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ON-SITE COSTS AND BENEFITS OF SOIL CONSERVATION AMONG HILLSIDE FARMERS IN EL SALVADOR

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ABSTRACT

This study analyses the relationships between farm income, adoption of conservation technologies and output diversification among PAES participants by comparing their performance at two points in time, 2002 and 2005, and against non-participants (control group) in 2005. An endogeneity test confirms that conservation adoption and diversification are endogenous. Therefore, the diversification and adoption equations are estimated first and the predicted values of both endogenous variables are used in a second step as additional explanatory variables in the farm income equation where the latter is estimated using the Tobit technique. The Tobit results are then used to generate the net present value (NPV) and internal rate of return (IRR) of the soil conservation and agroforestry component of PAES between 1998 and 2005.

Crop diversification and soil conservation practices exhibit a strong positive association with the length of farmers' involvement with PAES and their participation in social organizations. Soil conservation practices and crop diversification, measured by an entropy index, significantly increase farm income, which highlights the strategic role of diversification in fighting rural poverty. The positive association between conservation practices and income contrasts with the effects of conservation structures, which is negative but non-significant. A substantial body of literature increasingly recognizes that structures are expensive to build and maintain whereas they add little to the land productivity in the short run. Such drawbacks may clearly affect the profitability of these conservation technologies.

Then we compare cost and benefit figures over the life-span of PAES (1998-2005) to compute the IRR and NPV. Average income gains per family per year amount to $280, while the NPV is $13,674,100 at a 12% discount rate with an IRR of 48.45%. These indicators clearly reveal that the soil conservation and agroforestry component of PAES has been highly profitable, which is in line with similar evaluations of natural resource management programs in Central America and elsewhere. Finally, the estimates of NPV and IRR are robust, according to diverse scenarios generated using bootstrapping and sensitivity analysis.

INTRODUCTION

Natural resource degradation is pervasive in Central America and is mainly caused by poor land management while a rapid population growth forces an increasing number of farmers to upland areas in search of more land to cultivate. Without major changes in agricultural production strategies in the region, native forests are projected to disappear by the middle of this century (Kaimowitz, 1996; Utting, 1997). Environmental degradation also threatens regional food security, as indicated by the persistent drop in per capita production of corn and beans, the main staple crops (Johnson and Baltodano, 2004; Barbier, 2000; Conroy *et al*., 1996).

To respond to this bleak scenario, local governments with the support of international agencies have undertaken a series of public investment programs focusing on poverty reduction and the promotion of conservation technologies. One such effort is the Environmental Program of El Salvador (PAES). This program, which concluded in 2004, had a US $35.89 million price tag making it the largest public agricultural investment ever made in this country. The thrust of this project was to increase farm-household income through improved soil productivity, the adoption of conservation technologies and product diversification. PAES can be viewed as three separate projects, PAES1, PAES2 and PAES3, since each one was implemented in a different area by a different international consortium (for an overview of PAES, see Bravo-Ureta *et al*., 2006b).

Two previous studies have analyzed the on-farm benefits achieved by farmers participating in PAES. Cocchi (2004) uses farm-level data collected in 2002 from a sample of farmers participating in PAES (El Salvador) and in CAJON (Honduras) to estimate a model of technology adoption, diversification and household income wherein households simultaneously allocate assets to different activities. Results show that conservation practices, diversification and human capital formation have a strong positive effect on household income, contrasting with the negative effect of conservation structures. Output diversification significantly decreases income from staple crops but greatly increases cash crop income. These results reaffirm the strategic role of diversification in fighting rural poverty. However, the gains from a more diversified income portfolio do not occur without cost, since an extra activity added to the farm plan implies a reduction in the production of corn and beans (staples). This trade-off between diversification and subsistence food production suggests that switching to a more market-oriented production pattern may increase household food insecurity.

Bravo-Ureta, *et al*., (2003) and (2006b) also used the 2002 data to analyze the determinants of farm income among hillside farmers participating in PAES and CAJON. 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 results suggest that all 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. In addition, farmers who own most of their 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.

The objective of the present study is to extend the previous analysis of the relationships between farm income, conservation technologies and output diversification among PAES participants by comparing their performance at two points in time, 2002 and 2005, and against non-participants (control group) in 2005. The econometric results are then used to obtain estimates of expected net present values and internal rates of return associated with the project.

The rest of the paper is organized as follows. The next section presents the analytical framework used to examine the links between natural resource management and household income as well as the cost-benefit approach, followed by the discussion of the econometric and profitability results, including sensitivity analysis. The last section presents some concluding remarks.

I. EMPIRICAL MODEL OF SOIL CONSERVATION, DIVERSIFICATION AND HOUSEHOLD INCOME

Following Minten and Zeller (2000), the relationships among technology adoption, product diversification and household income can be stylized as a set of functional links, illustrated in Figure 1. The set of resources (assets) available to the household consists of natural capital (land, livestock, durables and environmental quality), human capital (education, experience, demographic attributes) and social capital (access to social networks and institutions). A set of external factors (socio-economic characteristics, the agro-ecological environment, input, output and financial markets, prices, wages, and infrastructure) also affect the household's decision-making process. The allocation of household resources combined with the external factors determines the income level of farm and off farm activities.

The mapping of assets to household income through both off and on farm activities can be considered as a production process, with assets corresponding to factors of production and income as the output (Winters *et al*., 2002; Barrett and Reardon, 2000). The allocation of assets to each activity is assumed to maximize farm income subject to a set of constrains. Moreover, the natural resource management projects under study motivate farmers to adopt soil conservation technologies and to diversify their product mix. These instruments are expected to improve farm production and productivity and thereby total household income. Finally, income improvement is considered a necessary condition for the sustainability of the changes introduced by the projects.

A key feature of this framework is that households simultaneously determine the allocation of assets to different income-generating activities (Winters *et al*., 2004). In the presence of simultaneous causality, OLS estimators are biased and inconsistent due to correlation between regressors and error terms. The standard prescription for dealing with these problems is the instrumental variables (IV) technique. If instrumental variables that are correlated with the explanatory variables but uncorrelated with the error terms are available, then IV regression yields consistent estimates (Deaton, 1997).

PAES has promoted at least 15 different soil conservation and agroforestry technologies. To facilitate model formulation and estimation, these technologies are classified into three groups: 1) soil conservation practices (crop residue mulching, minimum and zero tillage, crop rotation, green manure, and contour tillage); 2) soil conservation structures (terraces, ditches, live barriers, stone walls); and 3) agroforestry (intercropping, trees in contour, shades, trees dispersed in lots, and secondary forest management). Given the wide array of technologies disseminated by PAES, we construct two general indicators of adoption: 1) Area treated with soil conservation practices; and 2) Area treated with soil conservation structures and agroforestry combined.

The distinction between structures and practices is important because traditionally most resource management projects have focused on structures designed to stop water runoff, such as terraces and ditches. These structures are labor-intensive and expensive to construct, require costly maintenance and benefits usually accrue in the long run. Consequently, soil conservation programs do not have a very good track record regarding sustainable impact (Hellin and Haigh, 2002; Herweg and Ludi, 1999; Wiggins, 1981; Blaikie and Brookfield, 1987). To improve performance, programs are placing more emphasis on technologies that provide soil cover and recover organic matter, such as green manure, cover crops and improved fallows. Moreover, these practices are relatively inexpensive and demand little to no extra labor (Bunch, 2001; Scherr, 2000; Erenstein, 1999). Another important distinction is that farmers can choose the amount of land treated with conservation practices in each production cycle, while conservation structures are durable goods, and thus these choices could have been made years in the past. Therefore, for modeling purposes, in any given year, it is convenient to consider structures as exogenous and practices as endogenous.

Farm diversification is assumed to be endogenous following Culas (2003), IFPRI (2003), Weiss and Briglauer (2000), and Bruck (2001). The farmers in this sample 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). The number (count) of crops, excluding corn and beans, is used to construct the variable OD (Diversification). An alternative measure of diversification is the entropy index, which weights the value shares of a farm's activity by the log of the inverse of the respective shares (Culas, 2003), and can be expressed as:

$$\textit{1) Entropy index} = \mathrm{EN} = \sum_{i}^{n} P_i \log \frac{1}{P_i},$$

where P_i is the share of crop *i* on total farm income. This index takes the value of zero when the farm is completely specialized, whereas the maximum diversification is given by *EN*=log(n) (Weiss and Briglauer, 2000).

The empirical model of conservation, diversification and farm income is represented as:

2) ***Conservation*** *= f (social organization, visit, erosion, years with PAES, PAES1)*

3) ***Diversification*** *= f (social organization, visit, erosion, years with PAES, PAES1)*

4) ***Farm Income*** *= f (***Conservation, Diversification***, conservation structures, land, labor, off-farm income, age of head of household (HH), gender of HH, education of HH, slope, social organization, animal orientation, cash crop orientation, tenure, year, market access, local infrastructure, PAES1)*

All variables are defined in Table 1. The farm income equation includes explanatory variables representing household, household-head, farm, project, and location characteristics based on the literature on farm income determination (Finan *et al*., 2004, Winters *et al*., 2002, de Janvry and Sadoulet, 2001, and Dutilly-Diane *et al*., 2003). Equations (2), (3) and (4) are estimated using the Tobit technique to account for the fact that the dependent variables, adoption, diversification and income, are all bounded at zero. Similar specifications can be found in Asafu-Adjaye (2006), Sesaboa and Tol (2005), Corral and Reardon (2001), de Janvry and Sadoulet (2001), Fernandez-Cornejo and McBride (2002), Barrett *et al*. (2000), Adesina and Zinnah (1993), Gould *et al*. (1989), and Norris and Batie (1987).

II. Identification of PAES Impacts

In this section the strategy followed to identify the farm-level impacts associated with PAES is presented. Impact evaluation relies on the construction of a counterfactual situation to examine what would have happened to a group of beneficiaries had they not participated on a given project. The counterfactual outcome is never actually observed as people cannot simultaneously participate and not participate in a project. To generate counterfactual data it is necessary to establish a control or comparison group (those who do not participate or receive benefits) to compare it with the group under intervention. If there is data for a control group then "with and without" project comparisons are possible. Ideally, data for impact evaluation would be collected from the same set of households at least twice, before and after the intervention. Beneficiaries can also be compared before and after the intervention if baseline and follow-up data are available. Even if only post-intervention data are available, it is still possible to conduct a sound evaluation by choosing an appropriate design (Adam, 2006; Prennushi *et al.*, 2000).

The choice of methodology to determine the counterfactual is at the core of evaluation design and depends largely on how and when the evaluation is planned. The earlier an evaluation is planned, the greater the methodological flexibility, particularly in the choice of quantitative techniques. Two broad categories of such methodologies can be identified: experimental designs (randomized); and quasi-experimental designs (nonrandomized) (Adam, 2006; Ezemenari *et al*., 1999). Experimental designs are generally considered the gold standard and the most robust of the evaluation methodologies. By randomly allocating the intervention among eligible beneficiaries, the assignment process itself creates comparable treatment and control groups that are statistically equivalent to one another. This is a very powerful approach because, in theory, a control group generated through random assignment serves as a perfect counterfactual, free from the troublesome selection bias issues that often plague evaluations (Adam, 2006; Kerr and Chung, 2001; Baker, 2000).

For the purpose of this ex-post evaluation of PAES, no experimental design is possible, since there is no baseline and no randomized control group. Instead, quasi-experimental techniques were applied to select the treatment and comparison groups after the intervention occurred (Adam, 2006; Baker, 2000). Matching techniques were also employed to construct a comparison group that resembles the treatment group based on observed characteristics while statistical controls were applied to measure differences on farm income for the treatment group at two points in time (2002 and 2005) and between the treatment and comparison groups at a given point in time (2005), allowing respectively for before-after and with-without comparisons.

III. DATA

The data used in this study consist of detailed information obtained from surveys applied to representative samples of small scale farm households in El Salvador. The data set covers a wide range of variables including attributes of the households, land tenure status, inputs used and outputs produced, prices paid and received, technology adoption, soil conservation practices implemented, non-farm sources of income, and access to services such as formal education, credit, training, extension, and technical assistance. First, a sample of households participating in PAES was surveyed in 2002. These data were collected and analyzed by Bravo-Ureta *et al*., (2003), as part of a Technical Cooperation between the Office of International Affairs (OIA) at the University of Connecticut (UConn) and the Inter-American Development Bank (IDB). For the purpose of the current study, a sub-sample of the 2002 survey was re-surveyed in 2005, this time along with a control group of non-participating families.

To capture local effects, a community-level survey was applied in the 176 cantons included in the 2005 fieldwork to gather information on access to infrastructure, transportation, and input and output markets that might affect technology adoption/disadoption. A principal components analysis was then performed to summarize that information and create two new variables: Market Access, and Local Infrastructure. Market Access was created as a function of distance to the city, presence of local production cooperatives, presence of an output market, and access to transportation. In turn, Local Infrastructure was constructed based on access to electricity, and the availability of primary and secondary schools. This analysis was performed using the Princomp procedure in SAS. For both variables, Market Access and Local Infrastructure, a higher value denotes a higher level of market access or infrastructure availability, respectively.[1]

Table 1 displays variable definitions and their means. The table also includes the statistics for the tests of mean differences for the different samples. The data are disaggregated by survey year (2002 and 2005) and by groups under analysis (i.e., PAES beneficiaries, neighbors, non-neighbors). The tests of means reveal that farm income, measured in constant 2005 dollars, has increased significantly among PAES beneficiaries between 2002 and 2005 going from $1,864 to $2,318 or a 24% rise. These figures are also significantly higher that those from neighbors ($1,969) and non-neighbors ($1,981) for 2005. The average farm income for all the control group is $1,975.

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[1] A detailed discussion of the fieldwork and dataset and of the principal components results is found in Bravo-Ureta *et al*., (2006a).

An issue that needs consideration is the choice of functional form. Commonly used alternatives include the logarithmic and semi-logarithmic functional forms wherein, to avoid the calculation of the logarithm of zero, each observation is transformed by adding a small constant. This technique precludes the possibility of households being at a corner solution and there is evidence that the change of zero-values to make possible the logarithmic transformation is sensitive to the constant chosen (Soloaga, 2000; Carson and Cameron, 2000). Therefore, and given the presence of zero values in the dependent variables in equations (2), (3) and (4), the linear functional form is used in the analysis presented below. Recent studies using linear specifications include Wilkins *et al*. (2001), Finan *et al*. (2004), Winters *et al*. (2002), Taylor and Yúñez-Naude (2000), de Janvry and Sadoulet (2001), and Dutilly-Diane *et al*. (2003).

IV. The Measurement of On-Site Benefits and Costs of PAES

The financial performance of PAES is evaluated in this study using conventional Cost-Benefit Analysis (CBA). PAES includes a sizable initial investment followed by a stream of annual returns over the life of the investment; thus the use of CBA is appropriate. CBA employs discounting techniques to explicitly recognize the opportunity cost associated with the timing of receipt and expenditure flows (Richards *et al*., 1998). Regardless of some limitations, it is widely recognized that the careful application of CBA can greatly improve decision-making concerning natural resource management projects (Bekele, 2003; Bojö, 1992; Blaikie, 1987; Ekbom, 1995; Clark, 1996; Enters, 1998a, b). De Graaff (1996) also argues that in developing countries, where capital and skills are scarce and increasing current income has high priority, efficiency is still the major criterion and CBA is the dominant evaluation method.

In this study, we compare Project cost and expected benefit figures over the life-span of PAES (1998-2005) and compute the internal rate of return (IRR) and the net present value (NPV) using a 12% discount rate. Project costs are the annual expenditures on the soil conservation and agroforestry component of PAES from 1998 to 2004 as reported by Henríquez (2006).

To calculate annual project benefits we first estimate income gains per farm, which are equal to the total differential of Farm Income (equation 4) with respect to the length of the farmer's involvement with the project (years with PAES). For the i^{th} farm in year t, the total (indirect) effect of an additional year with PAES (x_{it}) on farm income (dY^F/dx_{it}) is the sum of the direct effects of x_{it} on **Conservation Practices** (equation 2) and **Diversification** (equation 3), that is,

$$5)\ IncomeGainperFarm = \frac{dY^F}{dx_{it}} = \frac{\delta Y^F}{\delta Adoption}.\frac{\delta Adoption}{\delta x_{it}} + \frac{\delta Y^F}{\delta Diversification}.\frac{\delta Diversification}{\delta x_{it}}$$

Equation (5) yields a coefficient that is applied to calculate the weighted average farm income (WAFI) gains as follows:

$$6)\ \text{WAFI}_t = \left(1/N.\sum_{t=1998}^{2005} n_t\right).\left(Benchmark\ Farm\ Income + \frac{d\,Y^F}{d\,x_{it}}.\,x_{it}\right),$$

where n_t is the number of families incorporated to PAES during year t, N is the total number of families participating in PAES during year t (the t^{th} cohort), and *Benchmark Farm Income* is the average farm income of the control group

($1,975.4), which is assumed constant between 1998 and 2005. Equation (6) is simply a weighted average of farm income, where the weights are the number of families receiving benefits during a given year, accounting for the differences in the extent of involvement with PAES of each group (cohort) of beneficiaries. Data on the number of families incorporated yearly were gathered from Henríquez (2006), while the length (Years) of the beneficiaries' involvement with PAES was obtained from the 2002 and 2005 surveys.

V. EMPIRICAL RESULTS

A. Econometric Estimation of Soil Conservation, Diversification and Farm Income

This section reports the Tobit estimates of soil conservation adoption, output diversification and farm income (equations 2, 3 and 4) for 260 PAES beneficiaries during 2002 and 2005. In order to determine the sensitivity of the results to model specification 10 alternative models were estimated as shown in Appendix 1. The first five models in the Appendix use entropy while the other five models incorporate a count variable to measure product diversification. Within each of these two sets of five models, the first model is a standard Tobit with no correction for endogeneity of conservation practices and diversification. The four remaining models are different specifications of endogeneity-corrected Tobit models, in which diversification and conservation practices are estimated in a first stage and their predicted values are included in a second step as additional explanatory variables in the farm income equation.

Before proceeding with the analysis, we examine the potential endogeneity of diversification and conservation practices using a simple test developed by Smith and Blundell (1986) for models with censored dependent variables. The procedure involves regressing the suspected endogenous on the explanatory variables, and including the residuals from these regressions in the final Tobit model. Under the null hypothesis, the model is correctly specified with all explanatory variables as exogenous. Under the alternative hypothesis, the suspected endogenous variables are expressed as a linear combination of a set of instruments. If the first-stage residuals are not significant in the second-stage regression, then exogeneity cannot be rejected. This test is equivalent to the more common Hausman test (1978) that compares coefficients of IV and OLS estimations (Cobb-Clark and Crossley, 2003; Garrett and Sobel, 2002; Holly, 1982). The results of the Smith and Blundell test confirm the assumption that conservation and diversification are indeed endogenous, since the parameters of residuals from the first-stage regressions are statistically significant.

The last row of Appendix 1 shows predicted farm income for 2005 for the ten models, computed by applying equation (6). The average of the ten predicted farm income values is $2,720. Based on the results concerning exogeneity and on the fact that model (3) yields a predicted farm income value equal to $2,783, which is very close to the overall average, the following discussion is based on this model.

Unlike OLS coefficients, Tobit coefficients cannot be interpreted directly as estimates of the effects of changes in the explanatory variables on the expected value of the dependent variable. Instead, marginal effects, which measure the percent change in income due to a one unit change in an explanatory variable, are computed as:

$$\text{7)} \qquad \frac{\partial E[y|\mathbf{x}_i]}{\partial \mathbf{x}} = \boldsymbol{\beta} \times Prob[L_i < y_i^* < R_i]$$

where L_i and R_i are the lower and upper bounds of the censored variables (SAS, 2006). Table 2 reproduces the estimates of model (3) along with the computed marginal effects for the conservation, diversification and income equations.

Twelve out of 30 coefficients (40%) reported in Table 2 are statistically significant. Both conservation and diversification are positively and significantly associated with the length of farmers' involvement with PAES and with participation in social organizations. An extra year with PAES raises the entropy index by 5.6% and expands the area treated with conservation practices by 0.22 *Manzanas*. In turn, the participation in social organizations increases the adoption of practices and the entropy index by 0.338 *Manzanas* and 9.0%, respectively. Membership in community or farmer organizations has been found to be effective in providing follow-up support to farmer-members (Lapar and Pandey, 1999; USAID, 1994). These results are in line with Rerkasem and Rerkasem (1996), who identified three key elements that have a significant role in sustainable land use management: 1) the availability of appropriate and cost-effective technological solutions; 2) the existence of social organizations and communal resource management; and 3) the ability of local people to participate in making crucial decisions related to land management.

The coefficients for expenditures on farm inputs (Cost) and labor on the farm income equation are all significant and positive, indicating the existence of a well-behaved production function. Diversification, measured as entropy, significantly increases farm income. This result highlights the strategic role of diversification in fighting rural poverty and is consistent with findings reported by Ruben and Clemens (2000), Nerlove *et al*., (1996), Delgado and Siamwalla (1997), and Immink and Alarcón (1993).

The income value of an extra *Manzana* with conservation practices is $466.2, which amounts to a 20% increase over the average farm income ($2,318) of PAES beneficiaries. The conservation practices included in this variable comprise ground-cover technologies such as crop-mulch/residue management, green manure and conservation tillage. Ground cover is increasingly recognized not only as a crucial soil conservation component but also in terms of its potential effects on land productivity. Therefore, technologies emphasizing ground cover tend to be profitable (Erenstein, 1999; López-Pereira *et al*., 1994).

The positive association between conservation practices and farm income contrasts with the effects of conservation structures, which is negative but non-significant. A substantial body of literature contains empirical evidence of poor private economic returns associated with conservation structures (Shiferaw and Holden, 2001; Erenstein, 1999; Wiggins, 1981; Blaikie and Brookfield, 1987). It is increasingly recognized that structures are expensive to build and maintain while adding little to land productivity in the short run (Shaxson *et al*., 1989; Douglas, 1993). Lutz *et al*., (1994) report several case studies in Central America and the Caribbean where physical structures seemingly lessen the available area for cultivation. Examples include construction of cutoff drains in Costa Rica and terraces in Guatemala that reduced the effective cultivation area by 14% and 15%, respectively. Such drawbacks may clearly affect the profitability of these conservation technologies. Further, terracing often entails movements of earth that brings unproductive soil to the surface (Erenstein, 1999; de Graaff, 1996). McIntire (1994) reviewed 20 conservation techniques in Mexico and found that cultivation and cropping practices, including vegetative barriers, were superior to structures in terms of profitability. On the other hand, a combination of diversion ditches and live barriers in Guatemala appears to be substantially more profitable than terraces, even if much less effective to control erosion (Lutz *et al*., 1994).

B. Net Present Value and Internal Rate of Return

Table 3 includes farm income, annual income gains, number of beneficiaries, total benefits and costs, and the NPV and IRR for PAES between 1998 and 2005. While costs and number of beneficiaries were provided by Henríquez (2006), income flows were obtained by applying equation (6), which yields a $280 annual income gain per beneficiary.

Figures in column (1) of Table 3 represent weighted average annual farm income per family, showing a persistent upward trend due to rising participation in PAES. The 1998 benchmark is the average income of the control group obtained from the 2005 survey. For simplicity, it is assumed that immediately before the beginning of PAES in 1998, potential beneficiaries and the control group had the same income level ($1,975), and that while the control group experiences no change, beneficiaries' income would improve due to PAES.

Gains (above $1,975) are initially observed in 2000, after the first 925 families incorporated during 1999 get $280 each in additional farm income. The weighted average incremental income per beneficiary for 2000 amounts to $45.4, which is the weighted average of $2,255 ($1,975 + $280) obtained by the first 925 families that joined in 1999 and $1,975 obtained by 4,775 families just incorporated in 2000 (column 2). Thus, it is assumed that the entire income gain occurs at the end of the year, as is common practice in benefit cost analysis. The weighted average incremental income grows rapidly overtime, as the lower income of new beneficiaries weights proportionally less than those with more years with PAES, reaching a steady state of $2,783 at the end of PAES in 2005, amounting to $807.1 above the benchmark of $1,975. Figure 2 depicts incremental income by cohort, depending on the starting year with PAES and for the whole project.

Total benefits at the PAES project level (column 4 of Table 3) are obtained by multiplying weighted farm-level gains (column 2) by the number of beneficiaries (column 4). The NPV, at a 12% discount rate, is obtained by subtracting column 5 (PAES Costs) from column 4, which yields $13,674,100 or $562.8 per family based on the total of 24,295 beneficiary families over the life of the project. The internal rate of return (IRR) equals 48.45%. Both indicators clearly reveal that the soil conservation and agroforestry component of PAES was highly profitable.

The profitability of PAES estimated here is consistent with similar evaluations of natural resource management programs in the region. Lutz *et al.*, (1994) surveyed several soil conservation programs in Central America, reporting high rates of return (60 to 85%) for various conservation measures on diverse crops in various settings. Current *et al.*, (1995) also used CBA to evaluate 21 natural resource management projects and all yielded positive NPVs under a broad range of conditions including a 20% discount rate. These authors claim that successful projects have worked with local communities, responding to local needs and preferences and offering farmers a broad basket of alternatives from which to choose. Demonstration plots and the use of contact farmers have been low-cost and effective means of technology transfer, and applied research has been important in identifying techniques and practices suited to individual regions.

Experiences from other parts of the globe are not as well-documented, but partial surveys suggest similar results to those available from Central America (UNDP, 2005). Wannawong *et al*. (1991), and Sullivan *et al*. (1992), show higher NPVs for agroforestry systems than for monoculture systems. A comprehensive review of 311 case studies on natural resource management programs in India by ICRISAT yielded an average internal rate of return of 22% (Tropp *et al*., 2006; Wani *et al*., 2003; Wani *et al*., 2004). Moreover, such studies often understate the benefits of soil conservation because they take into account only the impacts on crop productivity and do not incorporate other significant benefits, such as improved food security, enhanced credit worthiness and access to finance for farmers, protection of vulnerable habitats for maintaining biodiversity, and reduced contribution to global warming (UNDP, 2005).

C. Bootstrapping and Sensitivity Analysis

The robustness of the results has been examined by developing alternative scenarios. First we analyzed the effect of the variability of the income gain per family on the NPV and IRR. The income change generated for each year with PAES ($/family/year) is a random value and varies from sample to sample. Sample variability was generated by randomly drawing 1000 samples from the original sample of 520 observations by bootstrapping using proc surveyselect in SAS (SAS, 2004). The resampling experiment allowed the estimation of 1000 Tobit models and 1000 estimates of the NPV and IRR. The results are shown in Figures 3 (IRR) and 4 (NPV). Figure 3 indicates that PAES is profitable (IRR>12%) in 83% of the 1000 simulations, while Figure 4 shows that PAES would be profitable even if per family income gains were reduced from $280 to $118. Finally, we tested the sensitivity of the results to a reduction in the number of families receiving benefits while holding the per family income gain at $280/year. As shown in Figure 5, PAES would still be profitable even when the beneficiaries dropped to 42% from the total (24,295).

VI. Summary and Conclusions

This study examines the relationships between farm income, adoption of conservation technologies and output diversification among PAES participants by comparing their performance at two points in time, 2002 and 2005, and against non-participants (Control Group) in 2005. The analysis confirms the assumption that the adoption of conservation practices and diversification are both endogenous, since the residuals from first-stage regressions significantly affect farm income. Therefore, the equations for adoption conservation practices and output diversification are estimated first and the predicted values of both endogenous variables are used in a second step as additional explanatory variables in the farm income equation. The econometric results, obtained in all cases using the Tobit regression, are then used to obtain the NPV and IRR of the soil conservation and agroforestry component of PAES between 1998 and 2005.

Crop diversification and the adoption of conservation practices are significantly promoted by the length of farmers' involvement with PAES and by their participation in social organizations. Membership in community or farmer organizations has been found to be effective in providing follow-up support to farmer-members. Diversification significantly increases farm income. This result highlights the strategic role of diversification in fighting rural poverty and is consistent with those reported by Nerlove et *al*., (1996), Delgado and Siamwalla (1997), and Ruben and Clemens (2000).

The income value of an extra Manzana with conservation practices is $466.2, which amounts to a 20% increase over the average farm income ($2,318) obtained by PAES beneficiaries in 2005. The conservation practices included in this variable comprise ground-cover technologies such as crop-mulch/residue management, green manure and conservation tillage. The positive association between conservation practices and income contrasts with the effects of conservation structures, which is negative and non-significant. A substantial body of literature contains empirical evidence of poor private economic returns associated with conservation structures. It is increasingly recognized that structures are expensive to build and maintain whereas they add little to the productivity of the land in the short run. Such drawbacks may clearly affect the profitability of these conservation technologies.

The cost and estimated incremental income over the life-span of the project (1998-2005) are used to compute the internal rate of return (IRR) and net present value (NPV). While costs and number of families were provided by Henríquez (2006), income flows were obtained by computing the indirect effects of the number of years with PAES on farm income thru its direct effects on conservation and diversification. The incremental farm income that can be attributed to PAES is estimated to be $280/year/family. For simplicity, it is assumed that prior to the beginning of PAES in 1998, potential beneficiaries and the control group had the same (real) income level, $1,975, which corresponds to the average income of the control group in 2005. It is further assumed that the control group sees no change in income over the 1998-2005 period, while beneficiaries experience the estimated $280/year/family due to PAES. Total income gains grow rapidly overtime, as additional beneficiaries join the project reaching a steady state of $2,783/family at the end of PAES in 2005, which amounts to $807.1 above the $1,975 benchmark.

The NPV of PAES, at a 12% discount rate, equals $ 13,674,100 or $562.8 per family and the internal rate of return (IRR) equals 48.45%. Both indicators clearly reveal that the soil conservation and agroforestry component of PAES has been highly profitable. The profitability of PAES is in line with similar evaluation of natural resource management programs in Central America and elsewhere. Finally, the estimates of NPV and IRR are robust, as verified with diverse scenarios generated using bootstrapping and sensitivity analysis.

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ANNEX 1: TABLES AND FIGURES

Figure 1: Relationship among Resource Management Projects, Household Income and Sustainability

Map 1: Areas of Influence of PAES 1 and PAES 3

Table 1: Beneficiaries, Neighbors, and Non-Neighbors: Variable Definitions, Means, and Test of Means

Variable Definitions	2002	2005				
	Beneficiaries	Beneficiaries	Test	Neighbors	Non-Neighbors	Test
Farm						
Farm Income ($)	1864.8	2318.8	*	1969.4	1981.5	
Adoption of Conserv. Practices (Mz.)	1.77	2.3	***	1.4	1.5	
Adoption of Conserv. Structures (Mz.)	0.67	1.38		0.38	0.30	
Diversification (count)	1.1	3.1	**	2.3	2.8	
Entropy (index)	0.866	1.04	***	0.961	1.027	
Cultivated land (Manzana=0.7 Has.)	4.8	4.0	***	2.1	2.3	
Distance house-plot (Km)	0.9	1.1	***	1.0	1.2	
Tenure (% of own land)	64.6	73.1	***	66.9	77.8	*
Slope, 1 if >15% (%)	50.8	66.4		66.4	53.9	*
Hired Labor ($)	425.7	141.7		198.9	139.9	
Cost ($)	574.7	541.8	***	495.8	504.2	
Animal Products share on income (%)	12.5	29.3		21.1	20.2	
Cash-Crops share on income (%)	11.8	17.3		13.4	15.8	
Household						
Family size (#)	5.3	5.4		4.5	5.1	*
Off-farm income, 1 if earns (%)	53.85	31.15		36.92	36.15	
Age Household Head (HH) (Years)	48.3	51.8		50.1	51.2	
Gender HH, 1 if male (%)	84.4	84.4	*	88.3	89.1	
Education HH (Years)	2.8	2.6	***	2.9	3.7	***
Social organizations, 1 if participates (%)	52.7	50.8		15.6	21.9	
Erosion Perception, 1 if perceives (%)	86.9	32.3	***	46.1	43.8	*
Contact Farmer, 1 if extensionist (%)	10.4	10.4		0.0	0.0	
Project						
Years with PAES (Years)	2.7	3.6	**			
Frequency visits (# per year)	29.5	14.6		2.8	4.2	
Local Infrastructures	0.03	0.03		-0.02	-0.05	**
Access to Markets	0.06	0.06		0.12	-0.25	***

Test of Means *p < 10%; **p <5%;***p<1%

Table 2: Tobit Estimates of Conservation Practices, Diversification and Farm Income among PAES Beneficiaries 2002 – 2005 (N= 520)

	Conservation Practices			Entropy			Farm Income		
	Beta		ME	Beta		ME	Beta		ME
Intercept	0.5483			0.7872	***		-3260.2	***	
Participates in social organizations	0.4252	*	0.338	0.0908	***	0.090			
Freq. of visits	0.0003		0.000	0.0011		0.001			
Time with PAES	0.2776	***	0.221	0.0562	***	0.056			
Erosion awareness	-0.1148		-0.091	-0.0131		-0.013			
PAES1	0.9829	***	0.781	-0.1028	***	-0.102			
Labor							1.23	***	0.9
Cost							2.72	***	2.0
Predicted diversification							1778.6	***	1277.4
Predicted area with conserv. practices							649.1	***	466.2
Area with conservation structures							-41.3		-29.7
Gender							251.8		180.8
Age							-2.4		-1.7
Education							20.4		14.6
Market access							-89.7		-64.4
Local infrastructure							-89.2		-64.1
Off farm income							-372.8		-267.7
Tenure							62.4		44.8
Year							-125.4		-90.1
Animal Products share on Income							3197.7	***	2296.6
Cash-Crops share on Income							-212.3		-152.5
Slope							-82.65		-59.4
Distance house - plot							-82.57		-59.3

Likelihood Ratio Test	364	***

*p < 10%; **p <5%;***p<1%

Table 3: Benefits, Costs, Number of Beneficiaries, NPV and IRR of PAES: 1998 – 2005

	Average Farm Income ($) (1)	Annual Income Gains ($) (2) = ($1_t$) - ($1_{1998}$)	# Families (3)	PAES Benefits ($) (4) = (2) * (3)	PAES Costs ($) (5)	Benefits – Costs ($) (6) = (4) – (5)
1998	$1,975	0.0	0	0	1,183,260	-1,183,260
1999	$1,975	0.0	925	0	1,610,742	-1,610,742
2000	$2,021	45.4	5700	259,000	2,984,699	-2,725,699
2001	$2,143	167.3	11087	1,855,000	2,851,602	-996,602
2002	$2,249	273.6	18125	4,959,360	3,537,575	1,421,785
2003	$2,444	468.5	21161	9,912,955	2,689,258	7,223,697
2004	$2,569	594.0	24295	14,430,737	720,000	13,710,737
2005	$2,783	807.1	24295	19,608,548	0	19,608,548
NPV ($)				23,646,819	9,972,719	13,674,100
NPV/family ($)				973.3	410.5	562.8
IRR						48.45%

Discount Rate: 12%

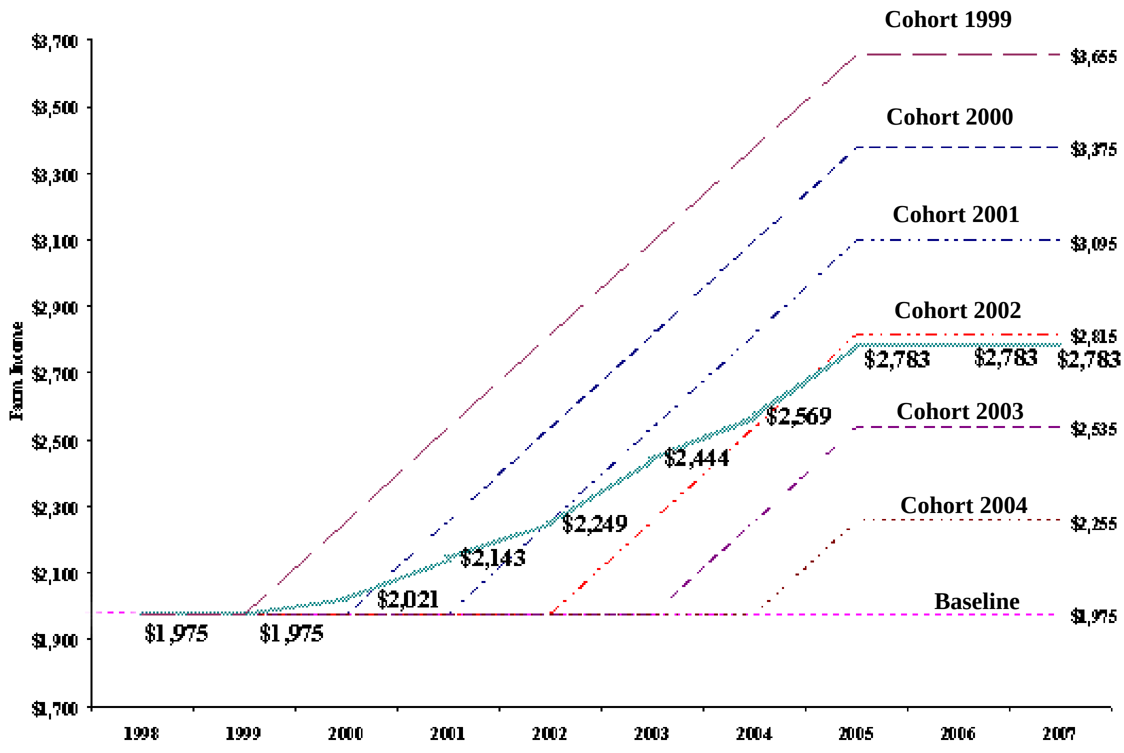
(1) Farm Income_{1998} = $1,975 = average farm income of the control group, assumed to be unchanged between 1999 and 2005.

(2) Annual Income Gains_t = Farm Income_t - Farm Income_{1998}

(4) PAES Benefits = Annual Income Gains * Number of Families

Source: Number of families and PAES costs were obtained from Henríquez, 2006.

Figure 2: Farm Income by Cohorts (Starting Year) and for all PAES: Beneficiaries 1998 – 2005



Starting Year with PAES

Figure 3: Cumulative Density Function of IRR Drawn from 1000 Random Samples

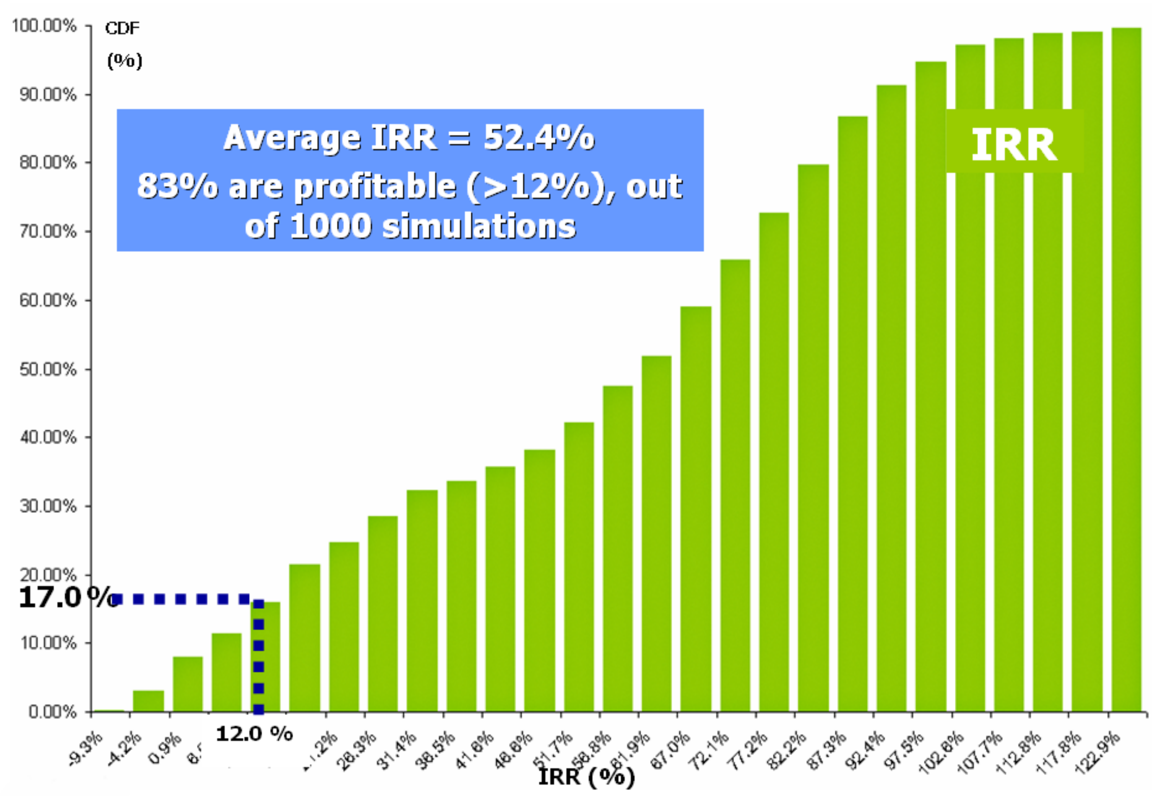


Figure 4: Relation between NPV and Income Gain per Capita Drawn From 1000 Random Samples

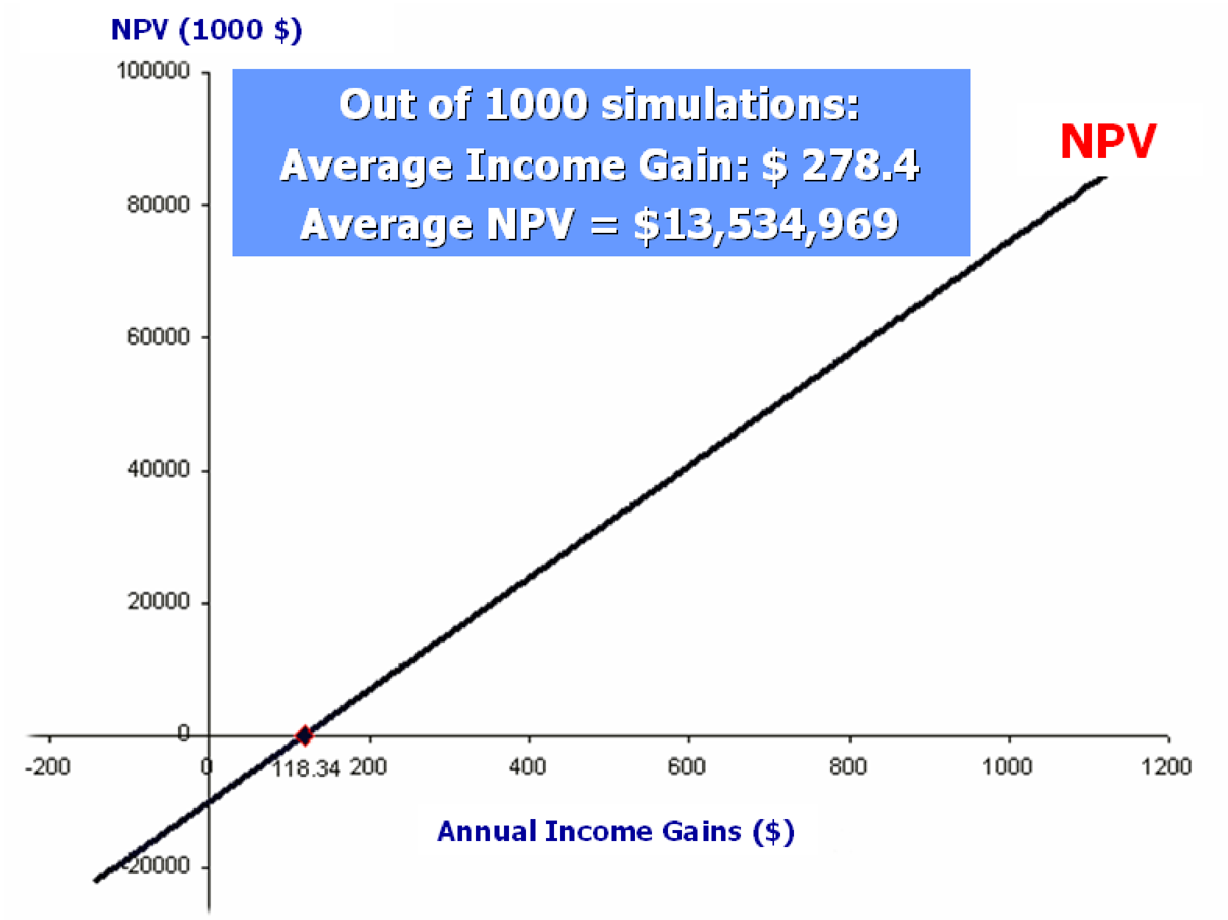
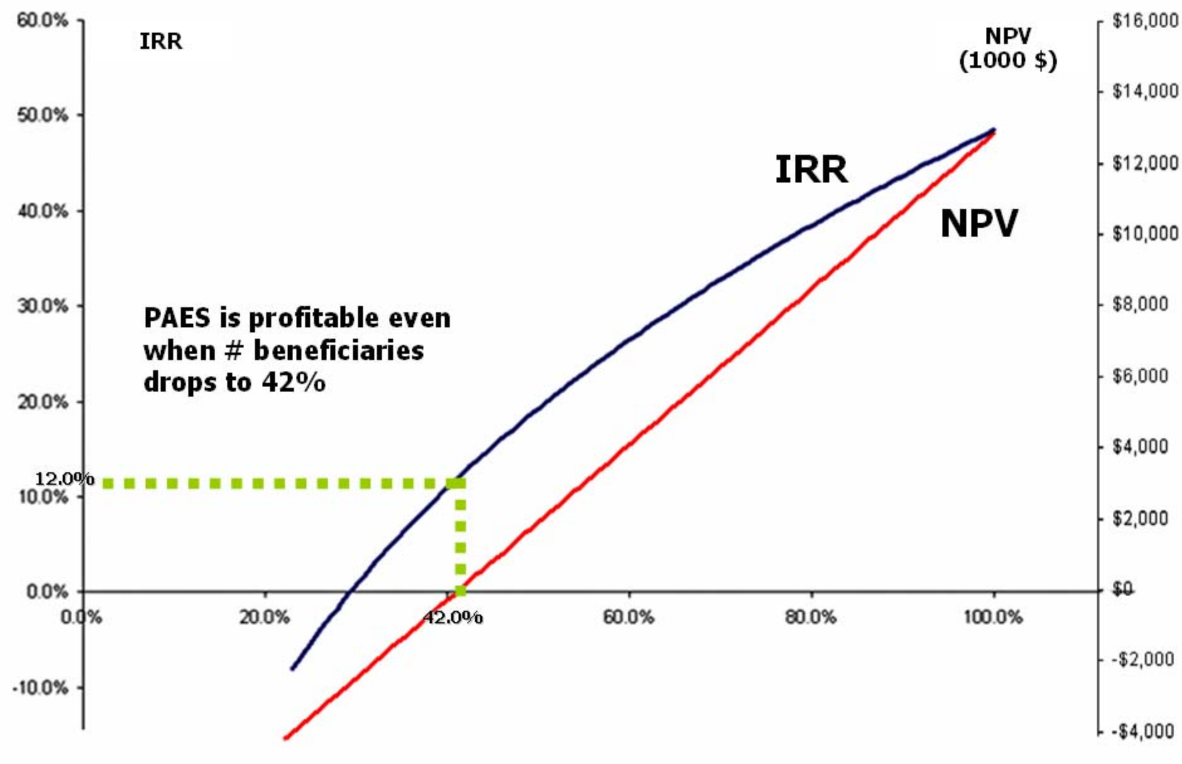


Figure 5: Cumulative Density Function of IRR Drawn from 1000 Random Samples



APPENDIX 1

Tobit Estimates of Conservation Practices, Diversification (Entropy) and Farm Income

		No Endogeneity		Models with endogeneity							
		(1)		(2)		(3)		(4)		(5)	
Conservation Practices	**Receives training**			0.361				0.367		0.36	
	Contact Farmer			0.079				0.073		0.08	
	Participate in social orgs.			0.323		0.43	*	0.314		0.32	
	Frequency of extension visits			-0.002		0.00		-0.002		0.00	
	Time with PAES			0.220	*	0.28	***	-0.079		0.22	*
	Time with PAES^2							0.056			
	Erosion awareness			-0.131		-0.11		-0.142		-0.13	
	PAES1			0.952	***	0.98	***	0.941	***	0.95	***
	Slope			0.280				0.296		0.28	
	Distance house-parcel			0.047				0.045		0.05	
Entropy	**Receives training**			0.054				0.054		0.05	
	Contact Farmer			0.062	***			0.062	***	0.06	***
	Participate in social orgs.			0.072	*	0.09	***	0.071	*	0.07	*
	Frequency of extension visits			0.001		0.00		0.001		0.00	
	Time with PAES			0.021		0.06	***	0.017		0.02	
	Time with PAES^2							0.001			
	Erosion awareness			0.032		-0.01		0.032		0.03	
	PAES1			-0.112	***	-0.10	***	-0.112	***	-0.11	***
	Slope			-0.014				-0.014		-0.01	
	Distance house-parcel			0.005				0.005		0.01	
Farm Income	**Labor**	1.22	***	0.798	*	1.23	***	0.817	*	1.25	***
	Cost	2.66	***	2.345	***	2.72	***	2.323	***	2.70	***
	Land			148.51	***			146.36	***		
	Land^2			-0.677	**			-0.659	**		
	Predicted entropy			2643.9	***	1778.6	***	2701.6	***	1887.3	***
	Predicted area w/practices			480.7	*	649.1	***	615.8	***	557.9	*
	Entropy	-307.6									
	Area w/practices	74.00									
	Area w/structures	-59.3		-204.4	***	-41.3		-211.5	***	-40.3	
	Gender	231.4		188.2		251.8		166.5		231.6	
	Age	-3.3		-2.5		-2.4		-2.7		-1.4	
	Education	11.1		7.2		20.4		7.8		17.0	
	Market access	-78.7		-70.5		-89.7		-101.1		-62.1	

	No Endogeneity		Models with endogeneity							
	(1)		(2)		(3)		(4)		(5)	
Local infrastructure	-104.5		-74.3		-89.2		-74.3		-75.7	
Off farm income	-304.4		-293.0		-372.8		-287.9		-348.7	
Tenure	70.1		-30.1		62.4		-9.6		149.5	
Year	-216.6		-116.1		-125.4		-198.7		-279.9	
Animal Products % on Income	3159.2	***	2583.1	***	3197.7	***	2591.7	***	3241.4	***
Cash-crops % on Income	-69.2		-166.4		-212.3		-178.9		-126.1	
Slope	-163.9				-82.6					
Distance house-parcel	-90.28				-82.6					
Receives training	260.34									
Frequency of extension visits	118.93									
Participate in social orgs.	168.92									
Frequency of visits	5.42									
Time with PAES	338.36	*								
Erosion awareness	179.63									
PAES1	375.95									
2005 Predicted Farm Income All PAES ($)	2,951		2,439		2,783		2,639		2,442	

*p < 10%; **p <5%;***p<1%

Appendix (Continued)

		No Endogeneity	Models with endogeneity			
		(6)	(7)	(8)	(9)	(10)
Conservation Practices (Tobit)	**Receives training**		0.361		0.367	0.36
	Contact Farmer		0.079		0.073	0.08
	Participate in social orgs.		0.323	0.43 *	0.314	0.32
	Frequency of extension visits		-0.002	0.00	-0.002	0.00
	Time with PAES		0.220 *	0.28 ***	-0.079	0.22 *
	Time with PAES^2				0.056	
	Erosion awareness		-0.131	-0.11	-0.142	-0.13
	PAES1		0.952 ***	0.98 ***	0.941 ***	0.95 ***
	Slope		0.280		0.296	0.28
	Distance house-parcel		0.047		0.045	0.05
Diversification (Negative Binomial)	**Receives training**		0.185		0.198	0.185
	Contact Farmer		0.804 ***		0.791 ***	0.804 ***
	Participate in social orgs.		0.224	0.323	0.207	0.224
	Frequency of extension visits		0.008	0.002	0.008	0.008
	Time with PAES		0.196 **	0.672 ***	-0.521	0.196 **
	Time with PAES^2				0.133 *	
	Erosion awareness		0.052	-0.601 ***	0.022	0.052
	PAES1		-0.287	-0.204	-0.309	-0.287
	Slope		-0.152		-0.111	-0.152
	Distance house-parcel		-0.023		-0.024	-0.023
Farm Income (Tobit)	**Labor**	1.20 ***	0.8 *	1.2 ***	0.8 *	1.2 ***
	Cost	2.55 ***	2.4 ***	2.7 ***	2.3 ***	2.7 ***
	Land		152.2 ***		149.9 ***	
	Land^2		-0.7 **		-0.7 **	
	Predicted diversification		608.2 *	202.1	843.4 ***	476.6 **
	Predicted area w/practices		407.7 **	587.1 *	467.4 *	502.1 *
	Diversification	310.7 ***				
	Area w/practices	48.6				
	Area w/structures	-54.3	-207.9 ***	-36.4	-233.3 ***	-42.7
	Gender	179.6	204.7	246.6	190.2	248.8
	Age	-3.0	-3.1	-2.5	-2.8	-1.8
	Education	20.0	7.4	24.9	3.7	15.9
	Market access	-100.9	-89.7	-117.7	-83.9	-70.8
	Local infrastructure	-260.5	-86.9	-87.8	-104.8	-90.3

		No Endogeneity		Models with endogeneity							
		(6)		(7)		(8)		(9)		(10)	
	Off farm income	-426.7	**	-276.8		-376.2		-269.7		-338.0	
	Tenure	57.2		-14.5		82.0		-20.6		153.8	
	Year	-789.5		-1054.2	**	-243.3		-1611.8	***	-1053.9	**
	Animal Products % on Income	2283.5	***	2556.3	***	3169.5	***	2569.6	***	3249.0	***
	Cash-crops % on Income	-1234	**	-199.2		-193.6		-217.7		-143.3	
	Slope	-187.1				-66.1					
	Distance house-parcel	-92.8				-81.7					
	Receives training	170.1									
	Frequency of extension visits	131.9									
	Participate in social orgs.	85.6									
	Frequency of visits	2.8									
	Time with PAES	291.9	*								
	Erosion awareness	110.7									
	PAES1	577.7	*								
2005 Predicted Farm Income All PAES ($)		2,816		2,836		3,152		2,536		2,817	

*p < 10%; **p <5%;***p<1%

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