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Title: Income Efficiency of Soil Conservation Techniques in Haiti

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INCOME EFFICIENCY OF SOIL CONSERVATION TECHNIQUES IN HAITI

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ABSTRACT

Soil erosion and environmental degradation are serious problems facing food security in Haiti. In 1999, the annual soil loss due to erosion was estimated at 36 million m^3 tons. The government of Haiti has been aware of these deteriorating conditions and has sought international assistance to reduce these problems. In 1993, the United States Agency for International Development implemented a soil conservation project and millions of dollars were spent on the encouragement of adoption of soil conservation measures; yet the problems of soil degradation is still menacing food security in Haiti. Hence the need to evaluate the impact of soil conservation in Haiti is important. A survey of 951 farmers, who adopted soil conservation techniques in Haiti, was conducted. The survey participants were composed of 83.6% males and 16.2% females. About 53.3% were illiterate and 42.9 and 4.0% received up to eight years schooling and primary education, respectively. The age group range included 8.5% who were less than 30, 30.8% who were between 30 and 45 years old and 32.6% who were between 45 and 60, and 28.1% who were above 60 years old. The results showed that the soil conservation techniques most commonly adopted by farmers were crop bands, alley cropping, rock walls, and gully plugs. Most farmers were satisfied with the soil conservation techniques adopted and they were aware of the benefits of these techniques. There was no significant difference in income per ha for the soil conservation techniques: alley cropping, rock walls and gully plugs. The net income per ha for crop bands was superior to that of alley cropping, rock walls and gully plugs. All models had a good fit as shown by a relatively high adjusted R^2 and a low mean square error. The model results showed in general the number of plots, the elevation, the number of trees greater than 10 centimeters in circumference, the evaluation of the soil by farmers as fertile and the number of crops unique to the soil conservation technique positively influence the net revenue per ha. The average age of head of household negatively influenced the net income per hectare.

Keywords: Income, Efficiency, Soil Conservation Techniques, Haiti

INTRODUCTION

Land degradation caused by erosion through intensive use of marginal lands is a major problem facing Haiti. The intensity and multiple consequences of soil erosion represent a real impediment to agricultural development in this island nation. In late 1930s, annual soil loss in Haiti was estimated at 7.0 million tons; some 40 years later, in 1978 soil lost due to erosion was estimated at 15 million m^3 (FAO cited by Norris and Beliard, 1999). A more recent estimate by the World Bank showed average soil loss in Haiti at 36.6 million tons per year (Association Internationale de Développement, 1990). The soil loss experienced in Haiti far exceeds that which can be considered sustainable soil loss that would allow for soil regeneration.

The Haiti government and international agencies have recognized the problem as one of the major setbacks to increases in agricultural productivity. They have been battling the problem ever since the break of the century. A number of soil conservation structures have been put in place with the assistance of donor agencies but these structures have been abandoned immediately after the project ended. In 1997, the United States Agency for International Development implemented a soil conservation project and millions of dollars were spent on the encouragement of adoption of soil conservation. However, there is little information on the impact of these soil conservation measures and how they influence farmers' income.

OBJECTIVE

Like several other countries, adoption and management of soil conservation practices in Haiti have not been impressive. Yet information on the effects of the soil conservation practices on net farm income and long term profitability is unknown. There have been studies (Bayard, Jolly and Shannon, 2006 & 2007) that have examined the factors affecting adoption, but few have examined the economic and financial benefits of soil conservation techniques. Therefore, the objective of the study is to evaluate farmers' perception of the efficiency of each of the soil conservation measures commonly adopted under this project, and to identify the factors that influence farmers' income from the adoption of these conservation measures.

METHOD

A survey of 951 farmers, who adopted soil conservation techniques in Haiti, was initiated in 1997 to evaluate the impact of soil conservation techniques. The survey was completed in 1998. A pre-tested survey instrument was used which included socio-demographic, farm, soil, ecology, cropping system, faming practices, types of conservation practices, crop distribution and marketing and other non-farm activities conducted by the rural households. All farmers who participated in the soil conservation program were interviewed.

The data from the questionnaire were entered into a Microsoft excel spread sheet and imported into SAS software package version 8.2 (Statistical Analytical System, Gary, NC). The data set was cleaned and then analyzed using SAS. Basic descriptive statistics were obtained for all variables. Analysis of variance was used to test whether there was difference between means of net income from crop value produced during the 1997 crop year per hectare of each soil conservation technique. The net income was determined by multiplying the volume or weight of crop as normally sold in the market by average market price. The average price the farmer indicated he obtained for sale of the crop was used for the calculation. All crops produced whether sold or not was used for the estimation of income. Since the farmers use very little inputs in the production of crops (Jolly and Prophet 1999) the net income is equivalent to returns above labor and land costs.

The survey participants were composed of 83.6% males and 16.2% females. About 53.3% were illiterate and 42.9 and 4.0% received up to eight years schooling and primary education, respectively. The age group range included 8.5% who were less than 30, 30.8% who were between 30 and 45 years old, and 32.6% who were between 45 and 60 and 28.1% who were above 60 years old.

Model

Multivariate analysis was used to develop a model to determine the factors that influenced net income per ha. for each soil conservation technique. The models assumed the form:

$Y_i = f(\text{DEM, SOCECO, PHY, CROP}_i, \text{CROP}_u)$,

where Y_i equals net farm income of CROP_i ,produced during 1977.

DEM= demographic factors, such as age of farmer, years of farming, size of household

SOCECO=number of workers, use of modern inputs, number of non-paid labor

PHY= Physical characteristics of farm, including elevation, slope, types of soil, farmer evaluation of soil characteristics, such as degree of erosion, depth and fertility
$CROP_i$= the crops produced including young trees planted
$CROP_{u=}$ the crops considered unique to this soil conservation technique.

We used the log-log model because of the anticipated shape of the production function. The log-log functional form also poses less problem of elasticity derivation.

RESULTS

Farming system
The farms surveyed were small and ranged in surface area from 0.1 ha to 11.0 hectares. Most of the farms (45%) were between 0.1ha and 1.5ha. The farms were located on sloping lands that can be considered too steep for profitable row crop enterprises. Only 31% of the lands were less than 20 degrees in slope, and 50.7% of the land was less than 30 degrees. Land transfers through sale in Haiti were limited. Only 43% of the lands studied were purchased, and 37% was inherited. Other system of ownership included joint farming arrangements, half lease and the use of public lands. A large number of cereal crops (sorghum, millet, and corn) were produced together with leguminous crops, such as peanuts, red beans, white beans, black beans and cowpeas. Also cassava, yams, potatoes, vegetables, and bananas were cultivated on these slopes.

Soil Conservation structures
The soil conservation structures commonly installed in Haiti under such projects are the crop bans, rock walls, contour hedgerows with alley cropping, and gully plugs. Farmers expressed their opinions on the advantages or the efficiency of each soil conservation technique in conserving soil.

Crop bands or band manger
Crop bands are rows of plants grown closely along the contours of slopes to restrict soil erosion, and to assist in the improvement of soil quality. These crops include sugarcane, pineapples, bananas, and other shrubs that produce an edible fruit. Farmers were asked to evaluate the importance of the benefits of these crop bands. In terms of improvement of crop quality 49.6 percent of farmers reported that these crop bands were very important, 56.8 percent stated that they were very important in providing food during the faming period, 53.6 percent indicated that they were very important in increasing farm cash revenue, 69.6 percent thought that they were very important for minimizing soil erosion and maintaining of soil fertility, and 20 percent thought that they provided animal fodder. In terms of disadvantages most farmers (84.8 percent) thought that crop bands occupied too much space. Also 84.8 percent of the farmers indicated that the crop bands provided too much shade, 85.6 percent thought that crop bands competed with the main crops, 67.7 percent thought that they provided a hindrance to animal grazing, and 58.9 percent thought that they required too much time for maintenance.

Alley cropping
Alley cropping, on the other hand, consists of growing crops between closely planted and regularly spaced hedgerows of fast-growing trees, usually nitrogen-fixing legumes, such as *Leucaena leucocephala, Leucaena diversifola, Gliricidia sepium, Calliandra calothyrsus, and Cassia siamea*. It has been suggested as an approach to improve soil fertility, and for controlling erosion (Bayard, Shannon and Jolly, 2004 & 2007). Alley cropping has been adopted because of its number of advantages and benefits. Farmers expressed their opinions and reservations about alley cropping. The wood from the hedgerows planted are often used for firewood, for making of charcoal, for maintenance of soil fertility and for fodder for animals. When farmers were asked whether these were important, fairly important or very important, 7.8 percent of farmers thought that the use of hedgerows for firewood was very important; 1.3 percent thought that hedgerows were very important to make charcoal; 17.8 percent thought that the leaves from hedgerows were a very important as a source of fodder for animals; and 33.5 percent said the that the leaves were important, fairly important and very important to maintain soil fertility. In terms of problems posed by hedge rows, 80.4 percent thought that the idea that hedgerows took up too much space was unimportant, and the same percentage (80.4 percent thought that) that the notion that hedge rows produced too much shade was unimportant, 78.5 percent revealed that the thought that hedgerows compete with crops for water was unimportant, and 53.1

percent thought that the problem of restriction to grazing livestock was unimportant.

Rock walls

Rock retention walls are built along the contour of slopes with the purpose of slowing down and diverting rainfall, controlling erosion of steep lands, and forming natural terraces over time (Toness *et al*. 1998, Bayard, Jolly and Shannon 2004). About 97 percent of the farmers rated the rock walls as important, fairly important, or very important for maintaining soil fertility, and about 94 percent rated rock walls important, fairly important or important for maintaining crop productivity. The same percentages of farmers thought that rock walls were important, fairly important or important (96 percent) for providing production space, while 97 percent thought that they were important, fairly important or very important for facilitating land cultivation. Though rock walls are blamed for occupying too much space on the farm, 67.5 percent of farmers thought that this accusation was unimportant. About 38.4 percent revealed that the thought that rock walls present difficulty for animal grazing was discarded as not important, and 26.1 percent of farmers believed that the accusation of too much time for maintenance was also not important.

Gully plugs

Gully plugs are similar to rock walls built along the contour in small, shallow streams to block stream flow to force soil sedimentation, and soil build-up for the purpose of growing crops. Materials such as logs of woods, used truck tires, and rocks are used to create the barriers. The efficiency of gully plugs and the inefficiency of performing the functions for which they are designed were evaluated by farmers. About 88.3 percent of farmers thought that gully plugs were very good, fairly good or good in terms of being technically sound. About 85.9 percent stated that the construction of gully plugs was good, fairly good or very good while 63.3 percent that farmers' ability to maintain the gully plugs was good, fairly good or very good. Gully plugs are also built with the intention that they will protect downstream users. Nearly 77.8 percent of farmers reported that gully plugs were good, fairly good or very good in protecting users down stream. About 87.5 believed that gully plugs provided resistance to rain fall whereas 94.9 percent believed that gully plugs rated good, fairly good or very good in enhancing soil productivity.

Income generation from soil conservation techniques

The cash value of crops produced on one hectare of land with the various soil conservation techniques was estimated by multiplying the volume or weight of crops produced during the current year by the market price. The revenue from crop bands was the highest (9,359.06 goudes) which amounts to US $468 (US$1.00=20 goudes). The revenue generated per ha from the rock walls was 6, 327.08 goudes or $316. The gully plugs produced 5,796.20 goudes or, $290. The alley cropping generated $257.00 or ha (Table 1). Using analysis of variance and a Tukey test we noted that there was no significant difference between the mean revenues generated from gully plugs, alley cropping and rock walls, but the mean revenue generated from the crop bands was significantly superior to that from the other soil conservation techniques.

Factors influencing income from the soil conservation techniques

Cop bands

The regression equation for the crop band model had a good fit as shown by the adjusted R^2 of 0.52 and a low mean square error (MSE) of 0.99 in table 2. The model adjusted R^2 value of 0.52 means that 52 percent of the variation of the dependent variable is explained by the variation of the independent variable. In this model, we see the number of plots, the elevation, the number of trees greater than 10 centimeters in circumference, the evaluation of the soil as fertile by farmers, and the number of crops unique to the soil conservation technique positively influenced the net revenue per ha. The average age of head of household negatively influenced the net income per hectare of the crop band.

Alley cropping

The alley cropping model had an adjusted R^2 of 0.38 and an MSE of 1.24 indicating a relatively good fit. (Table 3) The number of plots having the alley cropping structure per hectare, the elevation, the evaluation of the farmers as to whether the soil showed signs of erosion, and the number of crops unique to the soil conservation technique influenced the net income per hectare from the soil conservation technique. The average age of the head of household negatively influenced the net farm income.

Rock wall

The model for the rock walls had an adjusted R^2 of 0.52 and an MSE of 1.05. This indicates that the model had a good fit (Table 4). In this model, we see that if the farmers complained that the rock walls required too much maintenance, the slope, whether the farmer judged the soil as fertile, deep and the number of crops unique to the soil conservation technique. The average age of household negatively influenced the net income from rock walls.

Gully plugs

The regression equation had a good fit as shown by the adjusted R^2 of 0.51 and a low MSE of 1.02 which signify good model fit (Table 5). In this model, we see the number of plots with this soil conservation technique, the elevation, the number of trees greater than 10 centimeters in circumference, valuation of the soil as fertile by farmers, and the number of crops unique to the soil conservation technique positively influence the net revenue per ha. The evaluation of the farmer as to whether the soil was eroded and the average age of head of household negatively influenced the net income per hectare.

DISCUSSION AND CONCLUSION

The farmers surveyed were mostly older and had a number of years of experience in farming. Most of them were male, but there were more women heads of households than found in similar surveys by Bayard et al. Farmers produced on small farm plots which on the average was less than 1.0ha in size on hilly sloping lands. The levels of education observed are similar to that noticed by Dolisca *et. al*,(2006) and Bayard, Jolly and Shannon (2006).

The farmers' evaluation of the soil conservation structures showed that the farmers valued the benefits from the structures. The farmers did not place much importance on the negative aspects or disadvantages of the structures. From the farmers' responses the most important aspect of the soil conservation structure was to improve soil fertility and crop productivity. The farmers believed that the gully plugs were technically sound and could maintain the soil.

The soil conservation techniques most commonly used were crop bands, alley cropping (hedgerows) rock walls and gully plugs. It is not unusual that the crop bands generated higher income per ha than the other three techniques. The crop bands had the advantage in that they generated other cash income from the crops produced on the contour lines. Some of them may be high priced crops such as bananas, pineapples and sugar cane that can be traded during the hungry months when other crops are not in season.

The factors affecting the net income from the adoption of rock walls were generally the same for most of the soil conservation techniques. The elevation of the structure was positively associated with the net revenue from crop band, alley cropping and gully plug. While this may seem an aberration, one may explain the positive relationship to the farmers' decision to plant the higher priced vegetables on the highest elevations in order to increase their net revenues. In the case of rock walls, the elevation was not significant and one can link that to the physical effort required to build rock walls at high elevations unless rocks are abundant at these elevations.

Another observation to be made is that the net incomes for all structures were positively related to trees of 10 centimeters. This may seem unusual but under this project farmers were encouraged to plant trees. Farmers often sell the trees as poles when they attain a diameter of 10cm or more. Given the current state of deforestation in Haiti, forest trees for poles, lumber and charcoal have become important as investment capital and a valuable asset (Street, 1990).

Net farm income was negatively associated with the average age of head of household. As the farmers grew older they were less successful in adopting soil conservation measures.

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Table1: Average income of the various soil conservation techniques

{tc "Least Squares Means " \f C \l 2}
{tc "TECH " \f C \l 3}
{tc "LSMeans " \f C \l 4}

TECH	INCOME LSMEAN
BAN (Crop Bands)	9,359.06019
MIS (Rockwall)	6,327.07892
RAJ (Gully Plug)	5,796.20071
RAN (Alley cropping)	5,144.08706

Tukey test indicates that there is no significant difference in income for Rock walls, Gully Plugs and Alley Cropping, but the mean income from Crop Bands is superior to that of the other techniques Rock walls, Gully Plugs and Alley Cropping.
Income is measured in goudes. Twenty goudes=1$ US.

Table 2: Effects of Crop Band on Total Farm Income Using a Log-Log Model

{tc "Parameter Estimates " \f C \l 5}Parameter Estimates Adj-R^2=0.52; MSE=0.99					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	3.25826	1.33824	2.43	0.0171
Land Size	1	-0.21359	0.15616	-1.37	0.1751
Slope	1	0.23727	0.47749	0.50	0.6206
Number of Garden Plot	1	0.60367	0.27868	2.17	0.0332
Number of Yrs. In with PLUS	1	-0.31347	0.22007	-1.42	0.1581
Elevation	1	0.76041	0.13957	5.45	<.0001
Trees greater Than 10cm	1	0.21488	0.08666	2.48	0.0152
Was the Soil Fertile	1	1.57384	0.65833	2.39	0.0191
Was the Soil Deep	1	-0.72635	0.47825	-1.52	0.1327
Does the Soil shows sign of erosion	1	-0.09420	0.26370	-0.36	0.7218
Avg. House hold Age	1	-0.88716	0.25068	-3.54	0.0007
Avg. House Hold Yrs. In School	1	-0.12338	0.23550	-0.52	0.6018
Number of Crops Unique Crops Planted	1	1.04787	0.21139	4.96	<.0001

Land size is expressed in ha. Slope is measured in percent. The number of plots is a count variable. Elevation is estimated in meters above sea level. Soil fertility is a categorical variable based on farmers' perception. Erosion is a dichotomous variable based on farmers' perception.

Table 3: The effects of Alley Cropping on Total Farm Income Using a Log-Log Model.

{tc "Parameter Estimates " \f C \l 5}Parameter Estimates, Adj R^2=0.38, MSE=1.24					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	6.29423	0.80299	7.84	<.0001
Land Size	1	0.07652	0.06046	1.27	0.2061
Slope	1	-0.02740	0.22153	-0.12	0.9016
Number of Garden Plot	1	0.21234	0.11422	1.86	0.0635
Number of Yrs. In with PLUS	1	-0.02245	0.14241	-0.16	0.8748
Elevation	1	0.24493	0.08713	2.81	0.0051
Was the Soil Fertile	1	0.43307	0.26989	1.60	0.1091
Was the Soil Deep	1	-0.23451	0.25717	-0.91	0.3622
Does the Soil shows sign of erosion	1	0.06467	0.13811	0.47	0.6398
Avg. House hold Age	1	-0.74094	0.12809	-5.78	<.0001
Avg. House Hold Yrs. In School	1	-0.13359	0.12857	-1.04	0.2992
Number of Crops Unique Crops Planted	1	1.58771	0.11176	14.21	<.0001

Land size is expressed in ha. Slope is measured in percent. The number of plots is a count variable. Elevation is estimated in meters above sea level. Soil fertility is a categorical variable based on farmers' perception. Erosion is a dichotomous variable based on farmers' perception.

Table 4: The effects of Rockwalls on total farm income using a log-log model

Parameter Estimates, Adj R^2=0.52, MSE=1.05					
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	**1**	**4.15827**	**1.12163**	**3.71**	**0.0003**
	1	**0.74538**	**0.14905**	**5.00**	**<.0001**
Requires Maintenance					
Land Size	**1**	**0.03063**	**0.07433**	**0.41**	**0.6806**
Slope	**1**	**0.55247**	**0.29449**	**1.88**	**0.0617**
Number of Garden Plot	**1**	**0.00615**	**0.13484**	**0.05**	**0.9636**
Number of Yrs. In with PLUS	**1**	**0.06017**	**0.18764**	**0.32**	**0.7487**
Elevation	**1**	**0.19577**	**0.12985**	**1.51**	**0.1327**
Trees greater Than 10cm	**1**	**0.09584**	**0.05970**	**1.61**	**0.1095**
Was the Soil Fertile	**1**	**0.81047**	**0.34576**	**2.34**	**0.0198**
Was the Soil Deep	**1**	**0.69264**	**0.27634**	**2.51**	**0.0127**
Does the Soil shows sign of erosion	**1**	**0.18634**	**0.17716**	**1.05**	**0.2938**
Avg. House hold Age	**1**	**-0.87408**	**0.14965**	**-5.84**	**<.0001**
Avg. House Hold Yrs. In School	**1**	**-0.01405**	**0.14772**	**-0.10**	**0.9243**
Number of Crops Unique Crops Planted	**1**	**1.65957**	**0.13304**	**12.47**	**<.0001**

Land size is expressed in ha. Slope is measured in percent. The number of plots is a count variable. Elevation is estimated in meters above sea level. Soil fertility is a categorical variable based on farmers' perception. Erosion is a dichotomous variable based on farmers' perception.

Table 5: Effects of Gully Plug on total farm income using a log-log model

Parameter Estimates, Adj-R^2=0.51; MSE=1.02					
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	1	3.47696	1.19716	2.90	0.0042
Land Size	1	-0.03723	0.09806	-0.38	0.7047
Slope	1	0.51960	0.34230	1.52	0.1308
Number of Garden Plot	1	0.24228	0.16522	1.47	0.1443
Number of Yrs. In with PLUS	1	0.42865	0.25115	1.71	0.0896
Elevation	1	0.35139	0.11971	2.94	0.0038
Trees greater Than 10cm	1	0.21693	0.07308	2.97	0.0034
Was the Soil Fertile	1	1.42603	0.44349	3.22	0.0015
Was the Soil Deep	1	-0.49248	0.35820	-1.37	0.1709
Does the Soil shows sign of erosion	1	-0.35758	0.19512	-1.83	0.0685
Avg. House hold Age	1	-0.75171	0.20077	-3.74	0.0002
Avg. House Hold Yrs. In School	1	-0.02262	0.15740	-0.14	0.8859
Number of Crops Unique Crops Planted	1	1.45456	0.17150	8.48	<.0001