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The impact of soil conservation and output diversification on farm income in Central American hillside farming

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Abstract

This article analyzes the determinants of farm income among hillside farmers participating in natural resource management projects in El Salvador and Honduras. The farm income function was evaluated using a system of equations in which income is determined simultaneously by the farmer's decision to adopt soil conservation technologies and by the level of diversification (number of agricultural activities) on the farm. The database used comes from surveys administered to 678 beneficiaries of these projects during 2002. The econometric results suggest that all the variables related directly to land use (i.e., output diversification, soil conservation practices and structures, and the adoption of forestry systems) have a positive and statistically significant association with farm income. Also, farmers who own land enjoy higher farm incomes than those who do not. The results indicate that when investing in natural resource management projects, governments and multilateral development agencies should pay close attention to output diversification, land tenure, and human capital formation as effective instruments in increasing farm income.

JEL classification: Q12, Q24, Q55

Keywords: Farm income; Soil conservation; Output diversification; Human capital; Central America

1. Introduction

Poverty and environmental degradation are serious problems in Central America. Some countries of the region can be counted among the poorest in the world, and they suffer from deteriorating agricultural lands, shrinking forests, diminishing supplies of clean water, and the threat of growing ecological vulnerability from climate change and loss of biological diversity (UNDP et al., 2002). As a result, the sustainability of economic growth and development in the region is at risk, given that Central American economies are highly dependent on their natural resources (Grepperud, 1995; Lutz et al., 1994; Pelupessy and Ruben, 2000).

Peasant farmers in the region typically grow subsistence crops—mainly corn and beans—in sloping and marginal uplands. The agricultural development path has usually involved the migration of poor or landless farmers to public or open-access lands, who then clear forest areas, and cultivate staple crops for a few years before moving on to clear new plots. As migration increases and the pool of available land declines, farmers use land more intensively. Those unable to purchase agrochemicals face declines in soil fertility and productivity, and farming becomes unsustainable (Neill and Lee, 2001). For many resource-poor farmers, soil degradation exacerbates the continuous struggle for food security (Arellanes and Lee, 2003).

To address these problems, national governments, with the support of multilateral development banks and international donors, have been financing natural resource management projects in the region. Two projects of this kind that deserve special attention due to their magnitude and scope are the Environmental Program for El Salvador (PAES) and the CAJON Natural Resource Management Program in the Cajón watershed, Honduras. Both projects, which have recently concluded, were aimed at conserving renewable natural resources in the upper basin while improving the socioeconomic conditions of the rural population of the affected areas. To reach these goals, a variety of approaches has been implemented, ranging from enhanced soil productivity and adoption of environmentally friendly technologies to crop diversification strategies.

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Despite the significance of resource management and output diversification on the development of rural economies, studies linking these policy instruments with improvements in farm income are rare. Related studies focus mostly on identifying and quantifying the links between social variables and the adoption of environmentally friendly technologies, but do not evaluate the farm-level economic consequences of this adoption process (Jones, 2002).

Therefore, this article adds to the literature by providing an empirical analysis of farm income determination among participants of natural resource management projects in El Salvador and Honduras. A farm income model is developed wherein the decisions to adopt conservation practices and to diversify the output mix simultaneously depend on some of the variables that also explain farm income. To account for potential simultaneity bias, a system of three equations is estimated using two-stage least squares (2SLS).

The rest of this article is organized as follows. The next section gives an overview of the recent literature, followed by a discussion of the methodological framework and a description of the data used. The empirical results are presented and analyzed in the subsequent section, and the article ends with some concluding remarks.

2. Review of the literature

Hillside agriculture is prevalent among small-scale farmers in Central America, who typically are characterized by low productivity and high poverty rates. Moreover, their production practices have led to severe resource degradation (Hopkins et al., 1999; Lardé et al., 2000; Oldeman et al., 1990; Solís and Bravo-Ureta, 2005). Under these conditions, the social and economic development of peasant households must address the "critical triangle" of economic growth, poverty alleviation, and sustainability (Vosti and Reardon, 1997).

In developed countries, it has been shown that the implementation of intensive production systems is sustainable and feasible if accompanied by agricultural extension and related support (Arnold and Dewees, 1995; Scherr et al., 1997; Templeton and Scherr, 1997; Turner et al., 1993). However, while the diffusion of technologies suitable for more-favored areas has been quite successful (David and Otsuka, 1994; Hazell and Ramasamy, 1991), productivity-enhancing technologies to fight poverty in less-favored areas have been poorly studied and appear to have had less predictable results (Nerlove et al., 1996; Reardon and Vosti, 2003).

The literature on technology adoption has established that farmers adopt soil conservation technologies as long as these technologies bring economic benefits (Saín and Barreto, 1996; Scherr, 2000). Since Ryan and Gross (1943) showed that technology adoption varies from farmer to farmer, a wealth of studies have endeavored to explain the sources of this variability (e.g., Lindner, 1987; Feder and Umali, 1993; Feder et al., 1985; Rogers, 1995).

Factors used to explain adoption processes can be classified into three main groups: farmer characteristics, farm characteristics, and project characteristics. Within the first group, farmer schooling, age, gender, and erosion perception are commonly studied. Norris and Batie (1987) have found that younger farmers are more likely to adopt soil conservation technologies than older ones. Furthermore, farmers' perception of erosion as a problem is considered a pre-condition to adoption by Hopkins et al. (1999), Stonehouse (1991), Gould et al. (1989), Norris and Batie (1987), Ervin and Ervin (1982), and Earle et al. (1979).

Among farm characteristics, land tenure, plot slope, and access to credit have been studied by several researchers. Farm size has shown positive correlations with technology adoption in Westra and Olson (1997), Pender (1992), Norris and Batie (1987), and Carlson et al. (1981), and negative or nonsignificant effects in Caviglia-Harris (2002), Knowler and Bradshaw (2001), Agbamu (1995), and Hansen et al. (1987). Shultz et al. (1997), Lutz et al. (1994), and Wachter (1994) state that land owners are more likely to be innovators than those renting land. Slope has a positive effect in Winters et al. (2004), but nonsignificant effects in de Herrera and Saín (1999). Lastly, the connection between credit and technology adoption has exhibited mixed effects (e.g., Caviglia-Harris, 2002; Hansen et al., 1987; Napier, 1991; Pender, 1992; Saín and Barreto, 1996).

Recent studies reveal that off-farm work is an increasing component of total household income in rural Central America (Lanjouw, 2000; Ruben and Clemens, 2000). In El Salvador and Honduras, the contribution of off-farm income to total income had reached approximately 38% by the mid 1990s (Berdegué et al., 2000), while Hopkins et al. (1999) found that off-farm income had a positive effect on the adoption of soil conservation technologies in El Salvador.

Regarding project characteristics (e.g., policy instruments applied to promote rural development), agricultural extension is one of the variables most frequently analyzed. Agricultural extension is important in promoting technological change since it helps farmers to acquire a better understanding of the benefits of innovative production options (Feder and Slade, 1986; Marsh and Pannell, 2001). The positive effect of agricultural extension on the adoption of new technologies has been widely documented (e.g., Abdulai and Huffman, 2005; Hansen et al., 1987; Ramírez and Shultz, 2000; Saín and Barreto, 1996). Moreover, Shultz et al. (1997) found that the frequency of visits by extension agents has a positive and significant effect on the adoption of conservation technologies.

There is limited quantitative understanding of the determinants of household income in Central America. Among the few available studies, López and Romano (2000), and López (2000) analyze the case of peasant farmers in Honduras and in El Salvador, respectively. In both of these studies, the authors use socioeconomic and field characteristics to develop per capita income models. López and Romano (2000) conclude that to increase rural income in Central America, it is necessary

Fig. 1. Relationship between output diversification, soil conservation, farm income, and sustainability.

to promote the development of labor and credit markets. They also show that agricultural extension and education are extremely important for the progress of this region.

3. Conceptual framework and empirical model

Consistent with Johnson et al. (2002), Minten and Zeller (2000), and Pattanayak and Mercer (1998), the relationships among technology adoption, product diversification, and farm income can be modeled as the set of functional links depicted in Fig. 1. In this framework, a household resource set consists of natural capital (e.g., land, livestock, durables, and environmental quality), human capital (e.g., education, experience, and demographic attributes), and social capital (e.g., access to social networks and institutions). In addition, the household's decision-making process is also affected by a set of external factors, including the socioeconomic and agroecological environment, prices, wages, and input, output, and financial markets.

The links between a household's resources and income can be considered as a production process, with resources corresponding to factors of production and income as the output (Barrett and Reardon, 2000; Winters et al., 2002). The allocation of resources to activities is assumed to maximize household income subject to a set of constraints. Farmers allocate assets in a way that equates the marginal value product across activities. A key aspect of this approach is that households simultaneously decide the allocation of resources among different activities (Winters et al., 2002).

On the other hand, the natural resource management projects under analysis motivate farmers to adopt soil conservation technologies and to diversify their product mix. These technological changes should improve farm production and productivity and, consequently, should be reflected in greater household income. Finally, income improvement is considered a necessary condition for the sustainability of changes introduced by the projects.

In the relationships depicted in Fig. 1, the farm income model is subject to simultaneity bias since the decision to adopt a specific cropping pattern and soil conservation practices depends, for a given agricultural year, on some of the variables that also explain farm income.[1] To compute unbiased estimators, endogenous regressors must be uncorrelated with the error term. Thus, to account for potential simultaneity bias, the farm income function is estimated using the following three-equation system[2] (see Table 1 for variable definitions):

$$\begin{aligned}\text{Farm Income} = f(&\text{Diversification, Practices, Structures,}\\ &\text{Forestry, Family Labor, Hired Labor,}\\ &\text{Cost, Distance, Credit, Education, Age,}\\ &\text{PAES1, PAES2, PAES3, CAJON})^{3}\end{aligned} \tag{1}$$

$$\begin{aligned}\text{Practices} = f(&\text{Land, Slope, Perceives Erosion, Tenure,}\\ &\text{Distance, Credit, Off-farm Income,}\\ &\text{Education, Age, Gender, Coffee, Years,}\\ &\text{Visits, PAES1, PAES2, PAES3, CAJON})\end{aligned} \tag{2}$$

$$\begin{aligned}\text{Diversification} = f(&\text{Land, Slope, Tenure, Distance, Credit,}\\ &\text{Education, Age, Gender, Coffee, Years,}\\ &\text{Visits, PAES1, PAES2, PAES3, CAJON}).\end{aligned} \tag{3}$$

This system of three equations is estimated using two-stage least squares (2SLS). In addition, and for the purpose of comparison, the farm income equation is also computed using ordinary least squares (OLS).

Most of the explanatory variables included in this model have direct and indirect effects on farm income. For instance, Education (a continuous variable), has a direct effect on income in Eq. (1), and indirect effects due to the adoption of Practices in Eq. (2) and to Diversification in Eq. (3). To illustrate this point, we focus on the following abbreviated system

$$\ln Y = \alpha_1 + \beta_{YP}P + \beta_{YD}D + \beta_{YE}E + \beta_{YC}C + \sum \beta_Y X_Y, \tag{4}$$

$$P = \alpha_2 + \beta_{PE}E + \beta_{PC}C + \sum \beta_P X_P, \tag{5}$$

$$D = \alpha_3 + \beta_{DE}E + \beta_{DC}C + \sum \beta_D X_D, \tag{6}$$

where Y = Farm Income, P = Practices, D = Diversification, E = Education, C = Credit dummy, β are the unknown parameters, and X_Y, X_P, and X_D represent all the exogenous variables included in the system of equations in (1)–(3). The total effect of an additional year of Education on farm income, which is

[1] A similar problem has been raised by Gavian and Fafchamps (1996) and Feder et al. (1985).

[2] For our purposes, the current level of adoption of conservation structures and forestry can be considered to be largely fixed or established in previous time periods; thus, it is assumed that these two variables do not introduce simultaneity problems into the model.

[3] The farm income equation was computed using an exponential specification, where the right hand side is expressed in logarithms.

the sum of the direct effect plus the indirect effects, can be expressed as

$$\begin{aligned}\frac{dY}{dE} &= \frac{\delta Y}{\delta E} + \frac{\delta Y}{\delta P}\cdot\frac{\delta P}{\delta E} + \frac{\delta Y}{\delta D}\cdot\frac{\delta D}{\delta E}\\ &= \beta_{YE}\exp(K) + \beta_{YP}\exp(K)\beta_{PE} + \beta_{YD}\exp(K)\beta_{DE}\\ &= \exp(K)(\beta_{YE} + \beta_{YP}\beta_{PE} + \beta_{YD}\cdot\beta_{DE}),\end{aligned} \quad (7)$$

where exp(K) is the exponent of the income function in Eq. (4) evaluated at the mean of the sample.[4] A different approach is needed to calculate the marginal effects of the dummy variables since their partial derivates do not exist. For example, the marginal effect of the dummy variable Credit (C) is computed as

$$\begin{aligned}\frac{dY}{dC} &= \frac{\Delta Y}{\Delta C} + \frac{\delta Y}{\delta P}\cdot\frac{\Delta P}{\Delta C} + \frac{\delta Y}{\delta D}.\frac{\Delta D}{\Delta C}\\ &= \exp(K)\left(\frac{\Delta Y}{\Delta C} + \beta_{YP}\cdot\frac{\Delta P}{\Delta C} + \beta_{YD}\frac{\Delta D}{\Delta C}\right),\end{aligned} \quad (8)$$

where

$$\frac{\Delta Y}{\Delta C} = [Y \mid \bar{X}_{*}, C = 1] - [Y \mid \bar{X}_{*}, C = 0]. \quad (9)$$

Equation (9) represents the difference between the value of the income function when the farmers have access to Credit ($C = 1$) and when they do not ($C = 0$), with the remaining explanatory variables are measured at their mean (X_{*}).

4. Data and variable definition

The data used in this study consist of detailed farm-level information obtained from surveys administered to farmers participating in the PAES (El Salvador) and CAJON (Honduras) projects. Generally speaking, the CAJON and PAES projects seek to increase household income through improved soil productivity, the adoption of conservation technologies, and product diversification. In this study, PAES is treated as three separate projects PAES 1, 2, and 3, since each one has been implemented in a separate agroecological region of the Lempa River watershed and executed by different specialized entities relying on their own approaches and methodologies.

The farmers included in the data set were selected randomly from lists of producers associated with each project, and the interviews were conducted between May and August 2002. The sampling procedure in Honduras started by selecting randomly 48 out of the 240 communities participating in the CAJON project (20% of the total). Within each community, four to five farm households were randomly chosen, depending on community size. Overall, 210 beneficiaries were interviewed in Honduras. In El Salvador, data were gathered by surveying a random sample of 530 farm households drawn from a list of all beneficiaries located in 102 communities within the regions of Resbaladero, Texistepeque, San Juan Opico, Nueva Concepción, Tenancingo, and Guazapa. In sum, the whole database has a total of 740 observations; however, all surveys with missing or incomplete data necessary for this study were excluded from the analysis. Thus, the final data set encompasses a total of 678 observations.

The empirical model formulated for this study includes three dependent variables: Farm Income, Practices, and Diversification. Farm Income is the value of total farm production in US dollars, calculated as total output sold and consumed on the farm during the 2001–2002 agricultural year times the selling price as reported by farmers. The production used for home consumption is valued using farm-level selling prices. The variable Practices measures the total farm area with soil conservation practices (i.e., crop residual mulching, minimum tillage, crop rotation, green manure, and contour tillage).

Farm diversification is modeled assuming that the choice of specific productive activities is endogenous, following Culas (2003), IFPRI (2003), Weiss and Briglauer (2000), and Bruck (2001). The number (count) of farm income sources is used to construct the variable Diversification.[5] An alternative measure of diversification used in the literature is the entropy index, which is discussed in detail in Gollop and Monahan (1991) and Hackbart and Anderson (1978). However, the count is easy to calculate and interpret, and requires less information than the entropy index (Hendrikse and Van Oijen, 2000). Moreover, Lubatkin et al. (1993) report a high degree of correspondence between the count and more elaborate measures. In the present study, the correlation between the entropy index and the count is also high (0.85). Hence, the use of the count is a desirable alternative.

The explanatory variables incorporated in the empirical model were selected on the basis of the literature on farm income (e.g., Hill, 2000; López and Valdés, 2000; Ruben and Clemens, 2000; among others) and technology adoption (e.g., Feder and Umali, 1993; Ramírez and Shultz, 2000; Rogers, 1995). The impact of the projects on farm income is captured by the Visits made by an extensionist to the farm, and by the number of Years that the farmer has been working with the project. A set of dummy variables has been included to account for possible project and agroecological effects (PAES1, PAES2, PAES3, and CAJON). Table 1 presents the variable definitions along with their expected effects on Farm Income and Table 2 includes descriptive statistics of the variables used in the econometric models.

[4] Since farm income was computed using a semilogarithmic specification, $\delta y/\delta E = \beta_{\mathrm{YE}}\exp(K)$ (see Chiang, 1984, pp. 293–294).

[5] Farmers reported 24 different production items: corn, beans, eggs, poultry, sorghum, coffee, citrus, milk, hogs, mango, avocado, banana, bovines, sugarcane, white cocoa, tomato, cucumber, cabbage, watermelon, rice, yucca, pineapple, chili, and papaya.

Table 1
Definition of the variables used in the econometric models

Variable	Type	Definition	Expected effect on farm income
Endogenous			
Farm income	Continuous	Value of total farm production in US$, calculated as total output sold and consumed in the farm during the 2001–2002 agricultural year	
Practices	Continuous	Total farm area with soil conservation practices in Manzanas (1 Mz = 0.7 hectare)	+
Diversification	Continuous	Number of agricultural activities included in the farm plan during the 2001–2002 agricultural year	+
Exogenous			
Field characteristics			
Land	Continuous	Farm size (Mz)	+
Tenure	Dummy	1 if operator owns at least part of the farm, 0 if he/she does not own any land	+
Slope	Dummy	1 if average slope is greater than 15%, 0 otherwise	−
Credit	Dummy	1 if farmer uses credit, 0 otherwise	+
Distance	Continuous	Distance from house to parcel (km)	−
Coffee	Dummy	1 if coffee is produced in the farm, 0 otherwise	+
Family labor	Continuous	Total family labor in working days	+
Hired labor	Continuous	Total hired labor in US$	+
Cost	Continuous	Total variable cost in US$	+
Household characteristics			
Education	Continuous	Average level of education for household members ≥10 years old (years)*	+
Off-farm income	Dummy	1 if household earns off-farm income, 0 otherwise	±
Household head characteristics			
Age	Continuous	Age of the household head (years)	−
Perceives erosion	Dummy	1 if farmer perceives soil erosion as a problem in his/her farm, 0 otherwise	+
Gender	Dummy	1 if male, 0 otherwise	+
Project characteristics			
Years	Continuous	Number of years involved with the project	+
Visits	Continuous	Number of visits made by an extensionist to the farm	+
PAES1	Dummy	1 if the farm belongs to PAES1	±
PAES2	Dummy	1 if the farm belongs to PAES2	±
PAES3	Dummy	1 if the farm belongs to PAES3	±
CAJON	Dummy	1 if the farm belongs to CAJON (the omitted category)	±
Technologies			
Structures	Continuous	Total farm area with soil conservation structures (Mz)	+
Forestry	Dummy	1 if a forestry system has been adopted, 0 otherwise	+

*Rogers (1995) indicates that in rural areas in less developed countries, children who are 10 or older have basic reading and writing skills that can help their parents in several household and business-related activities.

5. Empirical results

Table 3 shows the OLS and 2SLS estimates of the income model presented in Section 3. The Breusch–Pagan test was used to check for heteroscedasticity, and, in both cases (i.e., 2SLS and OLS), the null hypothesis of homoscedasticity was rejected at the 1% level of significance. Thus, the appropriate correction was made using White's heteroscedasticity-robust covariance matrix (Greene, 1997).

In addition, the Hausman specification test was used to test for simultaneity between Practices, Diversification, and Farm Income (Hausman, 1978). This test revealed that contemporaneous correlation between the proposed endogenous variables and the error term in the Farm Income equation does exist at the 5% significance level. This result confirms the simultaneity assumption made in the empirical model, indicating that 2SLS is preferred over OLS. Consequently, the analysis to be presented is based on the results obtained using the 2SLS approach. For this latter model, 25 of a total of 47 coefficients are statistically significant at least at the 10% level. Moreover, the R-square indicates that the variables included in the model account for 52.2% of the variation in Farm Income.

Diversification, Soil Conservation Practices and Structures, Forestry, and Education are positive and significant determinants of Farm Income. Family Labor and Hired Labor also affect income in a positive way, although the parameter for the former variable is not statistically significant. Credit, introduced as a dummy variable in the three equations, is found to have no statistically significant effect in any cases. This is consistent with the mixed results reported in the literature. For instance, Ekanayake (1987) found a positive and significant effect of credit for rice farmers in Sri Lanka. In contrast, Deininger et al. (2004) reveal that the availability of credit at the local level had no impact for small-scale farmers in Colombia. Similar results are obtained by Binam et al. (2003) for coffee farmers in Côte d'Ivoire. It should be noted that Credit is considered exogenous

Table 2
Mean, standard deviation, maximum and minimum values of the variables used in the econometric models

Variables	Projects															
	PAES 1				PAES 2				PAES 3				CAJON			
	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min
Endogenous																
Farm income	1359.0	1764.1	13603.0	106.9	1598.0	2132.4	16000.0	142.5	1272.0	1130.2	8.146.0	116.7	1671.0	1903.8	13500.0	107.5
Practices	2.2	2.7	16.0	0.0	1.6	1.6	8.0	0.0	1.2	1.5	15.0	0.0	3.2	3.2	20.0	0.0
Diversification	2.6	1.2	7.0	1.0	2.8	1.2	7.0	1.0	2.8	0.8	9.0	4.7	4.8	1.9	10.0	1.0
Exogenous																
Field characteristics																
Land	5.3	10.3	98.0	0.2	4.8	9.7	80.0	0.6	3.9	3.2	20.0	0.5	7.7	15.8	151.0	0.4
Tenure	48.1	—	1.0	0.0	53.2	—	1.0	0.0	55.9	—	1.0	0.0	64.1	—	1.0	0.0
Slope	53.2	—	1.0	0.0	59.1	—	1.0	0.0	50.3	—	1.0	0.0	80.2	—	1.0	0.0
Credit	5.7	—	1.0	0.0	9.9	—	1.0	0.0	15.7	—	1.0	0.0	36.5	—	1.0	0.0
Distance	1.3	2.3	15.0	0.0	1.2	1.7	10.0	0.0	0.8	1.3	9.0	0.0	1.4	1.5	8.0	0.0
Coffee	51.3	—	1.0	0.0	5.3	—	1.0	0.0	4.4	—	1.0	0.0	46.8	—	1.0	0.0
Family labor	30.6	24.6	798.3	7.5	76.4	30.9	583.1	12.7	33.5	18.1	508.9	8.7	29.2	55.7	760.1	3.4
Hired labor	14.1	16.8	321.4	0.0	35.8	78.4	343.3	0.0	15.3	12.3	39.6	0.0	13.8	12.3	168.9	0.0
Household characteristics																
Education	3.3	2.2	11.6	0.0	3.4	2.3	12.0	0.0	4.0	2.4	13.7	0.0	3.4	1.9	10.5	0.0
Off-farm income	70.8	—	1.0	0.0	66.7	—	1.0	0.0	66.1	—	1.0	0.0	59.1	—	1.0	0.0
Household head characteristics																
Age	48.8	15.5	82.0	19.0	48.6	15.2	88.0	19.0	48.5	14.6	85.0	20.0	45.6	12.9	83.0	20.0
Perceives erosion	85.3	—	1.0	0.0	85.4	—	1.0	0.0	88.0	—	1.0	0.0	93.2	—	1.0	0.0
Gender	95.3	—	1.0	0.0	88.5	—	1.0	0.0	90.1	—	1.0	0.0	87.4	—	1.0	0.0
Project characteristics																
Years	2.6	0.8	4.0	1.0	2.9	0.9	4.0	1.0	2.9	0.9	5.0	1.0	4.1	0.7	6.0	2.0
Visits	1.9	0.8	3.0	0.0	1.8	0.9	3.0	0.0	1.9	1.0	3.0	0.0	2.2	0.8	3.0	0.0
Technologies																
Structures	0.5	0.6	2.9	0.0	0.6	1.4	12.4	0.0	0.6	0.8	4.5	0.0	0.3	0.5	3.3	0.0
Forestry	79.7	—	1.0	0.0	77.6	—	1.0	0.0	79.5	—	1.0	0.0	91.2	—	1.0	0.0
Observations			*156*				*171*				*159*				*192*	

in the present study, a practice commonly adopted in the agricultural economics literature (e.g., Abdulai and Huffman, 2005; Caviglia-Harris, 2004; Pender and Kerr, 1998). However, some studies have endogenized credit (e.g., Zeller et al., 1998), and this could be an area for future refinement of the model implemented here.

Off-farm income, again a dummy variable, is introduced as an explanatory variable in the Practices equation following a specification similar to the one used recently by Abdulai and Huffman (2005). Our results show that off-farm income has a negative but nonsignificant effect on the adoption of soil conservation practices. Negative off-farm income effects have been found by Mbaga-Semgalawe and Fomer (2000), Hopkins et al. (1999), and Bonnard (1995). This finding is consistent with the argument that off-farm income negatively affects the adoption of conservation technologies because it reduces the time available for agricultural work and because these farmers may be less concerned about improving land quality due to their orientation towards off-farm employment. In contrast, Abdulai and Huffman (2005) find a positive and significant effect for off-farm income on the adoption of crossbred cows in Tanzania.

Education is positively associated with the adoption of conservation technologies. Similar results are found in Erenstein (1999), López-Pereira et al. (1994), and Feder and Umali (1993), while other studies reveal inconclusive or negative outcomes (Caviglia-Harris, 2002; Hopkins et al., 1999; Hansen et al., 1987; Marra and Ssali, 1990; Rahm and Huffman, 1984; Warriner and Moul, 1992).

Land has a positive and highly significant effect on Practices and Diversification. This result suggests that households with larger farms are more likely to adopt new technologies and diversify their production plans. Land (measured in Mz)[6] is highly correlated with Practices and Structures (both measured in Mz). Therefore, Land had to be excluded from the income equation in order to achieve convergence in the estimation. Any adverse implication of such exclusion is mitigated by the fact that several authors have shown that in peasant economies the variables having the greatest direct effect on Farm Income are those related to land use patterns rather than the quantity of available land (e.g., López and Valdés, 2000; Mbaga-Semgalawe and Fomer, 2000; Sanders et al., 1995). It is important to reiterate that Land is included as an explanatory variable in the Adoption and Diversification equations, which

[6] Mz stands for Manzana, which is the unit commonly used in the Central American countryside to measure land area. One Mz is equal to 0.7 hectare.

Table 3
OLS and 2SLS estimates of income, practices and diversification [a] (*Standard errors in italics*)[b]

Variables	OLS				2SLS			
	Farm income		Farm income		Practices		Diversification	
Diversification	0.1836***	*0.0179*	0.2091**	*0.0840*	—	—	—	—
Practices	0.0459***	*0.0147*	0.0785*	*0.0456*	—	—	—	—
Structures	0.0803***	*0.0237*	0.0688**	*0.0456*	—	—	—	—
Forestry	0.1698***	*0.0605*	0.1591**	*0.0646*	—	—	—	—
Land	—	—	—	—	0.0847***	*0.0161*	0.0238***	*0.0061*
Slope	—	—	—	—	0.1321	*0.1787*	−0.3042***	*0.1162*
Erosion	—	—	—	—	0.1603	*0.2146*	—	—
Tenure	—	—	—	—	0.5142***	*0.1553*	0.3157***	*0.1141*
Family labor	0.0165*	*0.0100*	0.0175	*0.0107*	—	—	—	—
Hired labor	0.0009***	*0.0001*	0.0008***	*0.0001*	—	—	—	—
Cost	0.0002**	*0.0001*	0.0001***	*0.0000*	—	—	—	—
Distance	0.0114	*0.0174*	0.0126	*0.0149*	0.0761	*0.0653*	−0.0189	*0.0311*
Credit	0.0863	*0.0672*	0.0562	*0.0671*	0.2022	*0.2534*	0.0611	*0.1727*
Off-farm income	—	—	—	—	−0.1998	*0.1721*	—	—
Education	0.0298***	*0.0119*	0.0265**	*0.0113*	0.0470	*0.0389*	−0.0063	*0.0262*
Age	−0.0015	*0.0016*	−0.0019	*0.0017*	0.0111**	*0.0049*	0.0061	*0.0038*
Gender	—	—	—	—	0.2403	*0.2103*	−0.2555	*0.1858*
Coffee	—	—	—	—	0.3130	*0.2934*	0.3602*	*0.2134*
Years	—	—	—	—	0.1909*	*0.1063*	0.0070	*0.0712*
Visits	—	—	—	—	0.0646	*0.0880*	0.0016	*0.0239*
PAES 1	0.2549**	*0.1042*	0.3754*	*0.2018*	−0.1532	*0.2960*	−2.1386***	*0.2152*
PAES 2	0.4414***	*0.0913*	0.5740***	*0.1867*	−0.7921***	*0.2436*	−1.9321***	*0.2003*
PAES 3	0.3938***	*0.0936*	0.5155***	*0.1791*	−1.1634***	*0.2422*	−1.8473***	*0.2174*
Constant	5.2856***	*0.1872*	5.0483***	*0.3634*	−0.2513	*0.6739*	4.5487***	*0.5852*
Adjusted R-square[c]	0.5345		0.5222		0.2731		0.3156	
Sample size	678		678		678		678	

*$P < 10\%$; **$P < 5\%$; ***$P < 1\%$.
[a]Dependent variables: log of agricultural income, area with conservation practices, and number of crops adopted.
[b]Correction for heteroscedasticity was performed using the White's heteroscedasticity-robust covariance matrix.
[c]The system R-square in the 2SLS is calculated as the squared correlation between the observed and predicted values of each dependent variable (White, 1997).
—Variable not included.

makes it possible to measure the effect of farm size on Farm Income, albeit indirectly, as discussed below.

The parameters for the *dummy* variables introduced to capture location- and project-specific effects on Farm Income show that, *ceteris paribus*, farmers participating in PAES 1, 2, and 3 display statistically significant higher income levels than those associated with CAJON (omitted variable). The parameters of two variables introduced in the Practices and Diversification equations to capture specific project characteristics, Years and Visits, have the expected positive sign but low or no statistical significance.

Table 4 presents the marginal effects for all variables influencing Farm Income. Given the model specification, as explained in Section 3, the marginal effects are divided into three categories: direct, indirect, and mixed (direct and indirect). These marginal effects measure the change on Farm Income stemming from an additional unit of a specific explanatory variable, holding all other variables constant at their mean values. For example, the marginal effect of Diversification reflects the change in Farm Income associated with the incorporation of an additional agricultural activity into the farm plan.

The figures in Table 4 reveal that the variables directly associated with land use, which are also the key interventions of the projects under analysis, have some of the highest impacts on farm income. The highest direct marginal effect is for Diversification, where an additional enterprise included in the farm plan increases income by US$311, a gain of 21% with respect to the average farm income of the entire sample. This outcome confirms the strategic role that output diversification can play in reducing rural poverty. Similar results have been reported by Ruben and Clemens (2000), Delgado and Siamwalla (1997), and Nerlove et al. (1996).

The second highest direct marginal effect is for Forestry; those who have adopted one forestry system exhibit an increase of US$237 in farm income. Furthermore, an additional Mz under soil conservation Practices and Structures is associated with an increase in farm income equal to US$117 and US$102, respectively. A positive effect of soil conservation technologies is also reported by Knowler and Bradshaw (2001), Wandel and Smithers (2000), and Okoye (1998). These findings are important in analyzing the sustainability of environmental projects in peasant economies, because some technologies can be effective

Table 4
Marginal effects on farm income

Type of effect on farm income	Variables	Percent	US$
Direct	Diversification	21.0	311.0
	Forestry	16.0	237.0
	Practices	8.0	117.0
	Structures	7.0	102.0
	Family labor	1.8	26.0
	Years	1.6	25.0
	Hired labor	0.1	1.2
	Cost	0.0	0.1
Indirect	Tenure	11.0	158.0
	Coffee	10.0	149.0
	Erosion	1.3	19.0
	Land	1.2	17.0
	Visits	0.5	8.0
	Off-farm income	−1.6	−23.0
	Gender	−3.5	−51.0
	Slope	−5.3	−79.0
Mixed	Credit	8.5	126.0
	Education	2.9	43.0
	Distance	1.5	22.0
	Age	0.0	0.4
	PAES 1	−8.4	−125.0
	PAES 2	11.0	160.0
	PAES 3	3.8	56.4

in decreasing environmental degradation, but their adoption could be limited if they do not bring tangible economic benefits to farmers within a reasonable period of time.

Other direct marginal effects of particular interest are for Family Labor (US$26), Years with project (US$25), and Hired Labor (US$1.2). The large difference between Family and Hired Labor reflects the importance of treating these variables separately in analyzing peasant agriculture. The treatment of labor in farm models has received considerable attention in the development literature (e.g., Ajibefun and Daramola, 2003; Byiringiro and Reardon, 1996; O'Neill and Matthews, 2000; and Schultz, 1999), since it has been argued that family and hired labor may not be perfect substitutes owing to imperfections in the labor market typically found in less developed economies (Taylor and Adelman, 2003).[7]

The highest indirect marginal effect is for Tenure, indicating that households that own at least some of their land exhibit, on average, an increase of US$158 in their annual income relative to those that do not own any land. Another result worth pointing out relates to the marginal effect of Land, which indicates that an additional Mz generates, indirectly through its effect on Practices and Diversification, US$17 in additional Farm Income. Visits, which is an indication of the exposure of farmers to extension support, has a small but positive (US$8.0) effect, again, through both Practices and Diversification.

The largest mixed (direct and indirect) effect is for Credit (US$126), and this is in line with the findings reported recently by Abdulai and Huffman (2005) for Tanzania. The second most important mixed effect is for Education (US$43), which confirms the importance of human capital and is consistent with the findings reported by López (2000) in his study on rural poverty in Central America.

6. Conclusions and policy implications

This article examines the determinants of agricultural income among peasant farmers participating in natural resource management projects in El Salvador and Honduras. This analysis is accomplished by estimating a three-equation system in which farm income is determined simultaneously by the farmer's decision to adopt soil conservation technologies and by the cropping system implemented on the farm. The simultaneity assumption is supported by the results of the Hausman specification test.

The econometric results show a highly significant and positive association between output diversification and farm income. In addition, the adoption of soil conservation practices and structures and of forestry systems also contributes significantly to the improvement of agricultural earnings. These results lend support to the suitability of encouraging these types of investments as an integral part of resource management projects and, more broadly, of development strategies designed to alleviate rural poverty in Central America. The analysis also confirms that governments and multilateral development agencies should pay close attention to land tenure, access to credit, and human capital formation as effective instruments in increasing household income.

Finally, a formal economic evaluation of the actual impact of the resource management projects examined in this article, which is highly desirable, is not possible at this time given the lack of baseline data and of data for an appropriate control group. This is an area that merits careful consideration in the implementation of future projects of this type.

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[7] The authors are grateful to one of the anonymous reviewers for insisting that we revisit this issue, which made us go back to the original data and rework the information in order to separate labor into family and hired. In an earlier version of this article, labor was treated as an aggregate of family and hired, and the marginal effect obtained in that specification was US$0.90.

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