention of moisture and by stimulating improvements in the soil's physical structure. Estimates of yield increases due to improved retention of moisture were obtained from measurements of yield taken by project technicians. Plots treated with conservation structures were found to produce an average of 51 percent more corn and 28 percent more sorghum than untreated plots in 1988, a year of poorly timed rainfall, and an average of 22 percent more corn and 32 percent more sorghum in 1989, a more normal year. For this analysis, the lower estimates of increase in yield were used for each crop. The effects of improving the properties of soil were estimated using the SCUAF model. For the hedgerow system, projected crop yields increased between 0.7 and 3.4 percent a year (from the base year value). For the *ramp pay* and rock wall systems, estimated annual improvements in yield ranged from +0.06 to −0.6 percent. Conservation measures, however, also reduced the area available for cultivation, by 6 percent in the case of hedgerows and *ramp pay* and 9 percent in the case of rock walls.

Farm budgets were developed using data collected in a farmer survey conducted by project technicians. Where possible, this information was corroborated with information from other in-country sources (Taylor 1984). All costs and benefits are in real terms, and it was assumed that there would be no relative price variations during the period of analysis.

Using the data on physical flow and information on farm budget, a farm-level agricultural production model was developed based on a peasant farm of 1 hectare and used to examine returns to the *ramp pay* and rock wall measures. The results are shown in tables 10-1 and 10-2, respectively. In each case, the table presents the bleak economic future facing hillside farmers who do not adopt conservation measures. Under this scenario net revenue declines from G1,720 per hectare in the first year to zero in year twenty-four.[2] Production was assumed to cease at this point, although it conceivably could be abandoned earlier—a farmer would abandon hillside production when returns are inadequate to sustain household needs or when the opportunity cost of holding the land becomes greater than the sum of the projected annual returns.

The calculations show both *ramp pay* and rock walls to be profitable from the farmer's perspective over a fifty-year horizon. Of the two, *ramp pay* is more profitable, which is consistent with *ramp pay*'s much greater rate of diffusion. Rock walls have similar effects on yields, but relatively high construction costs. When comparing different conservation techniques, it is important to consider, however, that not all techniques are appropriate on all types of land and not all are equally consistent with specific objectives of farm management. These calculations are carried out with a discount rate of 20 percent, but conservation measures are profitable even at higher discount rates. At a 30 percent discount rate, for example, returns to *ramp pay* are G3,500 per hectare and returns to rock walls are G2,590 per hectare.

Sensitivity analyses showed these estimates to be reasonably robust to changes in assumptions. A 50 percent decrease in the estimated erosion rate decreases the net present value of the *ramp pay* and rock wall treatments almost 10 percent because the difference between yields on treated land and untreated land decreases as erosion rates decrease. The smaller this differential is, the more difficult it is to justify investment in soil conservation. This 50 percent decrease in erosion rates puts the estimate in the range of erosion found in other parts of Haiti (less than 100 tons per hectare a year on-farm). This implies that for areas with erosion rates lower than that found in Maissade, conserva-

Table 10-1. Analysis of Returns to Soil Conservation Using *Ramp Pay* on Hillside Farms in Maissade, Haiti, for a 50-Year Time Horizon
(gourdes per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*
Without conservation															
Yield (kilograms per hectare)															
Corn	1,180	1,110	1,041	971	902	832	762	693	623	553	484	260	0	0	0
Sorghum	1,510	1,421	1,332	1,243	1,154	1,065	975	886	797	708	619	333	0	0	0
Revenues	2,566	2,415	2,264	2,112	1,961	1,809	1,658	1,506	1,355	1,204	1,052	565	0	0	0
Crop production costs	847	828	808	787	765	742	718	692	665	636	605	477	0	0	0
Returns	1,719	1,587	1,456	1,325	1,196	1,067	940	814	690	567	447	88	0	0	0
Present value returns	1,719	1,323	1,011	767	577	429	315	227	160	110	72	2	0	0	0
With conservation															
Yield (kilograms per hectare)															
Corn	1,350	1,358	1,366	1,374	1,382	1,390	1,398	1,406	1,414	1,422	1,431	1,431	1,431	1,374	1,293
Sorghum	1,812	1,823	1,834	1,845	1,855	1,866	1,877	1,888	1,899	1,910	1,921	1,921	1,921	1,845	1,736
Revenues	3,007	3,025	3,043	3,061	3,079	3,097	3,115	3,133	3,151	3,169	3,187	3,187	3,187	3,062	2,881
Crop production costs	886	888	890	893	895	897	900	902	904	906	909	909	909	893	869
Conservation costs 55	50	50	50	50	50	50	50	50	50	50	50	50	50	50	
Returns	2,066	2,087	2,103	2,119	2,134	2,150	2,166	2,182	2,197	2,213	2,229	2,229	2,229	2,119	1,962
Present value returns	2,066	1,739	1,460	1,226	1,029	864	725	609	511	429	360	58	9	1	0
Returns to conservation															
Net benefits	347	500	647	793	938	1,083	1,226	1,367	1,507	1,646	1,782	2,141	2,229	2,119	1,962
Present value net benefits	347	417	449	459	453	435	410	382	351	319	288	56	9	1	0
Cumulative present vlaue net benefits	347	763	1,213	1,672	2,124	2,559	2,970	3,351	3,702	4,021	4,309	5,617	5,858	5,896	5,902
Net present value at 50 years	5,902														

Source: Authors' calculations.

tion treatments would have a less favorable net present value and that only low input techniques would be economically justifiable. The net present value of hillside conservation treatments also proved to be insensitive to changes in cost levels: a 50 percent increase in estimated conservation costs reduces net present values less than 10 percent.

Conclusions

Most soil conservation efforts in Haitian projects have used conventional approaches that have proven inappropriate and ineffective. As a result, few have had significant success. Successful projects in Haiti have demonstrated a thorough understanding of local conditions and have based approaches to developing and diffusing technology on project-peasant conversation rather than persuasion. These projects have also extended techniques through groups of farmers rather than individuals. These elements represent substantial departures from conventional soil conservation projects.

Mechanical measures, including bench terraces, contour rock walls, and canals have not been adopted without external incentives and have rarely been maintained. These techniques require substantial labor investments, produce little economic benefit, and are culturally alien to the peasant population. Vegetative techniques, on the other hand, have been widely adopted and maintained without the provision of external incentives. With the exception of lemon grass and vetiver hedges, vegetative structures have been widely adopted. These techniques provide multiple benefits (such as forage, soil moisture retention, and wood) and can be installed with limited investment of labor. Techniques that have been widely adopted in Haiti without external incentives usually combine components familiar to peasants (*ramp pay* and *bit*); are compatible with other agricultural and social activities; are simple and require low and nonfinancial installment costs; provide short-term economic returns (usually in the same agricultural season); are adaptable to the farmer's specific on-site conditions, management objectives, and preferences; and can be adopted sequentially at the farmer's specific pace of knowledge and decision accretion.

Erosion control has only been adopted when it results in thrift or increased economic gain—not when it saves soil. The techniques that have

Table 10-2. Analysis of Returns to Soil Conservation Using Rock Walls on Hillside Farms in Maissade, Haiti, for a 50-Year Time Horizon
(gourdes per hectare unless otherwise noted)

Indicator	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*20*	*30*	*40*	*50*
Without conservation															
Yield (kilograms per hectare)															
Corn	1,180	1,110	1,041	971	902	832	762	693	623	553	484	260	0	0	0
Sorghum	1,510	1,421	1,332	1,243	1,154	1,065	975	886	797	708	619	333	0	0	0
Revenues	2,566	2,415	2,264	2,112	1,961	1,809	1,658	1,506	1,355	1,204	1,052	565	0	0	0
Crop production costs	847	828	808	787	765	742	718	692	665	636	605	477	0	0	0
Returns	1,719	1,587	1,456	1,325	1,196	1,067	940	814	690	567	447	88	0	0	0
Present value returns	1,719	1,323	1,011	767	577	429	315	227	160	110	72	2	0	0	0
With conservation															
Yield (kilograms per hectare)															
Corn	1,305	1,313	1,320	1,328	1,336	1,344	1,352	1,359	1,367	1,375	1,383	1,383	1,383	1,328	1,247
Sorghum	1,752	1,762	1,773	1,783	1,794	1,804	1,815	1,825	1,836	1,846	1,857	1,857	1,857	1,782	1,675
Revenues	2,907	2,924	2,941	2,959	2,976	2,994	3,011	3,029	3,046	3,064	3,081	3,081	3,081	2,958	2,779
Crop production costs	886	888	890	893	895	897	900	902	904	906	909	909	909	893	869
Conservation costs	470	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Returns	1,550	1,969	1,984	1,999	2,014	2,029	2,044	2,059	2,075	2,090	2,105	2,105	2,105	1,998	1,843
Present value returns	1,550	1,640	1,378	1,157	971	815	685	575	482	405	340	55	9	1	0
Returns to conservation															
Net benefits	-169	381	528	673	818	962	1,104	1,245	1,385	1,522	1,658	2,017	2,105	1,998	1,843
Present value net benefits	-169	318	367	390	394	386	370	347	322	295	268	53	9	1	0
Cumulative present value net benefits	-169	149	516	906	1,300	1,687	2,056	2,404	2,726	3,021	3,288	4,513	4,740	4,776	4,782
Net present value at 50 years	4,782														

Source: Authors' calculations.

spontaneously diffused beyond project boundaries—*tram, ramp pay, kleonaj*—have been the product of indigenous technique and technical revision. There is thus an apparent effectiveness of "shared" knowledge between peasant and scientist. The availability of labor also may be important since no technique with high labor requirements has been readily adopted.

Notes

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2. Haiti's currency is the gourde.

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11. A Review of the Soil Conservation Sector in Mexico

John McIntire

Erosion reduces soil depth and moisture holding capacity, which in turn can lower crop yields, shorten fallow periods inappropriately, or induce agricultural encroachment onto lands not suitable for farming. With continuing erosion, farmland may lose all of its topsoil and no longer be suitable for crops. Although degraded land can be used for grazing, this sometimes exacerbates erosion by further depriving land of vegetative cover. Agricultural encroachment onto forestland may reduce the availability of fuelwood and timber as well as the capacity of trees to store moisture and afford protection from wind.

Much information is available on the extent of soil erosion in Mexico. Less is known, however, about the economic losses associated with erosion or about the costs and benefits of soil conservation measures. No comprehensive analysis has been done of the policy options available to the government for reducing erosion. This chapter analyzes the economic losses due to erosion in Mexico and the costs and benefits of controlling it. This analysis is followed by a discussion of the rationale for government action, if any, in combating erosion and the possible role of the World Bank in those actions.

General patterns of land degradation caused by erosion

Table 11-1 shows a recent estimate of the extent of Mexico's degraded land, which includes land affected by wind and water erosion, chemical pollution, and other causes, made by an international study (the Global Assessment of Soil Degradation—GLASOD; Anaya-Garduño and others 1989). The GLASOD classification of areas according to erosion hazard at an original scale of 1:7.5 million examined the type (water, wind, or chemical), degree (slight, moderate, or severe), extent (infrequent, common, frequent, very frequent, or dominant), and rate (slow, medium, or rapid) of erosion for major landforms in Mexico. This information is not detailed enough to permit an evaluation of productivity losses from land degradation, but it does give an overall impression of the extent of degradation.

Water erosion affects about 86 million hectares, while wind erosion affects 21.3 million hectares. The two combined contribute a significant share of the nation's degraded area. According to the GLASOD classification, 80 percent of the land surveyed in Mexico is eroded at least slightly. The principal type of land affected by water erosion is rainfed cropland, which comprises about 54 percent of all land surveyed (58.5 million of the 107.5 million hectares identified as suitable for crops, livestock, or forestry) and is more likely than other types of land to be moderately eroded (19.4 million of 53.8 million hectares classified as moderately eroded) or severely eroded (35.9 million of 44.9 million hectares classified as severely eroded). Most of the severe erosion also occurs on rainfed land. Moreover, most of the land suitable for irrigated

Table 11-1. Land Degradation Caused by Soil Erosion from Wind and Water in Mexico
(millions of hectares)

Type and percent of land affected	Degree of wind erosion			Degree of water erosion			All erosion		
	Slight	Moderate	Severe	Slight	Moderate	Severe	Slight	Moderate	Severe
Rainfed land									
1–5	0.0	1.7	0.0	0.0	1.3	16.8	0.0	2.9	16.8
6–10	0.0	4.6	0.0	2.2	2.8	0.0	2.2	7.5	0.0
11–25	0.0	0.8	2.3	0.0	7.1	6.3	0.0	7.9	8.6
25–50	0.0	0.0	0.0	1.0	0.0	3.5	1.0	0.0	3.5
More than 50	0.0	0.0	0.0	0.0	1.1	7.0	0.0	1.1	7.0
Total	0.0	7.1	2.3	3.2	12.3	33.6	3.2	19.4	35.9
Irrigated land									
1–5	4.6	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0
6–10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11–25	0.0	0.0	0.0	0.0	2.5	0.0	0.0	2.5	0.0
25–50	0.0	0.0	0.0	0.0	1.7	0.0	0.0	1.7	0.0
More than 50	0.0	0.0	0.0	0.0	2.7	2.7	0.0	2.7	2.7
Total	4.6	0.0	0.0	0.0	6.9	2.7	4.6	6.9	2.7
Livestock land									
1–5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6–10	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.9	0.0
11–25	0.0	3.9	0.0	0.0	0.0	0.0	0.0	3.9	0.0
25–50	0.0	1.2	0.0	0.0	0.7	0.0	0.0	1.8	0.0
More than 50	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Total	0.0	5.1	0.9	0.0	1.6	0.0	0.0	6.7	0.9
Forestland									
1–5	0.0	0.0	0.0	0.0	8.4	0.0	0.0	8.4	0.0
6–10	0.0	0.0	0.0	1.0	1.4	3.7	1.0	1.4	3.7
11–25	0.0	1.4	0.0	0.0	8.9	0.0	0.0	10.2	0.0
25–50	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.7	0.0
More than 50	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	1.7
Total	0.0	1.4	0.0	1.0	19.4	5.4	1.0	20.7	5.4
All land									
1–5	4.6	1.7	0.0	0.0	9.6	16.8	4.6	11.3	16.8
6–10	0.0	4.6	0.0	3.2	5.2	3.7	3.2	9.8	3.7
11–25	0.0	6.1	2.3	0.0	18.5	6.3	0.0	24.6	8.6
25–50	0.0	1.2	0.0	1.0	3.1	3.5	1.0	4.3	3.5
More than 50	0.0	0.0	0.9	0.0	3.7	11.4	0.0	3.7	12.3
Total	4.6	13.6	3.1	4.2	40.2	41.8	8.8	53.8	44.9

Note: Contains errors due to rounding.
Source: Anaya-Garduño and others (1989).

agriculture, livestock production, or forestry has moderate erosion, and this class of erosion is the most frequent on irrigated land.

Patterns of agricultural soil erosion

Analyzing the patterns of agricultural soil erosion should provide a consensus on the most severely affected areas, the quantities of soil lost, and the practices that prevent loss. Analyses of agricultural soil erosion in Mexico often use the method of the Food and Agriculture Organization of the United Nations (FAO) and the Conservation Foundation (1954). The method defines five classes of erosion, ranging from Class A, which has no manifest erosion and has an estimated mean physical productivity loss of 17 percent compared with the situation without erosion, to Class C, which has very severe erosion and an estimated productivity loss of 75 percent. The weighted average loss of productive potential for the nation is an estimated 35 percent, based on these five classes (SARH 1987).

Table 11-2 summarizes the extent of erosion at the state level in Mexico in 1982.[1] Rapid to severe erosion is common. A rough grouping by each state's main agroclimate shows little difference in the level of erosion among the main agroclimates. However, more detailed analysis by Maas and García-Oliva (1990) and by SARH (1987; see table 11-3) indicates that agricultural erosion is particularly severe and widespread in tropical areas.

These state-level data cannot serve to estimate the quantity of soil loss per unit of land. Soil loss depends on the amount and intensity of rainfall, erodibility of the soil, length and steepness of the slope, vegetative cover, and land use practices. The relation between erosion and these factors can be estimated statistically using the Universal Soil Loss Equation (USLE). Data from small experimental watersheds, in which conditions vary widely depending on the size of the plot, give differing results when analyzed with the USLE. For plots that are 10 square meters, the annual loss is an estimated 4.7 tons per hectare; for plots that are 50 square meters, from 0.9 to 4.7 tons per hectare; and for plots that are 7,000 square meters, 0.45 ton per hectare (Slater 1991).

Combining the information from the states and from experiments should give a rough estimate of the quantity of soil lost to erosion nationally. Available estimates diverge greatly, however. Maas and García-Oliva (1990, p. 29) place the share of the national area affected by rapid erosion at between 64 and 100 percent. They also observe that estimates of the amount of soil lost to erosion vary widely. In one study, the average national soil loss is calculated to be 2.7 metric ton per hectare, with a minimum of 0.2 metric tons per hectare in the north and a maximum of 7.4 in the seriously affected Pacific coast. In another study, based on the same data analyzed using a different method, the average was calculated to be 47 metric tons per hectare, with the range falling between 3 and 126 metric tons per hectare.

The Mexican evidence may be biased downward because many experiments have been done on plots with slopes less than 15 percent. Studies from sites with steeper slopes (mentioned in Maas and García-Oliva 1990) have shown soil losses of between 30 and 130 metric tons per hectare, with some values as high as 150, 300, and 500 metric tons found in mountainous areas with very steep slopes.

The impact of erosion on productivity

The on-farm costs of erosion arise from reduced yield, higher input costs, and changes from more to less productive uses of the land. These costs must be defined in order to estimate the tolerance level of soil erosion, which is "the maximum rate of annual soil erosion that may occur and still permit a high level of crop productivity to be obtained economically and indefinitely" (Sinner 1990, p. 11). At the tolerance level, the net soil loss and the yield costs of erosion are both assumed to be zero. Although the tolerance level is not an economic optimum because it does not equalize the marginal benefits and costs of soil conservation, it has agronomic significance and the virtue of being a practical target for conservation programs. The annual tolerance level has been estimated to be between 2.5 and 12.4 metric tons per hectare annually, depending on the depth and texture of the soil. An average of 5 metric tons per hectare a year is used in this study.

Reductions in crop yield

Erosion reduces crop yields by reducing the soil's capacity to hold water as well as by diminishing its depth and nutrient load. Only a portion of the water potentially available for plants can be retained in areas where surface runoff occurs, and the soil's capacity to hold water is further restricted when its depth is reduced. Crop yields are reduced by both the diminished water-holding capacity of the soil and the loss of nutrients occasioned by decreased depth. In the United States, estimates for reductions in yields of maize, wheat, and soybeans vary from 1.5 to 2.0 percent annually (Crosson and Stout 1983). Erosion also causes significant reductions in yield for several Asian countries (Doolette and Magrath 1990). In Africa, Lal (1987) reports declining yields of 2 to 5 percent a year on hillsides in southern Nigeria, while Nye and Greenland (1960) report declines in yield of as much as 83 percent for sorghum and 64 percent for pearl millet in subhumid northern Nigeria. No corresponding national estimate exists for Mexico.

Increases in production costs

Increases in production costs due to erosion have several components. To counteract the effects of erosion, farmers might apply more mineral fertilizers to replace lost nutrients or more irrigation water to replace higher runoff. Crop management may become more costly due

Table 11-2. Severity of Soil Erosion in Mexico, by State and Climatic Region, 1982
(thousands of hectares unless otherwise noted)

State and climatic region	*No manifest*	*Light*	*Moderate*	*Rapid*	*Severe*	*Total area*
Productivity loss compared with situation without erosion (percent)	17	22	37	38	75	35
Tropical states						
Campeche	1,630	2,038	917	306	214	5,095
Colima	125	21	88	234	62	521
Chiapas	4,557	2,123	477	64	0	7,442
Quintana Roo	1,611	1,915	504	252	756	5,035
Tabasco	760	887	380	127	380	2,534
Oaxaca	1,413	1,413	1,894	1,884	2,826	9,421
Veracruz	3,604	3,462	96	2	1	7,190
Yucatán	578	193	1,194	193	1,694	3,851
Central temperate highlands						
Distrito Federal (Mexico City)	23	62	12	1	0	148
Tlaxcala	17	71	209	77	10	403
Guanajuato	1,026	506	874	383	218	3,059
Guerrero	2,449	127	1,676	1,354	839	6,446
Hidalgo	501	63	397	522	605	2,087
Jalisco	1,864	81	1,459	4,134	467	8,106
México	516	919	611	28	7	2,146
Michoacán	961	120	1,382	3,245	300	6,009
Aguascalientes	27	82	192	110	137	549
Irrigated arid states						
Morelos	9	293	170	13	0	494
Nayarit	818	1,219	607	76	7	2,705
Puebla	102	1,923	851	357	131	3,392
Querétaro	138	23	367	207	413	1,148
Sinaloa	1,170	1,170	1,111	1,228	1,170	5,849
Sonora	3,286	2,373	4,016	3,103	5,477	18,225
Baja California Norte	1,003	1,146	2,364	1,791	860	7,163
Baja California Sur	870	1,015	2,174	2,029	1,159	7,247
Tamaulipas	2,229	796	2,388	1,353	1,194	7,960
Rainfed arid states						
San Luis Potosí	1,145	1,666	2,811	575	32	6,324
Chihuahua	4,427	4,250	13,188	2,109	681	24,561
Durango	3,459	247	4,817	1,235	2,594	12,532
Coahuila	301	1,654	4,662	6,911	1,504	15,040
Zacatecas	367	2,057	367	3,085	1,469	7,345
Nuevo León	260	1,693	1,497	2,731	826	6,510

Note: The total area does not equal the sum of the erosion classes because of errors due to rounding.
Source: SARH (1987).

to the increased variability of soils. Only the additional cost of replacing soil nutrients is discussed here. Colaciccio and Setia (1986) estimate the additional costs of applying mineral fertilizers to replace nutrients lost to erosion by (a) calculating soil loss due to erosion; (b) estimating the average nutrients in the soil lost; (c) calculating the nutrients lost to erosion; and (d) valuing those nutrients at the economic prices of replacement fertilizers. This has not been done here for lack of available information.

Changes in land use

A change in land use is defined as a switch from a more to a less productive use as a result of erosion (for example, shifting to a less productive crop that can tolerate erosion). Declines in

Table 11-3. Estimated Annual Soil Loss in Mexico, by Climatic Region
(tons per hectare a year)

Macroclimate	*Soil loss*
Tropical humid	3.9
Tropical dry	4.3
Temperate	2.3
Arid and semiarid	1.1

Source: SARH (1987).

productivity may lead farmers to shorten the fallow periods, and the resulting reduction in vegetative cover and nutritive value of grazing areas may lead to overgrazing and further degradation of the land, accelerate the formation of gullies, or destroy forests and woodlands faster than they can regenerate. Because no information is available on these shifts in Mexico, the economic analysis presented here excludes their potential costs.

Off-farm effects

Off-farm effects include sedimentation of waterways, dams, and other collection sites, which shortens the lives of reservoirs and irrigation systems. There is conflicting opinion about the economic costs of off-farm sedimentation. In the United States, Crosson and Stout (1983) argue that off-farm losses outweigh on-farm losses. A World Bank review (Doolette and Magrath 1990) of Asian countries found that off-farm losses are probably less important than on-farm costs because the proportion of watersheds with infrastructure is small compared with the total area affected by erosion. In Mexico, it has been calculated that 70 percent of eroded soil exits to the sea and 30 percent is deposited in lakes, rivers, and structures, implying that on-farm losses are greater than off-farm ones.

Economic analysis of soil conservation

Modest structural works, minimum tillage with maintenance of residual organic matter, or both can reduce physical soil loss to acceptable levels. However, little is known about the economic benefits to society and the financial benefits to the farmer of using such soil conservation practices. The following sections review some of the management techniques available for arresting the on-farm effects of soil erosion in Mexico.

Soil conservation techniques

Farmers have many traditional methods to arrest erosion. Wilken (1987) describes some that are employed in a semiarid area of Tlaxcala state, where erosion is severe:

- Check dams, which are built with earth and stone to block the flow of water and sediment in erosion gullies and then cultivated by planting the land formed behind the dam
- Sloping terraces, which are built with stone and earth borders to control erosion and runoff overflow adjacent to ditches that conduct excess water out of the field
- Bench or flat terraces, in which flat cropland is carved out of steep slopes and cultivated.

A report by the FAO (Slater 1991) further describes practices in four rural development districts in the states of México, Michoacán, Nuevo León, and San Luis Potosí. They include contour banks with ditches, check dams, stone contour dams, contour plowing, land smoothing, minimum tillage, tie ridging, and such cropping practices as composting, manuring, and applying crop residue. Farmers practice these methods sporadically.

Techniques developed by agricultural research

Considerable knowledge exists about soil and water conservation practices from the work conducted by the General Directorate of Soil and Water Conservation (DGCSA) and the continuing work of the Instituto Nacional de Investigación Forestal y Agropecuaria (INIFAP), Comisión Nacional de Agua, and Mexican universities. Starting in the 1960s, the Colegio de Postgraduados initiated research into soil erosion and runoff, cultivation effects, and the impact of structures on soil erosion. Most of this work was performed in the central highlands with a few discontinuous experiments in other agroecological areas. After the DGCSA was disbanded in the mid-1980s, the Colegio de Postgraduados at Chapingo, the Universidad Autónoma de México, and a few other universities were the only parties actively conducting soil conservation research, even though the mandate of INIFAP was the "improvement, use, and conservation of soil and water for agricultural use." Many techniques (described in table 11-4) have been developed in agricultural research, and some are in wide use.

Effects of soil conservation techniques

Increasing the vegetative cover of land tends to reduce erosion, although the estimated magnitude of the effect varies widely. A SARH review (1987) of the relative efficiency of vegetative cover and mechanical practices concludes that a crop that provides adequate soil cover, plus appropriate management of crop residue, would reduce erosion losses to tolerable levels, even in places where the erosive potential of the soil is very high. The same study estimates the value of vegetative cover for reducing erosion to range from 1 (the highest value on bare soil) to 0.001 (a pine forest). A maize or sorghum crop has a value of 0.1 to 0.9, or between 10 and 90 percent less than bare soil; maize and sorghum are probably much less effective than pastures (0.001) or such permanent crops as coffee and oil palm (0.1 to 0.3). The World Bank's study in Asia (Doolette and Magrath 1990) concludes that, in general, vegetative covers are more efficient than works or mechanical practices.

Benefits of soil conservation

The economic analysis for Mexico concentrates on three major crops that are grown largely under rainfed conditions: maize, beans, and sorghum. In 1990, rainfed maize was grown on 7.3 million hectares, rainfed beans on 2.0 million hectares, and rainfed sorghum on about 1.1 million hectares.

The decision to concentrate on these annual crops for the rainfed areas alone was taken for several reasons. Irrigated crops typically have less erosion because they are grown on level fields; in terms of the USLE, their slope factor is very small. Irrigated cropland is often more thoroughly covered throughout the year because more than one crop is grown; their cover factor is low. The irrigated areas of Mexico are located in more arid sites, where rainfall is both lower and less intense than in the tropics and where rain showers are less frequent and less erosive. Rainfed permanent crops often consist of trees, shrubs, sugarcane, or forages that provide good annual soil cover, thereby incurring less erosion. Moreover, such crops are often sown in drier areas, like those where irrigated field crops are grown and where their erosion risk is less serious than it would be in the tropics.

The economic impact of soil erosion on these three crops in Mexico has not been well quantified partly because of methodological and data questions. Those questions are reviewed briefly below.

Table 11-4. Conservation Techniques in Mexico

Type of practice	*Best environment*	*Costs over time*
Structures		
Vegetative barriers	Subhumid; humid	Moderate at outset
Bunds	Arid; semiarid	High at outset, then lower annual upkeep
Stone contours	Adaptable to all	High at outset, then lower annual upkeep
Drainage ditches	Subhumid; humid	High at outset, then lower annual upkeep
Flat terraces	Adaptable to all	High at outset, then lower annual upkeep
Backslope terraces	Adaptable to all	High at outset, then lower annual upkeep
Tanks	Arid; semiarid	High at outset, then lower annual upkeep
Check dams	Arid; semiarid	High at outset, then lower annual upkeep
Windbreaks	Arid; semiarid	High at outset, then lower annual upkeep
Tillage practices		
Contour plowing	Adaptable to all	Uniform
Tie-ridging	Arid; semiarid	Uniform
Subsoiling	Adaptable to all	Uniform
Stone removal	Adaptable to all	Uniform
Minimum tillage	Unknown	Uniform
Cultivation practices		
Animal manuring	Arid; semiarid	Uniform
Green manuring	Humid	Uniform
Crop residue use	Widely adaptable	Uniform
Crop rotation	Widely adaptable	Uniform
Forage crops	Arid; semiarid	Variable, depending on CMP

Source: Slater (1991).

Methodological and data issues

The major methodological assumptions used are as follows:

• *The estimate of a discount rate to weight future costs and benefits affects the net returns to soil conservation techniques.* The discount rate used here is the economic discount rate, defined as the real growth-adjusted rate (van Wijnbergen and Levy 1991); this is the cost of loanable funds to the country deflated by the expected rate of national economic growth.

• *The use of financial or economic prices affects the net benefits of erosion control.* Economic prices are used because they constitute the social opportunity costs of the resources used. The single exception is the discount rate applied to future costs and benefits; sensitivity analysis is presented that compares (higher) private rates with (lower) economic rates.

• *The number of years after which erosion begins to diminish crop yields affects returns.* It is assumed that average erosion occurs every year; hence crop yields decrease continuously, and the number of years before erosion is felt is zero. This assumption increases the costs of erosion by supposing that they occur earlier than they would if erosion manifested itself after a lag.

• *The number of years until soil conservation techniques begin to reduce erosion is related to the number of years until those techniques have their full impact.* It is assumed that conservation techniques have half of their maximum impact in the first year after they are initiated and their full impact in the second. This lag is due to the assumption that farmers need time to learn how to manage the new techniques effectively. This assumption reduces the benefits of erosion control by supposing that they occur later, which lowers their discounted value.

• *The permanence of soil losses due to erosion affects the degree to which land lost to erosion can be regenerated.* If soil losses are completely restored by soil regeneration, then they are not permanent and the net annual loss (gross loss minus regeneration) is zero. Since regeneration is rarely complete, the net loss (gross loss is greater than regeneration) is positive and permanent.

The following questions were asked of the data:

• What are the on-farm losses in crop yield due to erosion? The yield costs were modeled from information provided by Mexican researchers or from external sources where national information was not available.

• What are the incremental costs of soil conservation techniques? These costs were derived from farm management information provided by Mexican specialists, as summarized in tables 11-5 and 11-6. They were calculated as a function of the quantity of soil lost to erosion.

Plan of the analysis

This economic analysis reviews evidence presenting typical farming situations in five tropical states (Chiapas, Nayarit, Veracruz, Tamaulipas, and Oaxaca) and eight highland or semiarid states (Michoacán, México, Jalisco, Nuevo León, San Luis Potosí, Puebla, Tlaxcala, and Zacatecas). Nationally, about 7.3 million hectares were sown with maize in the 1990 spring/summer cropping season; of this, 3.3 million hectares were located in the eight highland/semiarid states and 1.7 million hectares were in the five tropical states. Another 2.0 million hectares were sown to beans in that season, including 1.0 million hectares in the highland/semiarid states and 0.2 million in the tropical states. About 1.1 million hectares were sown to sorghum, including 0.4 million in the highland/semiarid states and 0.1 million in the tropical states. Because of uncertainties in the available information, the analysis is limited to parts of the thirteen states where erosion is manifest. Based on the data in table 11-2, the areas in the three crops with greater than "no manifest" erosion are assumed to be proportional to the total area in each state with greater than "no manifest" erosion.

The following steps were then taken for each situation:

(a) The impact of the average physical soil losses on yields of maize, beans, and sorghum was calculated.

(b) The annual economic value of the yield losses was estimated.

(c) The average reduction in soil loss was calculated for each technique.

(d) The costs of soil conservation were calculated for each technique.

(e) The net present value of benefits for each combination of zone, state, crop, and technique was calculated to perpetuity, using equations 11-2 through 11-7.

(f) The net benefits were subjected to sensitivity analysis by varying the private discount rate, the effect of erosion control on crop yield, and the target level of soil loss.

(g) Estimates of the net present value of benefits to soil conservation on areas planted to maize, beans, and sorghum were aggregated to the national level by projecting them over the eroded areas in each crop in the tropical and highland/semiarid states studied.

The notation for the analysis is presented in table 11-7, and values of key parameters are summarized in table 11-8. The simplest estimate of the costs of erosion is the net present value of the economic cost of the annual loss in crop yield over a relevant period of time:

$$\text{(11-1)} \qquad \text{NPV} = \sum_{it} a_{it}(p_{it})\,[y_{it0}\, e^{(-r-k)t}]$$

In theory, the value of crop output could fall to zero. In practice, farmers would stop producing on severely eroded land if the value of output were less than the cost of production. It is therefore necessary to specify a maximum loss, given as 20 percent in table 11-8. Using equation 11-1 and the parameter values in table 11-8, the net present value of the loss to erosion is US$2.09 billion over a period of twenty-two years.[2]

Costs of erosion control techniques

The costs of tillage and cultivation practices differ over time. Structures are the most expensive when the initial outlay is made, and their costs fall as routine maintenance becomes the norm. The costs of cropping practices are more or less the same in each year of the investment. Because their initial cost is higher, structures are less profitable than cropping practices, other things being equal. Costs of seeds, plant cultivars, pesticides, and agrochemicals are assumed not to be affected by soil conservation control techniques and thus do not enter into the economic analysis of the incremental investments in conservation.

Incremental costs of supervision and extension related to soil conservation differ among programs for combating erosion. For supervising structures or cropping practices, such costs are estimated to be US$6 per hectare a year, based on the costs of extension programs. The incremental costs of supervising a land reserve program are assumed to be half the costs of supervising field techniques, or US$3 per hectare annually, because verifying participation in the reserve program can be done more quickly and less often than teaching soil conservation techniques.

The incremental costs of achieving the tolerance level of erosion are given by[3]

$$\text{(11-2)} \qquad c_{ij} - c_{in} = c_{\wedge j} + u$$

The supervisory costs of extending new soil conservation methods are assumed to be higher than normal extension costs, so $u > 0$. Because the cost per ton of erosion saved grows as farmers must work progressively harder to achieve those savings, it is assumed that $c_{\wedge j} < c_{\&j}$. The incremental costs of achieving the lowest feasible level of soil erosion are $c_{ij} - c_{in} = c_{\&j} + u$.

Tables 11-5 and 11-6 give the average annual costs and erosion indexes of various techniques, ranging from 1 percent to 193 percent of the average gross value of rainfed maize production (a cost, insurance, and freight price of US$140 per ton times an average yield of 2 tons per hectare).

Benefits of soil conservation

The gross benefits of crop production are yield times price, that is,

$$\text{(11-3)} \qquad G_i = y_i \times p_i$$

The benefits of soil conservation initially derive from higher crop yields. The incremental benefits of a soil conservation technique are crop price times the incremental yield attributable to conservation, or,

$$\text{(11-4)} \qquad G_{ij} - G_{in} = p_i(y_{ij} - y_{in})$$

The crop price is not affected by the incremental yield attributable to controlling erosion. The incremental yield (the term $y_{ij} - y_{in}$) has two components. The yield without soil conservation, y_{int}, slowly falls as erosion cuts crop yields over time; the expression used to approximate this is $y_{int} = y_{in0}(e^{-kt})$. With no erosion, the variable k is equal to 0 and the crop yield is the same every year. With conservation, yield, y_{ijt}, rises as the impact of erosion is attenuated. The expression to approximate this is $y_{ijt} = y_{in0}(1 + m)$ for all years. The variable m is a constant expressing the percentage that crop yields increase from what they would have been if erosion had continued with the same force it had before the conservation investments were made. Figure 11-1 illustrates these basic relations. The marginal impact of soil conservation is

Table 11-5. Costs of Soil Conservation Techniques and Soil Erodibility Index in the Tropics of Mexico

Type and name of technique	*Average annual costs (U.S. dollars per hectare)*	*Soil erodibility index, relative to native pasture x 100*
Structures		
Check dams	15	50
Stone barriers	66	33
Cultivation practices		
Contour furrows	26	20
No tillage	34	20
Minimum tillage	54	33
Cropping practices		
Mulching	10	33
Crop residue management	28	20
Spaced furrows	33	20
Planting in rows	54	33
Manure incorporation	65	13
Cover crops	85	47
Green manuring	201	13

Note: Costs, which are derived from data from the National Water Commission and converted to U.S. dollars at US$1 = Mex$3.1, include capital and variable costs.
Source: The soil erodibility index is derived from SARH (1987) and Maas and García-Oliva (1990).

Table 11-6. Costs of Soil Conservation Techniques and Soil Erodibility Index in the Rainfed Highland and Semiarid Areas of Mexico

Type and name of practice	*Average annual costs (U.S. dollars per hectare)*	*Soil erodibility index, relative to native pasture x 100*
Structures		
Contour banks with ditches	230/297/407/492/541	20
Check dams	221/235/332	50
Stone contours	179	50
Cultivation practices		
Contour plowing	15/17/18	20
Land smoothing	34	33
Minimum tillage	3/68/122	33
Subsoiling	176/225/334/375	33
Tie ridging	8/59/67	33
Cropping practices		
Compost	523	33
Cover crop	47/64	50
Crop residues	64/69/81	20
Manuring	468	33

Note: Different costs for the same technique are variations for different crops, production locations, soil types, and land slopes. Costs, which are derived from data from the National Water Commission and converted to U.S. dollars at US$1 = Mex$3.1, include capital and variable costs.
Source: National Water Commission; Slater (1991). The soil erodibility index is derived from SARH (1987) and Maas and García-Oliva (1990).

Table 11-7. Notation for Economic Analysis

Variable	*Definition*
y	Crop yield
a	Area cultivated of a crop
p	Price of a crop or fertilizer
c	Cost of a crop production technique
u	Incremental costs of supervising a soil conservation technique
v	Incremental costs of supervising a land reserve program
z	Land reserve payment to farmers
r	Discount rate
q	Quantity of erosion saved
k	Loss of crop yield from erosion (< 0)
m	Gain in crop yield from soil conservation (> 0)
G	Gross benefits to produce a crop
N	Net benefits to produce a crop
C	Total cost to produce a crop
E	Total cost of erosion
Indexes	
t	Subscript for year
i	Subscript for a crop
j	Subscript for a soil conservation technique
n	Subscript for land receiving no soil conservation technique
^	Subscript for tolerance level of soil loss
&	Subscript for lowest technically feasible level of soil loss

(11-5) $$\Delta y = y_{ijt} - y_{int} = y_{in0}(1 + m) - y_{in0}(e^{-kt}) = y_{in0}(1 + m - e^{-kt})$$

The net benefits of achieving a tolerance level of erosion with technique j for crop i in any year are

(11-6) $$N_{ijt} = G_{ijt} - G_{int} - c_{\wedge jt} - u_t$$

The discounted net present value of benefits for technique j and crop i is

(11-7) $$\text{NPV}_{ij} = \Sigma_t N_{ijt}(e^{-rt})$$

Results for the tropics

The tropics are divided into two distinct subregions, the dry tropics and the humid/subhumid tropics. The dry tropics cover 17 percent of the country, mainly in the states of Jalisco and Oaxaca on the Pacific coast and the states of Tamaulipas and Veracruz on the Gulf coast. The dry tropics have between 500 and 1,000 millimeters of annual rainfall and a growing season of between 150 and 270 days. The humid/subhumid tropics cover about 20 percent of the country, extending south of Oaxaca City to Guatemala, including parts of the Pacific states of Nayarit, Colima, Michoacán, Chiapas, and Guerrero as well as parts of the Gulf coast, from Veracruz to Quintana Roo with the exceptions of northern and western Yucatán. They are defined as having more than 1,000 millimeters of annual rainfall in a crop growing period of 150 days or more. The total areas for growing maize, beans, and sorghum in the five states analyzed cover 1.7, 0.2, and 0.1 million hectares, respectively, with 50 percent having erosion greater than the "no manifest" category.

The FAO classification defines about 14 percent of the total land area of the eight mainly tropical states as being severely eroded. The tropics are subject to more rapid erosion than temperate zones because rainfall is higher and more intense, soils are less fertile and more shallow, and, in some cases, slopes are steeper. Some tropical land management practices also accelerate land degradation. Slash and burn agriculture leads to rapid degradation of cleared land. Burning vegetation, although it converts some nutrients into forms that can enter the soil and destroys weeds and pests, exposes the soil to physical damage from intense showers while destroying organic matter and microorganisms essential to natural soil processes. Mechanical

Table 11-8. Key Parameters for Economic Analysis in Mexico

Variable	*Value*
Area cultivated of a crop, millions of hectares (a)	
Maize (32 states), total area	7.30
Tropical states (5 states) with erosion risk[a]	0.85
Highland/semiarid states (8 states) with erosion risk[b]	2.87
Beans (32 states), total area	2.00
Tropical states (5 states) with erosion risk	0.10
Highland/semiarid states (8 states) with erosion risk	0.87
Sorghum (32 states), total area	1.10
Tropical states (5 states) with erosion risk	0.05
Highland/semiarid states (8 states) with erosion risk	0.35
Crop yields, metric tons per hectare (y)	
Maize	
Tropical	1.50
Highland/semiarid	2.00
Beans	
Tropical	0.50
Highland/semiarid	0.75
Sorghum	
Tropical	1.50
Highland/semiarid	2.00
Crop prices, U.S. dollars per metric tons (p)[c]	
Maize	140
Beans	300
Sorghum	100
Fertilizer prices, U.S. dollars per metric ton (p)[d]	
Nitrogen	380
Phosphorus	280
Discount rates, annual percent (r)	
Economic	2.5
Financial	15.0
Costs of supervision, U.S. dollars per hectare	
Soil conservation techniques (*u*)	6
Land reserve program (*v*)	3
Erosion and soil conservation parameters	
Loss of crop yield with erosion, annual percent (*k*)	1.0
Maximum percent loss	20.0
Soil conservation productivity effect, gain in crop yield, total percent of yield with erosion (m)	
Low value	10.0
High value	40.0

a. 50 percent of the area in the tropical states has erosion greater than the "no manifest" category (table 11-2).
b. 87 percent of the area in the highland/semiarid states has erosion greater than the "no manifest" category (table 11-2).
c. Free on board from the farm.
d. Cost, insurance, and freight to the farm.

clearing can damage the soil by compaction and removal of the thin top layer.

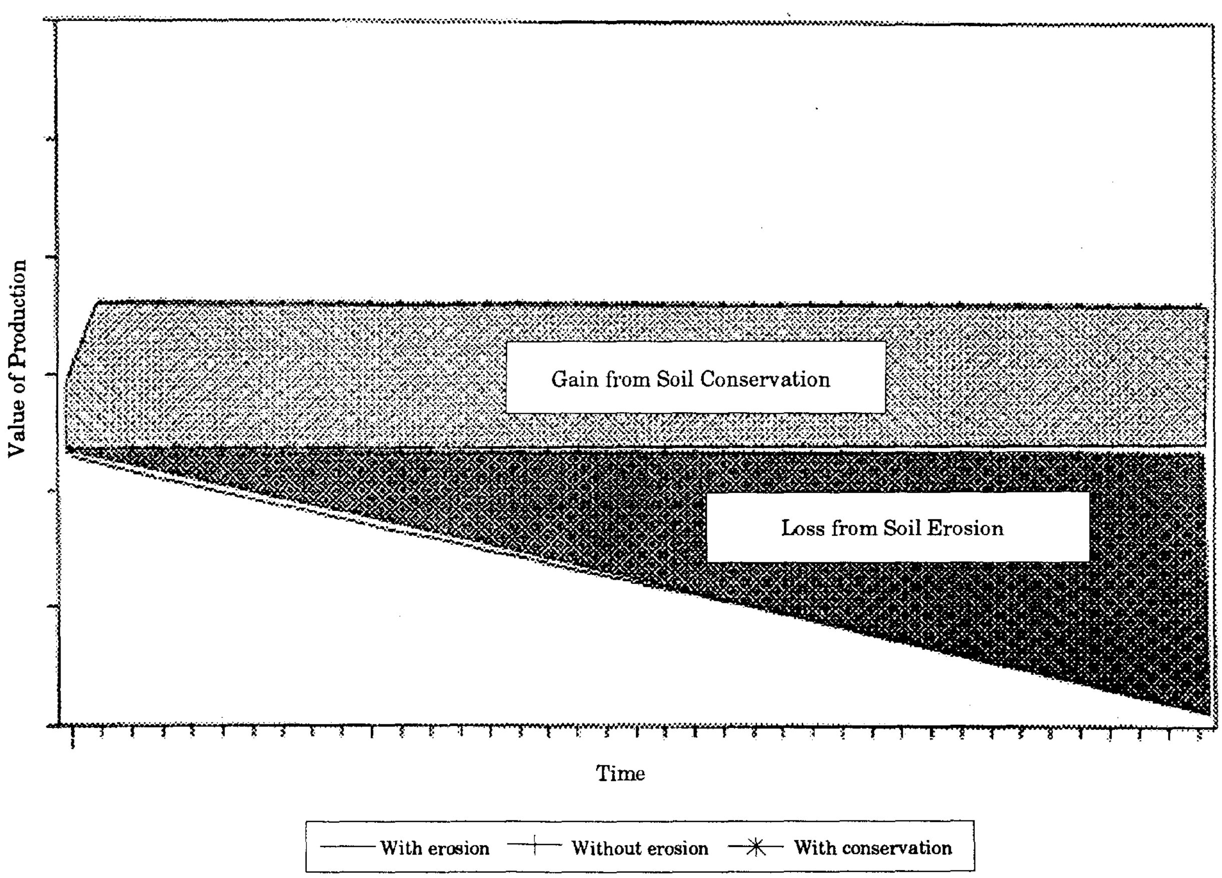
Table 11-9 shows results for annual erosion losses per hectare of 1 metric ton and 5 metric tons. The values are the average benefits per hectare gained by using profitable conservation techniques multiplied by the area sown to each crop, as shown in table 11-8. In tropical states, controlling erosion on land planted to the three crops examined is profitable for thirty-eight techniques, even when the gain in crop yield from soil conservation (m) is assumed to be relatively low (10 percent), giving a net present value of US$0.30 billion. The profitable techniques are nearly always cropping or cultivation practices.

Results for the temperate highlands and semiarid rainfed areas

The temperate highlands cover about 12 percent of the country in a central belt about 1,200 meters above sea level extending from Aguascalientes in the north to Oaxaca City in the south. This area corresponds approximately to the isoyhets of 500–1,000 millimeters of annual rainfall and a growing period of 100–150 days. The rainy season usually starts mid-May to early June and lasts three to four months. Year-to-year fluctuations in annual precipitation are considerable, and within-season distribution is subject to periods of drought as well. The semiarid and arid areas occupy over half the country. The southern limit is the 500–1,000 millimeters isoyhet and the 100-day growing period. About 10 percent of the area is severely eroded in the six states classified as rainfed arid (San Luis Potosí, Chihuahua, Durango, Coahuila, Zacatecas, Nuevo León). The maize, beans, and sorghum areas in the eight states analyzed are 3.3, 1.0, and 0.4 million hectares, respectively, with 87 percent having erosion greater than the "no manifest" category.

Farmers in the central and northern highlands use few soil and water conservation practices. The only widespread technique is some incorporation of animal manure, although this is not universal. Most farmers prepare the land using mechanical discs, frequently moving up and down the slope, not on the contour. Few use simple on-farm structures. The removal of maize stover from fields is almost ubiquitous, exacerbating the loss of nutrients and decreasing soil cover. Because of the severe risk of drought, frost, and hail, maize and other crop cultivars with relatively short growing seasons are difficult to develop, and in consequence, little crop rotation is practiced and virtually no cover crops are grown for soil protection.

Figure 11-1. Value of Crop Production as Affected by Erosion and Conservation



SARH and FAO have analyzed four rural development districts with severe erosion in the temperate highlands: Ameca (Jalisco), Atlacomulco (México), Montemorelos (Nuevo León), and Morelia (Michoacán). These districts are representative of maize farming in much of Mexico's temperate highlands, and the methods used to control erosion apply widely to the highlands. Farmers generally know something about these techniques and could apply them at low incremental costs. Only three of the techniques—stone contour walls, contour banks with ditches, and check dams—require construction work. The others are crop management practices, requiring neither new equipment nor great modifications in farming practices. Making such techniques suitable to local farmers requires only extension work to promote the most profitable techniques.

Table 11-9 displays the results for rainfed production of the three crops in the highland and semiarid states. Erosion control leading to a 10 percent increase in crop yields over a base situation to perpetuity is profitable in forty-eight cases, with a net present value of US$3.47 billion. The situation is somewhat better for maize and beans in the highland and semiarid states than in the tropical states, but not for sorghum, for which no technique is profitable.

Sensitivity analysis

The profitability estimates given here are subject to uncertainties because some doubts exist about the underlying data. Because of gaps in information about production locations, crops, and farming techniques, sensitivity analysis must be used to model the most probable im-

Table 11-9. Net Economic Benefits of Soil Conservation Techniques in Mexico, by Target Soil Loss
(net present value in millions of U.S. dollars)

Site	*Target soil loss of 5 metric tons*		*Target soil loss of 1 metric ton*	
	Net present value	*Number of profitable cases*[a]	*Net present value*	*Number of profitable cases*[a]
Low soil conservation productivity effect (10 percent maximum)				
Tropical states				
Total	298	38	295	35
Maize	255	25	245	25
Beans	27	9	33	6
Sorghum	16	4	17	4
Highland/semiarid states				
Total	3,472	48	3,454	48
Maize	2,974	43	2,991	43
Beans	498	5	463	5
Sorghum	0	0	0	0
High soil conservation productivity effect (40 percent maximum)				
Tropical states				
Total	1,857	80	1,800	80
Maize	1,686	40	1,627	40
Beans	116	24	113	24
Sorghum	55	16	60	16
Highland/semiarid states				
Total	11,561	92	11,156	92
Maize	8,731	82	8,441	82
Beans	2,125	9	2,044	9
Sorghum	705	1	671	1

a. A case is a combination of state, crop, and technique.
Source: Author's calculations.

pacts of certain practices. Sensitivity analysis of the effects of soil conservation on productivity and of the target quantity of soil loss is shown in table 11-9. Further sensitivity analysis of the discount rate, and its interaction with the productivity impact of soil conservation, is presented in table 11-10.

Impact of erosion control on productivity

If the impact that soil conservation has on productivity is high, the returns to investment in conservation measures are also high. This part of the analysis is highly speculative, however. Although the estimated impact of erosion on crop productivity is at least 37 percent in much of the country, the more detailed local evidence from Mexico, and estimates from the United States, show overall effects that are lower. It is therefore improbable that the average impact could be as high as 40 percent, although losses could exceed that figure in many sites. The economic returns to erosion control at such severely eroded sites would be highly positive, as shown in the bottom half of table 11-9. That the impact could be so great on severely eroded lands argues for accurately targeting the sites where erosion control measures are promoted since overall returns depend so much on the choice of site.

The target level of soil lost to erosion

Cutting the target level of soil loss to 1 metric ton, which is considered to be the lowest practical quantity for an annual crop, would have little impact on the number of profitable techniques and their average return (table 11-9). These results mean that producers could cut erosion below an average target quantity of soil loss with only modest external financial incentives.[4]

Private discount rate

In this analysis, the initial real private discount rate is 5 percent, or twice the real economic rate. Increasing the real private rate to 15 percent, or three times the initial rate, has a strong negative effect on the financial profitability of soil conservation (table 11-10). At a target soil loss of 5 metric tons and a soil conservation productivity effect of 10 percent, the net present value of financial benefits is US$2.13 billion at the lower rate and US$0.49 billion at the higher rate.

Is an erosion control subsidy justified?

The traditional argument for public subsidies is that negative externalities are associated with the economic activity subsidized. Several possible externalities have been identified with soil erosion.

Information as a public good

When private suppliers do not invest fully in soil conservation because they cannot capture all the benefits of developing practices that farmers can easily copy, government intervention is justified to supply farmers with information about potential practices. This is a typical reason given for public agricultural research and extension.

Divergence between economic and private discount rates

If farmers' private discount rates exceed their economic rates, then a subsidy can be justified in order to equalize the private and social benefits of soil conservation. A subsidy is justified because soil loss to erosion is permanent; that is, some of the soil lost beyond the tolerance level can never be recovered. This differentiates investments in soil erosion from other investments, such as investments in machinery, because losses caused by underinvestment in machinery are not permanent. When the private discount rate exceeds the social discount rate, producers discount the future (permanent) losses in land productivity at a higher rate than society does and underinvest accordingly. A subsidy for soil conservation might therefore promote investments and reduce losses to erosion. Even if this divergence only applies to smallholders without access to private credit, it still affects many Mexican farmers and is therefore of empirical significance.

Physical externalities

Even if soil conservation equalizes marginal benefits and costs on a given farm, erosion may still incur additional costs, such as siltation of dams and waterways or effects on adjacent farms. Government action to encourage farmers to stop the siltation of dams and waterways at its source is justified because the costs of private actions that reduce siltation are higher than the benefits. Although eliminating off-farm costs

Table 11-10. Private Profitability at Target Soil Loss of 5 Metric Tons in Mexico, by Private Discount Rate
(net present value in millions of U.S. dollars)

Soil conservation productivity effect, region, and crop	*Private discount rate of 5 percent*	*Private discount rate of 15 percent*
Low productivity effect (10 percent maximum)		
Tropical states		
Total	207	59
Maize	182	46
Beans	15	9
Sorghum	10	4
Highland/semiarid states		
Total	1,921	435
Maize	1,619	384
Beans	302	51
Sorghum	0	0
High productivity effect (40 percent maximum)		
Tropical states		
Total	972	255
Maize	878	227
Beans	64	18
Sorghum	30	10
Highland/semiarid states		
Total	5,851	1,557
Maize	4,399	1,180
Beans	1,086	282
Sorghum	366	95

Source: Author's calculations.

produces benefits to society, it gives nothing to the farmers who invest in soil conservation. Even if farmers capture the full benefits of eliminating soil erosion on their land, they capture no benefits by eliminating off-farm erosion. Farmers accordingly underinvest in soil conservation, and a subsidy is required to convince them to invest enough to eliminate the off-farm effects of erosion. Government action to convince farmers to stop the effects of erosion on adjacent lands is only justified if the farmers involved cannot contract among themselves by, for example, agreeing to collective action for soil conservation.

Other policies

Another possible justification is that past government policies—high fertilizer subsidies, distorted product prices, the imposition of production targets, inefficient rural credit policies—did not create full economic incentives to invest in soil conservation. In this case, subsidizing investments in soil conservation might be necessary to correct the effects of those distortions. This has not been considered in the analysis because some of those distortions have been removed in Mexico and because adequate information is not available to calculate the effects of the remaining distortions on investment incentives.

A last justification for government intervention concerns the consequences of historical land tenure policies on incentives to invest in soil conservation and other farm activities. Mexican law formerly did not grant full private rights to users of ejido land, a form of communal tenure. This failure might have given ejidatarios insufficient incentive to invest in their land, including soil conservation. According to a World Bank review (1990) of land tenure in Mexico, however, data gathered after 1970 indicate that ejidos are "likely to be at least as productive on average as private farms." More specifically, the report compares soil conservation, and other land investments, on ejidos and lands held under other types of tenure. The government has reformed the land tenure clauses of the Mexican constitution. Those reforms tend to eliminate distortions in the rural land market and give farmers more appropriate incentives for investing in soil conservation.

The calculation of possible subsidies depends on the profitability of available soil conservation techniques, which can be organized into three groups: (a) techniques profitable at the lower economic discount rate *and* the higher private rate (group A); (b) techniques profitable at the economic rate *but not* at the private rate (group B); and (c) techniques not profitable at the economic rate *or* the private rate (group C). If farmers have adequate information, they never adopt group B techniques because their private profitability is negative. Group C techniques do not justify a subsidy because their social profitability is also negative.

Group A techniques. If adequate information is available about group A techniques, farmers adopt them because they are privately profitable. No subsidy is necessary to induce farmers to conserve soil to the tolerance erosion loss; a subsidy to induce them to conserve to the lower minimum erosion loss is required, however. It is the difference between private profitability at the tolerance loss (5 metric tons) and the minimum loss (1 metric ton). This subsidy is not affected by any divergence between the private and social discount rates because it is calculated using only techniques that are profitable at specific private discount rates (see table 11-11).

The net present value of the subsidy, for the low soil conservation productivity effect, is US$34 million at a private discount rate of 5 percent and US$19 million at a private discount rate of 15 percent. At a given effect of conservation on productivity, the subsidy moves from the lower to the higher discount rate because average profitability falls. At a given private discount rate, the subsidy moves from the lower to the higher effect because average profitability rises.

Group B techniques. Group B techniques—positive social profitability and negative private profitability—might justify a subsidy because farmers would not adopt practices with negative private profitability, thereby depriving society of benefit from the use of such (socially) profitable practices. Few techniques belong in this category; most are in group A or group C, but the use of group A techniques may not be possible at some sites. This subsidy depends on a possible divergence between private and social discount rates; in table 11-11, it can be seen to rise sharply with the private discount rate and to fall from the weaker to the stronger effect of conservation on productivity. Because so few techniques are in class B, and because high subsidies are needed to compensate for the difference between the private and social discount rates, it would not be worthwhile to subsidize particular soil conservation practices in this manner.

Is a land reserve program more efficient than erosion control practices?

One alternative to subsidizing soil conservation techniques is to pay producers to leave land idle. Such a land reserve program is more efficient than soil conservation practices if it costs less per quantity of soil saved. There are no economic benefits to the land reserve program, which produces no benefits in higher crop yields or lower fertilizer costs because land is idle.[5] The only benefits are the environmental benefits of the soil saved from erosion; hence, only the net costs per ton of erosion saved can be compared for a land reserve program and a program of technical changes.

The cost per ton of erosion saved in the reserve is the net present value of the costs of supervision plus the reserve payment to producers, divided by the quantity of erosion saved; those costs are given by the variables v and z, respectively, in equation 11-8:

$$\text{(11-8)} \qquad \text{NPVR} / q = -\Sigma_t (v + z)_t \, (e^{-rt})$$

The variable q is the difference in erosion on the uncultivated reserve and the average erosion on the same land under cultivation. The reserve payment to producers is arbitrarily set at 20 percent of the gross benefits (yield times price) of output. Because a reserve program produces no gross economic benefits, its net benefits are always negative, as is evident from equation 11-6.

The cost per ton of erosion saved by introducing technical changes is the discounted present value of net benefits divided by the quantity of erosion saved. For a combination of one crop and technique, and letting q_j represent the erosion saved by technique j, that cost is

(11-9) $(\Sigma_j \text{NPV}_{ij}) / \Sigma_j q_j = (\Sigma_t N_{ijt} \times e^{-rt}) / \Sigma_j q_j$

Equation 11-9 is understood to have variants corresponding to groups A, B, and C, and the values resulting from it can be either negative (a net economic loss associated with a particular technique) or positive (a net economic gain).

If group A techniques could be generally extended, they would produce much higher positive net benefits than would a land reserve in both the tropical and highland/semiarid areas (see table 11-12). The conclusion is less clear for group B techniques, because they are so few, but they would generally be inferior to a land reserve. The land reserve would be vastly superior to the group C techniques—although a reserve would have negative net economic benefits, those negatives would be much smaller than the negative benefits of group C techniques. A land reserve program is more efficient than soil conservation practices only if the available practices are not profitable. This is essentially the finding of Sinner (1990) for the United States. Sinner's results have been criticized for minimizing the effects of supervisory costs in promoting soil conservation practices, but those costs, under Mexican conditions at any rate, have little effect on the decision to promote conservation practices or to reserve land.

Comparison to other results

The impact of on-farm erosion on productivity has been estimated in several countries. Although their methods and data differ, these case studies reveal significant on-farm economic losses due to erosion.

• In the United States, Crosson and Stout (1983) estimate that wheat, corn, and soybean yields declined between 1.5 and 2.0 percent

Table 11-11. Subsidies and Extension Costs Required to Achieve an Annual Erosion Loss of 1 Metric Ton per Hectare in Mexico with Group A or B Techniques, by Private Discount Rate
(net present value in millions of U.S. dollars)

Soil conservation productivity effect, location, and crop	*Group A*		*Group B*	
	Private discount rate of 5 percent	*Private discount rate of 15 percent*	*Private discount rate of 5 percent*	*Private discount rate of 15 percent*
Low productivity effect (10 percent maximum)				
Tropical states				
Total	17	5	44	418
Maize	17	4	0	384
Beans	0	1	30	17
Sorghum	0	0	14	17
Highland/semiarid states				
Total	17	14	861	1,268
Maize	0	9	861	1,268
Beans	17	5	0	0
Sorghum	0	0	0	0
High productivity effect (40 percent maximum)				
Tropical states				
Total	32	9	15	71
Maize	29	9	0	0
Beans	3	0	0	49
Sorghum	0	0	15	22
Highland/semiarid states				
Total	201	36	0	0
Maize	144	36	0	0
Beans	40	0	0	0
Sorghum	17	6	0	0

Source: Author's calculations.

from 1950 to 1980, costing farmers between US$0.5 billion and US$1.0 billion a year, or about 1.4 percent of the country's agricultural gross domestic product in 1980.

- In Mali, Bishop and Allen (1989) report that farm income declined between 2 and 10 percent due to crop yield losses from erosion.
- In Haiti, White and Jickling (1991) estimate the average internal rate of return to be 23 percent. To put it another way, the net benefits of controlling erosion are almost zero if farmers' discount rates are 20 percent.
- A World Bank (1990) review takes a slightly different approach and computes the cost of on-farm nutrient loss in different countries to be US$2.5 billion in Zimbabwe, US$315 million in Java, and US$100 million in the Philippines.

Estimates of the benefits of erosion control in Mexico

National estimates of the impact of erosion in Mexico show an average loss of 2.7 percent and a maximum loss of 12.3 percent for maize, expressed as a fraction of agricultural gross domestic product (see table 11-13). This is much smaller than the estimated productivity loss for Mexico's erosion classes as defined by GLASOD; the difference may reflect the more erosive rainfall and steeper slopes cultivated in parts of Mexico, which cause losses from soil erosion to be higher than they are in the United States.

There is no clear understanding of the economic costs and benefits of soil conservation practices at the farm level in Mexico. One study in Aguascalientes and Oaxaca was done in 1976 (Schramm 1978). Aguascalientes is located in a semiarid region with relatively low crop yields, while Oaxaca is located in a mixed temperate and tropical region with somewhat higher yields. A full economic evaluation of these experiments was not done, and only estimates of financial rates of return are available. At the time of the study, chemical and mechanical farm inputs were heavily subsidized and the exchange rate was overvalued, so financial results probably diverge substantially from economic ones. Some important results are as follows:

- The real financial rates of return to soil conservation practices ranged from –9 to 19 percent. Only Oaxaca had rates above 12 percent. These rates were probably lower than the real discount rates of farmers and hence did not encourage adoption of the techniques studied.
- The highest financial rates of return were with mechanically constructed terraces without vegetation. Deep plowing by itself, or with terrace construction, was not economical in either Aguascalientes or Oaxaca.
- About two-thirds of the benefits from soil conservation accrued from savings in soil nutrients and one-third from incremental crop output. The study by Colaciccio and Setia (1986) in the United States found that savings in soil nutrients were about 40 percent of the benefits and that incremental crop output was 60 percent.
- Average increases in maize yield were estimated to be 25 percent if only terraces were built, 20 percent if only subsoiling was undertaken, and 40 percent if both terraces and subsoil plowing were combined. Differences in financial rates of return between terraces and deep plowing were explained by differences in the costs of production.

Trueba and others (1983) conducted a detailed experiment with conservation practices in the state of Michoacán. They studied interactions among type of terrace (bench, wide base, spaced), tillage (none, minimum, traditional), and soil fertility amendments for maize, beans, vetch, and wheat. Their results are as follows:

- One experiment showed no statistically significant effect of the type of terrace nor method of tillage on maize yield. No economic analysis was done.
- A second experiment, involving the interaction of wide base terraces, constructed with three spacings, and type of tillage (none, minimum, and traditional), showed significant effects of the different treatments on maize yield and net benefits. All treatments except one repaid their initial fixed and operating costs in one year, and the remaining treatment repaid it in two years. The average financial rate of return of the eight treatments to perpetuity was at least 50 percent.
- The no-tillage treatment was the most profitable in the second experiment. The treatment would have cut erosion to very low levels although the effect was not measured with precision.

Policy and institutional analysis

To be justified, the social benefits of actions to control erosion must exceed their costs. The preceding sections show that controlling ero-

Table 11-12. Net Benefits of Land Reserve and Soil Conservation Techniques in Mexico at a Target Erosion Loss of 5 Metric Tons per Hectare
(net present value in millions of U.S. dollars)

Type of technique, location, and crop	*Soil conservation technique per ton of soil saved*	*Land reserve per ton of soil saved*
Group A techniques		
Tropical states		
Maize	105	-7
Beans	75	-6
Sorghum	69	-6
Highland/semiarid states		
Maize	620	-9
Beans	406	-8
Sorghum	0[a]	-7
Group B techniques		
Tropical states		
Maize	0[a]	-7
Beans	0[a]	-6
Sorghum	-37	-6
Highland/semiarid states		
Maize	-40	-9
Beans	0[a]	-8
Sorghum	0[a]	-7
Group C techniques		
Tropical states		
Maize	-156	-7
Beans	-139	-6
Sorghum	-142	-6
Highland/semiarid states		
Maize	-124	-9
Beans	-129	-8
Sorghum	-38	-7

a. No techniques were used.
Note: There are five tropical states and eight highland/semiarid states.
Source: Author's calculations.

sion produces significant net social benefits just by augmenting crop productivity alone. To justify public actions, externalities must exist that are intractable by private actions. Two major externalities have been highlighted: the private discount rate of poor producers is greater than the economic discount rate, and producers cannot capture the full economic benefits of investments in soil conservation because some information about soil conservation techniques is a public good. If these externalities exist, techniques to fight soil erosion would not be optimally supplied by the private sector and public investment would be necessary to reach optimal levels.

What measures have dealt with erosion?

During the period 1947–82 various conservation measures were applied to some 3.26 million hectares (see table 11-14). This area accounted for about 3 percent of the arable and pasture land of Mexico in 1982. The value of these investments was always small, being about US$10 million (in 1982 dollars) and averaging about 0.04 percent of Mexico's agricultural gross domestic product from 1950 to 1982.

There is no good analysis of DGCSA's efforts, but some partial information is available about its program and effects. Early conservation theory did not emphasize the tillage and cultural as-

Table 11-13. Costs of Soil Erosion in Area Planted to Maize in Mexico
(percent)

Effect	*Loss from trend yield growth 1955–85*	*Loss from erosion as a percent of 1988 crop value*
Strongest erosion effect	18.0	12.3
Average effect	4.0	2.7

Source: Calculated from U.S. data presented in Crosson and Stout (1983), table 5.9.

pects of conservation. The program frequently used heavy equipment to create structures such as terraces and contour banks. These structures were not always maintained by the beneficiaries and did not yield the expected economic results. Little training in conservation practices and techniques was given to local extension agents. The DGCSA operated independently of other SARH operations, so that the transfer of soil conservation knowledge was somewhat divorced from the extension of other improved agricultural practices. With the elimination of a centralized agency, nearly all public effort to transfer soil conservation techniques stopped. Only limited government and academic work continues.

Field visits discovered that several conservation practices had lapsed while others were being maintained and continued to provide benefit. Since many of the early conservation practices were oriented toward structures and constructed directly by the government, some had been abandoned. This did not always occur, and in some areas structures were not only being maintained but had even been extended recently.

Current soil conservation policy

A broad legal framework exists in Mexico for public actions in soil conservation. The most general laws for agricultural production are the General Law on Ecological Balance and Environmental Protection (1988), the Law of Soil and Water Conservation (1946), the Forest Law (1992), the Agrarian Reform Law (1991), and the Law of Rural Development Districts (1988).

The General Law of Ecological Balance and Environmental Protection, managed by the Ministry of Urban Development and the Environment, seeks to control environmental damage by requiring that proposed deforestation and other major changes in land use be assessed for their environmental impact. Once the required mitigation procedures are approved, the ministry grants permission for changes in land use. The law was designed, in part, to stop the indiscriminate deforestation that occurred during 1973–76, when the Programa de Desmonte provided credit that allowed ejidos without land to bring into cultivation new lands that were forested or unused. Many of these lands were marginal and subject to erosion hazards.

This law generally has precedence over other laws affecting environmental issues in agriculture. The Law of Soil and Water Conservation has no promulgated regulations and is inactive. SARH administers the Forest Law that governs environmental and conservation activities in designated forest areas. The Law of Rural Development Districts confers certain powers on rural development districts, including the power to undertake soil conservation activities in collaboration with producers' groups.

The National Plan for Agricultural Modernization defines agricultural strategies from 1990 to 1994. The program seeks to increase the production of major food and animal products by improving productivity and using natural resources more efficiently, giving priority to the appropriate use of water and soil. As part of that plan, the government's soil conservation policy in the 1980s viewed soil conservation extension and works as part of an effort to extend profitable and sustainable agricultural practices. There were several steps in this change.

- DGCSA was downgraded to a subdirectorate in 1984 and later eliminated.
- In the remaining years, responsibility for soil conservation was decentralized to individual states, which did not receive specialized budgets or programs. Most soil conservation programs ceased, except where local interest was strong and political backing was present.
- The responsibility for water conservation passed to the Comisión Nacional de Agua.
- In 1991 the government re-formed the SDCSA

Table 11-14. Public Investment in Soil Conservation in Mexico, 1950–82

Year	Cumulative number of hectares (millions)	Total cost (millions of 1982 U.S. dollars)	Share of agricultural gross domestic product (percent)
1950–54	1.18	19.85	0.006
1955–59	1.49	32.08	0.009
1960–64	2.35	32.70	0.002
1965–69	3.27	30.41	0.003
1970–74	5.12	116.60	0.024
1975–79	8.40	45.89	0.048
1980–82	9.09	38.10	0.033

within SARH, giving it responsibility for soil and water conservation but only four professional staff. The SDCSA's initial approach has been to try to arrest erosion on croplands and pasturelands before addressing communal and forestry lands.

Involvement of the World Bank

The World Bank has had limited involvement in soil conservation throughout Latin America. In Mexico, Bank support has taken the form of credit, support to extension, limited help for agricultural research, and financing of erosion control practices through projects such as PLANAT, PIDER III, and PRODERITH I and II. Although limited, information about the lessons to be learned from that experience indicates that adequate research and extension, including a body of existing profitable techniques, are necessary for a project's success.

The World Bank's principal erosion control activity in Mexico is the PRODERITH II Project, which provides technical assistance to the project's executing agency, training to staff and producers, and assistance with soil conservation activities on about 50,000 hectares. A recent interim review of PRODERITH II determined that this activity was successful, albeit on a very small scale, and worthy of continued support. The project emphasized relatively simple works with cropping practices, not physical structures, and involved groups of producers in designing and executing them.

Another approach is the Agricultural Technology Project, which supports soil conservation research, stressing the generation of innovative practices, economic analysis of those practices, and use of cropping practices, not field structures. It tests a pilot extension component in four districts that have severe soil erosion and will expand that component if the initial experience is successful.

Notes

1. Results of a 1962 survey are not presented separately because not all states were surveyed again in 1982.
2. A billion is 1,000 million.
3. The year subscript is not shown unless otherwise noted.
4. The net present value of benefits is sometimes higher at the lower target erosion rate because the incremental costs of some minimum tillage techniques are negative (that is, they save costs).
5. Excluding benefits derived from the off-farm effects of reduced erosion.

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Part Two: Institutional, Social, and Cultural Dimensions

12. Technoeconomic, Organizational, and Ideational Factors as Determinants of Soil Conservation in the Dominican Republic

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The concept of culture is occasionally introduced into discussions of economic development as a catchall residual construct to explain behaviors and attitudes difficult to explain using straightforward economic cost-benefit analysis. With respect to soil conservation, different societies (or different communities within the same society) may differ in their inclination to innovate, in their willingness to adopt externally introduced innovations, in the type of innovation that emerges as the preferred form of land use, and in the speed with which change spreads locally. Some groups may simply reject all proposed innovations. When the differences in preferences among groups are not easily attributable to an identifiable environmental, technical, or economic factor, the inclination is to hypothesize that some cultural factor is operating.

To the degree that the term culture is invoked simply to label the noneconomic, the aesthetic, the cryptic, or the unpredictable dimensions of human behavior, it is functioning not as a genuine explanatory construct but rather as a substitute for explanation. This chapter argues that the concept of culture can be effectively operationalized for use by persons concerned with economic development. For soil conservation, a well-defined model of culture can permit the identification, description, and analysis of causal factors that would escape scrutiny or fall through the cracks of standard cost-benefit analysis. The information gathered on two projects in the Dominican Republic constitutes the raw material for this attempt to take an operationalized approach to culture.

This chapter concludes that although expectations of increased economic payoffs were the force driving the farmers' willingness to engage in soil conservation, this drive was not worked out through a straightforward "homo economicus" calculation in which individual farmers anticipated increases in crop productivity. Soil conservation decisions, rather, were mediated by additional social and ideational factors that filtered each farmer's perceptions of potential payoffs. Although they are not particularly mysterious in themselves, nor do they nullify the operation of more straightforward economic considerations, these filtering variables are difficult to incorporate into straightforward economic analysis.

The fieldwork underlying this report was conceived as an anthropological supplement to an economic analysis of soil conservation practices carried out by the World Bank in the Dominican Republic. The selection of the general research question was made by Ernst Lutz of the World Bank's Environmental Policy and Research Division, who posited that, although many factors enter into land use decisions, an acceptable cost-benefit ratio may be the prime determinant of a farmer's decision to adopt (or not to adopt) a soil conservation practice. Other factors were recognized as well. Although the major thrust of the World Bank's research was a technical analysis of economic costs and benefits, a brief anthropological supplement was contracted to explore these other factors.[2] The guiding hypothesis of that supplement was that perceived economic returns to soil conservation are the prime determinant of whether Dominican farmers adopt soil conservation practices, but that other factors operate as filters influencing either the perception itself or the threshold above which the perception is converted into action.[3]

This component of the research adopted a simple case-study approach that compared and contrasted two program strategies for promoting soil conservation among Dominican farmers. It was felt that a comparative glimpse of two approaches would yield more insights into the possible determinants of adoption than a single case study would.[4]

The region chosen was the municipality of San José de Ocoa. First, the documentation on the projects of that region was reviewed, and then two data-gathering trips were made to the research region, one a week-long trip and the other a two-day follow-up trip. A major goal was to visit as many sites as possible from each of the two projects and to converse with project personnel and participating farmers. The principal guide and contact person for this trip was Ing. Carlos Bonilla, former regional coordinator of the MARENA project and current field director of the FIRENA project. Of even greater importance were the contacts made with farmers. The longer trip consisted of visits to villages, interviews with men and women, hikes through protected and unprotected upland fields in the company of farmers, a day-long meeting at which farmers discussed the pros and cons of agreeing to new land use behaviors, and an overnight stay in the house of one farmer. In one-on-one and small group interviews, the farmers' perceptions were elicited of the cost-benefit ratios of both the traditional farming practices and the soil-conserving land use practices that had been promoted by development projects and adopted by many local farmers. This chapter analyzes the findings pertaining to the utility of the concept of culture.

Conceptual framework and guiding assumptions

Anthropologists use the concept of culture in two distinct senses. In its more generic sense, culture refers to a generalized human capacity to invent, diffuse, adapt, and transmit from one generation to the next new behaviors. Used in this sense, it is analogous in some ways to the concept of intelligence as used by psychologists. When used with an article, however, "a culture" refers to a specific cluster of behaviors, objects, beliefs, and rules that a particular human group has produced (or adopted).[5] Used in its more restricted second sense, the concept of "a culture" distinguishes the behaviors, objects, beliefs, and rules of one human group from those of another.

This second understanding of culture is more germane to the purposes of development agencies. Discussions of the impact of cultural variables on soil conservation imply a difference among human groups, and cultural variables are often understood to be distinct from economic variables. That is, whereas some cultures may predispose their members to be receptive to the invention or adoption of new technologies, researchers often ask whether other cultures may be less open to such innovations for cultural reasons, independent, at least in part, of the objective technical, ecological, or economic advantages of the proposed innovation. Stated a bit differently, if this notion of culture as an independent variable is on target, two farming communities with identical economic activities but different cultural orientations might respond differently to one and the same proposed soil conservation innovation. Some such implicit hypothesis appears to underlie discussions of culture that occur among development specialists.

The contention that noneconomic factors determine the timing or shape of land use innovations borders on the obvious. The problem is to incorporate these factors into one's description and analysis of real-life systems. The proposed model construes a culture as a system containing three universal components. The guiding assumption of this approach is that any human culture can be disaggregated and at least partially operationalized into three autonomous but interlinked subsystems: (1) an underlying technoeconomic component,[6] (2) an organizational component, and (3) an ideational component. Cultures differ in the content of these components, but every human culture must make provision for all three.

This discussion of soil conservation is organized around the concept of a cultural system containing these three components. Such a tripartite evolutionary framework has been used by anthropologists to analyze entire social systems. The guiding assumption is that these three components are universal subsystems found in every society, that these subsystems are functionally linked, and that they therefore evolve together. Within this framework, every cultural system has evolving technoeconomic, organizational, and ideational subsystems.[7]

This tripartite analytic scheme is generally applied to the analysis of entire social systems as units. This chapter modifies and adapts the model, however, to make it useful for analyzing targeted subdomains of behavior rather than entire social systems. The targeted domain is soil conservation.

If soil conservation is viewed as a limited form of cultural system, the technoeconomic component of a soil conservation system consists of material interventions applied by humans to protect or restore individual plots of ground, the tools used to apply those interventions, and the mechanical and vegetative structures that result from their application. This material component of a soil conservation system is, so to speak, the vertically oriented cluster of downward inputs used by farmers to protect or restore their soil.

In contrast, the second component of a soil conservation system—the organizational component—consists of all the horizontal person-to-person, group-to-group, or institution-to-institution linkages activated to carry out the technical and material interventions. The organizational component of soil conservation includes the following elements:

- Local land tenure and land access rules, insofar as these rules affect the long-term profitability of investment in improved land use practices
- Labor recruitment strategies that a farmer or other interested party (such as a project organizer) uses to apply soil conservation technologies (family labor, wage labor, and intracommunity exchange labor are the major varieties found across cultures)
- Farmer organizations created to mediate the flow of outside resources and information
- The chain of linkages between outside institutions (including international funding agencies and urban governmental institutions in the host country) and local groups, insofar as these linkages exert an impact on the land use decisions of farmers.

The third cluster of variables to be analyzed as a discrete subsystem within any system of human behavior is the ideational component. The ideational component of soil conservation includes the following elements:

- Underlying value orientations within the local population concerning land (for example, custodial versus extractive attitudes, focus on short-term versus long-term horizons, and so forth)
- Local perceptions and popular beliefs concerning the determinants of soil fertility and the negative impacts of erosion
- The local store of knowledge concerning various soil-protecting or soil-restoring alternatives and beliefs concerning the potential payoffs from using these alternatives.

In principle, this tripartite model can be applied to traditional systems of soil conservation that emerge spontaneously. In view of the rarity of such "uncontaminated" traditional processes in the modern developing world, however, this chapter focuses on soil conservation systems explicitly designed by trained technicians to be adopted (and, of course, fine-tuned and modified locally) by traditional farmers.[8]

Conservation as a system: hypothetical evolutionary scenario

Understood narrowly, soil conservation refers to the specific vegetative or mechanical measures that a landowner may apply to a given plot. Understood more broadly, however, the evolution of a successful soil conservation system entails three types of adjustments in land use.

First, a "zonification" of production occurs, which means a new functional differentiation between plots allocated to annual crops and plots allocated to perennials and other less intensive productive uses. In settings (such as the Dominican Republic) where a single holding may be split into plots in different ecological zones, this functional specialization can occur (and has begun to occur) within one and the same holding. Farmers who formerly cropped even steep hillside plots in annuals begin to distinguish between intensively cropped annual plots and extensively managed perennial stands.

Second, on intensively cropped annual plots farmers apply protective and restorative interventions. That is, "conservation" of steeper plots takes the form of a shift to perennials or other less intensive uses of land. Soil conservation techniques as conventionally defined—terraces, ridges, gully plugs, contour canals, vegetative barriers, and the like—focus on the plots set aside for intensive cultivation.

Third, if the process is successful, at a more advanced stage farmers also begin protecting plots over which they have no proprietary or usufruct control if the degradation of those plots might have a negative impact on their own land. For example, communities mobilize themselves to act directly, or to get authorities to act directly, against upland squatters who are endangering the downstream ecosystem by destroying the forest or undertaking similar activities. If this third facet of evolving conservation behavior occurs, then local communities themselves begin taking on vigilance functions conventionally assigned to public authorities.

This is clearly an idealized scenario. Nonetheless, all three of these processes have begun occurring in the region selected for examination within the Dominican Republic. Although the successful scenario is unfolding in the context of one program approach, it has not occurred in the other.

Two approaches to soil conservation

The deforested hillside landscape of San José de Ocoa is similar in many ways to that of other municipalities on the southern flanks of the Cordillera Central. The topography is hilly, and more fertile and more manageable stretches of flat bottomland tend to be located in larger holdings near the town.

Although more than half of the population of the Dominican Republic now lives in cities or towns, over 80 percent of the Ocoa municipality is rural. The vast majority of the rural population are descendants of migrants who settled the mountains less than three generations ago. They came from the lowlands, pushed by overcrowding and a scarcity of land. The result has been the deforestation of most of the region.

Today, the rural population lives principally by cropping annuals on small holdings. The specific crops grown differ from community to community, primarily because rainfall and temperature regimes vary from one micro watershed to another. In the northern sector of the municipality, higher villages with adequate rainfall grow coffee and beans. Communities at lower altitudes with flatter bottomland and decent road connections enter into agroindustrial relations with peanut-processing factories and grow peanuts as the major cash crop. Before the advent of gravity-fed irrigation systems, communities in the southern sector, which has lower annual rainfall, relied principally on drought-resistant chick-peas as their major cash crop. The communities studied most intensively for this research—newly irrigated hillside communities that have incorporated soil conservation into their hillside repertoire—are cropping (in order of importance) carrots, potatoes, beets, onions, radishes, cucumbers, and other vegetables for Santo Domingo markets. (Farmers cropping unirrigated plots at lower levels in the same communities still rely most heavily on chick-peas.)

Whatever the particular crop configuration, all of the communities in the region share six features in common.

(a) *Small average holding size.* Survey data that the residents of one village (Los Ranchos) themselves collected from about sixty farms in the community show an average farm size of about 25 tareas (about 1.5 hectares) cropped per household a year. Even if one doubles the average to take into account pastureland, fallow land, and other land not incorporated by villagers into their survey responses, the holdings are still small. The findings for this particular community are consistent with estimates given by members of other communities.

(b) *Strong community-internal differentials.* In Los Ranchos, the largest holding is 100 tareas, the smallest is 4 tareas. The standard deviation of such a distribution is of a magnitude to render questionable not only the concept of "homogeneous peasant community," but even the relevance of using a mathematical average to discuss landholdings. This skewed land distribution creates problems not only from an equity perspective but also from the point of view of the technology of soil conservation itself. Such distributional issues are often viewed as being hopelessly outside the realm of problems with which a funding agency or project can deal. Steps taken voluntarily by the community in question suggest, however, that such distributional issues may be more amenable to pragmatic policy intervention than is often believed.

(c) *Strong market orientation.* A recent study by the German government found that communities in the region reserve only about 5 percent of their total agricultural production for home consumption, consigning the rest to the market.

The entire population is heavily involved in cash markets and is dependent on food purchases for much of the year. Most of the crops are slated for sale in the nation's internal markets. Because of their involvement in markets, farmers are open to changes in cropping patterns as long as the short-term profitability of these changes can be made plausible. The same openness applies, other things being equal, to the incorporation of new soil conservation practices.

(d) *Heavy capital needs.* The shortage of land is the principal problem of many farmers, but, for practical purposes, the shortage of productive capital often keeps farmers from engaging in optimal use of their land. The heavy need for capital proved to be the gateway through which one of the soil conservation projects described here entered the region.

(e) *Unusually active farmer organizations.* Ocoa differs from other nearby municipalities because it has a uniquely active and effective local, private organization, the Asociación para el Desarrollo de San José de Ocoa, commonly known as the Junta. Unlike many town-based organizations in Latin America, which focus their developmental planning and fund-raising energies on projects of interest principally to town dwellers, the Junta serves as a major transmitter of developmental resources—and developmental ideas—for economic, health care, and educational projects in the rural areas.[9] Most of the villages in the area send representatives to and participate in the activities of the Junta.

(f) *Ecologically inappropriate agrarian technology.* All communities in the region—a characteristic of particular importance to this report—apparently practice a traditional agrarian technology virtually bereft of soil management techniques appropriate to the cropping of hillside plots. When undertaken by a population with appropriate soil conservation technologies, the agriculturally motivated removal of trees need not result in ecological devastation. But in the case of the Dominican Republic, including the rural areas of Ocoa, the two go hand in hand. The absence of soil conservation technologies presents no great mystery. The migrants to the hills brought with them agrarian technologies poorly adapted to the cropping of ecologically fragile slopes and passed these technologies to their offspring. Although farmers were repeatedly questioned about their knowledge of soil conservation practices before the projects began, they consistently denied earlier knowledge. The traditional agricultural practices learned from their elders, as several farmers insisted independently, were devoid of measures designed to protect the hillside slopes they farmed.[10]

The promotion of appropriate soil conservation techniques among smallholding farmers has been a matter of discussion for decades. The U.S. Agency for International Development (USAID) began financing conservation activities in 1981. As of the summer of 1991, the date of the visits to the area, soil conservation activities had been promoted for exactly one decade.

Two quite different types of projects have been attempted. Although both approaches focused on the same type of technical intervention (vegetative barriers, principally grass strips), they differed from each other along two critical dimensions:

(a) One approach focused principally on soil conservation as a major output of the project, which was undertaken without an additional economic catalyst; that is, soil conservation itself was the major program "offering" to the farmers. The other introduced soil conservation as an adjunct to a genuinely profitable technological shift, the installation of gravity-driven hillside irrigation systems. In this project, the most valued input was irrigation; soil conservation was an auxiliary productive and protective measure, but not the central offering on the project's menu.

(b) The funds of one approach were channeled through and managed by the Ministry of Agriculture in Santo Domingo. The locally active Junta was bypassed during both the planning and the management of the project. In the second approach, the Junta itself, in consultation with its rural clientele, established project goals and (above all) were the direct recipients of project funds. The ministry's financial participation consisted solely of paying the salaries of the state employees who were, in effect, assigned to the new project as managers and technicians.

Although the visit was too short to evaluate the contrasting results of these two approaches systematically and with any quantitative rigor, the two projects appear to differ markedly in their results. Project personnel and participating farmers unanimously agreed on this point. To add to the credibility of the comparison, many of the key personnel in the first project were retained for the second, and most of the communities that participated in the second project had also participated in the first. This situation provided an excellent opportunity to contrast the two approaches.

MARENA: SOIL CONSERVATION AS A MAJOR PROJECT GOAL

USAID approved project MARENA (Manejo de Recursos Naturales) in 1981. This US$11 million project was to pursue two major goals: (1) the "institutional strengthening" of the Secretaría de Estado de Agricultura (SEA), and particularly the Subsecretariado de Recursos Naturales (SURENA); (2) the promotion of soil conservation among hillside farmers in two major watersheds, including the one in which San José de Ocoa is located.

As is often the case in such projects, most of the funds were effectively captured in Santo Domingo by the targeted beneficiaries of the first goal: SEA and SURENA. Although the funds were disbursed, there is doubt as to whether SURENA was successfully strengthened. In interviews, current and former employees of SURENA seemed to agree that the institution is weaker now than it was in 1981.

This discussion focuses, however, on the soil conservation component. The technical focus of MARENA was on the use of *barreras vivas*, live barriers. Grass strips were the measure of preference, and the distance between one barrier and another varied according to the plot's slope.[11] Diversion canals were also constructed along every third or fourth vegetative barrier. The project did not build walls, ridging, or terracing, which had been tried in other projects on the island.

Farmers were understandably skeptical about using space on their small plots for vegetation that would decrease short-term yields. To deal with this dilemma, MARENA offered the incentive of credit. Two lines of credit were opened in the state-run Banco Agrícola: production credit and conservation credit. The credit was intended to serve two purposes: it would encourage farmers to use soil conservation interventions on their land, and it would enable them to practice an intensified form of agriculture that would offset any marginal loss to traditional productivity.

Since local campesinos are blocked as much by a shortage of capital as by a shortage of land, they are very interested in obtaining access to productive credit. Under MARENA, to acquire productive credit, farmers had to construct appropriate soil conservation devices on their land. They even had to borrow to do this. From the project's point of view, the central field-level goal was soil conservation. Productive credit was injected as a supplementary carrot to pursue the ecological goal that was foremost on the project's agenda. But small farmers have their own agendas, and for them, access to productive credit was the primary goal. Many credit-needy farmers viewed the installation of grass strips as a silly project hoop through which they simply had to jump. Farmers did this, somewhat lackadaisically, and generally using their own labor. The "conservation credit" that they ostensibly borrowed to pay for labor was often used for other purposes.

MARENA had problems from the outset. The most frequently cited problem was the large amount of project cash that remained in the capital city of Santo Domingo and, consequently, the small amount of cash that reached the project areas in Ocoa and Padre las Casas. According to the former Ocoa field director of the project, cash flow arrangements within the institution meant that the Santo Domingo–based office captured an inordinately high percentage of the funds. Field-level disbursements from the ministry to MARENA were both meager and delayed. A related problem was that MARENA bypassed the Junta, the dynamic private organization that had been formed by leading Ocoeños and that was already carrying out numerous activities in the rural areas. The Junta participated neither financially nor operationally in MARENA. Further problems were created by a new project director, who alienated members of all participating groups, including USAID project managers.

Because midstream and end-of-project evaluations showed some positive results, and because natural resource agendas were achieving increasing prominence in the Dominican Republic, USAID was reluctant to cease all activities in the project area or in the natural resource domain. Most of MARENA's problems appeared to be attributable to institutional arrangements. USAID decided, therefore, to finance a separate follow-on project channeled through a different institutional route. MARENA's original life span had been slated to run from 1981 through 1986. The ministry had been timely only in its disbursement of funds for internal institutional needs and had delayed the disbursement of funds for field operations. Because substantial sums had not yet been disbursed, an extension of an additional year was granted until the end of 1987.

Nevertheless, at the end of this period nearly US$1.5 million earmarked for field activities still had not been disbursed. USAID decided to reserve this as the start-up money for a follow-on project. This project differed from its predecessor at both the technoeconomic and organizational levels. Many of the personnel of MARENA, including the field director himself, were carried over into the new project. Because of radical shifts in technical emphasis and institutional channeling, the project was, in effect, totally new and was given a different name.

FIRENA: SOIL CONSERVATION EMBEDDED IN AN IRRIGATION CONTEXT

As MARENA began winding to a discouraging close, doubts about the economic value of soil conservation were already being voiced, not only by farmers but also by project personnel themselves. One of the more progressive and highly organized villages (Los Martínez) requested the installation of a gravity-driven sprinkler irrigation system. MARENA personnel agreed, provided several financial and organizational stipulations were met. For the first time in the history of the region, a community of small hillside farmers had access to irrigation. This experiment occurred too late to salvage MARENA and its lackluster attempts to focus on soil conservation. But it provided the guiding stimulus for redesigning the new project, FIRENA (Fondo de Inversión en Recursos Naturales). FIRENA differs from MARENA in two critical ways:

(a) The project focuses on the installation of gravity-driven sprinkler irrigation systems and is undertaken only in communities where such a technical option is available. Soil conservation is an obligatory technical adjunct rather than the main offering of the project.

(b) The project is managed in a mixed public and private implementation that bypasses the central offices of the Ministry of Agriculture in Santo Domingo. The Junta is the legal owner and implementer of the project, and funds no longer pass through the ministry. Technicians from the Ministry of Agriculture are still involved, however, as managers of the project.

These differences between the design of MARENA and FIRENA derive from differences in the actors who wrote the respective proposals. MARENA, brainchild of urban-based technicians, emphasized soil conservation. FIRENA, written with direct input from the Junta and its rural clientele, includes soil conservation but embeds it in the context of a much more important productive input, irrigation. MARENA was captured in its entirety by the Ministry of Agriculture; FIRENA is managed by the Junta.

FIRENA is much more restrictive than MARENA in its selection of project communities. The prime requisite for participation is the availability of sources of groundwater that can be tapped or diverted within a few miles of the community. Because no pumps are used, the water must be above the level of the fields to be irrigated, capable of being gravity-driven to catchment tanks within the community, whence it is channeled via plastic piping to the target plots themselves.

This decision created problems from a simple perspective of equity; many communities that could participate, or actually are participating, in soil conservation activities are excluded from the new project. From the perspective of economic development, however, the decision is more than justified. Investments in soil conservation by itself produce at best mediocre economic payoffs; all communities have equitable access to something of limited short-term productive value. In contrast, project investments in water stand a chance of doubling or trebling the number of crops that can be grown each year, increasing the yield per unit of each plot and substantially increasing the annual income of the participating families. From a simple conservationist perspective, access to water inputs creates local openness to soil conservation in a way not seen in communities where soil conservation is the project's major offering.

The feature that distinguishes FIRENA from other irrigation or soil conservation projects is the obligation imposed on beneficiaries to subdivide their holdings. During the project's design stage, the controversial decision was taken by the Junta to bar from the project any landowner with an irrigable plot who refuses to turn over a substantial portion of his land for rent-free use by community members who have no irrigable land. A landowner who wishes to be included in the irrigation system must turn over a specified percentage of his holding to neighbors.

The rules of the game, however, were structured so that participation is in the economic interest of landowners as well as of *asentados* (community members being "settled" on the plots). In no case have landowners been obliged to turn over more than half of their land to neighbors, and landowners with small amounts of irrigable land are required to turn over a substantially lower percentage. Furthermore, owners do not have to deed over the land to the neighbor. They merely sign a contract guaranteeing that as long as the water continues flowing, the *asentado* can crop the agreed-on plots rent-free.

This rule governing land redistribution is the most striking organizational feature of the new project, but other conditions and rules apply as well.

(a) All recipients of water, whether a landowner (*propietario*) or a settler (*asentado*), agree to cease cropping their upland plots in annuals and to begin planting them in fast-growing wood trees.

(b) They agree to cover all their plots, particularly the irrigated ones, with appropriate, project-approved soil conservation measures at their own expense.

(c) They agree to reimburse the project for the cost of installing the irrigation system, thus permitting project funds to be used again in other communities.

(d) They agree to refrain from bringing in outsiders as partners in the cropping of the land (because FIRENA does not provide production credit, farmers seek out such arrangements because they lack the capital to exploit the irrigated plots fully).

Under the conceptual model discussed in the introduction, all of these rules belong to the "organizational" domain of a soil conservation system. That is, they are conceptually distinct from and independent of the technical interventions applied on the hillsides themselves to prevent soil runoff. Yet without a system enforcing these (or functionally equivalent) organizational rules, most of the decisionmaking economic actors in the region simply would not find it worth their while to apply the technical interventions in the first place.

FIRENA responded to the defective organizational arrangements of the implementing institutions that also plagued MARENA with a creative administrative arrangement that neither fully depends on nor fully bypasses the institutions of the state. Its mode of project organization permits a publicly funded project to be managed by government employees at a level of efficiency more characteristic of privatized administration. Although the director of FIRENA and many of the project technicians are employees of the Ministry of Agriculture, which continues to pay their salaries, the project agreement places their day-to-day operations under the authority of the local Junta. The flow of project resources also bypasses the Ministry of Agriculture. The funds ultimately come from USAID's PL480 funds, which are generated by the local sale of surplus food. The money generated by this sale passes to the Controlaría General de la República Dominicana and is under the budgetary authority of the Secretariado Técnico de la Presidencia (Technical Secretariat). The Technical Secretariat authorizes the Controlaría to write checks for the project. Whereas under MARENA the Technical Secretariat would then have disbursed the funds to the Ministry of Agriculture, with the resulting problems already discussed, under FIRENA the funds are channeled directly to the Junta-controlled FIRENA office in San José de Ocoa. No ministerial functionary or office has authority to delay, divert, or otherwise obstruct the flow of cash to the project site. This arrangement constitutes an administratively effective alliance of governmental and nongovernmental strengths. It is a pragmatic, evolutionary compromise between the customary insanity of burying project funds in the maws of extractive ministries, on the one hand, and several more recent attempts to bypass the state completely, on the other.

Major project results

TECHNOECONOMIC COMPONENT

This report proposes an integrated scenario in which the spread of soil conservation has three dimensions: first, an internal "zonification" of production; second, the application of appropriate soil conservation methods to intensively cropped plots; and finally, the development of farmers' concern with the ecological condition of upland plots over which they have no control, but whose ecological mistreatment could have negative downstream impacts on their own holdings.

The differentiation between intensively cropped and extensively managed plots could not and did not occur in MARENA. The turn to extensive protective management of some plots presupposes that the farmer has access to both the land and the inputs required for a conversion to intensified production on smaller, more appropriate plots. MARENA had no such offering for the farmers.

In FIRENA, this internal conversion to internally differentiated production within the same holding can occur because the input of water opens up an intensification option not formerly available to the community. However, water is a necessary but not a sufficient condition. Even the technical objectives of the soil conservation component would have been sabotaged if a simultaneous organizational shift had not accompanied the introduction of irrigation. If the project had not dealt structurally with the dilemma of access to land, the ecological payoffs from the introduction of irrigation and soil conservation would have been at least partially neutralized.

Even in this community, a serious, unresolved dilemma must be recognized. The technoeconomic goal is to allocate all the land of a region to an appropriate use (including total nonuse in the case of some zones). The intensification of production has been achieved on some plots, but extensively managed production of the remainder of the community's land has not yet been achieved.

Some farmers have begun experimenting with planting fast-growing wood trees on unirrigated land. The current scarcity of wood in the Dominican Republic, and current market prices for wood of all types, whether for fuel or for construction, creates ideal commercial conditions for planting fast-growing wood as an income-generating crop. This option has been viewed as the ideal upland counterpart of the intensification of lower-lying land via irrigation. Several farmers were interviewed on this matter. One of them had pioneered the local planting of fast-growing wood for this purpose. He had consulted with wood merchants and learned that he could expect to receive RD$25 (about US$2.00 per tree at the exchange rate at that time) for the trees he had planted some four years previously. A spacing of 2 meters by 2 meters would yield 2,500 trees to the hectare. This would give a gross income of US$5,000 per hectare through a tree-growing cycle or, assuming a four-year rotation, US$1,250 per hectare a year. A number of factors—the costs of seedlings, labor, tree mortality, and the like—may reduce this, but the final outcome would more likely be higher than the US$5,000. Farmers would be paid US$2 per tree by an intermediary at the farm gate. If they transported the wood themselves to Santo Domingo, they would easily double this monetary yield.

For nearly eight years, this option of planting fast-growing wood as an income-generating crop has been talked about in the region. Numerous farmers are interested, but the current situation is a dismally spectacular illustration of the ability of structural variables to sabotage technoeconomic variables. Current Dominican forestry laws make it a criminal offense to cut any tree, including domesticated trees planted on one's own property, without permission from the army. (The forestry authorities are part of the Dominican military.) Several farmers did, in fact, plant trees for commercial purposes in the early 1980s and even secured prior authorization to harvest them. They even secured another permission before harvesting the wood. Nonetheless, the entire truckload of wood was simply confiscated at one of the army posts on the road to Santo Domingo. This structural condition makes planting wood a risky venture.

An even more macabre illustration of the sabotaging role of this structural impediment is seen on the irrigated plots themselves. Following faulty technical advice, several farmers planted *Eucalyptus camaldulensis* on the border of their irrigated fields, next to the road. The desiccating impact of the maturing eucalyptus caused serious crop losses within several yards of each tree, yet the landowners face fines and possibly even jail if they cut down the trees. The trees remain standing to this day, reducing the yield on intensively cropped irrigated plots.

To sum up, the internal differentiation of cropping between intensively and extensively cropped plots has begun to occur under FIRENA, but the process is still being impeded by the existence and enforcement of perverse government policies.

The second systemic facet of soil conservation is most commonly associated with the term in common parlance: the application of protective measures to plots cropped in annuals. In the technology of soil conservation itself, there was no fundamental break between the measures used by MARENA and those used by FIRENA. The principal soil conservation device is the planting of grass strips, with interspersed diversion canals.

All farmers participating in both projects had to plant such barriers as a precondition to obtain access to project resources (credit in one case, water in the other). The technical quality of the barriers, and the farmers' willingness to maintain them, seems to be much higher under FIRENA than under MARENA. Now that MARENA has ceased, farmers can let the grass strips wither with impunity. Although no formal survey was conducted, most of the MARENA plots seem to have reverted to their original condition. Although project personnel note with satisfaction that many farmers maintain their grass strips even though the project has ended, the vestigial remnants of barriers left to decay are a striking sight.

In contrast, the soil conservation activities in FIRENA communities appear to go beyond what is strictly mandated by project policy. In some irrigated fields, farmers have physically removed rocks from the center of plots to clear more land for irrigated farming and have placed them at the sides to create barriers. The grass strips are planted densely and carefully in straight lines. In the community of Los Martínez, the post-rainfall buildup of soil behind the barriers has resulted in configurations that strongly resemble bench terraces. To reach the irrigated valley, it is necessary to traverse several kilometers of dry, eroded, treeless landscape. On rounding a bend and entering Los Martínez, one sees aesthetically planted grass strips and quasi–bench terraces and has the impression of being suddenly catapulted out of the Caribbean and into Southeast Asia, Madagascar, or some other setting where soil conservation has a long tradition.

This vista of carefully protected irrigated hillsides gives wind to the sails of explanatory models that place heavy emphasis on the material underpinnings of social change. Although the soil conservation technology used and the messages promoted by FIRENA are similar to those of MARENA, the technical result has been quite different. The improved cost-benefit dynamics created by irrigation have given great impetus to soil conservation. Nothing analogous can be seen in the lackluster results in MARENA communities.

The third facet of an advanced soil conservation system involves the emergence of an awareness on the part of a "downstream" population that upstream behaviors have a negative impact on their own livelihoods and the emergence of mechanisms translating this awareness into action. This has begun to occur in the Ocoa area, but only in the FIRENA project.

The rules of the land reallocation system specify that if, for whatever reason, the irrigation project ceases, all plots will revert to their original owners. The major threat to the irrigation system is that the streams feeding the system will dry up. Farmers are aware that such a catastrophe could come in the wake of upland deforestation of the hills surrounding the streams. FIRENA communities, therefore, have organized vigilance committees to patrol, at their own expense, the public park areas above their communities. During the field visit, one of these committees reported the presence of illegal slash and burn agriculture above their community. The report was not filed solely to comply with project norms; the community affected held a meeting about the matter and contacted the forestry department. Two forest rangers came up, met with the community, and promised to take action.

Although one may not be optimistic about any follow-up on the part of the forestry department, one can nonetheless be impressed with the evolution among farmers of a concern for environmental matters even outside their immediate community. Not surprisingly, this concern is motivated not by the generic concerns that motivate environmental constituencies in the industrial world, but by immediate, pragmatic concerns with ensuring their flow of water. In the presence of such a bona fide material concern, no promotional campaigns are necessary to spur the farmers to take action against upland slashers and burners.

Organizational component

The land redistribution mechanism is by far the most important structural "invention" that has emerged in this project. Although inventions are conventionally associated with the domain of technology, the land reallocation mechanism, it can be argued, is an invention every bit as critical to soil conservation as technical interventions are. At first glance, this organizational decision to reallocate access to land appears to be an equity-driven humanitarian measure with little direct relevance to the technology of soil conservation. Such, however, is not the case. It is important to distinguish between external equity and internal equity. External equity between communities has had to be temporarily sacrificed under the FIRENA model because some communities benefit from water, while others do not. Internal equity considerations, however, threaten to sabotage even the technical objectives of the project.

The problem is as follows: even within communities fortunate to be within striking distance of upland water sources, the accidents of local topography and of local land tenure mean that only a small number of lucky landowners benefit from the newly installed system. This is not only problematic from a social, humanitarian perspective but also defeats the technical goal of promoting soil conservation itself. Farmers with land only on steep hills are forced to continue in their traditional ways, planting inappropriate annuals on land that should be covered with tree canopy and having little economic motivation to apply conservation measures since these new measures only generate meager increases in production. MARENA tried to reach such farmers, but with mediocre effects.

This is a pragmatic illustration of a theoretical point made earlier: the impact of a breakthrough at the technoeconomic level can be either facilitated or thwarted by organizational variables. For the introduction of irrigation to trigger more ecologically appropriate uses of community land, access to local land had to be reorganized. Some mechanism had to be instituted to permit poorer farmers who were restricted to land on higher slopes to shift their cropping to the irrigated plots. The solution adopted was the requirement that landowning beneficiaries of irrigation cede a given proportion of their holdings. This type of organizational invention, or some functional equivalent, is every bit as critical to the emergence of a soil conservation system as the technological measures applied.

A second major organizational "invention" made in FIRENA has already been discussed: the combination of public and private management. FIRENA's cash flow arrangements and lines of authority permit state employees to carry out major technical and managerial tasks without permitting capital-based offices to delay or divert the flow of funds to the field operations of the project.

IDEATIONAL COMPONENT

Although no hard data are available, both MARENA and, especially, FIRENA apparently succeeded in changing local beliefs and attitudes toward soil conservation. Farmers indicated that, at the beginning, they engaged in soil conservation in compliance with project norms and in expectation of obtaining project resources. If they could have acquired credit or water without soil conservation, most would have done so. Farmers were engaging in cost-benefit calculations of whether to practice soil conservation or not. The perceived costs were the apparent productivity lost by taking up space with grass barriers of questionable utility. The perceived benefits were the access to project incentives rather than the increased productivity of the protected plots.

In the case of MARENA, the carrot was access to credit. As discussed earlier, however, what was administratively categorized as "conservation credit" was in fact used for other purposes. In the case of FIRENA, the incentive was access to irrigation. All participants, whether landowners or *asentados*, were obliged to protect their plots with project-approved soil conservation interventions. In principle, they were also supposed to protect their upland plots, although the enforcement of this stipulation seemed meager.

At this start-up phase, it is highly doubtful that local farmers would have invested in soil conservation without project incentives. The difference between this domain and irrigation is striking. Farmers were willing to go into heavy debt to gain access to irrigated land; they were willing to commit themselves to substantial regular payments to reimburse the project for the pipes and other material inputs used to construct the irrigation systems watering their fields. The increased production derived from irrigation is so impressive and so secure that farmers leapt to gain access.

In contrast, the productive increments to be expected from soil conservation were viewed (correctly) by the farmers as neither impressive nor secure. Whereas the turn to irrigation was recommended spontaneously by the local population, soil conservation was initiated and promoted by outside agencies for reasons somewhat murky to the farmers. They could be (and were) coaxed to go along only under project-mediated incentives.

At this juncture, numerous farmers made unexpected comments: farmers in both projects who employ soil conservation measures indicated an apparently genuine appreciation of their value. They were asked questions about the value of soil conservation that were purposely phrased to sound skeptical and, possibly, to elicit admissions that farmers continued to practice soil conservation for extraneous motives generated by the project. These attempts were apparently misguided. The appreciation of the value of soil conservation now seems genuine on the part of those farmers who have practiced it for more than one or two cropping cycles.

What surfaced, however, was the widespread (and perhaps predictable) tendency to value soil conservation for its short-term protective, rather than its long-term productive, payoffs. That is, the advantages to soil conservation are generally phrased as the absence of the rilling and gullying that traditionally occurred on their plots. Farmers perceive the advantages of soil conservation more as the absence of damage to fields rather than as increments in production. Whatever the specific perceptions, however, conservation practices are now viewed as highly desirable. Several of the farmers interviewed berated themselves and their parents for not attending in the past to what now seems an obvious matter.

Summary and discussion

Culture as a system

In its traditional vernacular sense (culture as personal refinement, erudition, aesthetic appreciation, and so forth), the concept of culture has little value to analysts of soil conservation. The alternative definition developed here seeks to equip the term with utility for analyzing economic development. Doing so moves away from two other uses of the term common among anthropologists and sociologists: (1) culture as a personal or corporate worldview and (2) culture as the cluster of features that distinguish a particular society from others.

This chapter proposes instead a systemic definition of culture as a system of techniques, implements, behaviors, beliefs, rules, group structures, and other elements. Following the lead of other anthropologists, this kaleidoscopic hodgepodge of elements is organized into three logically coherent clusters: a technical-economic component, an organizational component, and an ideational component. Under this paradigm, a community's technology, its market system, and its profit-maximizing and risk-minimizing strategy are viewed as one component of (rather than separate from) its culture.[12]

Departing somewhat from conventional social science, which uses this paradigm to analyze entire societies, this chapter attempts to examine the specific domain of soil conservation using the paradigm. It might even be useful to analyze individual projects in this light, examining each project's technical and economic offerings, organizational and institutional channels of resource flows, and stated rationales, motivational messages, educational structures, and channels of information flow.

Primacy of technoeconomic variables

Lodging the economy and technology as components in a broader cultural system in no way detracts from their primacy. The use of this paradigm is perfectly compatible with an economic hypothesis of the priority of cost-benefit variables. The culture-system model only demands that the analyst also gather information on organizational and ideational variables and incorporate them into a description and analysis of a system. The three components are not autonomous. To the degree that they are a genuine system, change in one component triggers change in another. In theory, change could be initiated in the realm of ideas and trickle down to new organizational forms and new economic behaviors. In actuality, significant systemic change is more often impelled by changes at the base. Changes in technologies and cost-benefit ratios can trigger organizational and ideational change more often than vice versa.

A compromise proposition that is compatible with the findings of this research and that incorporates all three clusters of variables into a causal model would be the following. The emergence of soil conservation may possibly, but not necessarily, occur in the wake of, and as an adjunct to, some productivity-enhancing technical, economic, or commercial breakthrough—a profitable new crop, a productivity-enhancing technology, a change in market conditions, or the like—that enters a system of land use. In this research, the introduction of water was the catalyzing variable. To state the matter strongly, without some catalyzing technical or economic change that dramatically alters the lethargic cost-benefit regimes of traditional agrarian systems, it is unlikely that new soil conservation will spread, either through spontaneous local development or through project-mediated promotion. A significant decline in productivity can, of course, be one of those catalyzing factors.

Soil conservation: facilitator, not prime mover

In the search for technical or economic engines to drive change, soil conservation should not be assigned this role naively. The results of this brief investigation suggest that soil conservation is best analyzed (and promoted) as an ancillary, auxiliary force rather than as a prime mover in its own right.[13] That is, the short-term, productivity-enhancing capacity of soil conservation measures in isolation—in the absence of simultaneous breakthroughs in other technical or commercial domains—is quite reduced, at least in the cases studied here.

If these case studies can be generalized, innovations in soil conservation should not be expected to function as the catalyzing technical innovation that catapults a dormant agrarian system into forward movement. Rather, soil conservation as a domain is most effectively introduced as an ancillary adjunct to inputs more capable of generating increments in short-term productivity. This limitation of soil conservation is particularly true in the impoverished subsistence systems that have already come under stress in much of the tropical world. In such systems, enthusiasm for soil conservation is high only when the increments in productivity likely to come from new land use practices rise above a certain threshold. Soil conservation by itself rarely creates or sustains such threshold levels of increments. Rather, soil conservation is generally adopted in conjunction with, and in response to, other technological or economic shifts.[14]

Dominican farmers are more open to soil conservation measures when these measures are presented not as the principal element in the project, but rather as secondary, ancillary items in a menu featuring innovations with impressive short-term, income-generating potential. Gravity-driven sprinkler irrigation of hillside plots was the catalyzing input in this study; soil conservation came in its wake. In contrast, an earlier program that focused on soil conservation itself produced mediocre results in the same region. That is, although this research points to the primacy of economic factors in the spread of soil conservation, the perceived advantages of soil conservation itself paradoxically were not the catalyzing factor that spurred Dominican farmers toward the initial adoption of soil conservation. The catalyzing innovation observed here was gravity-driven hillside irrigation; soil conservation was a project-mandated adjunct without which farmers could not gain access to the water. Once irrigation entered the local farming system, however, with its radically altered cost-benefit ratio, farmers maintained soil conservation spontaneously, even when project monitoring became lax.

The role of organizational inputs

Even when soil conservation makes economic sense, the shift may not come spontaneously if essential social or political conditions are not present. Organizational variables—local land tenure arrangements, government policies concerning trees, institutional traditions regarding the use of donor funds, the presence or absence of farmer groups willing to pool labor for soil conservation—interact with cost-benefit variables to affect farmers' interest in soil conservation. Such variables must therefore be factored into descriptions and explanations.

The impact of social and political variables on soil conservation technology goes back in time. In ancient times, organizational prodding took the form of coercive labor levies by which states (the Incan state is a case in point) organized the construction of bench terrace systems. The installation of such systems is rarely if ever the product of decisions that small farmers make without the external influence of the community. Social and political variables intervene to determine whether objective technoeconomic potentials get converted into behavioral facts.

In the Dominican cases observed here, the social and political prodding took the form of a carrot rather than a club. The project made access to water contingent on a farmer's adoption of appropriate hillside soil conservation practices on irrigated plots. One could ask why farmers would not, when faced with irrigation possibilities, spontaneously devise their own soil conservation measures without external prodding. The answer would have to be that human social systems do not function in neatly mechanistic stimulus-response pathways. Evolving technology and cost-benefit regimes merely establish new objective economic potentials, but organizational and ideational factors heavily determine whether these potentials get translated into behavior. The irrigation variable (the technoeconomic input) created the conditions in which soil conservation might make more economic sense in the Dominican communities studied, but social and political engineering were necessary to ensure the conversion of that potential into behavioral reality. It is highly unlikely that soil conservation practices would have been adopted as rapidly, or at all, if the project had not created a strong incentive in that direction.

The role of ideas and messages

Where does the third level of the model, the level of ideas, enter the equation? If change must enter the system "from below," as is being argued here, does any role exist for programming in the realm of information and ideas, for new technical ideas, for the construction of educational messages, and for the promotion of a new overall conservation mystique?

The population among whom this research was conducted was, until a decade ago, unaware of several simple soil conservation measures whose application has since led to visible declines in rilling and gullying. Several farmers said independently that the application of these techniques led to substantial increases in the productive capacity of their land. Educational inputs—which clearly fall into the ideational component of our model—proved to be a key variable.

Just as the shift to conservation would not have occurred without social and political facilitation, the ideas, information, conservation values, and messages that embody these ideas are equally necessary. The project examined here delivered not only plastic pipelines to farmers but also one stream of messages about how to install and use the pipes and another about the why and how of soil conservation. Messages were not limited to factual information; an attempt was made to promote a new mystique of soil conservation as well. Placing emphasis on the determining power of cost-benefit factors does not eliminate the need for ideas and messages.

Observations made in this research suggest, however, two types of caveats concerning project-mediated manipulation of messages. In the first place, messages and exhortations can only act as facilitators and accelerators of change, not as prime movers. The developing world is dotted with poorly conceived soil conservation projects that lavishly fund the production of flip charts, slide shows, and motivational rallies as the prime causal agent in promoting soil conservation. Such a reliance on messages as the prime vehicle of change is flawed both theoretically and practically. In our culture-system paradigm, the message component of a soil conservation project should be conceptualized somewhat as the manual that accompanies a new computer. Excellent technology is not used if the intended users are ignorant of either its purpose or mechanics. Concepts and new information must accompany material inputs; computers must be accompanied by documentation.

But more than one soil conservation project has in effect allocated all of its resources to what would figuratively be the preparation of the manual—educational messages and motivational gimmicks—leaving impoverished farmers to figure out how to acquire the material inputs required to implement the instructions. The FIRENA project, in contrast, began with a bona fide material input—irrigation—to which farmers were given access. (It should be recalled that access was extended through reimbursable credit, not through gifts.) Then and only then were soil conservation techniques and messages built around the core input. In our causal model, information, ideas, exhortations, and other ideational phenomena are necessary systemic adjuncts to technical and economic change. Such messages and educational inputs are usually doomed to failure, however, if they are the project's principal offering.

The second caveat is that the power of demonstrations and messages (at least in the projects observed) increases substantially as a function of the socioeconomic similarity between the sender and receiver of the message. During the observations in the Dominican Republic, a group of farmers from another part of the country strongly reacted to and commented on the protected plots of farmers in a project community; it is doubtful whether an equivalent impact could have been achieved through demonstration plots managed by project technicians. These visitors listened to talks given by two participating farmers from the project community, and these talks appeared to elicit deeper responses than similar talks given by project personnel. A dilemma of this or any project is, of course, that such farmer-managed demonstrations or messages are not available until a project has already been successfully implemented in at least one community; project-managed demonstrations and talks are necessary, but in the long run, the motivational impact of the message depends somewhat on the identity of the message sender. The patterns of impact have yet to be analyzed in detail. On occasions, messages from high-prestige outsiders have greater impact than messages from locals. Observations underlying this research also indicated, however, the special power of messages emanating from peers already implementing the activities proposed.

Errors occur when projects erroneously attribute independent causal power to such messages and squander entire budgets on preparing messages, rather than on lodging these messages in their proper material context. No amount of educational promotion can induce sustained soil conservation practices in the absence of objective economic returns to these new behaviors. Programs placing excessive hope on educating minds as the prime vehicles of change may be founded on flawed premises. Despite these caveats, educational messages do have a role to play in spreading soil conservation. Although our model attributes causal primacy to objective cost-benefit factors, educational and other ideational inputs influence the direction and speed of change.

The question of artificial incentives

Informative and motivational messages, then, remain important. What about the issue of artificial incentives that are used by many projects? Should projects give extraneous rewards to farmers for soil conservation or artificially subsidize its cost? If objective cost-benefit ratios are the major sustainer of soil conservation, why becloud these ratios by introducing artificial benefits to farmers that may motivate compliance for spurious reasons unrelated to the objective benefits of soil conservation?

The matter merits much longer discussion than is possible here. The concrete experiences of the FIRENA project, as well as abstract principles derived from a culture-system model, argue for flexibility rather than dogmatism in this matter. Dominican farmers had no reason to believe in the efficacy of the new soil conservation measures proposed by project technicians; they applied these measures simply out of a desire to gain access to project water. Once installed under such partially artificial incentives, however, the measures impressed farmers as contributing substantially to their economic returns on irrigated plots (and further as adding an unprecedented order and aesthetic beauty to their hillsides). The soil conservation measures will probably be maintained in some fashion even if project policy ceases to make them mandatory. The artificial incentives seem to have functioned positively in this particular case.

In contrast, the earlier MARENA project is a case study in the misuse of artificial incentives. In that project, the major input was soil conservation itself, and the project made credit available to farmers willing to participate. Some of the credit was supposed to pay for the labor and inputs required for soil conservation; the remainder of the credit was for agricultural production. Farmers jumped at the opportunity to obtain credit and compliantly filled their hillsides with the required vegetative barriers (doing the labor themselves and using the credit for extraneous purposes). Because no new dynamic farming system was introduced, the increments in production that were derived from soil conservation were viewed as minimal to null. The farmers complied, but many of the barriers have since been abandoned.

The principle appears to be that if project technicians have solid reasons for believing that the soil conservation measures will be part of a transformed farming system with dramatically increased returns to farmer investments, then a role may exist for incentives that prime the system. Where increases to farmer revenues are tenuous, the use of incentives may be simply a project gimmick to engineer farmer compliance and the illusion of project success.

Analyzing perverse institutional impacts

The model proposed permits—or rather forces—negative institutional variables to be identified in the description and analysis of soil conservation programs. Even brief fieldwork within this framework uncovered two institutional glitches that sabotage projects in the Dominican Republic.

The first concerns early project monopoly of funds by predatory government agencies based in the capital city. The lackluster performance of MARENA occurred largely because the urban bureaucracy captured more than 85 percent of project funds. This capture was, in turn, made possible by the disbursement practices of USAID. The problem was rectified in the follow-on FIRENA project, in which money was channeled directly to a nongovernmental implementer in Ocoa. Government technicians were then assigned to the project. This arrangement is working. Thus the superiority of FIRENA can be attributed only partially to irrigation; if the channels of resource flow had not been readjusted at the outset, even FIRENA would have succumbed to the institutional predation that crippled its predecessor. The point at issue is that institutional variables are as important as technical variables in analyzing the progress of soil conservation.

The second institutional glitch, a matter of perverse policy, continues to paralyze the villages. As indicated earlier, a major goal of FIRENA was to restrict the cultivation of annuals to protected, irrigated plots and to convert steeper slopes to fast-growing, income-generating wood trees destined for sale in local pole and charcoal markets. But the current policy of the Dominican government is to prohibit the cutting of any wood, whether natural forests or trees planted by farmers on their own land. Several farmers allocated part of their holding to wood trees, only to learn that early government guarantees of harvest rights had been rescinded. The prohibition is so draconian that it affects even farmers who, under poor technical advice, had planted a small number of eucalyptus trees on the border of their irrigated plots. The trees are now competing for water and causing serious declines in production on those plots, but the farmers will be fined and incarcerated if they remove the trees.

Far from being tangential to cost-benefit analysis, these institutional variables either impede the flow of benefits by capturing funds for central offices or create serious costs to farmers by making it economically irrational for them to engage in otherwise rational economic behaviors, in this case the planting of trees. In standard economic analyses of soil conservation, these institutional variables would be considered tangential. In the culture-system paradigm proposed here, they are incorporated into the analysis.

CAN NONECONOMIC FACTORS BE QUANTIFIED?

Even descriptive data on these factors are useful for theoretically understanding the processes and practical programming of activities. Can they be quantified and, possibly, included in formal cost-benefit analysis? Although not attempted in this paper, it is not, in principle, impossible. The analyst might have to settle for a weaker ordinal level of measurement than the interval or ratio levels used in traditional economic analysis, but some numbers could potentially be assigned.

To illustrate, let us examine two villages, A and B, with similar economies and ecologies. Village A enjoys a well-organized farmer group with a positive track record in mediating farming systems projects. Village B has no such group. If the hypotheses discussed here are correct, even given identical plots and cost-benefit regimes, farmers in village A will respond more quickly to soil conservation than farmers in village B. A standard economic analysis, however, would show identical cost-benefit ratios for both villages.

The higher likelihood that the first village will respond could be captured in numbers by a threshold factor. The perceived profitability of the new interventions would have to be very high in village B to trigger action, but much lower in village A. The presence of a well-organized farmer group could be coded, for example, as a 20 percent threshold-lowering factor. If it would take an anticipated profit increase of RD$1,000 per hectare to spur village B into soil conservation, farmers in village A would be predicted to need only RD$800 more profit per hectare to engage in soil conservation. Positive factors (such as an active farmer group) would lower the required threshold. A negative factor, such as broken promises in earlier projects, would raise the threshold. The precise, appropriate figures are, of course, not known at this point. The actual factors and percentages used would have to be based on empirical data not yet available, and the manner of including them in equations would be explored by the economists responsible for precise numerical analysis. The point is, however, that the organizational and ideational factors discussed in these pages are amenable to some quantification.

Notes

1. In the execution of this work, the author benefited from the assistance of many people. He is grateful to Ernst Lutz of the World Bank for his invitation to carry out

this research and to Dr. José Abel Hernández for documentation on the projects and the regions. In San José de Ocoa, he received much assistance from the staff of FIRENA and from that of La Asociación para el Desarrollo de San José de Ocoa and is particularly grateful to Ing. Carlos Bonilla and P. Luis Quinn. Also, comments by Jan Bojo and Stefano Pagiola are gratefully acknowledged.

2. This was carried out by José Abel Hernández, who also selected the specific region and projects to be examined in the Dominican Republic; see chapter 9 of this volume.
3. In the nonmonetized tribal subsistence economies with which much of traditional anthropology used to concern itself, this hypothesis would have to be qualified. Returns to investment would have to be measured by a variety of nonmonetary payoffs, some of them difficult to measure. Such a qualification is, however, unnecessary in the Dominican Republic, where the rural population is heavily involved in production for local and international markets and where popular concepts of returns to investment are phrased in Dominican pesos. In the region where this research was carried out, the rural areas of San José de Ocoa, recent research financed by the German government has revealed that small farmers reserve less than 5 percent of their agricultural commodities for home consumption. The bulk is consigned to the market. Explicit monetary calculations are therefore central to the cost-benefit considerations governing the behavior of the population to be discussed here, including their decisions to use or not to use new soil conservation practices on their land.
4. The original intent was to study two projects in ecologically and socioeconomically different regions of the country, but this was abandoned in favor of examining two different program approaches to soil conservation implemented in one and the same region.
5. Many anthropologists restrict their definition of culture to the underlying rules and other ideational and attitudinal factors. As we shall see, the approach used here treats the cognitive dimensions of culture as merely one component of many.
6. The term technoeconomic has been coined in anthropology to refer generically to a cluster of underlying ecological, economic, technological, and demographic factors whose evolution triggers simultaneous change in the realms of social organizational and ideational systems. It is a compound term analogous in its morphology (although not in its meaning) to socioeconomic, psychosocial, sociocultural, and other similar labels.
7. This view assumes that the three subsystems generally do not have equally strong mutual causal impacts. At most times and in most cases, the evolution of the underlying technoeconomic subsystem will exert more causal impact on the evolution of the other two subsystems than vice versa. Economists would, on the whole, be sympathetic to this hypothesis of the causal priority of technical, economic, and other material factors. A model such as this performs the additional task of incorporating the "other" factors not as problematic afterthoughts, but as essential components of the overall system.
8. The distinction between these two types of systems should not be exaggerated; effective modern systems of soil conservation often draw on preexisting traditional systems. Nonetheless, it must be made clear at the outset that the systems being discussed would probably not have been adopted if external agents had not designed and promoted them.
9. The presence of this unusual organization has many causes, not the least of which is several decades of unusually effective activism on the part of a local priest. The Junta itself, though private, remains nonsectarian.
10. Farmers constructed certain types of small ridges for some of their crops, and these ridges were part of the traditional technology antedating project interventions. When asked about these, farmers replied that the traditional function of those ridges was to maximize water retention. The area is semiarid, and before the arrival of irrigation, farmers could produce only one crop a year. These ridges helped capture and hold the moisture. That is, the traditional ridges were not for soil conservation, but for water retention.

11. A species of vegetation (*limoncillo*) used in the original project was found to be defective; it withered and died after a short time, leaving gaps in the barriers. It was eventually replaced by hardier species.
12. This view of culture admittedly runs counter to the convention of contrasting cultural factors with economic factors; it rather subsumes economic elements as a component of a cultural system. This inclusive model in no way defines economics as a subfield of cultural anthropology. Economists and anthropologists not only have different conceptual tools and methods but also tend to focus their attention on different strata within the pyramid. Economists focus more on the bottom level of the pyramid; anthropologists traditionally allocate more attention to organizational and ideational phenomena. The fragmentation of scientific disciplines should not, however, blur our vision of the unified nature of the real-world systems being studied. A culture-system model attempts to recognize this unity and coherence.
13. This point has also been made by Norman Hudson, Francis Shaxson, Piers Blakie, and others.
14. Here we depart somewhat from traditional anthropological analysis, which has focused on the catalyzing impact of negative shifts. Several classic studies have described situations in which improved land management practices were adopted with a view not to enhancing profits, but simply to sustaining traditional levels of productivity per capita in the face of burgeoning populations or declining soil fertility. Valid as these analyses may be in their respective settings, in modern times such clusters of negative stress factors are losing their ability to trigger innovative land use strategies. The stress-driven innovations discussed in many classic studies occurred in populations with few, if any, nonagrarian alternatives. Communities in those settings, when confronted with declining production and no access to alternative agricultural land, were forced to use more labor-intensive techniques, such as soil conservation, to achieve even marginal increments in production. This is no longer the case in the Dominican Republic, where more than half of the population now lives in towns or cities; nor is it true in many other parts of the contemporary developing world, where farmers under stress are more likely to leave farming. Once a certain rural-urban demographic threshold has been crossed, and abandoning agriculture becomes a viable alternative, agrarian stress factors lose much of their capacity to stimulate widespread adoption of remedial conservation practices. Ecologically and economically stressed farming communities in such settings will be inclined, instead, to seek solutions in nonagrarian sources of income.

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13. Land Titling: Possible Contributions to Farmland Conservation in Central America

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In many developing countries, land rights are unclear, unspecified, or disputed, and legal titles are often missing (Leonard 1987; Southgate 1988). Such missing, attenuated, or insecure property rights are often thought to be an important cause of resource degradation because they reduce incentives to conserve resources. Many have advocated, therefore, the establishment or strengthening of exclusive property rights. Land titling and the provision of legal titles to farmers are thought to play an important part in reducing problems related to insecure tenure and, consequently, in encouraging land conservation (Feder and Feeny 1991; Lemel 1988). This chapter examines the possible contributions and limitations of using land titling as an instrument to increase security of tenure and support land conservation efforts in Central America.

The literature on the links between land tenure and land degradation can be grouped into two broad categories (Eckholm 1979). The first group addresses problems related to unequal landownership or farm size, such as the relationship among cropping systems, environmental degradation, and holding size or the push of poor farmers into marginal, vulnerable areas. The second group addresses problems related to security of tenure, such as the influence of insecure tenure on incentives to use land in a sustainable manner or the willingness to invest in land conservation. Although separating the two issues is sometimes difficult, this chapter focuses primarily on the issue of tenure insecurity.

The rationale of land titling for land conservation

Traditionally, economists have considered investments in conservation to be analogous to investments in enhancing the productivity of land. Investments in conservation might serve to prevent reductions in future income streams (Collins and Headley 1983), to increase future income streams (Feder and others 1988), or to increase the value of land as a capital asset (King and Sinden 1988; Palmquist and Danielson 1989). When property rights are missing or insecure, however, economic agents cannot be sure they will receive the benefits of their efforts and, therefore, have few incentives to invest. To the extent that investment does occur, the planning horizon and duration of investments tend to be short term (Johnson 1972). Exclusive property rights would restore farmers' incentives to invest in their land. For this to occur, it is quite important that property rights include both use and transfer rights as well as rights to obtain income from the asset.

Land titling can be defined either as the act of assigning rights (whether formal or informal) or as the provision of legal recognition to existing rights or interests. Here, the term is confined to the latter sense (Dale and McLaughlin 1988). The rationale for land titling rests on three objectives. First, and probably most fundamental, is the objective of increasing the security of tenure proper. Registered or titled land rights are more secure than unregistered rights because they are guaranteed by the state in case of conflict. Feder and others (1988), for example, explicitly equate secure tenure with legal title. "Security of ownership is defined . . . as the possession of legal rights of ownership, certified by an appropriate state-issued document." Promoters of land titling argue that the link between secure tenure and legal title makes land titles a necessary prerequisite for investments in farm productivity and land conservation.

The second objective of land titling is to increase the demand for and supply of credit. Many investments in farm productivity and land conservation require capital inputs. Lack of clear legal title prevents farmers from using their land as collateral for credit. This is particularly important in the formal credit market, where lenders rarely have personal or detailed information about prospective borrowers. Although titles are typically less significant in the informal credit market, informal credit tends to be much more expensive than formal credit and to be confined to relatively small, short-term loans (Feder and others 1988). To the extent that the incentives for farmers to invest increase, their demand for credit also grows (Roth and Barrows 1988).

The third objective of land titling is to foster land markets. It is widely believed that legal land titles are an essential prerequisite for the working of land markets (Stringer 1989; Feder and Feeny 1991). Legal land titles facilitate land transactions by reducing information costs and uncertainty about land rights. Without legal title, potential buyers of a piece of land cannot be certain that they are buying land from its real owners, or they have to incur high costs in order to get full and unambiguous information. Poorly functioning land markets tend to lower land values, other things being equal, because effective demand is limited. This can affect farm productivity and land conservation in several ways (Johnson 1972). First, incentives for conservation are reduced because owners cannot realize the benefits of investments if they sell the land. Second, low land values reduce the value of land as collateral, since the lender cannot easily sell the land to recover the lost credit. Credit, therefore, tends to be more expensive when land markets function poorly, and investment is reduced.

An influential case study

Proponents of titling often cite the study by Feder and others (1988) on the effects of land titles on investment and farm productivity in Thailand. This study investigates the links between title ownership, on the one hand, and access to credit and land values, on the other. The study considers the effects of title ownership on bunding (in which the field is divided into subplots by raised earth walls, thus improving water control and moisture retention) and the clearance of stumps (which increases the productive surface area). In two of the four provinces investigated, these two types of land improvements were significantly more common on titled than on untitled plots. The pooled data also showed a significant positive correlation between title ownership and land improvements.

The methodology employed by the study examined areas with two groups of farmers with identical attributes except that one group possessed legal title to the land and the other did not. Both groups came from similar sociocultural groups and operated in the same agroclimatic environment. In this way, the study attempted to ensure that any observed difference was due solely to the effect of titling.

The main function of titles in the study area was not to increase security, but to provide access to formal credit, which was readily available. In fact, there was no significant insecurity of tenure, in the narrow sense, even among untitled farmers. As Feder and others (1988, p. 37) point out,

> *when squatters were asked what they perceived as the most important advantage of possessing a secure landownership document . . . the majority stated favorable access to institutional credit . . . Only a few suggested protection from eviction or land disputes as important aspects of legal ownership.*

Since, under the circumstances studied, land titles were the missing link in investments, it is not surprising that the authors found a significant correlation between legal titles and investments in land. It is questionable, however, whether the positive results of the Thailand case study can be repeated in, or are very relevant for, other settings, such as Central America.

Land titling in Central America

If tenure is, in fact, insecure, which was not the case in the Thailand study, the ability and the willingness of governments to issue and enforce legal titles become crucial. For a property rights policy to be effective, fundamental rules governing the exchange of property rights are needed, as is an authority with the power to enforce those rights. Since informal or private enforcement of property rights can be very costly (De Soto 1989), the state has an important role to play in setting and enforcing the rules. Other necessary support services, in particular credit, must also be readily available for titling to have the desired effect. Yet in many developing countries the state is unable to provide this conducive environment due to limited financial and managerial capacities. Moreover, in environments with very inegalitarian agrarian structures, such as exist in Latin America, powerful vested interests often resist efforts to establish the infrastructure necessary for land titling, which they see as strengthening the government's capacity to implement agrarian reform. The World Bank confronted this problem in the northeastern region of Brazil when it tried to support the National Land Administration Program (World Bank 1985).

The institutional environment affects land titling in several ways. If enforcement of property rights is arbitrary or unpredictable, land titles may no longer provide secure tenure nor, therefore, incentives for land conservation. The problem of institutional weakness and instability has received increasing attention in recent years (De Soto 1989; World Commission on Environment and Development 1987). Weak and unstable institutions may actually be no different from a complete absence of legal titles. Moreover, the legal system is often not only erratic but also partial. That is, the state and its legal system often represent the interests of relatively small groups, such as urban elites or large landowners. For property rights to have the desired effect on land conservation policy, an impartial legal system must exist and be able to guarantee the property rights of all landholders, including smallholders and indigenous peoples.

Second, the widespread inability of governments to reduce transaction costs may also prevent the potential benefits of titling from being realized. Land titling will only fulfill its purpose if a land administration exists with both the technical and the human capacity to provide the infrastructure needed to delineate, record, and transfer land rights clearly. From the farmers' perspective, the potential benefits of land titles can be outweighed by the incurred costs. If the costs of land titles and titling activities are high, farmers might be better off making do with informal land rights. Unfortunately, in many cases, farmers must bear high costs to obtain and maintain an officially recognized and registered land title. An inadequate land administration infrastructure and an inefficient bureaucracy can make this process very complex, cumbersome, and expensive in both money and time. In Guatemala, for example, all title transfers and registrations are entered by hand into the General Property Registry, which has only two offices in the entire country (USAID 1987). Furthermore, Registry personnel are paid according to the value of the property processed, which leads to long delays and costs for poor smallholders (Instituto Guatemalteco de Derecho Notarial 1987). As a result, large numbers of small landholders cannot afford or have been unable to have their farms titled in the national land registry, and many informal transactions occur. This situation frequently leads to land disputes. Smallholders involved in such disputes are often forced either to abandon their farms to claimants or to attempt to purchase the land from them, since they cannot afford a court battle over possession (Development Associates 1982).

In a study on land tenure and land titling in Panama, Moquete and others (1986) estimated the costs incurred by farmers to obtain legal land titles, including survey costs, expenses for materials, a number of fees for registration and publication, a tax computed on the value of the land, travel costs to the offices of the Ministry of Agrarian Reform (MIDA), and lost income for the days spent at MIDA. Bribes were not included in the calculations. For farmers owning 10 hectares of land, titling costs amounted to approximately US$330 (US$33 per hectare). For farmers owning 50 hectares, on the other hand, titling costs came to US$1,100 (US$22 per hectare). Smaller farmers, therefore, incurred higher relative costs. Even in absolute terms, in any case, such amounts were far in excess of what smallholders could afford. The result was that only about one-quarter of all farms had legal titles (Moquete and others 1986).

As discussed above, another important role for land titles is to provide access to formal credit markets. However, credit market conditions are often such that many farmers do not, in reality, have access to credit, even if they have formal land titles. Under these conditions, the potential benefits of land titling are unlikely to be realized. In their evaluation of past titling efforts in Panama, for example, Moquete and others (1986) could not find any positive correlation between possession of a legal title and investment, land productivity, or land conservation activities. An important reason for this was that titles did not provide access to credit because banks were unwilling to provide credit to agriculture: they perceived the administrative costs of loans to smallholders to be too high and considered agriculture to be less profitable and riskier than other sectors. Similarly, Fandino, Coles, and Caballero (1986) found that land titles do not necessarily provide access to credit in Honduras.

The results of a brief study carried out in the Santa Barbara region in Honduras show that land titles may not be a necessary prerequisite for land conservation activities and that title ownership may not dramatically improve land use practices (Wachter 1991). Santa Barbara is the site of a USAID land titling project, which has been under way since 1982 and is one of the best-documented land titling projects. A sample of sixty-five farmers was interviewed. Although the relatively imprecise, primarily qualitative information that was collected does not allow sophisticated analyses, titling did not appear to have a significant impact on either rates of degradation or the extent of investments in conservation. For example, two-thirds of the farmers who reported erosion problems had titles, and almost all the farmers who experienced erosion problems used some kind of land conservation measure, whether they had titles or not. Most of the conservation measures observed—on both titled and untitled land—were relatively simple, low-cost measures such as biological barriers and stone walls. Only a few farmers built or maintained terraces, but again this subgroup included both titled and untitled farmers. Rates of use of chemical inputs also seemed not to be affected much by titling status.

In a study of the impact of land titling carried out in the same area of Honduras, Nesman and Seligson (1988, p. iii) conclude that,

> *The findings are that land titles are likely to be necessary but not sufficient . . . Whereas previous studies have suggested that agricultural development programs are constrained by insecurity of tenancy, this study shows that a tenure security program not combined with systematic efforts to deliver key inputs, especially credit . . . has little impact. . . . Previous studies based exclusively on cross-sectional analyses were flawed. Those studies assumed that because titled farmland was more productive than untitled land, granting titles to land that did not have it would result in increased productivity. This study suggests that titled land may well be more productive independent of title status, or that the title is one element in a causal chain of factors that result, over time, in greater productivity.*

Conditions for successful land titling

Unfortunately, the situation in Central America is very different from the almost ideal conditions found by Feder and others (1988) in Thailand. In order for titling to obtain positive results in Central America, numerous improvements are required. The legal system and the land administration need to be strengthened, and an appropriate enabling environment created. This means not only institutional reforms but also a move toward better governance (Landell-Mills and Serageldin 1991). In order to fulfill its functions, land administration must be impartial, efficient, and unbureaucratic (Israel 1987). Land information systems and land administration must be improved both quantitatively and qualitatively (Instituto Guatemalteco de Derecho Notarial 1987; Forsyth 1990) and must, in particular, be made available to farmers in remote areas. Since the extension and, in some cases, establishment of cadastral and other land administration services are often expensive, a good case can be made for more development assistance (Falloux 1989; Dale and McLaughlin 1988; Lawrence 1984; Simpson 1976).

Effective titling alone is insufficient, however. Access to credit for rural smallholders must be improved. Considerable attention must be paid to appropriate delivery mechanisms, since past credit programs have often proven very unsuccessful in reaching their intended recipients (World Bank 1990). For land titling to stimulate investments in conservation, cost-effective, locally applicable technologies must also be made available to the farmers who work the land. Information on erosion and related phenomena should be included in agricultural extension programs and should focus on a menu of ecologically sound and economically viable farm and soil practices (Anderson and Thampapillai 1990).

The extremely inegalitarian structure of landownership in Central America is also likely to hinder efforts to increase conservation. The vast majority of the rural population lives in poverty and operates very small holdings. These farmers lack the resources to buy additional land, even if large landowners are willing to sell it (Bell 1990; Stringer 1989). It has often been hypothesized that poverty causes discount rates to be particularly high in developing countries (Durning 1989; Pezzey 1989). This is very important for land conservation, since conservation measures often incur net costs at the beginning and produce net benefits only after a certain time span. The greater the discount rate is, the less likely are poor farmers to find adopting conservation measures to be profitable, even if they have titles and access to credit. To help alleviate these problems, redistributive land reforms have been demanded in the Latin American context (Todaro 1982; Atkins 1988; Thiesenhusen 1989). Redefining land rights in Central America is an intensely political matter, however, and history shows that any reform of land rights is likely to be very costly. Important land reforms in the twentieth century have occurred under rather special and often catastrophic circumstances, such as social revolutions or wars (Powelson 1988; Bell 1990). Despite the risks, at the end of the twentieth century and under the threat of environmental degradation, land reform should be reconsidered in Central America.

Final remarks

On the basis of property rights economics, land titling might appear to be an easy and promising policy intervention to increase productivity and encourage land conservation. The whole issue of land titling for land conservation is complex, however. The success of land titling depends on many factors, such as institutional development and the creation of an enabling environment. Although the critical factors that will determine the success or failure of land titling in Central America are known, little empirical research has been carried out. We largely grope in the dark when discussing the relative importance of the various factors and their precise relationship to one another. For land titling to be successful, these conditions have to be better understood.

Note

1. This chapter draws on a broader study of land titling and conservation prepared within the Environmental Policy and Research Division of the World Bank (Wachter 1992). The author would like to thank Antonio Brandão, Malcolm Childress, John English, Nancy Forster, Ernst Lutz, Stefano Pagiola, and David Stanfield for their valuable comments and suggestions. The usual disclaimers apply.

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14. Tenure Systems and Resource Conservation in Central America, Mexico, Haiti, and the Dominican Republic

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The use of natural resources depends on the actions of people, whose level of social organization includes individuals in households, community organizations, private firms, and the government. Decisionmaking on resource use is shaped by a variety of incentives, including people's need to survive and accumulate capital. Incentives are conditioned, in turn, by the base of biological resources, market and policy signals, legal structures, and sociocultural context. This paper examines a specific subset of conditioning factors: the influence of tenure regimes on the behavior of resource users.

Tenure regimes are the bundle of formal and customary rules created to govern access to and use of resources. These regimes may either encourage the sustainable use of resources or provide incentives for their depletion. Sustainable use of a given system of production is defined here as use that can be maintained in the face of changing demands over a long time horizon (Hart and Sands 1991). Tenure regimes, therefore, must be able to adapt to changes in population, policy, and market conditions if they are to foster practices that encourage the sustainable use of resources.

Tenure issues in resource management have been the subject of controversy. Recently, analysts have challenged the usefulness of the public/private dichotomy shaping much of that debate, and a growing body of literature indicates that various tenure arrangements can potentially promote sustainable use of resources. Carol Rose (1991) argues that private and public managers often use structurally similar techniques to administer environmental resources. Under any tenure system, effective managers must secure access rights for designated users against outside competitors and set responsibilities that shape resource use practices. Rose emphasizes that sustainability over time depends on the willingness and ability of the managers and users of resources to modify the system in the face of increasing demand for resources, whether due to population growth, market forces, or other factors. When increasing demand results in socially unacceptable levels of resource depletion, managers must tighten access and use regulations and maintain sustainable production even though such measures generally increase costs (Rose 1991). Social choices, therefore, govern how resources are allocated and used, and they determine whether resources are depleted or maintained.

One social option entails using market forces as the primary regulator of resource allocation and use. According to proponents of this view, optimal resource use is enhanced by removing distortions that keep the market from operating freely. The most radical proponents argue that economic self-interest adequately regulates resource use, since owners are conservation-minded so as to assure their own livelihoods. Critics counter, however, that users motivated by market forces alone can overexploit or mine resources for short-term gain or to pay for other investments. Furthermore, they argue that under free market conditions sudden shifts in policy or market signals can rapidly deplete resources and have potentially negative impacts on fragile ecosystems, such as tropical lowland forests, which do not easily regenerate.

A contrasting option entails having the state plan comprehensive resource management to determine appropriate land use. Historically, most Central American and Caribbean governments have engaged in some degree of planning, which has generally been implemented through legislation and regulation. That approach has not, however, promoted sustainable use of resources because enforcement, among other factors, has been poor. Recently, many analysts have advocated strengthening local control over resource use, arguing that improving access, decisionmaking power, and economic benefits for the poor will improve management. Debate persists, however, as to what balance of market forces, local control, and national regulation best promotes sustainable resource management practices.

This chapter examines interactions between tenure regimes and resource use practices in four case studies of forest and watershed management in Central America and the Caribbean. All four involve a history of state regulation that restricts open access to forest resources so as to slow depletion—an objective that generally has not been achieved. Three of the cases also involve recent state action to unfetter market forces, which has had differing impacts under different resource management arrangements.

Community management of natural resources in Mexico and Honduras

Indigenous groups in many parts of the world have traditionally managed common resources by establishing authorized user groups and setting well-defined rules to prevent overuse. However, modernization is making it increasingly difficult for local communities to implement rules independently and to maintain control over collective resources, thus creating a situation that can easily degenerate into open access (Lawry 1989). At the same time, neither direct state management nor privatization has assured the sustainable use of resources, especially under powerful market forces. Lawry suggests that the most effective management arrangements stand on two legs: a supportive state and strong local communities. Governments provide crucial backing for local managers by guaranteeing group rights to a given territory, creating and maintaining a favorable economic climate, and helping enforce rules. Communities, in turn, mobilize local participants, distribute income, and advise the government on effective rules. The case studies from Honduras and Mexico examine natural forest management under community control. The analysis contrasts the ability to survive increased market pressures with the competition for resources that has, in large part, resulted from changes in government policy.

Mexico

Approximately 70 percent of Mexico's 37 million hectares of forestland is under ejidal tenure (whereby the state grants villages rights to use land in their vicinity), communal management (the state grants indigenous communities the right to administer forest and pastureland communally), or both. Ejidos and indigenous communities have had relatively secure access to their traditionally claimed land, but their management power—particularly over forest resources—has been restricted. The state holds ultimate rights to that land as well as to the nation's forests (including those on private land) and exerts its control by mandating cutting permits and management practices.

Beginning in the 1940s, the Mexican government granted private and state logging firms twenty-five-year concessions to exploit national and community forests, an arrangement that gave concessionaires incentives to extract maximum benefits in the shortest amount of time rather than to manage forests as a renewable resource (Vargas 1991). Even more damaging, the system provided local peasants few direct economic benefits from forests, leading them to place a low value on trees and to shift land use toward agriculture and cattle ranching.

At the end of the 1970s, the twenty-five-year concessions granted during the 1940s terminated, and a window of opportunity opened for an alternative management system that would draw local communities into the productive process. During the 1980s, several communities were able to gain greater rights to establish their own systems of sustainable forest management. At least twenty-three community forestry organizations, whose declared goal was to "recuperate effective control of the forests and appropriate the productive process and benefits derived from forest activity," emerged in thirteen states (Vargas 1991). They proposed that state-owned enterprises and government technical services be transferred directly to their organizations.

The experience of Quintana Roo provides an example of community management of forests. Forests in Quintana Roo were being rapidly depleted before they were controlled by local ejidos. Although the area's private timber concessionaire had a sound plan for sustainable forest management, it did not give the rapidly growing population (swelled by government-promoted colonization during the 1960s) a stake in the forest's use and conservation. Approximately half of the 500,000-hectare concession was cleared during the 1960s and 1970s.

In 1984, an experienced technical team helped mobilize the area's ejidos into a community forestry organization, the Plan Piloto Forestal. The organization had political support from key individuals in state government and the national forestry department as well as financial and technical support through the Mexican-German Forestry Agreement, a program financed by the German Agency for Technical Cooperation. The technical team worked for an extended period with the local peasantry to develop a management system, often through trial and error. That collaboration resulted in several technical innovations that have increased jobs and revenues.

By 1989, twenty-five ejidos with approximately 250,000 hectares of forestland (representing about half the area's forestland) had joined the organization. Each ejido manages its own area, which ranges from 3,500 to 25,000 hectares. Profitability varies among ejidos, but all ejidatarios have significantly raised their income through forest management: mahogany harvesting (and sawing, in some cases) and chicle extraction (Snook 1991). Although the ejidos manage tropical dry forests under environmental conditions that favor mahogany regeneration, their current technical management practices may cause depletion over the long run (Snook 1991). The society has made significant progress in improving incomes, building institutions, and investing capital. In 1986/87, the society's gross revenues were US$1.25 million, most of which was reinvested in the enterprise. Recently it has gained access to profitable, "good wood" marketing channels for woods other than mahogany, which may improve technical practices (Snook, personal communication). The organization of Quintana Roo ejidos has incorporated as a business (*sociedad civil*), which has increased its autonomy from the state. Furthermore, under forestry laws passed in the mid-1980s, it employs its own foresters to oversee management.

Since 1988, state support for community forest management has declined and forestry policymaking at the national level has been in disarray. At the same time, the government has attempted to mobilize international capital to modernize forestry (Vargas, personal communication). The World Bank has recently extended a loan for roads, credit, and technical assistance to modernize forestry in the northern sector of the western cordillera, which encompasses lands of indigenous communities—the Tarahumara in Chihuahua and the Tepehuanes in Durango. The Mexican government has, in turn, allocated much of the planning and management to the private sector. As a result, there have been serious difficulties in trying to harmonize economic, ecological, and social priorities of the local indigenous communities, the state, and the private entrepreneurs. The Inter-American Development Bank is considering extending a loan for a similar project in Oaxaca and Guerrero.

It is not clear why the Mexican government is abandoning effective community management models established during the 1980s. The positive experiences in Quintana Roo and Oaxaca demonstrate the feasibility of modernizing forestry and implementing sustainable management under community control. Furthermore, no apparent barriers exist to employing international capital in such ventures. The conflicts in Chihuahua and Durango demonstrate the effect of excluding communities at early stages in the planning process. As communities become more organized and politically independent, it is increasingly difficult for the Mexican government and the private sector to appropriate as large a share of their resources as in the past.

Honduras

For much of its history, Honduras followed a "do nothing" strategy of resource management. In 1974, the government attempted to increase its control by nationalizing all forests, including trees on private lands (owners retained rights to the land), and by installing national and grassroots management entities. The Honduran Forestry Corporation (Corporación Hondureña de Desarrollo Forestal, COHDEFOR) was established to hold and manage forest resources and, apparently more important, to use forest products to generate funds for state programs. From its inception, COHDEFOR focused on production and marketing and exerted little effective management control (Johnston and others 1990). As a result, analysts charge that private timber companies with state-granted concessions have been mining the resources of pine forests (Leonard 1987). Clear-cutting is the primary silvicultural practice (in which all mature trees in a given area are harvested), and inadequate regeneration is a pervasive problem (T. A. White, personal communication). Similarly, COHDEFOR has not been concerned with controlling colonization, which has followed the roads built and clear-cutting undertaken by timber companies. Broadleaf forests (which are disappearing at four times the rate of pine forests) are being lost to the expanding agricultural frontier (Johnston and others 1990).

An estimated 40 percent of Honduras's rural population currently lives in forested areas. Resin tapping provides an important supplemental income for approximately 6,000 of Honduras's poorest and least-educated farmers during the cash-short period in the agricultural cycle. Sap can be extracted from a tree for twenty-five to forty years, providing tappers with a strong incentive to conserve forests. Resin tapping is, however, an unstable source of income and subject to dramatic international fluctuations in price.

Over half of the country's farmer–resin tappers are organized into forty-six cooperatives that fuse individual and communal interests around forest management. Members tap resin individually, while their local cooperatives provide group services, such as fire protection, collection points for marketing, and record-keeping. Although the national organization increased its effectiveness during the late 1980s, when it gained representation on COHDEFOR's board of directors and attempted to diversify resin markets by negotiating directly with U.S. and European companies, it has had only limited success in increasing profitability. Furthermore, it has not increased the security of the resin tappers' tenure. The state retains control over trees, while the land generally belongs to the state, municipalities, or private individuals. Cooperatives must renew their usufruct contracts with COHDEFOR annually.

The cooperatives have established a mixed record in sustainable forest management. One cooperative, formed during a community strike to block harvesting by a timber company, subsequently stopped logging on at least two other occasions. Many members have fenced in their extraction areas. In contrast, a relatively weak cooperative, struggling with leadership problems and a relatively unproductive pine forest, has been unable to deter logging on its own (Stanley 1991).

Effective cooperatives have been able to enforce rules for forest access and use and to replace the state as the primary institution preventing open access. Nonetheless, both the successful and unsuccessful resin cooperatives have been undermined by a number of factors, including insecure tenure. In the mid-1980s, COHDEFOR reduced support for the resin tappers' mixed (private, community, and state) tenure system and promoted instead state-local management schemes for large forest tracts. Under these Areas of Integrated Management, local communities contribute labor inputs and COHDEFOR provides technical advice, inputs, and marketing channels. Recent government efforts to privatize portions of the nation's forests and expand private lumbering have undermined both the Areas of Integrated Management and the cooperatives. Resin tappers' collective management areas frequently overlap Tributary Areas, where private timber companies have been granted exclusive rights. Viable extractive forest stands may soon be lost to private sawmills (Stanley 1991). If the state does not provide consistent, secure tenure, community-based resource management is difficult to sustain.

The macroeconomic and policy climate has also been unfavorable. Liberalization policies have caused the resin tappers' terms of trade to decline by increasing import prices and have eliminated their exoneration from import duties and sales tax. Although a devaluation of the lempira in March 1990 raised lempira earnings from resin exports, the creation of the oligopsonistic Resin Fund in 1988 meant that only minimal increases have been passed on to producers (Rodríguez 1991). Resin tappers have, therefore, been forced to reassess the profitability of resin extraction compared with that of timber cutting and alternative sources of income. In 1989, before the 1990 currency devaluation, resin and cone extraction showed a capitalized economic value of US$19.50 per tree. At that time, harvesting, with a discounted residual return of US$9.70 per tree, appeared less profitable than resin extraction. The relationship shifted after the devaluation, however. At 1991 prices, the net present value of US$6.60 per harvested pine tree exceeded the capitalized returns to resin and cone extraction, which dropped to US$3.80 (Stanley 1991). As a result, extractive pine stands may be logged and not regenerated.

Resin tappers' immediate responses to those economic signals have varied. The cooperatives struck for higher prices in 1990 but won only modest gains. At the same time, half of the individuals in one resin cooperative dropped out to join a corn production program sponsored by a private development agency. Others opted for migration and off-farm work. Clearly, resin tapping must remain profitable to sustain farmers' participation in forest management programs. The state, through its activity or inactivity, has played a major role in shaping profitability, in this case by creating an unfavorable macroeconomic climate and tolerating an oligopsonistic structure for marketing resin.

Summary

The Honduran and Mexican cases illustrate some of the factors that support or undermine sustainable resource management by community groups. In both cases, community organizations were generally able to hold their members to a forest management plan and give them an economic stake through jobs and, in the Mexican case, investment in health and education. Community management in both cases depended on meshing the interests of the national government and the communities around a common goal. The Honduran and Mexican governments each had statutory rights to trees and set rules for their use, which undermined the security of local communities' tenure and their ability to earn livelihoods from the forest. Prior to gaining community control, the Mexican ejidatarios either cleared forestland for agricultural use or migrated in search of employment.

The Mexican ejidos and indigenous communities enjoy more secure tenure than the Honduran resin cooperatives, since the state recognizes their traditional rights to a given territory. The policy opening in Mexico during the 1980s allowed some communities to gain greater control over managing forests, including the right to hire their own foresters to replace government employees. The community forestry movement is working to win greater autonomy from the state but depends on government acquiescence to get it. As supportive government factions have been weakened or eclipsed, communities have had greater difficulty gaining management rights. The Ejido Reform Law of 1992, which permits the privatization and sale of ejido property, unless it is forested, may further jeopardize community forestry. While appearing to make the tenure of individual ejidatarios more secure, the reform also provides an incentive for deforestation (Snook 1991).

Honduran resin tappers endure relatively insecure tenure because they have to renew extractive contracts annually. Yet, even with only moderate government support through COHDEFOR, some cooperatives have been able to delimit their extractive areas by fencing them to keep out competitors. With the decline in government support, however, Stanley (1991) foresees difficulties for the cooperatives. The change in policy created an unfavorable macroeconomic climate for the cooperatives, and the government has been granting sawmills and resin tappers rights to the same resource areas. The positive factors in the Honduran case (a biologically viable production plan that enjoyed widespread support and provided good income distribution) were not sufficient to outweigh factors that undermined success (unsupportive state policies, insecure tenure, inability to defend the management area against outside competitors, and a sudden drop in profits).

Resource management in the context of private tenure: the Dominican Republic and Haiti

Evidence suggests that resources can be overused and degraded in almost any tenure regime. No specific system of property rights can guarantee conservation. In both individual and community tenure regimes, resource use is conditioned by numerous variables, including market forces, policy signals, population density, legal structures, local custom, and structural factors, such as inequitable land distribution. It is difficult, therefore, to maintain sustainable resource use practices under either tenure regime. If sustainability is a desired goal, governments can impose rules to promote it, although monitoring and enforcement are costly. The case studies from the Dominican Republic and Haiti examine the sustainability of agricultural, livestock, and forestry land use in a context of private individual tenure, with varying levels of involvement by the state and nongovernmental organizations.

Dominican Republic

Plan Sierra, a development project founded in 1979, was designed to link poverty alleviation with environmental conservation (Thiesenhusen and others 1991). The project is located in the country's northwest quadrant in a frontier area settled over the past seventy years. Land is generally held under private individual tenure and has been used for shifting cultivation, cattle ranching, and forestry. The region is the source of major rivers with considerable potential for generating hydroelectric power. It is one of the country's poorest areas (43 percent of the population subsists below the poverty line), and land distribution is highly unequal.

Over the past seventy years, approximately 80 percent of the region's indigenous forests have been cut. Deforestation occurred rapidly during the dictatorship of Rafael Trujillo (1930–61), when sawmill concessions were granted with minimal oversight (de Janvry and Hecht 1984). The lumber industry, in turn, attracted a substantial labor force, some of whom remained in the area as shifting cultivators, clearing more forestland after the sawmills moved on. They were followed by cattle ranchers who fenced and privatized land. In 1967, the state attempted to break the cycle of resource degradation by nationalizing trees and prohibiting further cutting. Nonetheless, at that time its policing powers were ineffective, and contraband logging became widespread.

The first major effort of Plan Sierra was the Celestina forestry project, formed when the state, under power of eminent domain, transferred to Plan Sierra over 38,070 hectares of pine forest owned by a single family. Plan Sierra retained landownership and provided wages for approximately 100 poor families to harvest and replant trees and operate a sawmill. The project also sold them lumber (at subsidized prices to discourage contraband) for manufacturing furniture in small workshops. Although the Celestina model is widely regarded as successful, an evaluation team found that it was highly subsidized and its profitability overestimated (Thiesenhusen and others 1991).

Plan Sierra's second effort directed at poor smallholders was an outreach program designed to use low-opportunity-cost family labor to establish sustainable farm plots (*conucos*) using cultural practices such as composting, mulching with legumes, contour planting, and erosion barriers. Food-for-work was used to encourage the participation of smallholders. *Conucos* proved to be an effective technological and institutional package. Thiesenhusen and others (1991) found evidence that sustainable practices might be maintained even if food subsidies were eliminated, although they continued at the time of the study.

Although most of Plan Sierra's efforts concentrated on forestry and agroforestry, nearly half of the project area was devoted to pasture, including some of the most fragile lands with steep slopes and shallow soils. These lands contributed much of the sediment delivered to the region's rivers (Thiesenhusen and others 1991). On the one hand, available economic information suggests that a model strategy for small ranchers would have been to promote integrated farm management (improved pasture and water management, sustainable *conucos*, better animal health) rather than conversion to forest. On the other hand, forestry appeared to be economically profitable for the area's large ranchers, some of whom had already sold degraded pasture to purchase forest. Large owners were attracted to forestry by a unique set of circumstances. Plan Sierra gained a monopoly over legal timber cutting in the area by securing government approval for its sustainable forest management plan. At the same time, it enforced the government's ban on cutting timber outside such a plan. Most important, Plan Sierra's subsidies for reforestation were attractive to large owners.

Plan Sierra's management strategy involved full-cycle commercial harvesting of private forests. Owners were permitted to cut and sell trees as they mature over a thirty-five-year cycle. In 1991, forty-five private management plans had been approved, twenty were pending, and approximately 200 landowners had expressed strong interest. Of the area under management plans, 43 percent belonged to owners with over 900 tareas (56 hectares) of land.

The forest management program received substantial subsidies, as high as US$304 per hectare. Plan Sierra financed reforestation at a nominal interest rate and extracted payment only when forest products were harvested thirty-five years later. Moreover, real interest rates were actually negative. For a rancher planting 1,000 tareas (62 hectares), subsidies ranged from US$9,667 to US$18,839. Even with the highest current subsidies, however, poor smallholders could not afford to participate in the thirty-five-year forest management plan. To compensate for smallholders' short time horizon, Plan Sierra experimented with a "truncated forestry" model that allowed timber to be cut after fifteen years, but the early exit of some participants suggested problems. An annuity scheme to provide smallholders a steady return from forestry without prematurely cutting timber might provide a better solution (Thiesenhusen and others 1991).

Plan Sierra has achieved significant grassroots success by integrating forest management with measures to strengthen community institutions, improve the delivery of social services, promote nonagricultural jobs, and diffuse a model for sustainable agriculture and conservation education. The process has been slow and expensive, however, and the program faces a funding crisis brought on by national austerity measures, inflation, lack of government support, and a scarcity of international funds. Although the economic value of stabilizing critical watersheds might justify subsidies, subsidies and fee schedules will have to be reformulated so that persons who can afford to would pay a larger share of the program's full cost.

Haiti

The Haitian study area, a long-standing agricultural area in the southern part of the country, has suffered extensive resource depletion due to a combination of poverty and unstable tenure. Most forests have been cut, only limited perennial cover has been replanted, and soil erosion is widespread. Extensive soil erosion has left some areas unfit even for grazing, while runoff and siltation are jeopardizing hydroelectric power and irrigation projects. Most land in the area is highly fragmented, and, for a variety of reasons, many plots have been let out to secondary users under tenure arrangements that are sometimes insecure and unstable. Farmers generally own some parcels and farm others under various tenure arrangements. Formal and informal rules operate simultaneously to govern access to and use of land. A given parcel could belong to the state or an individual or constitute the undivided inheritance of a family group. It could have been acquired formally (with legal title) or informally (not fully documented according to legal specifications). Access could be primary (individual or joint, formal or informal ownership) or secondary (all forms of tenancy, caretaking arrangements, and some forms of usufruct). Joint-property and secondary-tenure arrangements apparently help rationalize access to the area's highly fragmented property and increase the survival options for poor farmers.

The USAID-financed Proje Sove Tè Project targeted a region encompassing 80,000 hectares and six major watersheds; McLain and Stienbarger (1988) focused on two watersheds, each with irrigated valley land. The study used case studies (in-depth interviews with seventeen farmers selected to represent maximum variation within each zone) and a more general survey (a census of the three communities where the case studies were conducted). The survey revealed that 44 percent of the plots were farmed by owners with direct access, while 56 percent were used under secondary access (mainly sharecropping, rental, and usufruct).

Decisions about land use were related to the size of landholdings, the quality and distribution of parcels, and tenure arrangements, among other variables. The quality of purchased land was generally high, while that of inherited land was mixed. Farmers tended to cultivate their most-fertile and least-eroded land personally. Quality varied on land given out in rental, sharecropping, or usufruct arrangements. Renters got high-quality land (since they would not lay out cash for poor land), as did managers overseeing coffee production. Sharecropped land was of mixed quality, depending on the agroecological zone, and the poorest land was given out in usufruct. Farmers were most likely to plant trees on fertile land to which they had primary access (less than 24 percent of parcels with planted trees had poor-quality soils). They had the strongest preference for planting trees on purchased land (which also tended to be the most fertile). That behavior might be partially explained by a need to establish boundaries. The most prevalent tenure arrangements—secondary access and undivided or informally divided family land—were associated with low tree-planting activity. Family lands generally carried restricted decisionmaking rights. Although co-heirs cultivated individual shares, they retained generalized rights to fruit, wood, and limited post-harvest grazing (which put young trees under periodic threat from animals). Some co-heirs were hesitant to plant trees, even though local custom allowed them individual rights to trees, because they did not know which section they would eventually receive. Similarly, short-term, secondary-access arrangements tended to inhibit owners and land users (renters, sharecroppers, and managers) from planting trees. However, tree planting was positively related to the stability of tenure (the length of time a farmer had worked a parcel), regardless of the form of access. A few farmers with secondary access expressed an interest in planting trees in order to improve their chances of eventually getting the land. Conversely, farmers occasionally expressed reluctance to do so, since the value of land with trees would increase and might induce the owner to take it back (T. A. White, personal communication).

Poverty and highly fragmented holdings fostered numerous secondary-access arrangements and led to frequent management turnover on some parcels. Land was given out for a number of reasons, including advanced age, insufficient labor, distance of the plot, avoidance of family conflict, and, most important, generation of cash. Families rented out or sold land to pay for health services, burial expenses, and children's boarding-school tuition and fees, since the area lacked public schools. The sale and rental of land in the area had increased since 1983, when Creole pigs (which had formerly helped cover such contingency costs) were eliminated due to U.S. government concern over the spread of African swine fever (McLain and Stienbarger 1988).

These results have important implications for conservation programs in poor, densely populated areas with highly fragmented holdings. Such areas are likely to have similarly complex land access rights that, along with poverty and culture, affect land use. Because of the multiple factors promoting short-term, secondary-access arrangements, land titling and registration are not necessarily desirable, although formal division and titling of undivided or informally divided family lands might encourage conservation activity on inherited land (McLain and Stienbarger 1988). However, a titling program for state lands might hurt land users, most of whom are subrenters or sharecroppers who could potentially be displaced from the land by the newly titled owners (Bloch, Lambert, and Singer 1988). In general, incentive systems need to be tailored to the constraints and opportunities available to different socioeconomic groups. Poor, labor-short households are not likely to participate in labor-intensive conservation efforts. The stability of tenure might be improved if the peasantry had better access to short-term loans to cover contingencies. Strengthening customary arrangements recognizing tenure rights to trees might also have beneficial results; the Haitian state's ban on timber cutting, even though ineffectually enforced, has undermined a potentially beneficial feature of Haitian custom—tenure rights to trees. When those rights have been guaranteed, tree planting has increased substantially (Murray 1988).

Summary

The cases in Haiti and the Dominican Republic differ dramatically in the level and impact of involvement by nongovernmental organizations. In Haiti, resource use practices were primarily conditioned by custom, socioeconomic circumstances, and the deteriorating condition of the resource base. In the Dominican Republic, on the other hand, Plan Sierra achieved a significant impact on watershed management, using a combination of education, demonstration projects, subsidies, and the enforcement of forest laws. Most important, it significantly changed the resource management strategies of the area's poorest campesinos through the sustainable *conuco* project, which could potentially diminish part of the driving force behind deforestation. Whether maintaining those results depends on subsidies is, however, an open question.

Summary and conclusions

Resource use practices are shaped by a number of factors, including tenure status, market forces, government regulation and policies, and local management plans. The case studies suggest that these factors can work in a synergistic manner. Government regulation failed to curb illegal timber cutting until it was enforced by a local resource management plan that also incorporated the resource users' economic self-interest. When local populations are excluded from the benefits of forestry, they often find it economically rational to clear timber illegally. Conversely, when they are able to increase their incomes through forestry, they often adopt a management plan and begin defending forest resources against outside competitors.

The level of grass-roots initiative varied in the countries studied. In Oaxaca, Mexico, communities themselves organized changes, while in the Dominican Republic, the Plan Sierra project acted on behalf of the local population. All the local management systems depended, however, on a favorable national policy climate. Sustainable resource management, therefore, appears to stand on three legs: positive economic incentives, some level of local management and oversight, and a government policy climate that promotes sustainability.

Group plans for sustainable resource management must be both technically and socially viable. It is relatively easy to meet those goals when population and market pressures are relatively low (or not increasing rapidly), social class and ethnicity are relatively homogeneous, and social custom maintains traditional management practices. That set of conditions is increasingly rare.

Although some analysts emphasize the importance of community involvement in formulating group management plans under all conditions, the limited evidence presented here suggests that community planning and administration of resource management strategies work better under certain social, cultural, and policy conditions. The indigenous communities in Oaxaca, Mexico, had a long cultural tradition that aided their organization. The Honduran resin tappers' cooperatives lacked such a history, but, in the successful ones, members had bonded through a common experience—the struggle to defend their use of the forest against encroachment by sawmills. The social and technical viability of their management system was undercut, however, by an unsupportive policy climate and lack of secure access to the forest. The case from the Dominican Republic suggests that resource users' support for a technically and socially sound management plan does not always depend on their direct participation in planning. Although local resource users had little role in designing the resource management plan, their acceptance of it was fairly high.

Positive economic incentives (income and its equitable distribution) are a second major factor affecting most sustainable management systems. Appropriate management plans might serve as a buffer over the short run if policy and economic incentives turn negative, especially if education helps instill in resource users the long-term economic perspectives required by sustainable production systems. Yet, ultimately, local populations must have secure livelihoods. When resource users' incomes from sustainable management decline, their support for those practices also erodes. In Quintana Roo, Mexico, local incomes dropped recently when Plan Piloto foresters decreased harvesting rates to improve the long-term sustainability of the resource base. Local support for the management plan weakened, although well-directed education might counteract that negative effect. Since 1990, structural adjustment policies in Honduras have diminished the profitability of sustainable resin extraction by shifting the terms of trade against the resin tappers' cooperatives. As a result, many tappers have abandoned extractive activities. In the Dominican Republic, government austerity policies have diminished support for Plan Sierra and threaten subsidy-dependent projects directed at the poor. It remains to be seen what impact the Ejido Reform Law and trade liberalization will have on the Mexican communities' forestry management programs.

More information is needed on the specific role that tenure regimes play in sustainable resource use. Can sustainable management practices be maintained solely by establishing secure access rights (such as land titles) without delineating and enforcing management responsibilities? How important is security of tenure versus stability of tenure (which means a low level of turnover, regardless of the tenure rights regime)? Rights to land and trees are often separate. What constitutes security of access to each? Under what conditions does a high level of local control promote resource management that is technically and socially sustainable? What balance of state and local power over planning and management supports that goal? What options exist if state and local goals conflict? What are the roles for intermediary institutions, such as community organizations, nongovernmental organizations, and local government? How can tenure regimes and local management plans adapt to changes in population, policy, and market conditions in order to maintain sustainable resource use practices? How can local plans provide economic incentives to local resource users and, at the same time, serve as a buffer against sudden shifts in economic and policy signals?

Note

1. This paper synthesizes research conducted by the Land Tenure Center on the influence of property rights systems on resource use. The author thanks Peter Bloch, Oliver Coomes, Ernst Lutz, David Stanfield, Denise Stanley, William Thiesenhusen, Alberto Vargas, Daniel Wachter, and Andrew White for their comments. All omissions and errors are the author's.

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15. Capital Investments on Smallholder Coffee Farms: An Empirical Study from Honduras

Malcolm D. Childress[1]

The recent expansion of coffee production in Honduras has incorporated many small farmers into an intensive agricultural activity with opportunities for improving income and capital formation. This incorporation has been accomplished with minimal capital requirements, since investments in coffee consist largely of the farmer's own labor. Coffee production has generated wage work in rural zones, preserved the environment by using low levels of inputs and combining coffee trees with shade trees and other crops, and strengthened the formation of a middle sector of peasant origin (Baumeister 1990). Yields are, however, the lowest in Central America, and growers themselves receive a comparatively small share of coffee's international price. The expansion of the coffee sector has occurred mostly because new areas have been brought into production. The continuation of this expansion is, however, limited by geographic and demographic constraints. Subsequent gains will necessarily have to originate in increased efficiency, and their consolidation will have to rest on sound ecological practice.

The future evolution of the structure of the coffee sector and its implications for the country's development are uncertain. If coffee holdings were concentrated in a small number of large holdings, the already large rural wage labor force would probably increase, depressing wages and slowing internal demand. Consolidating the small and middle sectors of producers could, however, conceivably strengthen internal demand while continuing to employ a significant part of the rural population as producers.

The low level of inputs typically used in coffee production is a major cause of low yields. Another factor is the low level of investment in conservation practices, new seedlings, and farm infrastructure. Conservation practices such as terracing and planting windbreaks and shade trees help prevent erosion and, in the case of shade trees, generate litterfall that helps maintain soil quality.[2] The ability of farmers to capture more of the international price of coffee is also connected with the storage and processing capacity of the farm. Increased investment in production, storage, and processing infrastructure would probably increase yields and the value added by the producer.[3] The allocation of investment is a crucial area for continuing to develop the sector in a period of foreign exchange constraints and low international prices.

Modeling the investment decision of individual growers is complicated. Factors that may affect the decision about whether and how much to invest include local policies and availability of credit, the profitability and cash flow situation of the farm, information about coffee technology, the planning horizon and expectations of the grower, the patterns of choice in the grower's allocation of household income, the cropping system of diversified farms, the opportunities to substitute labor for capital investment, and the tenurial status of the land in question.

The objective of this chapter is to assess the importance of tenure security for a farmer's investment in coffee, with the hypothesis being that security of tenure, as embodied in a property title, encourages investment for the following reasons: (1) the farmer with a marketable title can more easily procure the capital needed for such investment, and (2) the farmer with a legal title is more secure in the expectation that he will benefit from investments of capital and labor. Data gathered for an evaluation of the Honduran small farmers titling project (Proyecto de Titulación de Tierra, PTT) are reanalyzed to assess the role that titling plays in on-farm investments made by coffee farmers. This new analysis uses multivariate statistical techniques. Placing the impact of titling in a multivariate framework that also includes the size of landholding, cropping pattern, credit history, method of land acquisition, and off-farm income shows how land tenure arrangements affect the investment patterns of small coffee producers, controlling for these other factors. Earlier reports using this data set were concerned with project evaluation and did not focus on coffee in depth or use a multivariate technique for analyzing investment. Although qualifications are noted, the conclusions reached indicate that investments are more prevalent on titled parcels, but that factors such as the manner of acquiring the parcel and the length of time the farm has been owned are also influential. The results cautiously support the efforts of the state to title land and reveal a positive relationship between the farmer's level of education and the practice of bench terracing. They also show, however, a generally negative relationship between household size and investment. From the data it remains unclear whether this relationship is attributable to a tradeoff between household consumption and investment or to a substitution of labor for capital in some coffee farms.

The Honduran coffee sector

Since the 1950s the Honduran coffee sector has grown dramatically as an exporter to world markets. Total coffee production jumped from 309,400 quintals (22 quintals = 1 metric ton) in 1952 to 1,933,500 quintals in 1987, when Honduras accounted for 15 percent of Central America's coffee exports (Baumeister 1990, p. 8). Coffee now ranks second only to bananas, Honduras's top export.

In contrast with the country's other export crops, coffee is produced primarily on small family-operated farms. According to a 1981 report by the U.S. Agency for International Development (USAID), an estimated 80 percent of the total area planted to coffee was cultivated in groves of less than 25 acres, with an average coffee grove of 3.2 hectares (Williams 1989, p. 5). The number of farms growing coffee increased from 40,000 in 1979 to 66,000 in 1983. The largest increase occurred on farms with 0–10 manzanas of coffee (1 hectare = 1.41 manzana; Baumeister 1990, p. 10). Coffee is also the largest agricultural employer in Honduras, occupying 24 percent of the agricultural work force (Baumeister 1990, p. 5).

Besides its relatively recent emergence, the Honduran coffee sector is distinguished from its counterparts in other Central American countries by its relatively low level of technology, defined as cultivation methods and chemical inputs. Although this has resulted in yields that are among the lowest in Central America, it has also resulted in a limited demand by the sector for imported chemical inputs, thereby presenting a favorable net foreign exchange profile and imposing, potentially, a relatively light burden on the soils of the coffee-producing zones.[4] The sector generated in 1987 3 percent of the country's gross domestic product and, through export taxes alone, 5 percent of government revenue (Baumeister 1990, p. 5).

Table 15-1 illustrates the land-extensive path that the expansion of production has taken in Honduras as well as the increase in new produc-

Table 15-1. Coffee Plantings in Honduras, 1952–87
(in thousands)

Characteristic	*1952*	*1965*	*1972*	*1974*	*1979*	*1987*
Number of farms	39.2	49.8	38.6	48.7	40.0	66.5
Area in coffee production (manzanas)	—	115.7	—	101.6	145.3	198.6
Total coffee area (manzanas)	68.1	115.3	152.9	115.8	175.0	250.1
Production (quintals)	309.4	709.9	749.1	921.2	906.8	1,993.5

— Not available.
Source: Baumeister (1990); *Censo agropecuario nacional* (1952, 1965, 1974); IHCAFE (1972, 1979); USAID/IHCAFE (1987–88).

ers in the 1980s. Table 15-2 shows that the increase in the number of farms growing coffee is primarily the result of new coffee plantings on small and medium-size units.

In traditional Honduran plantings, approximately 1,600 to 1,700 trees are planted per manzana, with shade trees interspersed. Beginning in the early 1980s, renovation programs using new strains have sought densities of about 3,300 trees per manzana, generally without shade. These new varieties occupy less area, grow more rapidly, and have a higher productivity per tree. They also require heavier applications of fertilizers and pesticides because they absorb soil nutrients at a faster rate than traditional coffee trees. Experiences from other countries have shown that new varieties, because they are more prone to soil erosion than older varieties, require greater attention to soil conservation, primarily in the form of bench terraces, runoff traps, windbreaks, and contour grass barriers.[5] For a farmer lacking the resources to ensure continued use of inputs, the new, intensive techniques for producing coffee may be riskier than the traditional ones. For both types of coffee production, however, the causes of soil degradation are the same: runoff, leaching, and loss of nutrients.

New trees have been adopted primarily by small growers who were beneficiaries of a renovation project sponsored by USAID and IHCAFE (Instituto Hondureño de Cafe, the national coffee institute) and by operators of relatively large farms with more than 20 manzanas of coffee. By 1989, the USAID-IHCAFE project had renovated 11,900 manzanas with high-yielding varieties. An estimated 25,000 manzanas more of intensively grown coffee are found in the large farm sector (interview of USAID staff). With a total area of 209,000 manzanas in coffee production in 1984, new varieties are probably grown on less than 18 percent of the area in coffee production in Honduras.

The future evolution and impact of the Honduran coffee sector depend on many variables. Central among them is the extent to which small farmers balance investment in high-yield varieties and imported chemical inputs with investments in long-term infrastructure that preserves the soil resources of the coffee-producing regions and permits small and medium-size producers to be involved in the coffee market.

The study

At the outset of the USAID-sponsored land titling project in Honduras, the source of data for this analysis, much of the country's national and ejidal land was privately held with tacit state approval, but without formal state recognition of property rights. This pattern of land tenure, rooted in the historically low density of population and limited government apparatus, resulted in a "customary" system of defining and transferring rights to land. Under this system, land rights are recognized locally by possession and use. Various systems for recording transfers and resolving conflicts have evolved in Honduras, usually involving municipal leaders and local registries (Coles 1989).

The tremendous changes in the rural Honduran economy in the past forty years have stretched the adequacy of these customary forms of land tenure. Population increases, displacements of peasants provoked by the expansion of cattle ranching and cotton cultivation, and the

Table 15-2. Number of Farms and Production per Farm in Honduras, by Size of Coffee Planting, 1979 and 1988

Size of coffee planting (hectares)	*Number of farms* 1979	*Number of farms* 1988	*Production per farm (quintals)* 1979	*Production per farm (quintals)* 1988
Less than 1	7,510	13,189	1.8	1.8
1–2	9,563	14,515	5.2	6.5
2–5	13,285	22,933	12.2	21.2
5–10	5,815	10,939	29.2	52.7
10–20	2,602	3,791	67.8	117.5
More than 20	1,225	1,157	268.6	265.0
Total number	40,000	66,524	n.a.	n.a.

n.a. Not applicable.
Source: Baumeister (1990); IHCAFE (1979); USAID/IHCAFE (1987–88).

boom in coffee production after World War II created a rural smallholder sector that is more densely settled, more integrated with international markets, and more reliant on a national system of marketing and credit for its development than ever before.

Policymakers in the Honduran government came to believe that insecurity of tenure was creating a constraint to credit and investment in agriculture, particularly in the coffee sector. Much of the expansion of coffee production occurred on untitled national and ejidal lands. Although many holders of untitled parcels felt secure enough to plant a permanent crop like coffee, access to credit for expanding or renovating coffee plantings was hypothesized to be constrained by the lack of private title. Private titling of national land was and is an expensive procedure that requires government authorization, cadastral mapping, and a series of administrative steps. The transaction cost was hypothesized to be beyond the immediate budget of most small farmers.

With funding provided by USAID, the government instituted a titling project that began in 1982 and officially concluded in 1990 (although the small farmer titling program continues through the government's National Agrarian Institute). The project targeted small farms, and coffee farms in particular, for the cadastral mapping of landholdings and the issuance of formal land titles. To be eligible for title, a parcel was required to be between 5 and 50 hectares in size or, if smaller than 5 hectares, to contain a commercial stand of coffee. Fee simple titles (*dominio pleno*) were issued for specific single plots larger than 17 hectares (14 percent of titles issued), and family agricultural unit titles were issued for plots smaller than 17 hectares (86 percent of titles issued). Under the family agricultural unit title, one title was issued for all separate plots that comprised a family's holding. These titles cannot be sold or divided without approval of the National Agrarian Institute.[6] Once title was issued, the owner was obligated to pay the government for the land, usually over a twenty-year period. As of December 1989, the PTT had delineated and mapped 174,175 parcels of national and ejidal land used for agricultural purposes and had issued 32,029 property titles. Most of the titles issued were for parcels smaller than 5 hectares (55 percent), which means that small coffee farms were the major beneficiaries of the program.

The summary report of the Land Tenure Center of the University of Wisconsin-Madison (Stanfield and others 1990, p. S-1) provides the basic economic justification for the project:

> *The major objective of the titling project was to incorporate a significant portion of the untitled holders of national and ejidal land used for agriculture into the category of private landowners through the issuance of legal land titles. Over 60 percent of agricultural land in Honduras has been held and used without being legally titled. The PTT also aimed to strengthen the property registration system in Honduras, in order to provide more effective protection of the ownership rights therein recorded.*
>
> *Analyses of rural areas of Latin America and the Caribbean have frequently concluded that the lack of an adequately secure ownership title, especially for smallholders, is a major constraint on the development of agriculture in the region. The Honduran titling project's general goal was the removal of at least some of these constraints through the legalization of private landownership. The PTT proposes that more widespread possession of legal land titles should improve access to credit, farmer investments, levels of productivity, and the operations of the land market.*

In the analysis of investments on coffee parcels, the final report on the project discovered "no consistent differences between the titled and the control groups" (Stanfield and others 1990, p. 32). The present analysis expands the work of that project evaluation by reexamining the data in a multivariate framework using estimation procedures specifically suited to models with qualitative dependent variables.

The Data Set

A longitudinal evaluation was undertaken in the department of Santa Barbara in 1983 and 1988 and in the department of Comayagua in 1984 and 1989. The evaluation was managed by researchers from the University of Pittsburgh and the University of South Florida in association with the Land Tenure Center of the University of Wisconsin-Madison. In an attempt to measure the impact of titles on investment, productivity, access to credit, and land transfers, the evaluation carried out extensive sample surveys. These data are analyzed again in this chapter.

The survey design

The sample surveys carried out as instruments of the project evaluation were designed as two-point longitudinal panel surveys with a treatment and a control group. Surveys were carried out in two areas of the country, first in the department of Santa Barbara, with a control group in the neighboring department of Ocotepeque in 1983, and then in the department of Comayagua, with a control group in Comayagua and the adjoining department of Yoro beginning in 1985. The Santa Barbara sample was interviewed again in 1988 and that of Comayagua in 1989. The control groups were also interviewed a second time in 1988 and 1989.

In each case, two samples—a treatment and a control group—were drawn. The first sample was a group of cadastrally delineated, but as yet untitled, parcels located within the area of the titling project. The control groups were located in neighboring departments where the titling project was not active during the evaluation period. The sample frame in the areas targeted for titling consisted of area maps in which all the parcels were identified and located. The number of parcels in the samples was dictated by the target error level of plus or minus 5 percent and the number of mapped units in each region. In the Santa Barbara survey, a simple random sample of mapped parcels was selected. For reasons of cost, the Comayagua sample was selected by a cluster sampling technique.

The parcel, rather than the owner or manager of the land, was selected as the sample element. In this way, even parcels that changed hands over the course of the survey were studied again in the second interview. In total, 774 initial and second interviews were carried out in Santa Barbara and the control group in neighboring Ocotepeque (569 in the treatment group, 205 in the control group). In Comayagua and in the control group in Yoro, 429 first and second interviews were carried out (239 in the treatment group, 190 in the control group). Of these, 349 units in the Santa Barbara study and 260 in the Comayagua region grew coffee. These subsamples of coffee-growing units in both surveys are the primary focus of the present analysis (one observation from the Santa Barbara region had to be dropped because of serious coding errors).

An analysis was also executed for a subsample of parcels that were the only parcel belonging to the person interviewed. In questions of investment allocation, this subgroup of single-parcel coffee growers is the only group for which the survey obtained unambiguous information about the person's entire farm. Individuals with parcels in addition to the sample unit would presumably be rationalizing investments among all their land units, inhibiting the analyst's ability to make clear observations of investment behavior. This subgroup of single-parcel farms contained 212 observations in the Santa Barbara survey and 111 in the Comayagua study.

Coffee growers in the sample

Coffee growers were somewhat more highly represented in the survey sample than their true proportion in Honduran agriculture. This is not surprising since coffee farmers were one of the main targets of the titling program. Although this makes the sample results less generalizable for Honduran agriculture as a whole, it does reflect the use of national and ejidal land. Also, because most of the coffee farms surveyed are small operations, the subsample of coffee producers permits a closer examination of investment behavior among the smaller strata of coffee farms, the largest and fastest growing in the country. Table 15-3 summarizes the percentage of farms growing coffee in Honduras and in the sample.

Size distribution. The size distribution of the sample parcels roughly mirrors the national figures discussed earlier. The area planted to coffee is, however, concentrated in even smaller strata, with over half the parcels managing less that 2 hectares of coffee (tables 15-4 and 15-5 show the size distribution of single-parcel coffee farms in the sample and the percentage of the farms devoted to coffee).

Land use. Coffee tends to be the predominant activity on farms that cultivate it and especially on smaller, single-parcel farms (see table 15-6). In general, the farming system in both samples can be characterized as one in which commercial coffee planting is augmented by small quantities of subsistence food crops and, in some cases, livestock. In both departments, the average number of cattle kept is slightly more than one head.

Table 15-3. Percentage of Farms Growing Coffee in the Sample and in Honduras, 1974, 1979, and in the Baseline Surveys

Area	*1974*	*1979*	*Sample*
Sample			
Santa Barbara	41.0	49.8	69.4
Comayagua	33.5	32.7	51.0
Other areas			
Copán	33.1	26.3	n.a.
Cortes	22.2	20.1	n.a.
El paraíso	28.1	33.4	n.a.
La Paz	36.9	20.8	n.a.
Yoro	27.4	17.2	n.a.
Honduras	24.9	20.5	n.a.

n.a. Not applicable.
Source: Santa Barbara baseline survey, 1983; Comayagua baseline survey, 1985; *Censo agropecuario* (1974), vol. 6; IHCAFE (1979).

Table 15-4. Size Distribution of Single-Parcel Farms with Coffee, Santa Barbara and Comayagua, Honduras

	Santa Barbara		*Comayagua*	
Size (in hectares)	*Number*	*Cumulative percent*	*Number*	*Cumulative percent*
Less than 1	39	18.4	15	13.5
1–2	39	36.8	23	34.2
2–4	26	49.1	30	54.1
4–6	22	59.4	11	71.2
6–10	28	72.6	21	91.0
10–20	30	86.8	5	94.6
More than 20	28	100.0	6	100.0
Total	212	n.a.	111	n.a.

n.a. Not applicable.
Source: Santa Barbara baseline survey, 1983; Comayagua baseline survey, 1985.

Table 15-5. Size Distribution of Coffee Planting on Single-Parcel Farms in Santa Barbara and Comayagua, Honduras

	Santa Barbara		*Comayagua*	
Size (in hectares)	*Number*	*Cumulative percent*	*Number*	*Cumulative percent*
Less than 1	51	24.1	24	21.6
1–2	69	56.6	29	47.7
2–4	34	72.6	39	82.9
4–6	24	84.0	9	91.0
6–10	22	94.3	6	96.4
10–20	11	99.5	3	99.1
More than 20	1	100.0	1	100.0
Total	212	n.a.	111	n.a.

n.a. Not applicable.
Source: Santa Barbara baseline survey, 1983; Comayagua baseline survey, 1985.

Table 15-6. Use of Parcels on Coffee Farms in Santa Barbara, Honduras
(percent)

Crop	*Single-parcel farms*	*All farms*
Banana	2	2
Bean	2	0
Brush	13	10
Coffee	56	36
Corn	4	4
Forest	6	10
Pasture	16	2
Other	0	36[a]

a. The Comayagua land use data contain substantial fractions of cacao and sugarcane.
Source: Santa Barbara second interview, 1988; Comayagua second interview, 1989.

Coffee production. Table 15-7 presents information on yields in Santa Barbara and Comayagua that were obtained from the initial surveys in 1983 and 1985. Forty-two (15 percent) of the coffee farmers in the Comayagua survey had no production during the preceding year (these farmers are included in table 15-7). Most of these farmers had new seedlings that had not yet entered into production, but some had abandoned their planting because of drought, disease, and pests.

Acquisition and duration of holding. In Santa Barbara, coffee farmers had occupied their holding an average of thirteen years at the time of the initial interview, with a maximum of fifty-six years, only slightly higher than that for the sample as a whole. In Comayagua, the average length of occupancy was approximately ten years for all farms and thirteen years for coffee farms.

The majority of land in the sample was acquired through purchase (see table 15-8). Inheritance and occupation by squatting were the second and third most common methods of obtaining land.

Documentation. The variety observed in the method of acquiring land was also observed in the documentation of the parcels (see table 15-9). The more detailed information from the Santa Barbara sample indicates that, in addition to formal title, private documentation, no documentation, and *escritura pública* were relatively common forms of landholding.

Credit. The survey gathered data on the sources and amounts of loans made to respondents during the year prior to the initial interview. Similar data were gathered at the time of the second interview, although in the regression analysis only the initial credit data were used because the credit obtained in the second period cannot be considered a determinant of prior investments. Questions were asked about credit from both institutional sources (BANADESA, the government development bank; IHCAFE, the cof-

Table 15-7. Coffee Production per Manzana in Santa Barbara and Comayagua, Honduras, at the Time of the Baseline Surveys, by Number and Percentage of Farms

Production (in quintals per manzana)	*Santa Barbara*		*Comayagua*	
	Number	*Percent*	*Number*	*Percent*
0	14	4	42	15
0–1	66	19	32	11
1–2	63	18	22	7
2–3	42	12	13	5
3–4	44	12	21	7
4–5	20	6	15	5
5–6	21	6	15	5
6–7	12	4	5	2
7–8	12	4	14	2
8–9	6	2	10	5
9–10	16	5	10	4
More than 10	33	8	83	4
Total	349	100	282	100
Mean yield (all growers)	4.9	n.a.	10.0	n.a.

n.a. Not applicable.
Note: Mean for the 240 farmers with some coffee production was 11.7 quintals per manzana.
Source: Santa Barbara baseline survey, 1983; Comayagua baseline survey, 1985.

Table 15-8. Manner of Parcel Acquisition in Santa Barbara and Comayagua, Honduras

Manner of acquisition	Santa Barbara						Comayagua					
	Whole sample		All coffee growers		Single-parcel coffee growers		Whole sample		All coffee growers		Single-parcel coffee growers	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Inherited	198	25.6	72	20.7	72	20.7	131	30.5	93	35.8	47	42.3
Bought privately	463	59.8	221	62.3	132	62.3	220	51.3	132	50.8	51	45.9
Inherited and bought	22	2.8	3	0.5	1	0.5	46	10.7	18	6.9	6	5.4
Squatting	62	8.0	41	12.3	26	12.3	29	6.8	14	5.4	6	5.4
Municipal donation	20	1.0	11	3.8	8	3.8	2	0.5	2	0.8	1	0.9
Missing	9	1.1	0	0.0	0	0.0	1	0.2	1	0.4	0	0.0

Source: Santa Barbara baseline survey, 1983; Comayagua baseline survey, 1985.

Table 15-9. Parcel Documentation at the Time of the Second Interview, All Coffee Farms in Santa Barbara and Comayagua, Honduras
(number of farms)

Type of document	*Santa Barbara*	*Comayagua*
Escritura pública	16	—
Private document	59	—
Inheritance document	3	—
Municipal document	2	—
No documentation	28	—
Title	187	84
Other or missing	53	176[a]
Total	348	260

— Not available.
a. Information on documentation was only gathered for title in the Comayagua second interview.
Source: Santa Barbara second interview, 1988; Comayagua second interview, 1989.

Table 15-10. Amount of Credit Received during the Two Years Prior to the Initial Interview in Santa Barbara and Comayagua, Honduras
(number of farms)

Amount of loan (lempiras)	*Santa Barbara*	*Comayagua*
0	305	192
Less than 2,000	19	28
2,000–5,000	16	25
More than 5,000	8	15
Total	348	260

Source: Santa Barbara baseline survey, 1983; Comayagua baseline survey, 1985.

fee institute; private banks; cooperatives) and less formal sources (coffee traders, moneylenders, friends).

In both samples, a significant number of respondents had received no credit of any kind during the two years prior to the initial interview (see table 15-10). Of the Santa Barbara coffee growers, 305 (87 percent) had received no credit at all. Of the 43 growers who had received credit, 35 had received less than L5,000. Among Comayagua coffee growers, 192 of 260 farmers (74 percent) had received no credit of any kind. Of the 68 growers who had, 53 had obtained less than L5,000 (US$2,500) in loans during the two-year period.

Among coffee growers, almost no correlation exists between land size and credit (the correlation coefficient was 0.13 in Santa Barbara and 0.07 in Comayagua). In the Comayagua sample, approximately 80 percent of credit was spent on inputs, not capital investment. In Santa Barbara, only 4 percent of loans had any component that went toward capital goods.

Operator and household characteristics. Several characteristics of the farm household at the time of the initial interview were relevant to investment decisions. The mean number of years of education for all coffee growers in the Santa Barbara sample was only 1.3 compared with 2.16 in Comayagua. Mean off-farm income was L307 for households of coffee farmers in Santa Barbara and L388 for households in Comayagua (at the time, L2 equaled US$1). The mean number of persons residing in each household was just under seven in each survey.

Investment on coffee holdings

The number of coffee trees planted in new areas of the parcel during the years between the initial and the second interview is a basic indicator of investment. Although the survey recorded both trees planted in new areas and partially renovated plantings in existing coffee plots, for the purposes of this analysis only new areas planted to coffee are used to indicate investment because they clearly represent new investment rather than long-term management of existing groves. New trees planted in new areas in each of the years between the interviews are aggregated to create a variable of total new trees planted in a new area or an area of total renovation.

In Santa Barbara, new areas of coffee trees were rarely planted. Of the 348 farmers with some area in coffee, only 54 (16 percent) planted any new area on the survey parcel during the years 1983–87. Of these 54 farmers, only 9 planted more than 5,000 trees. Of the 212 farmers with coffee who possessed only 1 parcel of coffee (those whose entire farm consisted of the sample parcel), 40 planted new area to coffee during the time period. Of these, 5 farmers planted more than 5,000 new trees.

In Comayagua, the planting of new trees was only slightly more common than in Santa Barbara. Out of 260 parcels with coffee, 70 (27 percent) planted new trees in the years between the two interviews. Only 16 parcels (6 percent) planted more than 5,000 trees during that period.

Improvements to the farm constitute a second indicator of investment and consist of eighteen types of material investment on the survey parcel (see table 15-11 for the material investments made after the initial survey). These improvements include two infrastructural investments that have a direct impact on soil conservation: windbreaks and terraces. Soil conservation improvements were found on about one-fifth of the coffee holdings in Comayagua and on less than 10 percent of the coffee farms in Santa Barbara.

A third indicator of investment is the presence or absence of changes in the practice of planting new shade trees. Three types of shade systems were specifically investigated: bush shading, tree shading, and forest shading. Among the coffee parcels in Santa Barbara, 30 percent increased their use of bush shading during the study interval, 38 percent increased tree shading, and 26 percent increased forest shading. In Comayagua, 52 percent of the coffee growers changed their use of bush shading, 67 percent changed that of tree shading, and only 28 percent changed that of forest shading.

A fourth indicator of investment is measured indirectly through changes in yields. The relative change between the two periods is used to control for period-specific effects such as weather. In the Santa Barbara subgroup of all coffee farmers, the average yield declined 2.73 quintals per manzana between the two interviews: 95 parcels recorded negative changes in yields, 90 parcels increased yields, and, unfortunately, 163 parcels were missing values for one of the two points. These changes include parcels taken out of coffee production during the interval (the decline in average yield includes cases where yield dropped to zero because production ceased) but does not count parcels on which coffee was planted for the first time after the original interview.

In Comayagua, yields increased an average of 5.5 quintals per manzana on all coffee parcels; 19 percent of the parcels had declines in yield, and 35 percent had improvements of less than 3.0 quintals per manzana. The highest changes in yield were on parcels whose coffee trees entered production during the survey interval (cases where yield went from zero to positive because of new plantings).

Determinants of investment. Investment on

Table 15-11. Percentage of Coffee Farms with Improvements in Santa Barbara and Comayagua, Honduras

Type of improvement	*Santa Barbara*		*Comayagua*	
	All farms	*Single-parcel farms*	*All farms*	*Single-parcel farms*
Fencing	33	31	46	45
Well with pump	0	0	2	2
Well without pump	11	12	27	28
Livestock pens	7	5	5	5
Stone walls	2	1	10	10
Terraces	4	3	22	22
Windbreaks	8	9	23	28
House	36	49	52	56
Improvements to house	11	14	15	14
Concrete coffee patio	15	19	22	21
Manual depulper	31	40	30	27
Motorized depulper	1	1	8	7
Warehouse	6	6	5	3
Barn	12	12	6	5
Grain storage facility	3	5	16	18
Second house	1	1	0	0
Fermentation tank	13	16	25	23
Water piping	30	21	17	16

Source: Santa Barbara second interview, 1988; Comayagua second interview, 1989.

coffee farms is controlled by a complex set of factors that determine whether the expected net present value of the investment is greater, or preferable, to the available alternatives. Investments presume that the farmer has an income stream or endowment sufficient to pay for the investment or a supply of nonwage family labor to build the material improvement.[7] Investments furthermore invoke some idea of property rights and control of the land on which the investment is made. Microeconomic theory presumes that investment occurs when expected returns are positive. Expected returns decrease when doubts exist about the farmer's ability to capture returns because property rights are uncertain. In the Honduran case, the definition of property rights was certainly in a state of flux during the time of the surveys. Investments in coffee farms also require a long time horizon due to the longevity of the crop and the three-year delay between new plantings and harvests (this three-year period is the same for both traditional and newer varieties of coffee). The long time horizon and the volatility of coffee prices complicate the calculation of potential returns. Tradeoffs between immediate gains achieved using chemical inputs and labor must be compared with future gains achieved from instituting new plantings, field improvements, or construction of storage and processing facilities. For smaller farmers, the risks associated with investments may be even higher because their endowment levels are relatively low, as is their ability to diversify risk across a number of parcels or crops.

For reasons associated with ease of collection, reliability, and their implication for the titling project, this analysis uses capital, durable indicators of investment rather than investments in inputs or labor, except as they are captured in the changes in yields.

Variables in the model of investment decisions. Taking these factors into account, a model of determinants of investment decisions is specified, based on a group of hypotheses suggested by economic theory, the scholarship of coffee, and analyses of the titling project. Because the analysis uses data gathered with somewhat different objectives and because the intent of this chapter is to take advantage of existing data to advance general discussion of the question of investments rather than to test rigorously a single, narrow hypothesis, the models proposed are not meant to be comprehensive representations of the investment decision. They aim, instead, to test the strength of association between several important variables associated with the security of land tenure while controlling for key variables other than tenure that may also influence investment decisions.

The independent variables in the model are the following:

1. Amount of credit received in period 1
2. Household off-farm income in period 1
3. Size of total landholding of farmer
4. Percentage of survey parcel in coffee
5. Number of years occupying the survey parcel
6. Number of years of education of the farmer
7. Total number of persons in the household
8. Dummy for possession of legal title (measured in period 2)
9. Dummy for acquiring parcel from parents (inheritance or purchase)
10. Dummy for acquiring parcel through occupation.

The continuous variables used in the model are all measured in the first period so that the model can detect investments made as a consequence of circumstances present in the initial period.

Dependent variables for changes in practices and number of new trees are measured during the interval between the initial and the second interview. Therefore they may be interpreted as following directly from conditions in the first period.

The dependent variables for capital improvements other than tree planting were measured by asking parcel owners in period 2 if they had ever made the improvement to the survey parcel. In other words, the survey recorded the presence or absence of an improvement that may have been made on the parcel at any time. This means that the predictor variables should not necessarily be interpreted as having any causal relationship with the improvement variables, but rather as being associated with the presence or absence of the improvement. In other words, because the investment could have been made before the original interview, the causal arrow between predictor variables and investments could point in both directions.

Given the schedule and design of the evaluation, the titling teams did not enter the survey region until after the initial interviews had been completed. This means that the dummy variable for titling, in particular, must be carefully interpreted. Neither the exact date of title receipt (and for that matter title application and adjudication) nor the exact date of the improvement is known. Therefore, with the titling variable, the model is designed to make a probabilistic statement about the association between having a title and making an improvement compared with all parcels without title.

Although most of the independent variables are self-explanatory, some discussion of the hypotheses informing their inclusion in the model is appropriate. The credit variable is important because, although it has been shown that little credit goes toward capital improvements, greater access to credit should increase liquidity and free resources to invest in improvements or inputs. Of course, credit that cannot be repaid can burden growers and inhibit further investment as well. Given the relatively favorable position that coffee occupies as a marketable cash crop in Honduras, however, credit should contribute positively toward investments.

Off-farm income also has the potential to increase liquidity in the household, freeing up resources for investment. If, however, the allocation of household labor to off-farm activities reduces the amount of labor available for coffee production, the income-generating benefits of off-farm labor may be offset.

The total size of landholding, although not correlated with access to credit among the coffee growers surveyed, might still be expected to be a positive predictor of investment activity because many capital investments (coffee equipment, grain storage) are scale neutral over the range of farm sizes studied, and their cost therefore represents a proportionally smaller fraction of income for a larger farm than for a smaller one.

The percentage of the parcel devoted to coffee would also be expected to be positively associated with the type of investments being examined because many are specific to coffee cultivation.

The number of years of ownership is expected to be a positive indicator of investment because length of ownership permits a grower more time to harness resources—savings, credit, or family labor—to make investments. For these reasons, this is also an important variable to control so that tenure effects are not distorted by the variation among length of ownership.

The number of years of education of the parcel owner is included in the model as a possible proxy for management skill. Although the variation in educational level is fairly small, given the generally low level of education in the survey, its inclusion as a predictor is more general and easier to interpret than other potential variables concerning management ability, such as previous attendance at an extension course.

The last continuous variable in the model is the total number of persons in the household. This is another area in which the contribution toward investment could be either positive (because additional family labor might be available on the parcel) or negative (because resources might be allocated away from investment and toward household consumption).

Aside from the previously mentioned dummy variable for titling, other dummy variables in the model are designed to measure associations between the method of acquiring the parcel and subsequent investment behavior. These are the only variables in the model that can be interpreted as having a causal or at least a clearly sequential relationship to the dependent variables. Because the acquisition of the parcel necessarily pre-dates the owner's investment activity, the acquisition variables can be seen as initial conditions for future activity on the parcel. In each case, the dummies for inheritance and squatting are compared with the general case of acquisition through purchase.

Model estimation results

These independent variables were specified in a series of models using each of the four types of investment indicators discussed earlier as dependent variables.

Improvements

Because the data on improvements represent binary choices—to make the improvement or not—a series of probit models was used to measure the association between the independent variables and the probability that the improvement will be made. First, the model was used with an aggregate variable representing the presence of any improvement on the parcel. Next, the regression was run separately on six specific improvements chosen for their particular relevance to the ecological maintenance of the land or to the processing and storage of coffee. These improvements are terraces, tree windbreaks, concrete patios for drying coffee, storage buildings, grain storage facilities, and coffee fermentation tanks. All of these regressions were performed first using observations from each group of coffee producers and then using observations from the coffee growers with single-parcel farms.

In the Santa Barbara survey, both the years of ownership and the title dummy variable proved to be significant predictors of a high probability that the parcel would have some form of improvement (see table 15-12).

As discussed earlier, the significance of the titling variable cannot be interpreted as a causal explanation for improvements because they could have been made before, during, or after titling. However, the variable's significance does suggest that even if possessing a title is not a causal contributor to improvements, growers who made improvements must have been more likely to be titled and, by inference, to have actively sought title for their parcels.

In the subgroup of single-parcel coffee farms in the Santa Barbara sample, any improvement made on the farm was noted by the survey. For this reason, the interpretation of results is more precise for single-parcel farms than for all coffee farms. In farms with multiple parcels, improvements made to parcels other than the one in the sample are not apparent in the data. In this way, the single-parcel cohort serves as a check on the larger cohort of all coffee farms in the sample and can be expected to show more significant relationships.

Within this subgroup in Santa Barbara, only the titling dummy variable proved to have a significant coefficient as a predictor of an im-

Table 15-12. Significant t-Statistics for Coffee Farms with Any Improvement in Comayagua and Santa Barbara, Honduras

Structure and variable	*Santa Barbara*		*Comayagua*	
	All farms	*Single-parcel farms*	*All farms*	*Single-parcel farms*
Credit	1.9	..	..	..
Years of ownership	2.4	..	..	..
Title	6.7	5.4	2.5	..
Percent of farm planted to coffee	..	..	-3.9	..

.. Not significant.

provement. This result is in accordance with the results found for the larger sample of all coffee farms. The years-of-ownership variable is significant for the whole group, but not for the single-parcel group, perhaps because years of ownership and ownership of multiple parcels are positively related. The consistency of the titling dummy variable is important because it suggests that, at the very least, when other factors are controlled, coffee parcels with title have a significantly higher probability of having some improvement than parcels without title. As the further results show, however, the significance of the titling dummy variable is very limited for specific improvements.

In the Comayagua sample of all coffee growers, title also proved to be a significant and positive predictor, while the percentage of the parcel planted to coffee was a negative predictor. A possible interpretation of this result is that the Comayagua growers place priority on investments in planting the coffee itself and that growers with larger coffee plantings may have less time and money to engage in soil conservation or infrastructural investments. This tendency may also be related to a life cycle in which farmers first invest in coffee trees and subsequently make additional investments in their farms. Although the average length of landholding is almost identical in Comayagua and Santa Barbara, some variation of the concept of a life cycle might help explain why the percentage of coffee on the parcel is different for the two areas. In the estimation for the single-parcel growers, none of the variables showed a significant coefficient in the probit model.

Soil conservation

In order to focus the analysis specifically on improvements that are relevant to soil conservation, terraces and windbreaks were used as the dependent variables in the probit model.[8] The statistically significant predictor variables are summarized in table 15-13.

As is seen repeatedly in the results for Santa Barbara (in contrast to much of the data for Comayagua), increasing the percentage of the parcel dedicated to coffee production is a predictor of a low probability of having terraces. Two hypotheses offer rationales for this unexpected result. One is that in a resource-constrained household economy, a higher percentage of coffee requires a greater allocation of family work effort, limiting the quantity of labor left to make improvements. The second hypothesis is similar but considers cash, instead of labor, as the constraining factor. Small growers with a high percentage of their land in coffee may lack the resources at the margin to invest in controlling erosion. A third explanation may be found in the methodological caution offered above. If multiple-parcel growers tend to make improvements such as terraces on other parcels and to neglect the survey parcel because of specific topological characteristics, and if the survey parcel contains a high percentage of area in coffee, the results found in the probit analysis could be seen. If the last hypothesis were true, the result obtained would be misleading and would call for additional data measuring investments on all parcels.

The positive coefficient of the variable for years of education is consistent with the general

Table 15-13. Significant t-Statistics for Coffee Farms with Soil Conservation Investments in Comayagua and Santa Barbara, Honduras

Structure and variable	*Santa Barbara*		*Comayagua*	
	All farms	*Single-parcel farms*	*All farms*	*Single-parcel farms*
Terraces				
Percent of farm planted to coffee	-2.4	..	..	3.5
Education of owner	..	2.2	1.9	..
Number of persons in household	..	-3.4	-2.6	..
Windbreaks				
Percent of farm planted to coffee	-2.4	-2.9	..	3.9
Inheritance	-2.6	-2.9	..	..
Total land	..	-2.5	..	..
Title	..	..	2.2	..

.. Not significant.

notion that improved farming practices are associated with higher levels of education.

The negative relationship between terracing and household size suggests that in larger families, resources may be shifted toward maintaining the family rather than improving the farm. This result is difficult to interpret without additional information. Accounts of small-farmer agriculture in Latin America often stress the positive contribution that family labor makes to production and accumulation. On the one hand, this result could be interpreted, at least superficially, as a case in which that contribution might be undermined by the cost of supporting the family. On the other hand, the result could indicate circumstances in which labor is preferred to capital. Some of the perceived need to make infrastructural investments may be lessened by the availability of family labor. This hypothesis is consistent with the notion that farmers with insecure property rights may be more willing to substitute labor for capital.

In the Comayagua sample of all coffee growers, only the percentage of coffee was a predictor of terraces. In this case, though, the effect was positive, which is consonant with the original hypotheses but contradicts the results found in Santa Barbara. One of the limitations of the data is that no systematic accounting of the difference between the two regions could be used to account for the observed differences in investment behavior.

The second specific improvement used as the dependent variable in the probit model is that of tree windbreaks, an improvement that is also potentially valuable for soil conservation and plant protection. This improvement was rarely encountered in both regions.[9] In the cohort of all coffee growers in the Santa Barbara survey, the variable for the percentage of coffee on the survey parcel was a significant, negative predictor, as was the dummy for acquisition through inheritance. One explanation for this result might be that inheritors value their land less than purchasers do. An alternative explanation could be that purchasers of land tend to have more savings to begin with than inheritors and thus are more able to pay for the materials and labor involved in constructing windbreaks.

In the single-parcel subgroup, this estimation showed negative coefficients for the percentage of land planted to coffee and for the total landholding of the grower. Again, these results run counter to expectations. The persistent negative sign on the percentage of coffee suggests that the methodological problem is probably not affecting the results. The fact that total landholding was also a negative predictor of the probability of a parcel having windbreaks may indicate that larger parcels require more attention and labor for basic productive activities, leaving less time and money to invest in windbreaks.

Again, the Comayagua results are at odds with those from Santa Barbara. In the Comayagua cohort of all coffee farmers, the percentage of land in coffee was the only significant predictor of the probability of having windbreaks, but the effect was positive as originally hypothesized.

Shading practices

The next group of dependent variables tested concerns changes to different shading practices. Bush and tree shading involves planting new bushes and trees, while forest shading refers to the intermixing of coffee plants in an already forested area. In all cases, the changes refer to practices needed by traditional coffee planting. The intensive, high-yield varieties are grown without shade. The statistically significant predictor variables are summarized in table 15-14. Title is significantly associated with the change to bush shading.

The negative signs of the titling variable in forest shading and the total land variables in bush and tree shading may be indirect evidence that growers with larger farms or with secure title are moving away from the traditional varieties of shade-grown coffee and toward varieties grown in full sun.

Physical structures

Improvements to the physical structure for processing and storing coffee or grains constitute the third group studied. These improvements include concrete patios for drying coffee, storage buildings, and coffee fermentation tanks. The statistically significant predictor variables are summarized in table 15-15.

The concrete patio is one of the more common improvements found in both regions and is a component in a basic system of first-stage processing and storage of coffee. The positive sign on the title status variable and the negative sign on the acquisition through squatting dummy

Table 15-14. Significant t-Statistics for Coffee Farms with Changes in Shading Practices in Comayagua and Santa Barbara, Honduras

Structure and variable	*Santa Barbara*		*Comayagua*	
	All farms	*Single-parcel farms*	*All farms*	*Single-parcel farms*
Bush shading				
Total land	-2.0	..	..	..
Inheritance	-3.5	-3.0	-2.1	..
Off-farm income	..	..	..	-2.4
Title	..	3.5	..	..
Tree shading				
Total land	-2.0	..	..	..
Off-farm income	..	..	..	-2.5
Forest shading				
Percent of farm planted to coffee	-3.7	-3.3	..	2.6
Title	..	..	-2.5	-2.8

.. Not significant.

Table 15-15. Significant t-Statistics for Coffee Farms with Physical Structures in Comayagua and Santa Barbara, Honduras

Structure and variable	*Santa Barbara*		*Comayagua*	
	All farms	*Single-parcel farms*	*All farms*	*Single-parcel farms*
Concrete patio				
Percent of farm planted to coffee	-3.3	-2.9	4.2	..
Years of ownership	..	2.5	..	..
Title	2.9	3.0	..	..
Inheritance	-3.7	-2.6	..	..
Squatting	-3.4	-2.5	..	..
Number of persons in household	..	-2.8	..	..
Storage building				
Percent of farm planted to coffee	-3.8	-3.0	4.9	..
Inheritance	-2.5	..	-2.1	..
Squatting	-2.0	..	..	..
Number of persons in household	-3.0	..	..	..
Off-farm income	..	..	2.3	..
Credit	..	..	-2.0	..
Total land	..	..	2.6	..
Title	..	..	2.3	..
Grain storage bin				
Percent of farm planted to coffee	-2.6	..	4.7	..
Number of persons in household	-3.2	-2.6	-2.5	..
Title	..	2.1	..	..
Fermentation tank				
Inheritance	-3.0	..	..	..
Squatting	-2.9	-2.1	..	..
Number of persons in household	-5.0	-4.4	..	..
Total land	..	2.4	..	..
Percent of farm planted to coffee	..	..	3.5	..
Years of ownership	..	..	..	-2.9

.. Not significant.

variable are consistent with the hypothesis that growers who have the most tenuous claims on their land are unlikely to invest in improvements beyond the basic investment in the coffee trees themselves.

In the single-parcel cohort, the results are in accordance with those for the large sample of all coffee growers. The significance of title reinforces the hypothesis that title is important to coffee-specific investments.

In the Comayagua observation for all coffee farmers, the percentage of the parcel planted to coffee was the only significant predictor of concrete patios, again reinforcing the idea that the model does not account for a hidden variable distinguishing Comayagua and Santa Barbara.

The second physical structure considered is the *bodega* or storage building. In this case, the positive coefficient on the off-farm income variable is consistent with the hypothesis that higher off-farm income may free cash to invest in improvements. Why this result is particular to storage buildings is not clear.

Among the multiple-parcel coffee growers in Comayagua, the results are mixed. Although generally consistent with prior hypotheses, the negative relationship with credit is somewhat contradictory and casts doubt on any clear-cut relationship between security of tenure, credit, and investment in permanent structures.

The third improvement examined is the grain storage facility—a silo or bin of any sort. Again the title variable proved to be a positive predictor of the investment in Santa Barbara, while the number of persons in the household proved to be a negative one. This is an interesting variable to consider when examining the possibility of substituting labor for capital investments. It seems unlikely that benefits similar to those of a grain storage facility could be obtained by a substitution of labor. In this case, the negative relationship between household size and physical improvements suggests that it may be plausible to investigate whether the additional consumption in larger households reduces infrastructural investment, all things being equal.

The last physical structure considered is the coffee fermentation tank or *pila*. The results are similar to those obtained for the other physical structures and again reinforce the observation that methods of land acquisition other than purchase are associated negatively with investment in physical structures. Also the finding that total landholding is positive only for the investments in physical structures, where the average cost of a single structure is lower for larger operations, supports the hypothesis that certain "lumpy" investments are more economical for larger farms.

New coffee trees

The third indicator of investment—the number of new coffee trees planted between the initial and the follow-up interviews—was specified as the dependent variable in a tobit model with the same independent variables used in the probit models. The results are summarized in table 15-16.

These results lend further support to those obtained for physical structures, although they provide little support for either of the potentially competing hypotheses proposed to explain the negative relationship between household size and investment. Also, the title dummy is not a significant predictor. This is consistent with the observation that all of these farmers had, by definition, already made some investment in coffee plants before the titling process began. These data underscore the difficulty of attempting to describe a simple relationship between having a formal government title and making an investment.

Table 15-16. Significant t-Statistics for Coffee Farms with New Coffee Trees in Comayagua and Santa Barbara, Honduras

Structure and variable	*Santa Barbara*		*Comayagua*	
	All farms	*Single-parcel farms*	*All farms*	*Single-parcel farms*
Squatting	-2.3	..	..	..
Number of persons in household	-2.9	-2.3	..	..

.. Not significant.

Conclusions

Although it should be stressed again that this analysis is intended to be exploratory and suggestive rather than definitive, several general conclusions are apparent. First, the association of title with improvements at the broadest level (any improvement at all) indicates either that owners of titled parcels are making more improvements on their land or that owners are making improvements and then pursuing title to protect their land, to use it for collateral, or to facilitate its sale. Both interpretations are consistent with the objectives of the titling program. The strength of the association generally disappears, however, in the estimations for specific improvements. When it is a significant predictor, it is consistently positive.[10]

The second most consistent result seems to be the negative association between acquisition of the parcel through means other than purchase with subsequent investment. Of course, this finding cannot be reduced simply to a land tenure argument. It would be important to know if characteristics omitted from the present analysis also distinguish growers who did not purchase their land. Squatters may also be displaced and poor, which would diminish their tendency to invest.

A third interesting and potentially important result is the generally negative impact of family size and off-farm income and improvements. Both of these variables have to do with the allocation of resources within the household system. On the one hand, if the family's contribution of labor to capitalization in the farming operation is offset by its consumption needs, then the notion that the Honduran small-farm coffee sector will consolidate itself on the basis of a household supply of labor may be mistaken. On the other hand, if capital investments can be replaced by family (or wage) labor, low levels of capital investment beyond the coffee plantings themselves may pose no obstacle to accumulation. This issue deserves additional empirical attention.

The apparently contradictory results obtained for the variable of the percentage of parcel planted to coffee suggest that a difference exists between growers in the two regions. This is one reason that the two regions were handled separately throughout the analysis. Although the difference remains a question for those interested in the regional variation among coffee growers in Honduras, the results obtained for the tenure variables are generally consistent across both regions.

The analysis of soil conservation investments is limited by the lack of specific indicators of soil quality or erosion and by the few conservation variables included in the analysis. Nevertheless, it is valuable to look at conservation investments in the context of a variety of investments. The most salient observation of the analysis is the descriptive fact that improvements such as terraces and windbreaks were very rarely encountered in the survey. Although the data provide evidence that is admittedly preliminary and sometimes contradictory, they also provide some support for the connection between level of education and conservation practices and a strong indication that larger households are less likely to have engaged in soil conservation improvements in Honduras. The results suggest some of the issues important for modeling investment behavior on small coffee farms and several areas where competing hypotheses require further testing before policy implications can be drawn.

Notes

1. The author would like to thank David Stanfield, Nancy Forster, and Brad Barham at the University of Wisconsin-Madison and Daniel Wachter, Stefano Pagiola, and Ernst Lutz of the World Bank for their comments and suggestions on earlier drafts. All remaining errors of fact or interpretation are his own.
2. The impact of conservation practices on yields varies considerably with soil conditions and slopes and topology. Quantitative data on the impact that conservation practices have on coffee yields are scarce, but anecdotal evidence from farmers and extension workers in Honduras suggests that in the absence of conservation practices, some coffee plantings take longer to reach full production (which usually occurs at three years) and have a shorter period of peak commercial production. Some areas, particularly in southern Honduras, have been eroded so much that they have been abandoned for coffee growing. The Santa Barbara and Comayagua study areas tend to have relatively stable soils, and farmers and extension agents apparently consider erosion to be a long-term concern

rather than an imminent danger. Valencia (1989, pp. 54–62) reports that the effects of runoff, leaching, and chemical fertilizers on soil have caused serious losses to coffee's productivity. Pudgiharta and Pramono (1988, pp. 1–8) report surface runoff of 0.64 percent and soil erosion of 0.03 ton per hectare a year on a coffee plantation with 20 percent slopes.

3. Although in this discussion, it is only possible to indicate the nature of the tradeoffs between imported inputs and capital investments, their quantitative measure is an important issue that merits a full analytic treatment.
4. High-yield varieties of coffee metabolize soil nutrients at a much faster rate than "traditional" varieties. This is mostly because they are grown in full sun, which permits more rapid photosynthesis.
5. See de Graaff and Dwiwarsito (1990). The authors found bench terracing the most financially sound conservation investment for slopes up to 30 percent in a mixed coffee and forest area. See also Bunch (1989).
6. The proposed Agricultural Modernization Law being debated in Honduras in early 1992 would drop the 5-hectare minimum for noncoffee holders to be eligible for title. It would also drop the provision requiring the National Agrarian Institute to approve the sale or transfer of family agricultural unit parcels.
7. The contribution of nonwage labor can be thought of as equivalent to the opportunity wage. If the opportunity wage approaches zero, however, as it may for certain individuals at various times of the year in the coffee-growing regions, family labor can be considered "costless" compared with other factors. This does not imply that family labor is free or "cheap" because returns from the farm are in some fashion captured by nonwage family laborers. Furthermore, the marginal contribution of family labor must be compared with the marginal benefit of paid labor to ascertain the "shadow" price of family labor.
8. Not all growers need terraces, even if they can afford them. For this reason, strong associations with particular variables were not predicted in the absence of a measure of susceptibility to erosion that could provide a way of controlling for the relative necessity of terracing.
9. Again, not everybody needs windbreaks. A limitation of the data set used is that no measure was available for soil loss or runoff.
10. The exception in forest shading practices is plausible because titled farmers could presumably feel more secure in changing to more intensive systems of coffee production.

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16. Adoption of Soil Conservation in Tierra Blanca, Costa Rica

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In recent years, the northern zone of Cartago has experienced very high rates of erosion, leading the Costa Rican government to declare it an emergency area (Cortés and Oconitrillo 1987b; Bronzoni and Villalobos 1989). This rapid erosion is the result of the area's conversion to horticultural production. Prior to 1978, only 15 percent of the area was devoted to horticulture; in this period, soil losses were acceptable, around 12 metric tons per hectare a year. By the end of the 1980s, however, horticulture had become the main activity, occupying 81 percent of the area (Villalobos 1988), and soil loss had reached an estimated rate of between 50 and 200 metric tons per hectare a year. The recent installation of a sprinkler irrigation system covering 60 hectares is likely to intensify land use and, consequently, worsen erosion even further.

In addition to concern over the possible effects of erosion on agricultural activity, which occupies 78 percent of the economically active population in the area, there is also concern over sedimentation of the Cachí reservoir, which lies downstream. Northern Cartago, and especially the watershed of the Reventado River, is a major source of sediment for this reservoir. These problems have resulted in considerable interest among producers, national institutions such as Servicio Nacional de Conservación de Suelo y de Agua (SENACSA), Servicio Nacional de Aguas Subterráneas Riego y Avenamiento (SENARA), and Instituto Costarricense de Electricidad (ICE), and community associations such as Coopetierrablanca in confronting the problem of soil degradation.

The northern part of Cartago has been the site of conservation programs, beginning in 1942 with work carried out by the Instituto de Asuntos Interamericanos as part of a vegetable supply program for the U.S. Army stationed in Panama. In 1948, the Servicio Técnico Interamericano de Cooperación Agrícola and the Servicio de Extensión de Costa Rica began a joint program that lasted eight years. Other programs include the Civil Defense, which operated after the eruption of Irazú volcano from 1963 to 1965, and a program of the Food and Agriculture Organization of the United Nations, which operated in 1986. At the present time, however, no permanent program for technical assistance in soil conservation exists in the area.

This chapter reports on research carried out in the area influenced by a pilot irrigation project executed by SENARA in the upper watershed of the Reventado River in Tierra Blanca, Cartago. That study attempted to identify the reasons why conservation works have a low level of adoption in the area and proposed alternative solutions that would help achieve sustainable horticultural production. Its goal was to reduce water erosion to the permissible level—12 to 20 metric tons per hectare a year—taking into consideration the socioeconomic, cultural, and agricultural conditions faced by farmers.

Methodology

The study began with a rapid appraisal of the rural area carried out by a team of agronomists and sociologists. Forty-seven farmers in the area of the SENARA project in Tierra Blanca were visited. For each farmer, information was collected on the dominant production systems, on the characteristics (altitude, location, and average slope) of their plots, and on the type of erosion predominant in the area. Discussions with farmers sought to understand the problems limiting their production systems. Two questionnaires asked them about the socioeconomic, cultural, and agricultural aspects of their farms: a Rapid Rural Appraisal was conducted to gather qualitative data, while a questionnaire was used to gather quantitative data from a subsample of farmers stratified by farm size.

The data obtained were analyzed using the Statistical Analysis System statistics program. Two indexes were developed: the first measured the rate at which individual farmers adopted the soil conservation package recommended by SENACSA for the area (MAG/FAO 1989), while the second measured the total adoption rate of the recommended package. Each index ranged between 0.0 (no adoption) and 1.0 (complete adoption). Index values below 0.3 were considered low, between 0.3 and 0.5 average, and above 0.5 high (Rodríguez 1984; Gómez 1988; Gorbitz 1975).

The main problems limiting horticulture in the zone were identified during the interviews with farmers and technicians, and these were prioritized into a list of the five problems that farmers considered to be most important. The causes of these problems were identified and possible solutions discussed at a workshop attended by farmers and soil conservation technicians. The alternatives were evaluated according to their effectiveness, the ability of farmers and technicians to understand them, their compatibility with dominant production systems, their risk, and the institutional support required for their implementation. Possible topics of research were suggested by the problems for which no causes or possible alternative solutions were identified.

Description of the study area

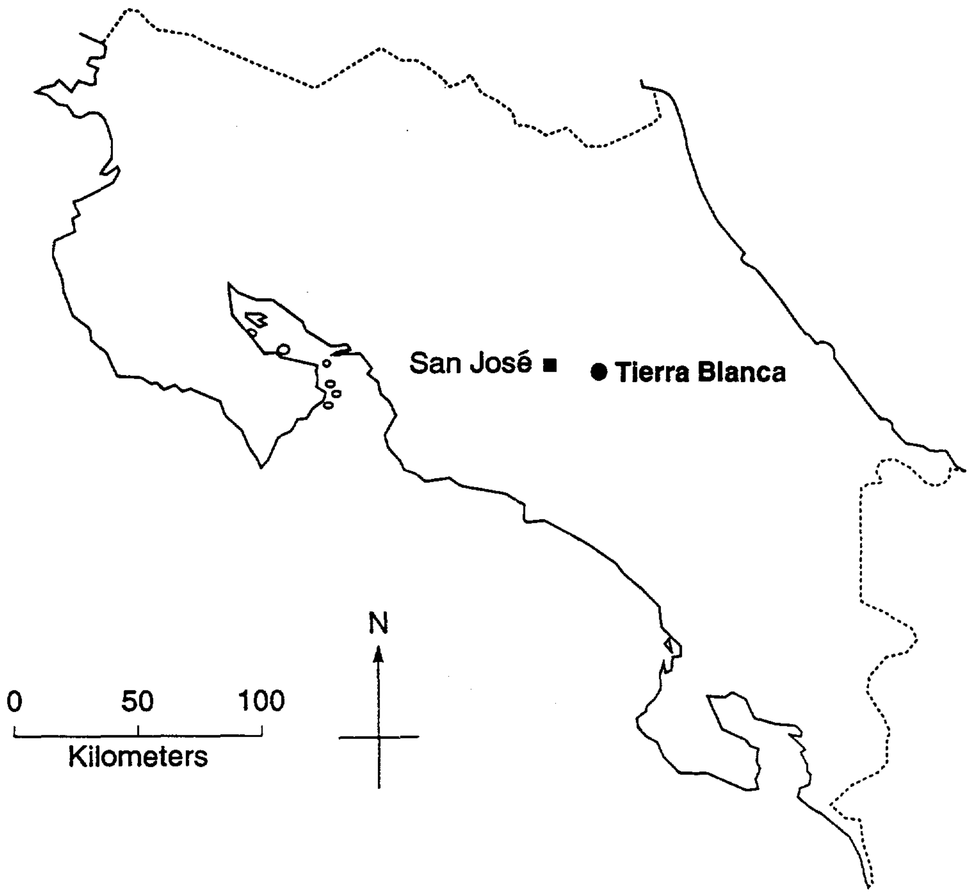
The study area covers 60 hectares in the upper watershed of the Reventado River and is located at an altitude of 2,200 to 2,400 meters above sea level (see figure 16-1). The climate is lower montane wet forest, according to the Holdridge life zone classification system. Average annual precipitation is 1,513 millimeters, with a potential evapotranspiration of 1,228 millimeters. The driest months are from December to April. The predominant soils are Dystrandepts of volcanic origin. These soils are deep (more than 90 centimeters), highly fertile, and very susceptible to erosion. The topography is moderately undulating. The average slope of the soil is 13 percent, with a range of 2 to 70 percent. One-third of the land has slopes greater than 15 percent, while a further 43 percent has slopes between 8 and 15 percent. The remainder of the area lies on slopes of less than 8 percent. The average plot size is 1.1 hectare, with a range of 0.2–2.9 hectares. The area has a good natural drainage system composed of the Sanatorio Stream and the Reventado River.

All farmers in Tierra Blanca have access to a sprinkler irrigation system and can produce crops year-round; the first crop cycle begins in May and the second in October. The main activity is horticulture, and the main crops produced are potatoes, onions, and carrots. Typical crop sequences include potatoes-onions, potatoes-carrots, or onions-carrots.

Machinery is used considerably during cultivation, particularly for land preparation; for example, 70 percent of farmers in the study area use tractors for plowing. Agricultural machinery is rented either from Coopetierrablanca or from other farmers. Chemical inputs are also used heavily; one to three applications of herbicides (using a hand-pressurized pump) are typically performed in addition to one or two weedings during each crop cycle. Large doses of fertilizer are also applied, often far in excess of the recommended rates; applications of phosphorus, for example, are ten times greater than recommended. Inputs are obtained from the cooperative or from commercial suppliers. All crops are harvested manually, four to five months after planting. Most crops are sold through middlemen. Prices often vary considerably; potato prices varied 56 percent during 1991, as did onion prices.

Tierra Blanca is a stable community with almost no outmigration. All farmers in the project area own the plots they cultivate, either directly or through a family member; 70 percent have some primary education; 61 percent are less

Figure 16-1. Costa Rica: Location of the Tierra Blanca Study Site



than forty years old. All belong to the Junta de Usuarios del Proyecto de Riego (the union of users of the irrigation project), which administers the sprinkler irrigation system under the supervision of SENARA.

Soil degradation

The northern zone of Cartago has been declared an area of emergency because it registers such a high rate of wind and water erosion. Soil loss through wind erosion has not been measured, but gross soil losses exceeding 100 metric tons per hectare a year have been measured on plots with runoff water (Cortés and Oconitrillo 1987a). Not all this soil is lost to agriculture, however, since some is deposited on fields in the lower parts of the watershed. Considerable quantities of soil do eventually leave the watershed, however, suspended in the Reventado River or airborne; much ends up in the Cachí reservoir in Cartago. Sediment delivery to the reservoir has not yet been quantified, but the Instituto Costarricense de Electricidad is presently carrying out studies for this purpose (Ing. Alexis Rodríguez, personal communication).

These high rates of degradation have several causes, chief among which are the intensity and inappropriateness of land use in the area. According to the U.S. Department of Agriculture land classification methodology, lands in class III, with slopes between 8 and 15 percent, require soil conservation works, while lands in class IV, with slopes above 15 percent, should not be planted to annual crops (MAG/FAO 1989). According to this classification, 76 percent of the soils in the area (45.5 hectares) are overused, since vegetables are cultivated on slopes above 8 percent without any special conservation works.

Farmers employ specific practices that contribute to degradation. For example, 58 percent of the farmers who use tractors plow up and down the slope, and conservationist plowing (plowing along the contour) is practically nonexistent. This is a result of using tractors to prepare the soil, since they run the risk of turning over on slopes that exceed 15 percent. The dominant shape of fields—rectangular with the long edge parallel to the slope—also limits the possibility of preparing land along the contour. Most farmers (82 percent) prepare the soil using at least two methods (cutting with a plow and cross) before planting; all break up the soil with a rotary tiller, which allows the soil to be easily washed away by water and blown away by the wind. The use of heavy machinery also compacts the soil, which decreases water infiltration, and leaves the surface with little rugosity and with small furrows along the slope, thus contributing to water erosion as well.

The effect of soil erosion on yields has not been quantified: 46 percent of the farmers interviewed did not notice any decrease in yields, probably thanks to the deep, fertile soils found in the area. However, 52 percent indicated that although yields remained the same, they had to increase the amount of fertilizer applied. This may indicate the progressive loss of soil productivity due to the effect of erosion.

A distinct but equally worrisome environmental effect of the highly intensive land use practices in the region is the high incidence of pests and diseases, which are becoming a serious problem. Uninterrupted plantings of crops such as potatoes, onions, and carrots attract numerous pests and diseases. Unfortunately, excessive use of pesticides means that many of the pests and diseases endemic to the zone have developed resistance to the chemicals used.

Soil conservation practices

Despite the high level of concern over soil erosion, the institutions responsible for managing natural resources have yet to undertake any concrete program for confronting the problem in the region. Some efforts are under way, but they are isolated. For example, SENACSA is installing demonstration plots on some farms but does not have a concrete program or sufficient technical personnel. Only 24 percent of the farmers interviewed had received any technical assistance in soil conservation, and none had received hands-on demonstrations.

Given the characteristics of the area's soil, relief, and climate, SENACSA recommends eighteen kinds of conservation structures and practices (MAG/FAO 1989). The two primary types of soil conservation structures used in Tierra Blanca are hillside ditches (79 percent of farmers) and drains (94 percent). No terraces were observed in the study area. Two types of soil conservation practices can be distinguished: protective plantings such as windbreaks and agricultural practices such as crop rotation and conservationist plowing. Farmers used four of the practices recommended for the area: crop rotation (90 percent of farmers), planting along the contour (90 percent), application of green fertilizer (12 percent), and live barriers (3 percent).

Data from the farmer interviews were used to evaluate the rates at which farmers adopted the technical soil conservation package. The index of adoption rate of the recommendations varied between from 5.6 and 33.3 percent, while the index of total adoption rates was 24.5 percent, both of which are considered low (Gorbitz 1975; Gómez 1988). An ANOVA of the index of adoption rate with other variables showed that adoption was not significantly affected by the farmer's education or by whether family or contract labor was used. Adoption rates were found to be significantly higher, at the 10 percent level, if manual labor was used for conservation. When stratified by plot size, adoption rates tended to increase with land area.

In addition, the conservation structures and practices that had been implemented do not fulfill the technical specifications for highly efficient control of water erosion. Numerous design problems were observed. Hillside ditches, for example, were not permanent; 64 percent of farmers eliminated them after each crop cycle. Moreover, ditches were built on slopes exceeding the recommended range, and spacing between successive ditches was too great (Michaelsen 1980; FAO 1986). Drains were constructed without protective structures to dissipate energy. The single case of live barriers observed in the study area used species that give little cover and are short-lived, such as oats and wheat.

Despite the low rates of adoption of conservation measures, the majority of farmers interviewed felt that soil conservation was vital for maintaining crop productivity. Practically all advocated the establishment of demonstration plots, and 90 percent indicated that they might be willing to supply an area of their small farms for this purpose, showing interest in a permanent soil conservation program.

Two major reasons seem to explain the low rates of adoption. First, many of the recommended works and practices had not been tried in the area, so their benefits had not been demonstrated. The region's farmers are business-oriented and reluctant to take risks. For proposed technical changes to be accepted, their effect on yields and on farm income must be proven.

Perhaps most important, however, is that most of the recommended conservation practices were not compatible with the predominant system of production. Plowing along the contour on the area's high slopes will only be made possible by the introduction of small machinery or oxen.

Conclusions and recommendations

Until such changes in machinery become possible, the degradation problem could be alleviated by improving the efficiency and promoting the widespread adoption of the simple practices of soil conservation already being implemented by farmers. Such improvements would probably be possible if technical assistance, training, and demonstration plots were made available to farmers.

Based on the results of the study and the farmer-technician workshop, a project for managing the upper watershed of the Reventado River is now being formulated. A package of ten conservation works and practices is being recommended, based on structures currently in use and simple agricultural practices such as the use of green fertilizer and crop associations.

Note

1. This chapter is a short version of the author's master's thesis (Melo 1991). The author is grateful for the collaboration of CATIE, SENARA, SENACSA, the cooperative of Tierra Blanca (Coopetierrablanca), and especially to the Junta de Usuarios del Proyecto de Riego del SENARA. The author is also thankful to Fernando Ferrán, Jorge Faustino, Carlos Rivas, and Carlos Reiche for their valuable comments and discussions.

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17. Factors Affecting Land Use and Soil Management Practices in El Salvador

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Issues of appropriate land use have increasingly become the focus of research on environmental sustainability (Daly and Cobb 1989; Repetto and others 1989). At the heart of this perspective is the view that if economic development is to be sustainable, the ecological systems on which economic production ultimately relies must also be preserved (Tisdell 1988; Repetto and others 1989; Lutz and Daly 1990). Despite the ongoing debate about what this means in practical terms (Conway 1983, 1985; Tisdell 1988; Solórzano and others 1991), there is little doubt that land use patterns in El Salvador are straining the environment. This chapter examines the factors affecting land use and soil management in El Salvador.

The list of factors that influence agricultural conditions and practices is long and varied (Harriss 1982). This chapter focuses on two factors that play significant roles in shaping the elements of agricultural practices and conditions in El Salvador: size of holding and form of tenure. Size of holding is based on the total area under a given producer's control. For purposes of the present study, tenure is defined as the legal terms by which an agricultural producer actually working a piece of land has access to it. Four categories of tenure are used here: (a) owner; (b) renter; (c) beneficiary of Decree 207 (individual producers working plots they received through Decree 207, phase III of the agrarian reform); and (d) member of a reform cooperative (farms formed and worked collectively as a result of phase I of the agrarian reform). In some cases, owners and renters who are working land not provided to them as a result of the agrarian reform are referred to collectively as the nonreform sector; beneficiaries of Decree 207 and members of reform cooperatives are referred to collectively as the reform sector.

Although this study provides important insights into the parameters of the relationship between agriculture and the environment, it cannot directly measure the impact of agricultural conditions and practices on the environment. Therefore, this chapter does not examine specific elements of cost and productivity or actual amounts of soil and nutrient loss. Such information is not available, either in the current data set or from other sources.

The data

The present study is based on four data sets, compiled separately between 1987 and 1989, that form a composite of agriculture in El Salvador:

- The third census of the agrarian reform cooperatives (PERA 1987)
- The 1987 survey of beneficiaries of Decree 207 (PERA 1988a)
- The 1988 El Salvador agricultural land ownership and land use survey (Gore, McReynolds, and Johnston 1988)
- The 1989 El Salvador small renter survey (McReynolds and others 1989).

A framework was created to integrate these data sets so that they could be used in aggregate form as a substitute for an agricultural census. The ultimate goal in combining them was to achieve the highest possible degree of comparability with the 1971 agricultural census.

The composite data set resulting from these sources is comprehensive and powerful. Nevertheless, certain considerations should be borne in mind. First, the component data sets were collected independently, without the goal of compatibility. In some cases, this caused difficulties in constructing aggregate variables, sometimes precluding certain data from being used. Second, the scope of the surveys was extensive rather than intensive. The objective of each survey was to gather broad information on a category of producers, rather than to collect highly focused data on specific practices or conditions. The aggregate data base, therefore, touches on a wide range of topics without providing intensive depth on any one. In particular, the data only indicate whether a given producer does or does not use certain practices; no information was available on intensity of use.

Land use

Several noteworthy changes in land use occurred in El Salvador between 1971 and 1988 (Gore, McReynolds, and Johnston 1988). Fallow land—land not cultivated but suitable for cultivation—almost doubled, rising to 14 percent of all agricultural land. More than half of the increase can be accounted for by a more than 10 percent decrease in total pastureland during this period (McReynolds and others 1989). A drop in cotton hectarage, from 64,000 to 12,000 hectares, and a 20 percent decline in the amount of land in infrastructure and other unclassified uses also explain some of the increase in idle land. Large-scale cattle operations and cotton cultivation were both affected by the years of the civil conflict (Wise 1986; Liévano and Norton 1988) and by the global decrease in commodity prices and the declining terms of trade for El Salvador during the 1980s (Liévano and Norton 1988). Although an increase in fallow land would appear to be beneficial from an environmental standpoint, it must be viewed as a temporary, war-related phenomenon. Moreover, it has been accompanied by intensified production on some existing agricultural lands and the use of marginal, previously unused lands.

Despite the growth in fallow land, total cultivated land increased 41,000 hectares between 1971 and 1988. In part, the expansion in cultivated land can be explained by the increase in the total amount of land in agriculture. Many of these lands had previously been defined as unusable for agriculture or had not been in agricultural use. For example, an additional 17,000 hectares in cultivation came from forest or mountainous terrain. This suggests that some Salvadoran farmers have been forced to cultivate land that had previously been considered unfit for agriculture and that is, therefore, likely to be only marginally productive and vulnerable to degradation. This would support the hypothesis that the poor distribution of resources contributes to environmental degradation (Durham 1979).

The proportion of land allocated to each of the major categories of land use—and particularly the amount of land in cultivation—differs significantly by size of holding (see table 17-1). Producers with less than 2 hectares use 71 percent of their land for crops compared with a national average of 39 percent, while farmers holding 20 to 50 hectares cultivate only 29 percent of their land. The reverse is true for pastureland: farmers cultivating 20 to 50 hectares have the highest share, 45 percent, of their land in pasture, while the smallest producers devote less than 7 percent to such use; the national average is 33 percent. Every size group but the smallest has more than 12 percent of its land idle. The highest portion of fallow land, 20 percent, is held by farmers with 100 to 200 hectares. Combined, producers with over 100 hectares account for more than one-third of all idle land. Similarly, the largest farmers have the greatest share of land in forest, while farmers with 2 to 5 hectares have the lowest.

Among small producers, land use also varies significantly across tenure groups (see table 17-2). Beneficiaries of Decree 207 cultivate the largest share of their land (93 percent) and have the smallest in pasture (5 percent). Owners, on the other hand, cultivate the smallest share of their land (51 percent) and maintain the most in pasture (18 percent). In both categories, renters more closely parallel the reform farmers. Given the nature of renting, it is not surprising that these producers leave so little land idle. It is surprising, however, that they have the largest share of their land in forest, 4 percent compared with an average of less than 3 percent among all small producers.

Table 17-1. Land Use in El Salvador, by Size of the Producer's Holding
(percent)

Size of holding (hectares)	*Cultivated*	*Pasture*	*Forest*	*Not used*	*Not usable*	*Infrastructure*	*Total*
0.0–1.9							
Row	71.0	6.5	3.2	5.7	1.9	11.7	100.0
Column	18.3	2.0	6.2	4.2	4.0	29.9	10.1
2.0–4.9							
Row	56.1	21.6	2.5	12.2	3.3	4.2	100.0
Column	13.8	6.3	4.6	8.3	6.6	10.0	9.6
5.0–19.9							
Row	31.7	42.6	3.4	14.2	4.9	3.2	100.0
Column	17.2	27.4	13.7	21.4	21.7	16.8	21.1
20.0–49.9							
Row	28.7	44.9	4.7	12.7	6.8	2.2	100.0
Column	13.8	25.7	16.8	17.0	26.9	10.4	18.8
50.0–99.9							
Row	37.2	34.7	4.0	16.6	5.0	2.5	100.0
Column	11.4	12.5	9.1	14.1	12.5	7.5	11.9
100.0–199.9							
Row	33.0	35.7	4.8	19.6	4.2	2.7	100.0
Column	8.4	10.7	8.9	13.8	8.7	6.8	9.9
200.0 and up							
Row	36.0	27.4	11.5	16.0	5.1	4.0	100.0
Column	17.1	15.4	40.7	21.2	19.6	18.6	18.6
All producers							
Row	39.0	33.0	5.2	14.0	4.8	4.0	100.0
Column	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Land use also varies significantly across tenure groups among large producers (table 17-2). Cooperatives have the highest share of land in crops (43 percent) and forests (13 percent) and the lowest in pasture (24 percent) and left idle (10 percent). Owners, on the other hand, have the least cultivated (32 percent) and the most idle (21 percent). Renters have the highest allotment of pasture (37 percent). The high pasture rate for renters is corroborated by higher average numbers of livestock per hectare for renters than for owners.

Although small producers use their land more intensively and thus, potentially, in the least sustainable manner, two important qualifications should be borne in mind. First, as noted by Thiesenhusen (1989), small producers are often blamed for ecological destruction when they are, in fact, the victims of the poor distribution of land and other forces beyond their control. Their limited amount of land, capital, and technical assistance are all inducements to overexploit the land. Second, although larger holders have more fallow land—in both relative and absolute senses—the reality is that larger holdings are generally higher quality and therefore capable of producing greater yields. Large landholders have the luxury of keeping more land out of production.

Another important land use issue is the distribution of crop types. As Tisdell (1988), Thiesenhusen (1989), and Lutz and Daly (1990) have argued, different types of crops have different environmental impacts. In particular, annual crops, including basic grains, have a much greater potential for causing serious erosion than perennial crops.[2] Nontraditional crops are also important because they provide both genetic diversity and economic stability by expanding the options for producers facing mar-

Table 17-2. Land Use in El Salvador, by Size of the Producer's Holding and Form of Tenure
(percent)

Size of holding and form of tenure	*Cultivated*	*Pasture*	*Forest*	*Not used*	*Not usable*	*Infrastructure*	*Total*
Producers with less than 5 hectares							
Owners							
Row	50.6	17.5	3.5	13.0	3.7	11.7	100.0
Column	54.6	85.5	84.1	95.5	96.3	92.8	68.0
Renters							
Row	84.0	9.3	4.4	0.4	0.9	1.0	100.0
Column	13.8	6.9	15.9	0.5	0.9	1.2	10.4
Beneficiaries of Decree 207							
Row	92.8	4.9	0.0	0.0	0.0	6.0	100.0
Column	31.6	7.6	0.0	0.0	0.0	6.0	21.6
All small producers							
Row	63.1	13.9	2.8	8.9	2.6	8.7	100.0
Column	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Producers with more than 50 hectares							
Owners							
Row	31.9	35.2	4.2	21.0	4.7	2.3	100.0
Column	56.9	71.0	41.0	78.4	61.3	45.7	63.7
Renters							
Row	39.4	36.8	2.4	13.9	4.2	3.2	100.0
Column	2.5	2.6	0.7	1.8	2.0	2.2	2.2
Reform cooperatives							
Row	42.5	24.4	13.1	9.9	5.2	4.9	100.0
Column	40.6	26.3	58.3	19.8	36.7	52.1	34.1
All large producers							
Row	35.6	31.6	7.6	17.1	4.9	3.2	100.0
Column	100.0	100.0	100.0	100.0	100.0	100.0	100.0

ket instability and potential crop failure (Altieri and Anderson 1986; Lipton and Longhurst 1989). For the purpose of examining their distribution, crops are divided into three groups: basic grains, export crops, and other crops. Basic grains include corn, beans, rice, and sorghum; export crops include coffee, cotton, and sugarcane; while other crops encompass many nontraditional crops such as watermelon, cantaloupes, okra, and sesame. Basic grains and traditional export crops account for over 90 percent of all cultivated land in the country. In 1971, export crops accounted for 43 percent of all cultivation, while basic grains and alternative crops accounted for 51 and 6 percent, respectively. The relative shares of each group were almost the same in 1988 (McReynolds and others 1989).

The proportion of land allocated to each type of crop in El Salvador varies significantly by size of holding (see table 17-3). Basic grains cover a much larger share of the land of small farmers than of larger ones, while the reverse is true for export corps. Producers with less than 2 hectares maintain 76 percent of their cultivated land in basic grains and only 15 percent in traditional export crops. Conversely, holders of 50 to 100 hectares put just 15 percent of their land in basic grains and dedicate over 80 percent to export crops. Overall, producers with holdings of 5 hectares or less plant more than half the total land area in basic grains in El Salvador, but just 14 percent of the land under export crops. Farmers with 100 or more hectares, on the other hand, account for only 8 percent of the land in basic grains but control over 36 percent of the land in export crops. The two groups planting the largest share of land in other crops are the smallest farmers (24 percent) and the largest (23 percent).

Cropping patterns also differ by tenure group (see table 17-4). Among farmers with less than 5 hectares, Decree 207 farmers plant the largest share of land to basic grains—94 percent—while renters and owners plant 80 and 59 percent, respectively. Conversely, owners have the most land under export crops, 28 percent, com-

Table 17-3. Type of Crops Grown in El Salvador, by Size of the Producer's Holding
(percent)

Size of holding (hectares)	*Basic grains*	*Export crops*	*Other crops*	*Total*
0.0–1.9				
Row	76.3	14.5	9.3	100.0
Column	34.5	7.6	23.5	9.3
2.0–4.9				
Row	70.8	18.4	10.8	100.0
Column	20.0	6.0	17.1	9.6
5.0–19.9				
Row	67.9	24.1	8.0	100.0
Column	24.0	10.0	16.0	21.1
20.0–49.9				
Row	36.1	59.4	4.5	100.0
Column	10.1	19.4	7.1	18.9
50.0–99.9				
Row	14.6	80.2	5.2	100.0
Column	3.4	21.6	6.7	11.9
100.0–199.9				
Row	17.5	75.6	6.8	100.0
Column	2.9	14.7	6.4	9.9
200.0 and up				
Row	18.6	66.1	15.3	100.0
Column	5.0	20.7	23.1	18.6
All producers				
Row	49.1	42.2	8.7	100.0
Column	100.0	100.0	100.0	100.0

pared with 9 percent for renters and less than 1 percent for Decree 207 producers. Nonreform producers have more of their land under alternative crops than do reform producers, whose proportion of land planted to alternative crops increases as farm size increases: farmers in cooperatives with holdings over 5 hectares plant nearly one-fourth of their land to alternative crops. Even among smallholders, therefore, small amounts of additional land can make significant differences in patterns of use. This indicates that perhaps limited size, rather than form of tenure, is a key determinant of cropping patterns. Among large producers, cooperatives plant the largest share of land to basic grains, 18 percent, and renters the least, 7 percent. The overwhelming proportion of land is in export crops: renters devote 89 percent of their land to export crops and owners devote 80 percent, while cooperatives only plant 58 percent of their land to export crops.

Overall, reform cooperatives have the greatest diversity of crop types and are the most likely to plant alternative crops. The opposite is true for small beneficiaries of Decree 207, who are less likely than their nonreform counterparts to plant alternative crops. The dichotomous nature of cropping patterns within the reform sector reflects the intent of El Salvador's agrarian reform to preserve the export base of the large haciendas and the food provision role of the small parcels. In this respect, the near absence of export crops on Decree 207 beneficiary farms is consistent with the objectives of the reform.

Soil management

Preventing degradation in soil quality depends on the use of appropriate soil conservation techniques (Blaikie and Brookfield 1987). In this section, six measures of soil conservation are

Table 17-4. Type of Crops Grown in El Salvador, by Size of the Producer's Holding and Form of Tenure
(percent)

Size of holding and form of tenure	*Basic grains*	*Export crops*	*Other crops*	*Total*
Producers with less than 5 hectares				
Owner				
Row	59.4	28.2	12.4	100.0
Column	41.2	90.7	64.8	68.4
Renter				
Row	80.1	8.9	11.0	100.0
Column	15.1	7.7	15.6	10.4
Beneficiary of Decree 207				
Row	93.6	0.8	5.6	100.0
Column	43.7	1.6	19.6	21.1
All small producers				
Row	74.2	16.0	9.8	100.0
Column	100.0	100.0	100.0	100.0
Producers with more than 50 hectares				
Owner				
Row	15.2	79.7	5.1	100.0
Column	56.8	62.3	26.3	63.6
Renter				
Row	7.4	89.2	3.4	100.0
Column	4.8	12.0	3.0	2.3
Reform cooperatives				
Row	18.0	57.7	24.3	100.0
Column	38.4	25.7	70.7	34.1
All large producers				
Row	15.4	73.4	11.2	100.0
Column	100.0	100.0	100.0	100.0

analyzed: permanent plants, live barriers, dead barriers, improved drainage, borders, and terraces. Even though the available data do not permit measurement of the impact of these techniques, they do provide an understanding of the parameters of the problems and the extent of the need to alter practices. The figures for land area under conservation cited in this section are only an approximation, since they represent the sum of all land owned by farmers who practice a given soil conservation technique. Producers may not use that practice on all their land. In addition, the absence of data on soil conservation techniques used on the reform cooperatives and differences in data collected on Decree 207 beneficiaries prevent a full comparison of conservation measures adopted by different tenure groups.[3]

Over 26 percent of Salvadoran farmers consider their soil to be good, 58 percent consider their soil to be average, and 17 percent consider it to be poor.[4] Perception of soil quality is significantly related to size of holding. In general, larger landholders give their land higher ratings: over 31 percent of holders with 50 hectares or more classify their land positively, while only 24 percent of those with under 50 hectares do so. Holders of 2 or fewer hectares give their land the worst ratings. These evaluations offer subjective evidence in support of the comparative fertility advantage of larger farms in El Salvador. Perceptions of soil quality also vary across forms of tenure. The best overall ratings were found among renters—less than 1 percent deem their land to be poor. The important finding here is that less than one-fourth of the producers perceive their soil as good and that nearly one-third of Decree 207 beneficiaries classify their soil as poor. This supports the view that reform farmers may be saddled with poor soil, which might be a factor in increasing environmental degradation and social differentiation (Diskin 1989). It also may explain, in part, the high use of inputs among Decree 207 beneficiaries.

Live barriers—trees and hedgerows—are the most frequently used soil conservation tech-

Table 17-5. Use of Soil Conservation Techniques in El Salvador, by Size of the Producer's Holding and Type of Conservation
(percent of producers)

Size of holding (hectares)	*Permanent plants*	*Live barriers*	*Dead barriers*	*Improved drainage*	*Borders*	*Terraces*	*Total*[a]
0.0–1.9							
Row	6.9	14.5	9.8	3.6	4.4	1.3	16.4
Column	62.7	60.3	51.3	65.5	61.5	62.5	58.2
2.0–4.9							
Row	12.9	27.2	21.1	2.7	7.7	3.1	30.1
Column	22.7	21.9	21.4	12.7	11.9	12.1	20.6
5.0–19.9							
Row	6.6	18.8	23.3	4.3	8.4	2.0	26.7
Column	9.0	11.7	18.2	11.7	17.5	14.3	14.1
20.0–49.9							
Row	8.3	21.6	29.4	8.4	10.4	2.6	32.4
Column	3.2	3.7	6.4	6.4	6.0	5.2	4.7
50.0–99.9							
Row	14.2	36.0	33.4	10.8	11.0	7.4	38.7
Column	1.5	1.7	2.0	2.3	1.8	4.1	1.6
100.0–199.9							
Row	17.8	31.2	22.7	15.5	15.5	6.9	34.3
Column	0.8	0.5	0.6	1.4	1.1	1.6	0.6
200.0 and up							
Row	17.0	24.2	15.7	18.3	22.2	6.5	26.4
Column	0.1	0.2	0.2	0.1	0.2	0.2	0.2
All producers							
Row	7.8	17.0	13.3	3.8	5.7	1.8	20.1
Column	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a. The total reflects producers who used one or more of the techniques.

nique, followed by use of dead barriers—retention walls of dead organic matter such as logs (see table 17-5). Less than 10 percent of all farmers use permanent plants, improved drainage, or borders. Despite the mountainous terrain found in El Salvador, less than 2 percent of the producers employ terraces. Use of each of the six soil conservation techniques is significantly related to size of holding. With few exceptions, large producers are more likely to employ soil conservation techniques than are smaller farmers. Indeed, the smallest producers are the least likely to employ dead barriers, borders, and terraces and the second least likely to use the other three practices. Holders of 50 to 100 hectares are the most common users of dead barriers, terraces, and live barriers, while holders of 100 to 200 hectares are the second highest users of soil conservation techniques. Nevertheless, in no size category do more than one-third of the farmers employ any one technique, nor do such techniques cover more than 22 percent of the land area.

Among producers with small holdings, renters are the most frequent users of live barriers, improved drainage, borders, and terraces (see table 17-6). Owners dominate only in the use of dead barriers. The degree to which renters use soil conservation techniques is surprising, since prior research indicates that without long-term, guaranteed access to land, soil retention practices will not be employed (Collins 1986; Thiesenhusen 1989).[5] This finding is particularly interesting since these producers think they have the best soil of all small producers. Still, it is important to remember that small farmers account for less than 20 percent of all renters. The dearth of conservation activities by owners may be explained by shortages of funds or, perhaps, as Collins (1986) contends, by the

Table 17-6. Use of Soil Conservation Techniques in El Salvador, by Form of Tenure and Type of Conservation
(percent of producers)

Form of tenure	*Permanent plants*	*Live barriers*	*Dead barriers*	*Improved drainage*	*Borders*	*Terraces*	*Total*[a]
Owner							
Row	7.7	17.4	15.1	3.1	6.8	2.3	20.5
Column	65.6	68.4	75.9	54.5	80.2	85.5	68.1
Renter							
Row	5.2	34.8	11.0	11.8	10.8	2.5	35.8
Column	7.0	21.4	8.9	32.3	19.8	14.5	18.6
Beneficiary of Decree 207							
Row	9.4	7.6	8.9	2.2	n.a.	n.a.	11.7
Column	27.4	10.2	15.2	13.2	n.a.	n.a.	12.1
All producers[a]							
Row	7.8	17.0	13.3	3.8	5.7	1.8	20.1
Column	100.0	100.0	100.0	100.0	100.0	100.0	100.0

n.a. Not applicable.
a. Reform cooperatives are not included in this table.

need to secure off-farm work that detracts from the opportunities they have to work on their own land. Decree 207 farmers are the most frequent users of permanent plants but otherwise use fewer soil conservation techniques than do nonreform farmers.[6] Data were not available for the reform cooperatives, but PERA (1986) indicates that the use of these techniques is "common" on cooperatives.

Among large producers, a greater portion of owners use permanent plants, live barriers, dead barriers, and terraces, while renters have the highest rate of use of borders and improved drainage. These differences reflect variations in land use and cultivation. For example, the greater use of permanent plants and of live and dead barriers among owners is likely due in large part to the production of coffee, which requires not only the soil retention but also the shade provided by permanent plants. Barriers are also used to mark specific areas of cultivation. The extensive use of borders and improved drainage among large renters is related to the preponderance of cattle ranching. Drainage allows more area to be in pasture, while borders are used to contain cattle.

Conclusions

With little land in forest, pasture, or fallow, the practices of small producers have a disproportionately large potential to affect the environment. These farmers use their land intensively, rely heavily on annual crops such as basic grains, and use few conservation measures. Since small farmers as a group also tend to have less access to credit and technical assistance than larger farmers (McReynolds, Johnston, and Geisler 1992), they probably use their land in a less sustainable manner than large producers. However, several important points must be borne in mind. Although small producers are sometimes blamed for ecological destruction, they are, in fact, victims of the poor distribution of land and systemic environmental problems that preceded them (Thiesenhusen 1989). Where agrarian reform alters these constraints, peasant producers typically engage in intensive production on their new parcels (Berry and Cline 1984).

In El Salvador, producers with similar size holdings but different tenure status often have similar farming practices. For example, small producers of all forms of tenure are more similar in their use of soil conservation techniques than are either large and small renters or large and small owners. Despite the importance of size within tenure, some patterns hold for all producers of a given form of tenure. In addition, owners have the largest share of their land in pasture, the most unused land, and the least cultivated land. On the other hand, although an increase in conservation practices is generally assumed to accompany more secure tenure, this is not the case in El Salvador. For reasons that are not entirely clear, renters are as likely, and among small producers more likely, to employ soil conservation techniques as are owners. They do, however, use their land the most intensively. The reform sector is a mix of the best and worst environmental practices, depending on the type of reform beneficiary. For example, Decree 207 beneficiaries have the greatest share of their land in cultivation, have the worst soil, and employ the fewest soil conservation techniques. Members of reform cooperatives, on the other hand, have the most forest, the least land in cultivation, and the most in alternative crops.

Notes

1. This chapter summarizes the results pertaining to land use and soil management practices contained in a broader study by the authors of agricultural practices and environmental sustainability in El Salvador (McReynolds, Johnston, and Geisler 1992).
2. According to Lutz and Daly (1990), a rule of thumb is that erosion on land planted with coffee is about one-fourth of that on land planted with annual crops, although actual erosion varies within a wide range, depending on factors such as slope, soil quality, crops, and cultivation techniques.
3. While nonreform producers were asked what techniques are employed on their property, Decree 207 farmers were asked what techniques they have added since becoming owners. Soil conservation activities undertaken on these lands before the reform, therefore, are not included, which is likely to bias apparent usage rates downward.
4. These are optimistic assessments compared with a 1980 estimate that 54 percent of the land in El Salvador was not suitable for agriculture and only 17 percent was good (MAG 1981). There are, however, no known assessments of the accuracy and reliability of these data.
5. It is possible that many of these soil conservation techniques had already been implemented when the land was rented.
6. However, if activities undertaken prior to the reform had been included in the survey of Degree 207 farmers, higher levels of soil conservation activity might have been observed. In addition, PERA (1985, 1986, 1987) notes that use of conservation techniques is increasing. If these trends continue, the differences between small producers in the reform and nonreform sectors may be negligible in a few years.

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18. Practical Experiences and Lessons Learned by Vecinos Mundiales from Soil Conservation Work in Rural Communities of Honduras

Gabino López Vargas and Agustín Pío Camey[1]

Vecinos Mundiales (World Neighbors) is a nongovernmental organization that works in poor rural communities and extends knowledge about soil conservation and other subjects. This chapter describes the organization's approach and some of the lessons based on its experiences in Honduras.

Criteria for selecting a community

To receive assistance, a region must experience problems of low production and environmental degradation; it must encompass twenty-five to thirty communities in areas surrounding the main population center; and those communities must have between ten and twenty families in which children are malnourished. Another criteria is that no other institution is already doing the type of work that Vecinos Mundiales is interested in doing. The following are the characteristics that Vecinos Mundiales seeks in the communities it serves.

- *Low agricultural production.* The areas of Güinope, Cantarranas, and Choluteca, where the organization's efforts are concentrated, experience problems with low production of crops such as corn and beans (8 to 10 quintals of corn per manzana and 4 to 6 quintals of beans per manzana). Although the farmers have not requested it, these areas obviously need techniques for improving the production of basic grains, which would improve the farmer's way of life. An interesting case is that of Mr. A. Vásquez in San Antonio de Flores, whose beans used to produce barely 25 pounds for every pound of seeds planted. After acquiring technical knowledge (soil preparation, fertilization, systems of planting, and pesticide control), he now harvests up to 150 pounds of beans for each pound of seeds planted.
- *High rate of malnutrition.* Through observation and interviews, Vecinos Mundiales determines the seriousness of the malnutrition and the need for assistance and also evaluates the sickness and mortality of infants.
- *Environmental deterioration.* When production of basic grains is low, farmers often clear and burn plots of land covered with forest. In various rural areas of Choluteca, small forests are still being cleared, especially for producing and selling firewood in the city. As a consequence of this continuous burning and clearing of forests, rainwater has been reduced so much that in some years crops have been lost. In most parts of the departments of Choluteca and Valle, crops are lost because rains are very scarce and irregular. In such cases, communities in which Vecinos Mundiales begins working should have some water and irrigation. This is a preference, not a requirement, because it allows the organization to demonstrate that the recommended techniques are good and, above all, to win the confidence of farmers.

In selecting communities, Vecinos Mundiales gives much importance to the problems of soil erosion, even though farmers may not assign the same importance to it. To the extent that they can observe improvements in crops through measures of retention, fertilization, and soil conservation, farmers become aware of the need for conserving the soil. They then begin to convince others of the positive results that can be gained through conservation measures.

• *Land with different topographic conditions.* Areas that have lands with diverse topographic conditions are preferred because they allow farmers to realize that different technologies can be used for each area. Also, at least some communities should be accessible so that representatives from other communities can visit their works (take educational trips).

• *Domestic animals not separated from living areas.* Communities in which animals are not confined need help or technical assistance. In the communities of San Lucas, El Paraíso, and of San Ramón, Choluteca, this is one factor that promotes disease.

The beginning of soil conservation work in Honduras

In 1981, Vecinos Mundiales established the first soil conservation program in the municipality of Güinope, the department of El Paraíso, Honduras. Work began in four communities around Güinope and also in the urban center. In the initial stage, farmers did not believe in soil conservation. Many claimed that breaking up the soil was foolishness, that constructing ditches on contour was for burying people, and that collecting dung for preparing compost was a dirty job. Others complained that nothing grows in these places and that it is better to move to other areas when the land becomes useless.

After six years of intensive work, Vecinos Mundiales managed to assist thirty-five communities in Güinope, San Lucas, San Antonio de Flores, part of the municipality of Oropolí, and Maraita. The production of corn increased and reached an average yield of between 50 and 60 quintals per manzana. Some farmers produced up to 90 quintals per manzana, as occurred in Galeras, Manzaragua, El Hato, El Guayabo, Sabana Abajo, El Retiro, and even the urban center of Güinope. The rapid increase in yields was due to the use of poultry dung, which was plentiful in those days and was not used for anything else.

In Güinope and its eleven rural areas, such as the municipalities of San Antonio, San Lucas, and other surrounding towns, Vecinos Mundiales initially became acquainted with people who only knew about corn, beans, cabbage, potatoes, and coffee. They were not familiar with other types of vegetables or how to consume them. Now, those towns plant many vegetable crops, such as carrots, beets, broccoli, lettuce, garlic, onions, chilies, cucumbers, and others. They have also learned how to consume them as a result of the organization's nutrition and hygiene program.

In 1987, programs were initiated in Cantarranas, Francisco Morazán, and San Ramón Choluteca. Those areas are located between 400 and 600 meters above sea level, where the climate is hot and very dry, especially in Choluteca, which is hot and very harsh. In this zone, ecological control is weak, and people have lost confidence in their ability to produce because crops have failed because of strong droughts, attacks from pests, uncontrollable winds, and other problems.

The program for San Ramón, Choluteca, uses the same process used in Güinope. At first, only four communities were being assisted in the introduction of furrows on contours or minimum tilling, the use of organic fertilizer such as compost, the use of crop residues, and the introduction of green fertilizers (velvet beans, *dólicos lab-lob*, Gliricidia foliage, and others).

Three years later, the work was being continued in twenty-five communities where, since these farmers had convinced others of the success of the works they themselves had experimented with on a small scale, farmers were contributing to extension work voluntarily. In other cases, farmers who had benefited from the program dedicated a day's work to teaching others about what they had learned through experience.

Technical training helps to make individuals aware that they are the only persons responsible for resolving their own problems and, above all, that they have the capacity and the intelligence to do so with little effort. An example is the case of the Zelaya family in the village of Pacayas, Güinope. This family received training for more than two years. At first, it appeared that they would not change. However, as the techniques were applied and the results were positive, they began to reflect on the reasons for their success. They were taught that the recommended practices were the reason for the improvement and that this was what they should do to improve their future. (All of these activities were done in groups and based on the analysis of a real case that they themselves selected.)

Cantarranas has two different zones: one is in the lower area, where all the previously mentioned problems exist, and the other is located in an area with normal rainfall and cool climate. Cantarranas is a few kilometers from the capital city of Tegucigalpa. Therefore, some farmers feel that working in the city is easier than doing agricultural work. In other cases, the close distance is favorable, especially when production begins to increase, and farmers have to bring their produce to market.

Principal techniques of soil conservation recommended in the communities

The principal techniques recommended for conservation and fertility of soils are practical and simple: diversion ditches, vegetative barriers, dead barriers, furrows on contour lines, minimum tilling, construction and management of an A-frame, and the elaboration and use of organic and green fertilizers.

Diversion ditches

Diversion ditches are designed to reduce the speed of the flow of water. Their size and spacing are flexible and depend on the texture of the land. In general, they should be about 30 centimeters deep and 90 centimeters wide with a trapezoidal cut on each side. A ditch of this type has the capacity for retaining 200 liters of water per linear meter. When lands are very dry, level ditches are used to store rainwater. When lands have drainage problems, sloping ditches are used to channel runoff safely off the slope.

Vegetative barriers

Vegetative barriers are one of the most encouraged and recommended practices for conserving soil. They supplement and reinforce other practices such as good preparation of the soil or the construction of ditches. If rains are heavy, ditches fill up with soil and prepared soil can be easily washed away and lost. Vegetative barriers prevent soil from passing downslope, function as a sieve that allows water to enter the ditch in a natural way, and help form natural bench terraces over the years.

Vegetative barriers have multiple functions: they retain soil, prevent erosion, and contribute to the production of feed for livestock, thus avoiding the need to use land for pasturing. Farmers who do not have livestock can use the vegetative material to make organic fertilizer.

The varieties of pasture most often used for barriers are those that are locally known as napier enano, king grass, *pasto imperial*, common fodder, rice, wipi grass, and, in some cases, sugarcane. The first two varieties, for example, grow well from sea level up to 2,000 meters above sea level; they are efficient in protecting the soil; they do not allow small amounts of soil to wash away; they are good for livestock feed; they do not have to be planted every year; and they have no disease problems.

Dead barriers

On rocky lands, farmers are advised to construct rock barriers on contour lines to facilitate their work activities. The accumulation of crop residues (such as corn stalks and *maicillo*) can be established in the form of a ridge along the contour lines to help conserve the soil at least during the crop season.

Farmers who clear lands covered with small shrubs, called *guamil*, are taught to use them to construct ridges rather than to burn them because they improve the fertility of the soil. Some farmers use around twenty-five man-days per manzana (0.7 hectare) to clear and construct ridges in lands with *guamil*, which is equivalent to approximately L250 of labor.

Turning up the soil

The constant burnings, the poor management of lands, and the lack of organic material compact the soil, preventing the roots of plants from developing well. They also prevent rainwater from penetrating the soil and allow it to run freely on the surface. This causes erosion and floods in lower areas. To avoid this problem, farmers are taught a technique called intensive soil turning. This technique consists of turning up the soil to a depth of 20 to 30 centimeters, which not only facilitates the entrance of the rainwater but also allows plant roots to develop better. It also generates greater circulation of air and eases the task of clearing the land. This technique is generally considered difficult because it demands a lot of work (ninety man-days per manzana), depending on the texture and structure of the soils.

Because the results are positive, diffusing the method is relatively easy. To introduce a technology, it is always important to experiment on a small scale, and as farmers become aware of the benefits and learn the technology, the process of extension continues. For a project to be successful, works and demonstrations must be well carried out and gain the credibility of the rest of the community.

Minimum tillage

The technique of minimum tillage contributes to protecting the soil and saves work. It saves an estimated 50 percent of man-days per manzana compared with turning up the soil. The method better prepares the area for cultivation and eliminates the need for very large ditches; rather, each furrow acts as a small terrace or ditch. This technique of soil management avoids the problem of erosion because the soil is cultivated in furrows 30 centimeters wide and clearing is not intensive. The technique of working in the furrow is accepted especially by farmers who have lands with steep slopes. This practice has gained acceptance largely because it does not require the entire land to be turned up and can be applied in very steep land (70 percent) without having to make diversion ditches. Also, each furrow prepared in the form of a ditch acts as a small diversion ditch.

Organic fertilizers

To make better use of the natural resources, farmers are taught to prepare their own organic fertilizer. The following ingredients are used: residues from crops, pulp from coffee and other materials that decompose easily, plenty of green or dry weeds, and dung from any animal, provided that it is recently defecated. Farmers initially prefer to experiment with this technique on a small scale.

The use of organic fertilizers is the key to improving the soil and increasing crop production. If organic material is used in clayey soils, the texture of the soil improves, making it easier to cultivate. Similar results are obtained in sandy soil with leaching problems.

Organic fertilizer is cheaper than chemical fertilizer; it conserves moisture on poor land; it contains more nutrients than chemical fertilizers; and it improves the microbial life of the soil and helps other nutrients become soluble. The quantity of organic material recommended for each linear meter is from 2 to 3 kilos per square meter or 4 kilos per square meter if it is broadcast.

Although some farmers use dung from various types of livestock and in different states of decomposition, the direct application of dung is not recommended. The fertilizer should be processed since pests multiply in unprocessed dung. Crops of corn have been lost because cow dung was directly applied without being processed. Cow dung itself does not cause damage, but it attracts *ronrones*, or adult beetles, which lay their eggs in it, especially in the last months of the summer. When the first rains come, insect pests (*gallina ciega*) appear.

Green fertilizers

The advantages of using green fertilizers have been discussed for many years. No plant meets all the requirements for green fertilizer of good quality as well as velvet beans, locally known as *mucuna*. This is a leguminous plant that develops plenty of foliage and fixes nitrogen in the soil. It produces between 50 and 75 tons of green material per hectare in a period of six months, especially if it is planted during the first rains of May.

It is generally thought that green fertilizer must be buried or incorporated into the soil. According to many years of experience and after many experiments in different areas of Honduras, Vecinos Mundiales has found that small farmers accept a crop better if it serves a double purpose. Therefore, beans are planted because they produce foliage, which serves as organic material when it decomposes; seeds, which are used to produce flour and tortillas; and food, since they contain vegetable protein. They also serve as livestock feed. The most important aspect is that green fertilizer is very inexpensive.

In addition to velvet beans, other legumes such as *dólicos lab* can also be used. These legumes grow well in hot and dry areas and are tolerant to drought. They have not been widely accepted because they are attacked by pests and are more demanding of fertile soils. The two varieties of legume seeds mentioned have developed well from sea level up to 1,800 meters of altitude.

In general, these legumes are called green fertilizer because they are grown like any other crop, and they fertilize the soil at a low cost. Any farmer, even a poor farmer, can use them. Also, they indirectly serve as a herbicide because they help control weeds.

Fertilizer beans, or velvet beans, grow well in lands with relatively fertile soil, but slower and scantily on less fertile soils. To minimize this problem, farmers who are already familiar with the behavior of fertilizer beans plant corn together with beans to take advantage of the natural fertilizer. First, they make sure that fertilizer beans are adapted to the local climate and do not require any type of fertilization. The same legume obtains the nutrient it needs from the soil and incorporates a great quantity of nitrogen.

Once the seeds are harvested, the foliage can be used in many ways. Some farmers incorporate it directly into the furrow of the already prepared soil, where it decomposes rapidly. Others construct ridges with it in furrows, where it functions as dead cover (mulch). This method does not require much work and is relatively cheap; it controls a large quantity of weeds; farmers do not have to use much labor to clean the furrows; and when the soil has been prepared for the next crop, the decomposed material is moved close to the furrow.

In general, few farmers really incorporate bean fertilizer while it is green. They are ashamed to cut completely developed plants and thereby lose the opportunity to obtain seed that could serve as food for people or animals. When cattle consume seeds from the bean fertilizer, their milk production gradually increases to five or six times the normal production.

Methodology for soil conservation work with communities

Once experience has shown that a rural development program should be initiated, Vecinos Mundiales begins on a small scale by recommending a few techniques with a simple baseline study for detecting problems that affect the people and their environment. As the program grows, so does the participation of people.

Baseline study

The study should be simple and should determine the current levels of production, land tenancy, salaries, and activities of the majority of the people. Soil and forest deterioration and aspects related to the malnutrition of children are also important. The most important aspect is not to take too much time away from farmers and people, especially by making them fill out long questionnaires and forms. This initial baseline study should be expanded during the first year of the program. No study should be carried out in a community if there is no intention of working there. Also, the baseline study should be carried out by the same field technicians who will be working in the area because this allows them to have a clear idea from the beginning of the problems to be solved.

Interviews

In the beginning, the coordinator of the program and his/her field technicians ask the local authorities for information on the number of villages, the number of inhabitants, and the patrimonial aspects of the town. Also, it is necessary to consult local leaders, although those leaders often only help at the beginning, and new leaders may emerge during the training process. In the initial phase, leaders encourage neighbors to participate in meetings, training, exhibitions, and educational trips. To undertake educational trips, it is necessary to select farmers with successful plots. Since the program must begin on a small scale, the project should not promise to cover all the villages nor attempt to carry out studies on all of them.

Training and teaching

After the interview and promotion process is complete, training is initiated directly in the field. Training is practical and involves farmers who, on a voluntary basis, wish to apply the recommended techniques. Project staff are taught not to behave like teachers but rather to interact with farmers like equals. Small plots, a few techniques, and native varieties and local tools are used. The objective is to introduce a few changes and to appreciate what local farmers are already doing. Seeing positive results encourages farmers to increase the practices on their land, according to the possibilities available to them. The process is voluntary and apparently slow, but it is firm because no incentives are offered.

After the first plots are installed and the results are seen, more people become interested. At this point, training is repeated so that the first participants reinforce the knowledge they have already gained and assist others by teaching in the field. The teaching process incorporates visual aids that compare different plants, land with and without material, and other simple and practical aspects. Training plans that indicate the days and hours farmers can realistically attend training sessions are drawn up in consultation with the farmers. For example, in the community of Zurzular, farmers prefer to receive training once a week in the afternoon.

During the training process, farmers are encouraged to share with others. In this process, leaders emerge who, with their technical knowledge, later become extensionists within the program. This does not mean that professionals lose their function; rather, their support is needed most at this time.

The diversification of crops

After observing the production of basic grains increase through the use of soil conservation and other techniques, farmers generally want to enlarge the area they devote to producing vegetables and fruits. Vecinos Mundiales supports and assists the diversification of farm practices without forgetting that improvement of the soil is a basic activity.

The increase in the number of farmers

After the first few years of work, other communities observe the initial results, especially the increase in yield on large plots and on lands with structures for retaining and enriching soils. This experience attracts farmers from other communities who request technical assistance. At this stage, greater acceptance is easier to achieve. Because more communities are involved, more field assistants are needed. Farmers who are already trained may be contracted to assist with training and thereby achieve a multiplier effect. Farmers are contracted for a period of two or three days a week so that they do not leave their land unattended. This is a key element in sharing and demonstrating techniques to other farmers.

Practicing what you preach is the best way to convince with effectiveness. Farmers who are already trained will teach the technologies they have learned and will simultaneously learn other techniques. These local promoters need to receive a lot of moral support and be shown how they should share their knowledge. It is important to remember that for them, the teaching process and the transfer of technology tend to be new activities.

The need for meetings with field personnel

Holding meetings with field personnel is essential to carrying out the project's objectives successfully. This is a good way to discuss the problems encountered and how to solve them, to share the successes obtained, and to learn to make decisions together, which contributes to the training process.

The duration of the activity in a community

The program should be carried out in a community for five or six years, depending on the interest shown by the inhabitants and the techniques they wish to use. The intensity of the initial technical assistance should be reduced gradually because farmers want to carry out their own activities. For example, in the first or second year, courses can be provided every eight days; in the third and fourth year, this may drop to every fifteen days; and in the last two years, it may drop to once a month. Each program defines the work policy that is convenient for it. Also, individual visits to farmers decrease, as happened in Güinope, where such visits have obtained good results.

Priorities in the activities to be carried out in a community

Initially, training is a priority and should be based on soil conservation techniques and enrichment of the soil. Planting a vegetative barrier is not enough to increase the production of corn and ensure that it is maintained or continues increasing. Farmers must understand the role that air, sunlight, water, nutrients, and micro and macro organisms of the soil contribute to the formation of the grain as well as the role that the forest plays in the entire system and in human life. They must also realize the responsibility they have to be good administrators of nature and the potential they have to make nature useful and to have a better life, not only in the present but also in their own future and in that of future generations. Messages about priorities must originate with those ideas. For example, if water is plentiful, the climate is cool, and wild animals and forest abound in a community, the program emphasizes that these rich, natural resources can be easily destroyed or ecologically altered if individuals do not understand their importance and know how to manage them.

The acceptance of a project in the community

Generally, programs that seek to increase the small farmer's production of basic grains through soil conservation techniques achieve ready acceptance, particularly when work has already been initiated by small groups of volunteers. Gradually, more farmers join the program as they begin to see positive results. In a community, total acceptance is not expected, although acceptance is generally between 60 and 80 percent. Even when the program is withdrawn from the area, farmers who were trained continue to help others adopt the techniques they learned.

Every program has some farmers and persons who never participate: some because they do not own land, some because they are busy with other activities, and still others because they simply do not want to conform. Vecinos Mundiales does not dedicate its efforts to these persons because real participation should be voluntary and because the door is open to everyone who would like to participate.

Cultural and social patterns

Small farmers have valuable traditional practices. Creole seeds, for example, often are resistant to pests and diseases, simple and inexpensive tools help obtain good results, and farmers often have knowledge about the best planting period, about rainy seasons, and about how to store grains. Technicians who try to change those systems will fail because those systems have served farmers for a long time and are valuable experiences. In Güinope, for example, one farmer did not accept a new variety of corn because the creole corn he had conserved for a long time provided better cover, did not allow insects to attack the grain, and was sweeter. In another case, the project attempted to introduce a variety of high-yielding black beans, but it was not accepted because the people were accustomed to consuming red beans. So, projects should build on existing knowledge and try to achieve gradual changes.

Factors that contribute to the effectiveness of extension of soil conservation practices

To have success, the project must be timely and technicians must keep appointments with farmers, who have multiple activities and responsibilities. Carrying out promises generates companionship, sincerity, appreciation of the farmers, and greater participation. For example, the community of Rancho del Obispo learned rapidly about the application of soil conservation techniques because the technician took into consideration the criteria mentioned above. Generally, nothing should be promised that cannot be delivered.

Technicians should not avoid friendship with farmers solely because their academic backgrounds differ, since this hurts the farmers' dignity. The best way to work is through dialogue, which allows technicians and farmers to exchange knowledge and experience. On repeated occasions, farmers have accepted the work of Vecinos Mundiales because its teachings are simple and stimulate their own knowledge and experience.

From the beginning, the institution should select its technical practices. Experience shows that diversion ditches, organic material, narrow furrows, and a little chemical fertilizer are the key elements. After this, farmers should help select the techniques they want to add.

Institutions sometimes make the mistake of introducing a prefabricated technological package. Although some farmers may want to try it at the beginning, many will abandon it afterwards. When farmers really participate in the selection of technologies, there is a common commitment, and obtaining the objectives becomes the responsibility of all participants. In Güinope and in El Paraíso, in addition to teaching soil conservation, Vecinos Mundiales tried to promote fish culture, grafting of fruit trees, new types of plowing, planters, and water pumps. These techniques achieved little success, however, because the moment was not right, and farmers did not truly need them.

Note

1. The authors are technicians with Vecinos Mundiales, Honduras. The opinions of this document are theirs and do not represent the official position of Vecinos Mundiales.

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