The Adoption and Management of Soil Conservation Practices in Haiti: The Case of Rock Walls

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Abstract

Farmers are usually reluctant to adopt measures to reduce the toll of soil erosion; and even when soil conservation structures are adopted, farmers fail to manage them. This study investigates factors that influence adoption and management of soil conservation structures in Fort-Jacques, Haiti. The results show that personal characteristics of farmers, institutional factors, such as local group membership, training in soil conservation, per capita income and size of farm influence soil conservation adoption in Forte-Jacques. Age, education, per capita household income, participation in local groups, the interaction of per capita household income and farmers' age influence rock wall management.

Introduction

Land degradation has been identified as one of the most serious ecological and economic problems facing tropical countries such as Haiti. One particular problem associated with land use is soil erosion. Early efforts to restrict environmental damages emanating from soil erosion have focused on mechanical structures, such as rock walls. Rock retention walls are structures built along the contour of slopes with the purpose of slowing down and diverting rainfall runoff, controlling erosion of steep lands, and forming a natural terrace over time (Tones, Thurow, and Sierra 1998). This technique is particularly simple and effective in reducing soil loss (Hallsworh 1987; Williams and Walter 1988).

Despite the effectiveness of rock walls in controlling soil erosion and the reported high returns on investment, its diffusion throughout Haiti is limited. When the practice is adopted, the structures are not adequately maintained (Lea 1996). Previous studies, attempting to explain the reluctance of Haitian farmers to adopt and manage soil conservation structures in Haiti, especially rock walls, mainly focused on two major factors: land tenancy and investment costs (Saint-Dic 1981; Jean-Pierre 1984). Since rock walls have been used in some areas as Fort-Jacques, legitimate questions may be raised as to

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what causes farmers to adopt and manage such a soil conservation practice in this particular locale.

Objective

This investigation concentrates on the adoption and management of rock walls in Fort-Jacques and has two objectives:

1) To identify and analyze factors influencing farmers' decisions to adopt rock walls; and
2) To examine the factors which play a significant role in the management of this land improvement technology.

Theoretical Framework

Several studies (Ervin and Ervin 1982; Napier 1991; Bultena and Hoiberg 1983) have been conducted to explain farmers' attitudes toward adoption of new technologies. Some researchers (Rahm and Huffman 1984; Lee and Stewart 1983; Amin 1999; Traoré, Landry, and Amara 1998) used binary choice models to measure the probability of farmers adopting soil conservation practices. A second group of researchers (Ervin and Ervin 1982; Gould, Saupe, and Klemme 1989; Featherstone and Goodwin 1993) evaluated the adoption level by the number of practices used on the farm; and adoption of soil conservation technologies is measured by the capital expenditures made for installation (Norris and Batie 1987).

Some studies indicate various factors that influence on-farm adoption of soil conservation practices, including socio-demographic characteristics of farm operators and physical features of the farm. Physical and environmental characteristics such as farm size, slope length, degree of slope, and soil erodibility also affect the adoption of conservation practices (Rahm and Huffman 1984; Barbier 1990). Some studies (Burton, Rigby, and Young 1999; Featherstone and Goodwin 1993; Gould et al. 1989; Norris and Batie 1987) indicate that a farmer's age influences adoption, and others education (Ervin and Ervin 1982).

Economic and financial factors, such as farm and off-farm income and risk aversion, are found to influence adoption decisions (Featherstone and Goodwin 1993; Norris and Batie 1987; Gould et al. 1989; Shields, Rayuniyar, and Goode 1993). Farm income positively influences adoption of technologies while off-farm jobs inhibit this decision.

Institutional factors such as land ownership, membership in farmers' organizations, and technical assistance have been found in some studies to influence on-farm adoption of conservation practices (Francis 1986). Insecurity of tenure reduces farmers' incentives to invest in land conserving practices (Lee and Stewart 1983), while membership in local groups has a positive and significant effect on the adoption of such technologies (Burton et al. 1999). Finally, perceptions of erosion problem are found to be positively associated with the adoption of conservation practices (Santos, Thurow, and Thurow 2000; Bultena and Hoiberg 1983; Anim 1999; Traoré *et al*. 1998).

The decision on whether or not a farmer chooses a technology may be represented by Y, which takes on a value of 1 if he adopts and 0 if he fails to adopt. Suppose that $U(A, X, H)$ represents a farmer's perceived benefit of adopting soil conservation practices, and *C* the perceived costs of non-adoption. A farmer's choice can be represented as:

$$Y = 1 \quad \text{if } U(A, X, H) > C \tag{1}$$

$$Y = 0 \quad \text{if } U(A, X, H) < C, \tag{2}$$

where A is the asset position of the farmer and this includes the farm situation, X represents socio-demographic factors, and H is the preference parameter. It is shown that this can be represented by a logistic regression model (Foltz 2003).

Unlike the adoption process, factors influencing farmers' decisions to manage or maintain conservation structures have not been extensively studied. Management of rock walls consists of repairing breaches in the walls and increasing the height as the soil accumulates. It is generally argued that farmers do not properly maintain the structures established on their plots. Nevertheless, Santos et al. (2000) reported farmers' intentions to continue maintaining rock wall structures in Honduras.

Farm operators may manage their conservation structures well, simply maintain them, or may neglect them. In the case where the structures are well managed we may relate this to a "well managed structure, in the case of maintenance we may say "average management", but in the case of neglect we may say "poor management". These management types may be represented by a multinomial decision model. Under the multinomial response model, if there are N categories, the probability that a farmer is in a particular category, P_j, is given by:

$$P_j = \exp(\beta'_j X) / \sum \exp(\beta'_j X) \tag{3}$$

where j is equal to 1 if management is poor, 2 if average, and 3 if management is good. X represents a vector of explanatory variables for farmer i with j level of management, and β the coefficient of the parameters.

Methodology

Study area

The study was conducted in Fort-Jacques, a mountainous area, located at about 30 miles south-east of Port-au-Prince, the capital of Haiti (18^0 13' N, 78^0 W). The zone varies in elevation from 900 to 1,400 meters above sea level and has a mean annual temperature of 22^0 C. The average annual rainfall is about 1,200 millimeters (mm) distributed in a bimodal pattern with rain occurring from February to May, and from August to November.

Farmers in the Fort-Jacques area produce a diversity of high-valued vegetable crops, such as cabbage, carrots, tomatoes, potatoes, onions, beans and lettuce on small farms for the local market. The farming systems in the area are highly intensive, with a fallow period lasting from one to three months.

Data collection

Prior to the survey, several trips were made to visit the zone and to discuss the objectives of the study with agricultural cooperative managers, and religious, and community leaders. With the help of area farmers and leaders, we obtained a list of farmers from which a random sample was drawn. The final sample was composed of 115 farmers including 68 rock wall adopters and 47 nonadopters. Data were collected through face-to-face interviews with selected farmers, and an evaluation of the management of rock wall structures established on at least one plot of the farm in question.

Information was gathered on farm family characteristics (age, marital status, education, training in soil conservation, and group membership), farm situation (size, land tenure), and implementation and management of rock walls. Basic information on crop and livestock production, off-farm employment, and income was also collected.

After each interview, the enumerator was taken to a selected plot "treated plot" on which rock walls were installed to assess the level of management of the established structures. The choice of this plot was based on its proximity to the farmer's home, or on the presence of the respondent on a treated plot at the time of the interview.

Assessment of the management levels of established rock wall structures was done by asking respondents to declare whether the structures on their selected plots were poorly, fairly, or well managed. Each enumerator assessed the management levels of the plots based on criteria generally accepted among conservationists. The criteria used in this process included observations of the general conditions of the rock walls, and the surface erosion on the treated plots, the length of breaches in the walls, and the regularity of damage repairs. A score of 9, 6, and 3 was given to each parameter evaluated if the condition was good, average, or poor (appendix). Based on the overall total score obtained for each plot, the level of management of rock walls was classified as good, average, and poor. Third, an evaluation was conducted by a technical agent with experience in soil conservation practice, particularly rock walls. This specialist successively visited all plots already evaluated and categorized the levels of management into poor, average, and good, based upon his observations. For each method of evaluation, a value of 1 was given if management was poor, 2 if average, and 3 if management of the structures was good.

Model specification

We use a probit model to analyze adoption and management of rock walls applying Maximum Likelihood procedures. The dependent variable (Y) in this case is a dichotomous variable with a value of 1 for adopters of rock walls and 0 for nonadopters. The model can be represented as follows:

$$P(Y_i = 1) = F(\beta_i X_i) \tag{4}$$

where P is the probability of adopting rock walls, F is a cumulative density function, X_i represent a vector of the explanatory variables, and β_i $(i = 0,\ldots.n)$ are parameter coefficients. The independent variables used to estimate the coefficients of the adoption model are defined in table 1.

The second model examines the factors explaining the differences among farmers in terms of management of the conservation structures established on their plots. Given the three levels of management previously defined, a multinomial probit model was used to investigate factors influencing management of rock walls in Fort-Jacques. The model is as follows:

Table 1. Definition of the independent variables used in adoption and management models of rock walls

Adoption	
Variable	Definition
Age	Number of years of the respondents
Gender	1 if respondent is male; 0 if female
Marital status	1 if respondent is married; 0 otherwise
Education	1 if respondent has a formal education; 0 otherwise
Group membership	1 if respondent is a member of a local group; 0 otherwise
Training in soil conservation	1 if respondent has a training; 0 otherwise
Size of farm	Number of hectares of land operated
Per capita income	Annual per capita income of household
Crop dependency	Share of crop revenues in total family income
Management	
Variable	Definition
Age	1 if age<= 45; 2 if 45<age<=65; 3 if age>65
Education	1 if respondent has a formal education; 0 otherwise
Group membership	1 if respondent is a member of a local group;0 otherwise
	1 if respondent has a training; 0 otherwise
Training in soil conservation	*1 if less than 5; 2 if 5 to 7; 3 if greater than 7*
People in the household	1 if less than \$40; 2 if \$40 to \$120; 3 if above \$120
Per capita income	1 if crop share of income is less than 50%; 2 if 50 to 75%; 3
Crop dependency	if above 75%
Size of the treated plot	1 if less than 0.25 ha; 2 if 0.25 to 0.50; 3 if above 0.50
Distance of the treated plot from home	1 if less than 5 minutes; 2 if from 5 to 10; 3 if more than 10 minutes
Ownership of the treated plot	1 if direct ownership; 0 otherwise

$$\text{Prob } (Y_i = j) = F(\beta_i X_i) \tag{5}$$

where j is equal to 1 if management is poor, 2 if average, and 3 if management is good; X_{ij} represents a vector of the explanatory variables for individual i with j level of management, and β, the coefficient of the parameters. The explanatory variables used in the management model are seen in table 1. Age and income is the interaction variable which shows the changes in relationship between the endogenous variable income and the exogenous variable age across levels of adoption.

Results

Profile of respondents

The average age of all farmers interviewed is about 51 years. A significant percent of farmers interviewed (50 percent) had no formal education. In the area of Fort-Jacques, only 21 percent of the farmers declared they received some training in soil conservation. Those with knowledge of soil conservation techniques mentioned that they received their training from a religious organization implemented in the area. Approximately 69 percent of the respondents do not belong to local groups. Some 31 percent of the respondents are members of agricultural cooperatives that offer agricultural inputs at affordable prices. The average number of people in a household is 6.21, and farmers primarily use family labor. The average number of workers available per ha in a household is about 14.

Characteristics of the farms and farming system in Fort-Jacques

Farmers in this zone operate an average of three plots located at various distances from their home. The average size of a farm is 0.62 hectare (ha) within the range of 0.04 and 4.26 ha. Farmers operate their lands under various tenure arrangements, including direct ownership, rent, inheritance, and sharecropping. For each farm, we define a security index, indicating the degree to which farmers control land resources in Fort-Jacques. This index is calculated by dividing the number of hectares directly owned by the farmer by the total land area operated. The average index of land security is 0.19, indicating that farmers in Fort-Jacques have limited control over the land they operate. The farming system in this area is characterized by intensive vegetable crop production.

Adoption of rock walls in Fort-Jacques

Farm operators in Fort-Jacques have used rock walls as a soil conservation measure for several decades. According to the respondents, rock wall structures observed in the area are, on average, 10 years old, ranging from one to 30 years. The size of the plots on which rock walls are established ranges from 0.04 to 0.65 ha; the average size of a treated plot is 0.26 ha.

The time required to walk from a farmer's home to a treated plot averages 10 minutes. The distance varies in time from 1 to 40 minutes, with 45 percent of the plots being between five and 10 minutes away. Rock walls in Fort-Jacques are established on plots with average slopes of 28 percent. The slope of all evaluated plots varies from 10 percent to 60 percent.

Factors influencing adoption of rock walls

Findings of the rock wall adoption model are reported in table 2. The model has a good predictive power with 77.5 correct predictions. The likelihood ratio chi-square of 30.07 for 9 degrees of freedom ($p = 0.0004$) suggests that the null hypothesis is that all coefficients (except the constant term) are zeros is strongly rejected. Gender, membership in local organization, training in soil conservation practice, size of farm, and per capita income appear to be significant determinants of the adoption of rock walls in Fort-Jacques. Male farmers are more likely to invest in rock walls as a soil conservation measure than female farmers. The adoption of rock walls is labor and cash intensive, it is considered as a man's job. However, female farmers, who have the financial resources to hire labor, have been noted to adopt rock walls on their farms.

Age and education are also important factors influencing adoption of rock walls in Fort-Jacques. Our study shows both variables have a negative influence on adoption of rock walls in Fort-Jacques. These results are in line with findings by Gould et al. (1989). However, the results show that training in soil conservation practices positively influences the adoption of rock walls. Another factor that has a positive impact on the probability of adopting rock walls in Fort-Jacques is the per capita income. Featherstone and Goodwin (1993) found that differences in income influence investment in soil conservation by Kansas farmers. Erwin and Erwin (1982) found that cash farm income affects adoption of soil conservation structures. In Fort Jacques, past soil conservation projects have helped with the establishment of rock walls on some public lands that are eroded. However, the majority of farmers have implemented structures on their plots with their own financial means.

Size of farm and membership in local organizations are significant determinants of adoption of rock walls, but they have negative signs. As size of farms increases, the probability that farmers will adopt rock walls decreases. This finding seems to contradict results of Featherstone and Goodwin, which indicate a positive relationship between size of farm and adoption of soil conservation practices. As mentioned by farmers, rock wall installation is physically and financially demanding. Even though investment in such structures may be profitable in this area, it may be financially difficult to establish large numbers of structures required on a relatively large farm to reduce erosion while ensuring the farm family survival.

Farmers who participate in local organizations are less likely to adopt rock walls. Previous research (Ervin and Ervin 1982; Burton et al. 1999) indicate that group membership stimulates adoption of soil management practices by providing timely and accurate information to farmers that enable them to make sound farming decisions. It is important to place our results in the context of the research area. Originally, strategies to promote rock walls in several locations in Fort-Jacques focused on community groups. Farmers in the area state that not all members benefit from such groups. Therefore, they prefer making their own decisions with regards to implementing rock wall structures on their plots.

Management pattern of rock walls

The efficiency of a structure depends upon its level of management. All farmers interviewed in Fort-Jacques acknowledged that they maintain the structures on their plots. Two major operations are undertaken to maintain the structures: repair of breaches by arranging rocks in the walls, and increase in the height of the walls when there is over-accumulation of soil behind the walls. Farmers stated that it is not necessary to frequently maintain the rock walls. However, 70 percent of the farmers interviewed declare they manage the structures once a year.

A Kruskal-Wallis test was conducted to determine whether there was a significant difference in the score distribution of the three evaluations. The results reject the null hypothesis that the distribution of scores associated with the level of management of each farm is identical in the three evaluations. The row-mean score difference is equal to 14.22 with 2 degrees of freedom and a p-value of 0.0008. These results suggest that the distribution of the level of management among the three evaluation methods is not identical. Indeed, the score mean of farmers' evaluations is 1.69, whereas those of enumerators and specialist are 1.97 and 1.93, respectively. Therefore, the score used to rate the management of structures established on each plot was determined by the average of the three evaluations.

Factors influencing management of rock walls in Fort-Jacques

Table 2 shows the results of the polytomous model of factors leading to farmers' ability to manage the structures established on their plots. Given a correct prediction of 72.3 percent of the probabilities, the model provides a significant amount of power for evaluating the factors that influence management of soil conservation structures. The model has a likelihood ratio chi-square of 17.84 for 10 degrees of freedom (p=0.08). Thus, the model has an acceptable fit. The variable age has a coefficient of -4.28, suggesting that ability to skillfully manage the rock wall structures negatively related to age of the farmer. Older farmers are less likely to manage rock wall structures established on their plots than the younger ones. Featherstone and Goodwin (1993) also found that age was negatively related to investment in long term conservation.

The level of per capita income is an influential factor in the management of conservation structures as implied by the negative and significant sign of this variable. The coefficient of this variable is -1.34, suggesting that as per capita income increases, farmers seem to invest less in management of rock walls. Farmers with higher levels of per capita income feel less pressure to maintain the structures than the less fortunate ones. Individuals with high levels of income often rely on hired labor for their farming activities. Participation in local groups and the interaction between per capita income and age have significant effects on farmers' ability to manage rock wall structures. The coefficient for group membership is -0.7828, indicating a negative influence of this factor on the probability of management of rock walls. Farmers who participate in local groups are less likely to manage rock wall structures well than those who do not belong to groups. Farmers in this zone may have developed a reluctance toward participation in community groups. Also, the level of education is negatively related to the management of rock walls. More educated individuals place greater emphasis on finding jobs outside the community instead of managing soil conservation structures on their plots. The interaction between age and per capita income has a positive influence on farmers' ability to management conservation structures established on their plots.

Table 2. Probit estimates of factors affecting adoption and management of rock walls

Management			
Independent variable	Estimated coefficient	Standard error	T value
Constant	0.0152	0.7718	.196
Age	-0.02**	0.0114	1.754
Gender	1.2383*	0.5205	2.379
Marital status	0.3132	0.3054	1.026
Education level	-0.6729*	0.2982	2.256
Group membership	-0.8513*	0.3109	2.738
Training in soil conservation	1.054*	0.3922	2.687
Size of farm	-0.4027**	0.2276	1.459
Per capita income	0.0001*	0.0000075	13.333
Crop dependency	0.4846	0.4364	1.110
Correct predictions: 77.5%			
R^2 = 0.23			
Likelihood ratio chi-square = 30.07 (p=0004)			
Management			
Independent variables	Coefficient estimate	Standard error	T Value
Intercept 3	5.1887*	1.9512	2.659
Intercept 2	6.4225*	1.9907	3.226
Age	-4.2821*	1.7279	2.478
Age^2	0.6312**	0.3821	1.652
Education	-0.6205*	0.3522	1.762
Training in soil conservation	0.6273	0.3890	1.612
Membership in local group	-0.7828*	0.3935	1.989
Number of people dependent of the household	-0.3181	0.2057	1.546
Per capita income	-1.3374*	0.6381	2.095
Age & Per capita income	0.8721*	0.3804	2.292
Size of the treated plot	-0.0357	0.2328	0.153
Distance of the treated plot from home	0.0835	0.2135	0.391
Ownership of the treated plot	0.0838	0.3335	0.251
Correct predictions: 72.3%			
R^2 = 0.23			
Likelihood chi-square = 17.84 (p = 0.08)			

* and ** significant at 5% and 10% levels, respectively

Conclusion

Farmers' behavior toward adoption and management of rock walls in Fort-Jacques area is influenced by social and economic factors. Gender of the respondents, training in soil conservation, and per capita income are found to be positively and significantly influential in the adoption of rock walls. The results imply that male farmers are more likely to adopt rock walls than females. Also, training in soil conservation practices raises farmers' awareness of the potential damage of soil erosion, and consequently positively affects the adoption of conservation measures. Nevertheless, implementation of rock walls is cash demanding. Farmers with higher per capita income seem more likely to invest in rock walls than low income farmers. Larger farms and group membership inhibit the adoption of rock walls as evidenced by the negative sign of the coefficients. Limited resource farmers, whose survival depends on the piece of land they operate, are more likely to adopt rock walls since their livelihood depends on the productivity of the land because of limited alternative employment opportunities in the area.

Results of the multinomial probit model reveal that age, education, group membership, and per capita income negatively influence the ability to manage the rock walls, while age^2 and the interaction between age and per capita income positively influenced the management. Factors influencing management of rock walls may be different for each farmer or group of farmers depending upon the constraints they face.

The research results suggest that physical, social and economic factors influence the adoption and management of rock walls. This study confirms the findings of previous researchers, and has contradicted the results of a few on the adoption process of soil conservation by limited resource farmers. The method is unique in that actual measurements were used to determine the factors that influence the management of rock walls. Readers must, however, note that the sample size was small and that the results may be particular to this locale where market forces emanating from the distribution of high-valued crops may have a tremendous influence on limited resource farmers' behaviors.

References

Anim, Francis D. K. 1999. "A note on the adoption of soil conservation measures in the Northern Province of South Africa." *Journal of Agricultural Economics* 50 (2): 336-345.

Barbier, Edward B. 1990. "The farm-level Economics of Soil Conservation: The uplands of Java." *Land Economics* 66 (February): 199-211.

Bultena, Gordon L., and Eric O. Hoiberg. 1983. "Factors affecting farmers' adoption of conservation tillage." *Journal of Soil and Water Conservation* 38 (May-June): 281-284.

Burton, Michael, Dan Rigby, and Trevor Young. 1999. "Analysis of the determinants of adoption of organic horticultural techniques in the UK." *Journal of Agricultural Economics* 50 (1): 47-63.

Ervin, Christine A., and David E. Ervin. 1982. "Factors affecting the use of soil conservation practices: Hypothesis, evidence and policy implications." *Land Economics* 58 (3): 277-292.

Featherstone, Allen M., and Barry K. Goodwin. 1993. "Factors influencing a farmer's decision to invest in long-term conservation improvements." *Land Economics* 69 (1): 67-81.

Foltz, Jeremy D. 2003. "The economics of water-conserving technology adoption in Tunisia: An empirical estimation of farmer technology choice." *Economic Development and Cultural Change* 51 (2): 359-372.

Francis, P. A., 1986. "Land tenure system and the adoption of alley farming." In *Alley Farming in the Humid and Sub-humid Tropic*. Proceedings of an International Workshop held in Ibadan, Nigeria, March, 10-14, ed. B.T. Kang and L. Reynolds.

Gould, Brian W., William. E. Saupe, and Richard M. Klemme. 1989. "Conservation tillage: The role of farm and operator characteristics and the perception of soil erosion." *Land Economics* 65 (2): 167-182.

Hallsworth, E. G. 1987. *Anatomy, physiology, and psychology of erosion*. Chichester, England: John Wiley and Sons, Inc.

Jean-Pierre, Joël 1984. "L'aménagement de bassins versants face aux contraintes paysannes." M.S. thesis, Université Laval, Québec.

Lea, John Dale (Zach). 1996. "Project Plus monitoring and evaluation case study results." Unpublished manuscript, SECID/Auburn PLUS Report.

Lee, Linda K., and William H. Stewart. 1983. "Land ownership and Adoption of Minimum Tillage." *American Journal of Agricultural Economics* 65 (2): 256-64.

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

Norris, Patricia E., and Sandra S. Batie. 1987. "Virginia farmers' soil conservation decisions: An application of Tobit analysis." *Southern Journal of Agricultural Economics* 19 (1): 79-90.

Rahm, Michael R., and Wallace. E. Huffman. 1984. "The adoption of reduced tillage: The role of human capital and other variables." *American Journal of Agricultural Economics* 66 (4): 405-413.

Saint-Dic, Roosevelt 1981. "Systèmes de tenure et lutte anti-érosive en Haiti." M.S. thesis, Université Laval, Québec.

Santos, Hector, Amy P. Thurow, and Thomas L. Thurow. 2000. "Linkages between investment in extension services and farmers' adoption of soil conservation practices in Southern Honduras." Technical bulletin No 2000-02, USAID/Soil Management CRSP/Texas A & M.

Shields, Martin L., Ganesh P. Rayuniyar, and Frank M. Goode. 1993. "A longitudinal analysis of factors influencing increased technology adoption in Swaziland, 1985-1991." *The Journal of Developing Areas* 27 (July): 469-484.

Toness, Anna S., Thomas L. Thurow, and Hector S. Sierra. 1998. "Sustainable management of tropical steeplands: An assessment of terraces as a soil and water conservation technology." Technical bulletin No 98-1, USAID/ Soil Management CRSP/Texas A & M.

Traoré, Namatié, Réjean Landry, and Nabil Amara. 1998. "On-farm adoption of conservation practices: The role of farm and farmer characteristics, perceptions, and health hazards." *Land Economics* 74 (1): 114-127.

Wiggins, S. L. 1981. "The economics of soil conservation in the Acelhuate River Bassin, El Salvador." In *Soil and Conservation: Problems and Prospects*, ed. R.P.C. Morgan. Chichester.

Williams, L. S., and B. J. Walter. 1988. "Controlled-erosion terraces in Venezuela." In *Conserving Farming on Steeplands*, ed. W. C. Modedenhauer and N. W. Hudson: Soil and Water Conservation Society. Ankeny, Iowa.

Appendix

Criteria used in management assessment of rock walls and associated scores

1. **Conditions of the established structures**
   Rock wall height clearly higher than the soil level (9)*
   Rock walls partially covered with soil (6)
   Rock walls extensively covered with soil (3)
2. **Length of breaches in the walls (percentage of the wall length)**
   Less than 10% of the wall length (9)
   Ten to 50% of the wall length (6)
   Over 50% of the wall length (3)
3. **Regularity of breach repair**
   Often (9)
   Sometimes (6)
   Never (3)
4. **Evidence of soil erosion in the plot**
   Insignificant evidence of erosion (9)
   Limited evidence of erosion (6)
   Significant evidence of soil erosion (3)

*numbers in parenthesis are scores