A Case Study of the Adoption of Soil Conservation Technology in El Salvador: A Fusion of Productivity and Conservation Components

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1. Introduction

The reduction of soil degradation is a key factor for maintaining the long-term productivity of agricultural systems on hill slopes. The use of inappropriate crop management practices has had severe consequences for the deterioration of natural resources, including forests, soils, and water. Among the most damaging practices of hillside agriculture are the indiscriminate cutting of trees, annual burning of crop residues, and mechanical land preparation, all of which leave soil unprotected during the rainy season. These practices may be responsible for soil losses of 170-3600 t/ha each year (Lal 1984, National Research Council, 1991). Therefore soil and water conservation are important requirements of sustainable cropping systems for hill slopes.

As concern over soil degradation and erosion has increased, concern about the factors that affect the adoption of soil-conserving practices, such as conservation tillage, has also increased. Several factors affecting the adoption of conservation tillage have been identified, particularly in temperate and subtropical environments (Anderson and Thampapillai, 1990; Napier, 1991; Thampapillai and Anderson, 1991). Successful adoption of soil conservation practices for maintaining crop productivity requires attention to the technical, institutional, environmental, and socioeconomic factors that condition farmers' adoption behavior. Napier (1991) concludes that the most important barriers to adoption of soil conservation practices are institutional factors such as land tenure problems, lack of access to credit, amount of public land available, degree of development of a land market, and lack of technical information related to the practices. The most important technological factors found to influence adoption include landscape slope, moisture regime, crop rotation, soil type, degree of soil degradation, and the type of traditional technology (Crosson, 1981; Saliba, 1983; Rahm and Huffman, 1984). Farmer and farm characteristics, including family composition, degree of education of the farmer and his/her family, farm size, degree of risk aversion, and farmers' sensitivity to short- and

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long-term changes, awareness of erosion as a problem, social attitude, education, and degree of involvement in communal activities are also cited as important influences on adoption decisions (Anderson and Thampapillai, 1990; Saliba, 1983; Epplin, and Tice. 1986; Ervin and Ervin, 1982; Crosson, 1981). Lee and Stewart (1983) concluded that tenure, farm size and erosion hazard were significantly related to adoption of conservation tillage.

Although any of these factors is likely to affect farmers' decisions to adopt resource-conserving practices, often there is not conclusive evidence on the adoption process itself (Lockeretz, 1990). Furthermore, there seems to be a tendency to see conservation goals as inconsistent and even antagonistic with the aims of crop productivity (Thampapillai and Anderson, 1991).

This paper will 1) show strong evidence of adoption of conservation tillage and present hypotheses to explain why technology for both improved maize productivity and soil conservation was disseminated successfully in the Metalio-Guaymango area of El Salvador and 2) dispute the argument that conservation and productivity goals are always antagonistic.

Linking Productivity and Sustainability

Throughout the 1970s, with the spread of the Green Revolution in wheat and rice, the adoption of agricultural technology was encouraged through the use of a *package* of agronomic inputs. This approach was used widely in developing countries with varying degrees of success. On the one hand, despite much effort at "complete packages" , evidence has often shown stepwise adoption of individual components (Byerlee and Hesse de Polanco, 1986). On the other hand, combinations and packages are sometimes deemed essential for technology adoption (Nagy *et al.*, 1988; Pachico and Borbon, 19??).

The technology advocated in El Salvador consisted of the following interrelated recommendations: 1) use of hybrid maize seed, 2) nitrogen (N) and phosphorus (P) fertilization at planting and at first weeding, 3) reduced sowing distances to increase plant density, and 4) insecticide application (Walker, 1980; Sosa and Moscardi, 1977). In El Salvador, traditional extension methods, coupled with a package approach, conditioned the thinking on research and extension at the Centro Nacional de Tecnologia Agropecuaria (CENTA) for many years (Walker, 1980).

Evidence suggests that this package was adopted widely during the 1970s. For example, the first maize hybrid was released in 1955, but hybrid maize seed was not adopted until 1963-65, when H3 and the later-maturing hybrid, H5 (Walker, 1980) were released and widely promoted as part of a package.

In 1973, the Extension Agency of the Ministry of Agriculture and Livestock (MAG) initiated a program called the "*Programa de Producción Tecnificada de Granos Básicos*" (PPTGB), with the objective of increasing production of maize and sorghum in southwestern El Salvador (the Metalio-Guaymango area). Initially, the technological alternatives were chosen from the package widely promoted throughout the country, plus soil conservation practices that forbade the traditional practice of burning crop residues and encouraged their use as mulch. Table 1 outlines the main practices promoted in the area during this period. It appears that farmers did not adopt the complete package step by step but rather they used maize hybrid seed, fertilizer and herbicide in combination to raise yields in the short term.

This program brought about key changes in production practices in the Metalio-Guaymango cropping system, as described by Calderon *et al.* (1991). Farmers stopped burning crop residues and used them as mulch spread over the soil. Instead of sowing seed in an irregular pattern of hills, farmers began planting in rows along a leveled contour. Maize hybrids replaced local varieties, and increasing amounts of N-P fertilizers were applied.

Although the widespread adoption of conservation tillage in Metalio-Guaymango has been documented, little has been said about why other areas with similar characteristics did not attain the same degree of success. Practices directed at increasing crop productivity diffused widely throughout El Salvador, but the soil-conservation practices did not. The discussion that follows seeks to explain the reasons for success in Metalio Guaymango.

The Metalío-Guaymango Area

Metalío-Guaymango is located in the departments of Ahuachapan and Sonsonate in southwestern El Salvador (Figure 1). The topography is characterized by a series of upland hills with slopes ranging from 40 to 90% (García et al. 1966); the elevation ranges from 10 to 250 masl. The soils of the region are mainly reddish inceptisols and entisols, with a pH between 5 and 6.5, a low soil phosphorus content, and sandy loam to sandy clay loam textures. The annual average rainfall over the past decade was 1961 mm, unimodally distributed from May to December. September is the month of greatest rainfall but there is a marked drought period during July and August (*canicula*). The annual mean temperature is 26°C.

About half of the total area of approximately 14,000 ha is devoted to agriculture. The remaining area consists of natural and planted pasture or woods, or is used for purposes other than agriculture. Although wood is highly valued as fuel, only 5% of the total area is forested. Most of the cropped area is sown to grains (maize, sorghum, beans), but maize-sorghum intercropping is the dominant cropping pattern.

In this system, maize is sown by hand in May once the rains are established. At maize flowering, sorghum -- a local unimproved variety, very tall and photoperiod sensitive -- is sown in the middle of the maize rows. Shaded by the maize crop, the sorghum intercrop develops slowly until the maize stalks are doubled over around September before harvest. The sorghum flowers in October and is ready for harvest by January or February. During the dry season in February, March, and April, animals graze the stover left in the fields.

2. Conceptual Framework for Viewing Adoption of a Productivity/ Conservation Recommendation

The adoption of productivity-enhancing, resource-conserving technology in Metalio-Guaymango can be viewed as a three-stage process. Each stage is described below, along with preliminary hypotheses (in italics) explaining why the conservation component was adopted successfully.

Stage 1: Forming a productivity/conservation recommendation. *The conservation component was widely accepted by farmers in the area because it was integrated into a single recommendation with one or more productivity components. In combination, these components formed a "productivity/conservation recommendation." The productivity components increased land productivity and were profitable for most farmers in the short term.*

The productivity components (hybrid seed, N and P fertilizer, insecticide and herbicide) of the package provided an immediate increase in productivity and profitability. For example, the introduction of hybrids H3 and H5 raised maize yield potential to about 5.5 t/ha in El Salvador (Walker 1980). Furthermore, experimental results from the area showed that H5 responded very well to N and P fertilization. The average experimental yield with applications of 120 kg N/ha and 40 kg P/ha reached 5.0 t/ha (Rodríguez *et al.*, 1985). In farmers' fields the increase in productivity was also remarkable. In 1973, average yields of intercropped maize and sorghum were about 1.0 t/ha of maize and 0.7 t/ha of sorghum (Calderon *et al.*, 1991). These yields had risen to 3.3 t/ha and 2.9 t/ha in 1992 (Table 2).

The conservation component aimed to enable farmers to minimize soil erosion and increase soil moisture conservation by distributing crop residues uniformly over the soil instead of burning them. These practices were more labor intensive and therefore more costly for farmers than the simple act of burning. Furthermore, no immediate impact on yield was expected from their adoption. Table 3 shows the partial budget and the estimated profitability of the entire package evaluated at 1970-75 input/output prices. Although the conservation component shows a cost increase in the short run, the increase in productivity and gross benefits compensates for the higher costs. In addition, the productivity/conservation package as a whole is profitable for farmers, providing a marginal rate of return of 137%. Note that the improved practice is much more capital intensive than the farmers' practice, especially in the use of chemical inputs.

Joining both types of components into a single recommendation avoided a problem commonly associated with the adoption of resource-conserving technologies alone, which is that farmers must weigh costs and benefits over the short term vs. the long term. In this instance, farmers did not have to make a tradeoff between short- and long-term benefits.

Stage 2: Linking the productivity and conservation components. *The conservation components are tied to the productivity components so that farmers cannot separate them or differentiate between their short- and long-term effects. The goals are to 1) prevent farmers from breaking the package into individual components; 2) provide incentives to use the conservation components.*

Given the different length of time needed for productivity and conservation components to produce net revenues, it is necessary to tie all components to ensure adoption of the conservation component. Although the links between components may take different forms, institutional and economic links were the most common features of the strategy developed by the PPTGB in Metalio-Guaymango.

The PPTGB organized farmers into *Grupos Solidarios* (GS), voluntary groups formed of a minimum of three farmers, generally from the same place. These groups were the only means for farmers to gain access to both credit and technical assistance, because credit was not provided to individuals but to the groups.[2] To be eligible for credit all members of a group had to adopt the complete technology package. The organization of the groups thus not only provided incentives to farmers by giving them access to credit but also made all group members responsible for ensuring that no individual in the group violated the agreement to stop burning crop residues (Calderon *et al.*, 1991). Therefore, the mechanism of the *Grupos Solidarios* decreased the costs of individual monitoring, frequently mentioned in the literature on natural resource conservation, as it was in the best interest of every group member to ensure that no-one in the group burned crop residues and thus rendered the whole group ineligible for credit. Further incentives to adopt soil conservation practices were provided by the extension agency through field tours and soil conservation contests (Calderón, 1973; Calderón *et al.*, 1991). The winners of these contests received inputs (fertilizer, herbicide, tree seedlings) or equipment (backpack sprayers, gloves, protective glasses, field boots). The importance of educational programs for promoting adoption of conservation tillage have been discussed by Dicksey (1991).

The PPTGB also substantially improved farmers' access to technical assistance. The information passed on to farmers through different media and training methods -- radio, field days, films, and presentations -- did not differentiate explicitly between the short- and long-term productivity gains offered by the productivity/conservation recommendation. The success of the PPTGB is illustrated in Tables 4 and 5. A growing number of farmers became involved in the program and the area under conservation tillage increased over time (Table 4). The estimated pattern of diffusion over time is shown in Table 5.

Stage 3: Restricting the duration of incentives and disincentives. *If the key technical requirements for adoption are fulfilled, the institutional incentives eventually can be removed. The technical prerequisites for the long-term success of the productivity/ conservation recommendation are that: 1) the complete recommendation must be compatible with the farming system, and 2) the conservation component must be effective in minimizing resource degradation and must be profitable in the medium/long term.*

Meeting these two technical requirements is necessary if farmers are to continue with the conservation component after the system of incentives and disincentives is dismantled. In

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2 Nonadopters, in comparison, faced an implicit system of disincentives. For example, they had no access to credit or inputs. The disincentives were enforced strictly -- at times by public officials and sometimes by the armed forces (Calderon 1973).

the case of Metalio-Guaymango, the greatest challenge comes from the use of crop residues as forage during the dry months of the year. For the conservation practice to be compatible with the system (and sustainable), enough crop residues must be available for cattle to graze during the dry period and still leave sufficient residue for the conservation component to work. There are two important variables in this relationship. The first is the amount of stover left by the cropping system at the beginning of the grazing period, which is a function of system productivity, soil characteristics, and mulch decomposition rate. The second is the number of cattle and duration of grazing in the field, which in turn is a function of relative prices and the value that farmers place on soil conservation.

Table 6 shows the amount of crop residues left over at the beginning and end of the grazing period in three areas of El Salvador. The amount of crop residue produced in Metalio-Guaymango is similar to that produced in Texistepeque where a similar cropping system exists, and exceeds the amount produced in Opico where the predominant system is maize followed by beans. Crop residues disappear at a lower rate in Metalio-Guaymango than in the other locations. Thus the amount of crop residue that remains for use as mulch is sustantially greater than it is in the other two areas.

The second technical requirement to ensure continued adoption is that after a period of time the conservation component must be profitable to the farmer. It also conveys an implicit argument to expand farmers' planning horizon to incorporate the value of soil conservation in their utility function. In an informal survey of 107 farmers in 1990, 45% of the farmers interviewed in Metalio-Guaymango cited soil conservation as a reason for not burning residues (Table 7). This commitment to use crop residues as soil cover is also reflected in the forage market. In Metalio-Guaymango farmers who rent land for grazing stipulate that about 50% of the crop residue must remain on the land at the end of the grazing period. This value decreases to 30% in Opico and 20% in Texistepeque (Choto y Sain, 1993).

3. Lessons for research, technology transfer, and policy

The adoption of conservation tillage in Metalío-Guaymango took place because of a confluence of technical, institutional, and economic factors. Attempts to transfer conservation components by themselves to other areas may fail because of technical factors (e.g., insufficient crop residues because of low system productivity) or economic reasons (e.g., the high value of residue used as forage). An often overlooked yet critical technical factor in successful adoption of soil conservation tillage is the requirement that minimum tillage and residue management must go together (Heimlich, 1985). In the case of Metalío-Guaymango both zero tillage and improved residue management comprised the basic elements of the conservation component of the integrated recommendation.

If the experience gained in Metalio-Guaymango is to be useful for farmers elsewhere in El Salvador, or in other Central American countries and Mexico, a carefully integrated technology transfer strategy must be devised. Widespread adoption of conservation tillage resulted from the amalgamation of the conservation components with a profitable set of productivity-enhancing technological alternatives that yielded visible benefits in the short term. Institutional and economic incentives were needed at the beginning of the process to tie the productivity and conservation components together and ensure adoption of the whole recommendation in the short run. This called for coordinated action between research, extension, and credit institutions. The presence of an extension system closely linked to the provision of credit, and the use of farmer groups rather than individual farmers as the medium for disseminating information and credit, were fundamental for the success of the PPTGB in Metalio-Guaymango.

To ensure system compatibility (and hence continuing adoption) in the medium and long term, and eventually make formal incentives unnecessary, an increase in system productivity and effective resource conservation must be achieved concurrently. Failure to meet these requirements could reverse the adoption of conservation practices over time. Fujisaka and Cenas (1993) presented evidence of disadoption of contour hedgerows in the Philippines as farmers found that the conservation technolgies did not meet their productivity requirements.

It should be noted that the presence of livestock in the farming systems of Metalío-Guaymango is an important factor conditioning the continuing success of the technology. Livestock numbers affect the amount of crop residues available for mulch. Overgrazing, aside from its obvious effect of reducing soil cover, also can result in soil compaction. Therefore, system productivity should be raised to a level that permits an equilibrium between cattle grazing and a threshold stover level for effective soil conservation.[3] Further research is needed on how many cattle can graze the available stover, and on how changes in relative prices affect livestock numbers and consequently the amount of residue

[3] Other factors can also lead to overgrazing and increased soil degradation, such as the absence of ways to prevent cattle from grazing freely. In this sense, policies that improve farmers' access to credit for wire fences might indirectly assist the adoption of conservation practices by fostering a formal market for crop residues.

left at the end of the grazing period. Alternatively, more research on improved sources of animal feed during the dry period would help alleviate pressure on crop residues.

Several issues are crucial in planning future natural resource management research and technology transfer in the region. First the importance of conventional agricultural research to develop viable technological alternatives that are productivity-enhancing, resource conserving and are compatible with farmers cropping systems; second, the need for mounting an effective extension campaign to incorporate the value of conserving soil into farmers' planning horizon. In this regard, the role of NGOs and private sector organizations will become increasingly important. Policy measures that increase farmers' planning horizon will also contribute to farmers' recognition of soil value and their appreciation of conservation technologies. Finally, any system of incentives and disincentives should be designed with a clear idea of the length of time they must remain in place.

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Table 1. Soil conservation and land productivity and practices promoted in the Guaymango area.

Type of practice	Practice
Soil conservation practices	1. Not burning crop residues. (Use of herbicides was recommended to replace the traditional practice of burning crop residues.) 2. Placing crop residues between plant rows[4] 3. Use of living and dead barriers. 4. Laying out the field and sowing maize and sorghum along a leveled contour.
Land productivity practices	1. Use of maize hybrids H3 y H5. 2. Increased plant density. 3 Application of N and P fertilizer. 4. Application of herbicides and insecticides.

Source: Adapted from Calderón *et al.* (1973).

[4]At first farmers were advised to place crop residues in the rows between the plants, following the contour, to form a barrier preventing erosion. Later this recommendation was changed and farmers were asked to distribute crop residues uniformly over the field.

Table 2. Change in average yields of maize-sorghum intercropping system, Metalío-Guaymango, El Salvador, 1974-89

Year	Maize yield (t/ha)	Sorghum yield (t/ha)
1963	0.70	0.60
1970	0.97	0.70
1974	1.00	0.70
1978	2.34	1.50
1983	3.20	2.00
1989	3.23	2.10

Source: **Data 1963, 1978, Calderon F (1974, 1990); Data for 1983-89 from Mendoza (1985)**

Table 3. Partial budget and relative profitability of the package: land preparation, variety, plant density, fertilizer application, and herbicides and pesticides (Metalio-Guaymango 1972-75)

Item	Farmers' practice	Improved practice
Maize yields (t/ha)	1.09/1	3.20/2
Maize price ($/t)	80	80
Gross benefits ($/ha)	**87.27**	**256.00**
Chopping and burning	6.9	0.0
Chopping "matocho"	0.0	1.6
Cost of Gesaprim	0.0	7.6
Cost of Gramoxone	0.0	3.8
Cost of application	0.0	3.3
Total cost land preparation	**6.9**	**16.4**
Seed cost ($/ha)	13.3	18.33
Labor for planting	2.3	2.88
Total cost of variety x density ($/ha)	**15.71**	**22.51**
N cost ($/ha)	0.0	31.0
P2O5 cost ($/ha)	0.0	18.3
Labor for fertilizer application ($/ha)	0.0	4.9
Total fertilizer cost ($/ha)	**0.0**	**54.2**
Cost of Gramoxone ($/ha)	0.0	3.8
Labor ($/ha)		3.3
Cost of manual weeding ($/ha)	6.6	0.0
Total cost weed control ($/ha)	**6.6**	**7.1**
TOTAL COST THAT VARY ($/ha)	29.2	100.3
NET BENEFITS ($/ha)	58.1	155.7
MRR (%)		**137%**

1/ Average yields in Western Region, El Salvador, 1970-75.
Source: MAG *Estadísticas de Economía Agropecuaria. Anuarios 1969-1980.*
2/ Experimental yields of verification trial reported by Mendoza, V. (1990)

Table 4. Trends in numbers of *Grupos Solidarios* (GS), total number of farmers in groups, and cumulative area under conservation tillage, Metalío-Guaymango, El Salvador, 1974-1983

Year	Number of GS	Number of farmers in GS	Area under conservation tillage (ha)
1973	0	0	0
1974	12	82	18
1975	34	187	238
1976	45	272	316
1977	66	382	473
1978	88	564	727
1979	112	699	935
1980	143	979	1482
1981	164	1,033	1508
1982	281[a]	1,356[a]	1,932[a]
1983	398	1,678	2,356

Source: Calderon et al. (1991).

[a] Estimated as the average for 1981 and 1983.

Table 5. Estimated time diffusion pattern of soil conservation practices in Metalío-Guaymango, El Salvador

Interval	Middle year	Number of cases	Relative frequency	Cumulative frequency
Before 1970	1970	17	0.16	0.16
1970 -1972	1971	18	0.17	0.32
1973-1975	1974	9	0.08	0.40
1976-1978	1977	25	0.23	0.63
1979-1981	1980	30	0.28	0.91
1982-1984	1983	6	0.06	0.96
1985-1987	1986	4	0.04	1
Total		109		

Source: Departamento de Validacion y Socioeconomia del CENTA. First informal survey, 1990.

Table 6. Average grain yield and stover availability during the dry season in three areas of El Salvador

Area	Cropping system	Grain yield[1] (t/ha)	Initial measure at harvest[2]	Yield of leftover residue by month (t/ha)		
				1st	2nd	3rd
Guaymango	Maize-sorghum	2.9 maize 3.3 sorghum	(Dec-Jan) 9.7	(Feb). 8.5	(March) 7.9	(May) 6.7
Texistepeque	Maize-sorghum	3.8 maize 3.4 sorghum	(Dec-Jan) 10.9	(Jan) 5.3[3]	(March) 4.6	(April) 2,2
Opico	Maize-beans	4.3 maize 1.2 beans	(Dec-Jan) 6.9	(Jan) 6.9	(March) 4.6	(April) 2.4

/1 Experimental yield according to Sosa (1992).

/2 Estimated using the following harvest indices: maize (45%), sorghum (35%), and beans (50%).

/3 This measurement does not include the weight of the standing sorghum stalks.

Table 7. Main reasons given by farmers for not burning crop residues, Metalio-Guaymango, El Salvador, 1990

Reasons	Frequency
Erosion control	0.45
Expect yield to increase	0.06
Institutional restrictions	0.23
Previous experience	0.10
Recommendation	0.17

Source: Unidad de Socioeconomia y Validacion, CENTA. First informal survey, 1990.