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Abstract

Trees can be considered as investments made by economic agents to prevent depreciation of natural assets such as stocks of top soil and water. In agroforestry systems farmers use trees in this manner by deliberately combining them with agricultural crops on the same unit of land. Although advocates of agroforestry have asserted that soil conservation is one of its primary benefits, empirical estimates of these benefits have been lacking due to temporal and spatial complexity of agroforestry systems and the nonmarket aspect of soil capital assets. This study designs and applies a bio-economic framework for valuing the soil conservation benefits of agroforestry. The framework is tested with econometric analysis of data from surveys of households in Eastern Visayas, Philippines, where USAID/Government of Philippines introduced contour hedgerow agroforestry in 1983. By constructing a weighted soil quality index that also incorporates measures of soil fertility, texture and color in addition to erosion, we extend previous economic studies of soil resources. This index is regressed on a variety of farming and site specific bio-physical variables. Next, we use a Cobb–Douglas profit function to directly relate agricultural profits and soil quality. Thus, the value of soil conservation is measured as a quasi-rent differential or the share of producer surplus associated with a change in soil quality. Because this framework assumes the existence of markets, the assumption is tested by analysing the statistical significance of consumption side variables, e.g., number of household members, on production side variables, e.g., profits. Instrumental variables are used to handle the endogeneity of the soil index in the profit equation. Seemingly unrelated regression (SUR) analysis is used to accommodate correlation of errors across the soil and profit equations. Regression results reveal the importance of agroforestry intensity, private ownership, land fragmentation, and familiarity with soil conservation as positive covariates of soil quality. Analysis of production data indicate the importance of market prices, education, farming experience, farm size, topography, and soil quality as positive covariates of household profits. Investments in agroforestry to improve or maintain soil capital can increased annual agricultural profits by US$53 for the typical household, which is 6% of total income. However, there are significant up-front costs. Given that small farmers in tropical uplands are important players in the management of deteriorating soil and forest resources, policy makers may want to consider supporting farmers in the early years of agroforestry adoption. Published by Elsevier Science B.V.

Keywords: Agroforestry; Contour hedgerows; Soil consevation; Bio-economic framework

1. Introduction

Agroforestry encompasses a spectrum of land use in which woody perennials are deliberately combined with agricultural crops and/or animals in some spatial or temporal arrangement (Lundgren and Raintree, 1982). Advocates have long contended that soil conservation is one of its primary benefits. The presence of woody perennials in agroforestry systems may affect several bio-physical and bio-chemical processes that determine the health of the soil

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substrate. The less disputed effects of trees on soil include: amelioration of erosion; maintenance or increase of organic matter and diversity; nitrogen fixation; enhancement of physical properties such as soil structure, porosity, and moisture retention; and enhanced efficiency of nutrient use (Nair, 1993).

Scherr (1992) argues that the theoretical basis for rigorous economic analysis of agroforestry practices is lacking and empirical analyses are rare. For example, after reviewing 108 agroforestry project evaluations, Scherr and Müller (1991) report that only 8% assessed economic costs or benefits, 10% assessed changes in product supply and less than a third assessed impacts on yield. The paucity of economic valuations of agroforestry can be explained in part by the spatial and temporal complexity of agroforestry systems and the multiple inputs and outputs that characterize agroforestry (Mercer, 1993; Scherr, 1992). In a rare study, Ehui et al. (1990) evaluated the profitability of alley farming systems with a farm budgeting approach and a 10-yr time series data set from field trials in South-western Nigeria. However, the study did not isolate soil conservation benefits. While there are a few economic analyses of the long term potential of agroforestry (Ehui et al., 1990; Francisco and Mercer, 1995; Sullivan et al., 1992), almost none of them disentangle soil conservation benefits.

Although economic analyses of soil conservation from other land uses are relatively common, few empirically estimate the value of soil conservation. Economic analyses of soil conservation have primarily been of four types. The first type uses dynamic control theory to determine the set of conditions under which individuals and society choose optimum levels of soil conservation (McConnell, 1983; Barbier, 1990). Second, programming models have been used to evaluate public support for soil conservation (Burt, 1981). The third set includes adoption studies of soil conservation technologies (e.g., Gould et al., 1989). Finally, resource accounting studies of soil erosion have used benefits transfer techniques in which parametric 'values' associated with natural assets are transferred to similar settings (Magrath and Arens, 1989; Clark et al., 1985). No empirical work known to the authors directly estimates the value of soil conservation or the price of soil resources.

The objective of this study is to design and test a framework for valuing the soil conservation impacts of agroforestry. [1] Our analysis examines one of the most crucial values of soil conservation, its role in maintaining and enhancing agricultural productivity, for two reasons (Lutz et al., 1993). First, since the farmer is the primary soil conservation decision maker, only a tyrannical state or a massive subsidy program could induce soil conservation in the absence of substantial economic benefits for the farmer. Second, land use problems are generally dependent on site-specific biophysical characteristics which often vary significantly even within small areas. A farm-level approach is more appropriate for incorporating site-specific events than society-level approaches requiring aggregation of heterogenous variables.

On-site benefits to farmers may not be the largest benefit of soil conservation (Brooks et al., 1992); however, given the central role of farmers in conserving soil, on-site benefits are likely to be the most crucial, especially in less developed countries. For example, it has been argued that while in the U.S. the off-site benefits clearly outweigh the on-site gains, for developing countries the opposite holds true (Dixon, 1997). In any case, the market value of the preserved agricultural productivity provides a lower bound of the value of soil conservation. Estimation of this value should help policy makers determine the appropriate levels of support for agroforestry.

Specifically, we develop an econometric approach for valuing on-site soil conservation benefits and apply it to a case study of contour hedgerow agroforestry in the Philippines. Following a brief description of the case study, we develop the theoretical framework for isolating and estimating the on-site soil conservation benefits of agroforestry practices in Section 2. In Section 3, data from the Philippines case study are summarized. Econometric results are presented and discussed in Section 4. Conclusions are presented in Section 5.

[1] This study is part of a larger effort by the USDA/USAID Forestry Support Program and the US Forest Service's Southern Research Station to develop and test data collection and analytical techniques for assessing the socio-economic impacts of agroforestry projects (Mercer, 1993).

1.1. Contour hedgerows in the Eastern Visayas, Philippines

From 1983 to 1988, USAID and the Government of Philippines established agroforestry projects on the island of Leyte in the Eastern Visayas, Philippines. The primary agroforestry practice introduced by the USAID projects was contour hedgerows, a form of alley cropping. Contour hedgerows are a set of agroforestry practices in which food crops are planted between hedges of woody perennials established along the contours of sloping upland farm plots. Prunings from the hedgerow trees or shrubs are placed at the up-slope base of the hedges to trap the eroding soil so that over time natural terraces are formed. In the Philippines, contour hedgerow techniques are often referred to as SALT (Sloping Agricultural Land Technology). The hypothesized primary benefits of SALT are erosion control, enhanced soil nutrient availability, weed suppression, and enhanced fuel and fodder production. However, the hedgerows may also produce increased demand for scarce labor and skills, loss of annual cropping area, difficulty in mechanizing agricultural operations, and excessive competition with the crops for soil nutrients, light, and water (Nair, 1993).

Contour hedgerow farming, and agricultural systems in general, in the uplands of the Eastern Visayas have been the subject of a few previous economic studies (Armenia et al., 1990; Cruz et al., 1987). These studies conclude that to some extent contour hedgerows have met the ex ante expectations regarding prevention of soil erosion and improvement of soil fertility. Because of additional labor requirements and reduction in annual cropping area, the net financial returns (during the first few years after adoption) are not significantly greater than the traditional practices. In these studies, however, all agro-ecological factors, including soil thickness, topography, fertility, site quality, have been addressed by a single binary variable, if at all. Our econometric study employs a richer specification of agro-ecological variables, as well as more comprehensive behavioral models to isolate soil conservation benefits of agroforestry in the Eastern Visayas, Philippines. The analysis takes up Sanchez's (Sanchez, 1995) challenge that the unsubstantiated, and sometimes sentimental, enthusiasm for contour hedgerows in the previous decade, should be evaluated with empirical evidence and objective analysis.

2. Theoretical framework

Economic values of soil conservation from agroforestry can be viewed as the product of three sets of functional relationships in Fig. 1 (Freeman, 1993). Stage 1 quantifies the relationship between the extent of agroforestry practice and soil quality. Stage 2

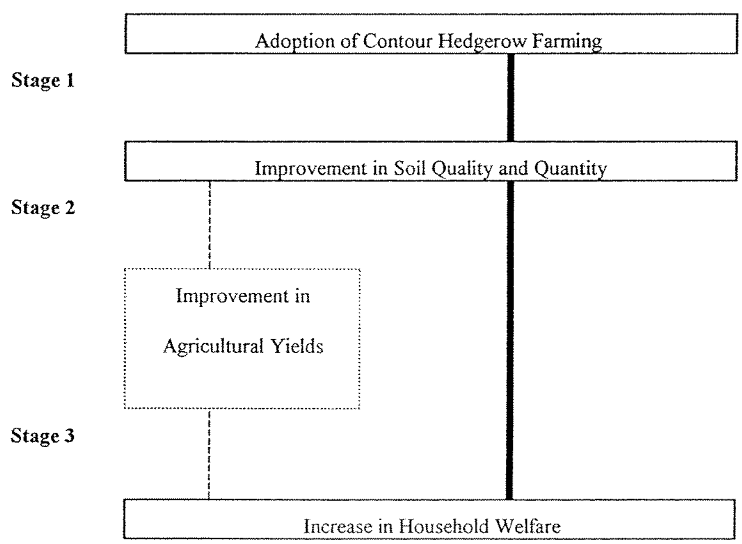

Fig. 1. Three stage framework for valuation of soil conservation benefits of agroforestry.

correlates soil quality and individual household agricultural production. Stage 3 links household production to monetary measures of economic welfare. Stages 1 and 2 represent bio-physical relationships which are evaluated in economic terms in Stage 3. Functional relationships for each stage are presented below.

2.1. A three stage conceptual framework

2.1.1. Stage 1

The following two equations represent the primary functional relationships in Stage 1:

$$S = S(Z, T)$$

$$W_t = S = S_t - S_{t-\tau}$$

Soil quality (S), a stock variable, is a function of management practices (T), including agroforestry practices, and a vector of environmental variables (Z) composed of geologic material, topography, climate, time and biota. Soil conservation (W_t), a flow variable, is defined as the difference between two levels of soil quality associated with and without agroforestry or a change in the soil stock variable (S) since the time of adoption of agroforestry practices (τ) in Eq. (1).

2.1.2. Stage 2

In Stage 2 of the framework, the objective is to relate W to the agricultural production profile which includes yield (Y) and allocation of inputs (x) as in Eq. (2). Soil conservation serves as a fixed input in short run agricultural production.

$$Y = Y(S, x) \tag{2}$$

2.1.3. Stage 3

The final stage establishes the link between some measure of economic welfare and agricultural productivity as induced by soil conservation. In Eq. (3) below, the money value of the agricultural production affected by soil conservation (V) is a function of production (Y), and vector of prices (P_Y):

$$V = V(Y, P_Y) \tag{3}$$

To implement the framework for the Philippines study, we develop and estimate a set of econometric equations that describe the agroforestry adoption decision, the resulting soil quality changes, and their impacts on farm profits (our welfare measure). First, a probit model is estimated to identify factors driving agroforestry adoption. This allows us to calculate a household specific selectivity variable (inverse mills ratio, λ) with which we can address the self-selection bias in the succeeding empirical stages using the Heckman two-step approach (Maddala, 1983). Second, the Heckman selection model is applied to a soil equation to relate agroforestry practices and soil conservation. Parameters from these models are used to simulate two levels of soil conservation, W_1 and W_0, associated with the presence and absence of agroforestry practice. Third, the selection model is also used to estimate a profit equation which examines the impacts of soil conservation on agricultural profitability. The parameters from the profit equation are then used to calculate the marginal value of soil conservation in terms of marginal profitability. Finally, simulated soil conservation levels and estimated marginal values are combined to calculate incremental values of soil conservation. Each of these sub-models is discussed in detail below.

2.2. Agroforestry adoption and calculation of the selection parameter (λ)

The inverse-mills ratio, λ, which measures the probability of the household being an adopter, is used to address self-selection bias that may result because adoption of agroforestry was a voluntary choice exercised by households. This is not a sample selection problem of the type that requires truncated regressions because data exist for nonadopters. Here, using the Heckman two-step formulation, the self-selection issue addresses 'treatment effects' or 'program evaluation' issues (Maddala, 1983). In the first step, a household specific self-selection variable, λ, is estimated with the following probit model:

Adoption Equation

$$\text{Prob}(\text{Adopt} = 1) = \gamma' K + \epsilon_1$$

from which $\lambda = \dfrac{\phi(\gamma' K)}{1 - \Phi(\gamma' K)}$

where K is a set of variables explaining the adoption decision, ϕ and Φ are the probability density and cumulative distribution of the error term, respectively. The choice of the independent variables, K, follows the literature on land use technology adoption (Lohr and Park, 1994; Gould et al., 1989) and agroforestry adoption in this region (Francisco and

Mercer, 1995; Armenia et al., 1990). The set K includes awareness of contour hedgerow technology, experience with planting trees on farm, steepness of farm, assistance from project officials, dependence on farming income, education of household head, and the number of years the household has resided in the village. In the second step, λ is used as an explanatory regressor in the soils equation (Eq. (5)) and profit equation (Eq. (6)) to account for bias in the estimates due to self-selection.

2.3. Effect of contour hedgerow adoption on soil conservation

The relationship in the first stage of Fig. 1 between soil conservation, W, extent of agroforestry practices, T, a vector of environmental attributes, Z_p, socio-economic characteristics, Z_c, and a selectivity variable, λ, is modeled econometrically as:

Soils Equation

$$W = \beta_T T + \beta_p Z_p + \beta_c Z_c + \beta_l \lambda + \epsilon_2$$

While details are provided in Section 3, W is a weighted combination of the quantity of soil erosion and the quality of soil described by fertility, color, and texture. T, an index of agroforestry activities, is comprised of the following: (1) the portion of farm area with contour hedgerows at the time of installment, (2) the number of years of agroforestry practice, (3) the rank assigned by respondents to soil conservation as the reason for adopting hedgerows, (4) the number of years that households have engaged in other soil conservation practices, and (5) the frequency of mulching activities. The set of five Z_p environmental variables are comprised of dummy variables for land type and site, steepness of farmland, water quality and extent of land fragmentation. The three household variables, Z_c, include tenure status, farming record and experience with trees on the farm. Given the scant literature on models of this kind, the specification in Eq. (5) has relied on a combination of bio-physical and socio-economic variables that intuitively are likely to affect soil conservation.

2.4. Effect of soil conservation on agricultural profitability

Estimating Stage 2 of the conceptual framework in Fig. 1 requires relating adoption of agroforestry to agricultural yield and the allocation of production inputs. In general, depending on data availability, agronomic analyses of soil productivity use one of the following three approaches for estimating yield as a function of soil properties: (1) systematization of observed yield levels, (2) statistical analysis of observed yield levels and (3) bio-physical simulations (Lutz et al., 1993). While Sidhu and Banante (1981), and Aune and Lal (1995) are examples of agro-economic research that relates individual soil characteristics to agricultural yields, aggregate soil quality indices are rarely, if ever, used.

Exploiting dual profit functions allows theoretically correct and empirically meaningful insights without explicitly estimating the primal production relation (Maler, 1991). Because the Philippines data allow calculation of profits and include variable, noncollinear prices, the production relation is described as a Cobb–Douglas profit function as follows:

Profit Equation

$$\ln \Pi = \alpha_{py} \ln P_y + \alpha_{px} \ln P_x + \alpha_{pv} \ln Z_{pv} + \alpha_{ex} \ln Z_{ex} + \alpha_t T + \alpha_w W + \alpha_l \lambda + \epsilon_3$$

where Π = profits; P_y = output prices; P_x = input prices; Z_{px} = fixed inputs; Z_{ex} = fixed exogenous public inputs; T = index of agroforestry practices; W = index of soil conservation attributes; α = estimated parameter coefficients; ϵ_3 = error term; ln = natural logarithm.

A Cobb–Douglas (C–D) profit function is used in Eq. (6) because it provides a first order differential approximation to the true profit function regardless of whether the C–D specification represents the true technology (Chambers, 1988). [2] A Box–Cox approach is also used to test for linearity of the esti-

[2] The normalized Quadratic and generalized Leontieff are flexible form second order approximations that do not impose the estimation burdens of a translog system (Chambers, 1988). However, with three outputs, two inputs, and eight fixed inputs for the Leontieff and Quadratic this still implies a 46 and 51 parameter system. Estimation of a simplified Leontieff function, with 27 parameters, did not produce encouraging results; only two of the twenty seven parameters were significant.

mated equation. Definition of W as a nonessential fixed factor implies that W should be treated as a parameter that results in neutral technological shifts akin to a dummy variable. [3] Constraints are imposed on the estimated price parameters to satisfy linear homogeneity in prices. By construction, the C–D specification is symmetric with respect to cross-price derivatives. The signs of the coefficients on the price regressors indicate monotonicity. Homogeneity, symmetricity and monotonicity (in prices) are conditions that ensure that the estimated function is theoretically consistent (Chambers, 1988).

The endogeneity of the land use choice should have a bearing on the statistical model. Given the temporal lags implicit in ecosystem processes relating to soil and water resources, the initial level of land use choice should have a significant impact on agricultural production in later years. Such a land use choice, represented by T (the agroforestry index), is realized earlier than the current year profits, Π, the dependent variable. T is a lagged endogenous variable that should be uncorrelated with the error in what has been described as a triangular or recursive system of equations (Greene, 1993). Over the long term, it is possible that changes in agricultural profitability may induce changes in the nature and extent of T and create endogeneity. However, in this model of current year profits, T is exogenous.

It is also possible that agricultural profitability and soil conservation, or the associated error terms, ϵ_2 and ϵ_3, are contemporaneously correlated. Following the logic of Zellner's SUR system, cross-equation residuals may improve statistical efficiency of estimation. Because the index of soil conservation service, W, is the dependent variable in the Eq. (5), cross-equations error correlation implies that the soil conservation index would be correlated with the error in the second (profit) equation in the SUR system. In order to avoid asymptotic bias the soil index is instrumented by its fitted value (based on estimated parameters from Eq. (1)).

The inverse-mills ratio, λ, is included in the specification because adoption of agroforestry was a voluntary choice exercised by households. It is possible that households who possess some innate skills regarding contour farming or other special capabilities are more likely to adopt agroforestry. This self-selection may induce a bias in the empirical model if agroforestry adopters, as opposed to nonadopters, have a greater likelihood of higher profits, Π. The agroforestry adoption Eq. (4) is used to estimate the household specific value of λ in the first step of the Heckman two-step model. Similarly to the case of the soil equation (Eq. (5)), the second step is the profit equation (Eq. (6)).

2.5. Value of soil conservation

The profit equation (Eq. (6)) above can be used to estimate changes in household welfare as producer surplus (quasi-rent differential) resulting from soil conservation induced productivity changes, assuming analytical recursivity of household production and consumption allocations. The recursivity assumption can be tested by examining the statistical significance of consumption side variables, such as number of adults in the household, on estimated production relationships. If the recursivity assumption is rejected, welfare changes could be evaluated from reduced form input demand curves that are based on household specific prices and consumption side variables (Lopez, 1984). Given the large proportion of households in the Philippines case study that reported input and output prices and the proximity of roads to the sites, we assume that markets exist; therefore, we use the dual profit function approach. The use of profit, or any dual function for that matter, requires combining Stages 2 and 3 (in Fig. 1), and reduces the valuation to a two-stage analysis (Garcia et al., 1986).

Thus, the value of soil conservation is measured as a quasi-rent differential or the share of producer surplus associated with soil conservation (a change in soil quality). Eq. (7) shows how the estimated profit function is used to calculate the marginal quasi-rent, v_i, attributed to soil conservation:

Marginal Value

$$v_i = \frac{\partial \hat{\Pi}_i}{\partial W} = \hat{\alpha}_w \hat{\Pi}_i$$

[3] 113 The original Cobb–Douglas function prior to taking natural logarithm is: $\pi = e^{\alpha w W} e^{\alpha 1 \lambda} e^{\alpha t T} P_y^{\alpha p y} P_x^{\alpha p x} Z_{pv}^{\alpha p v} Z_{ex}^{\alpha p e x} \Rightarrow e^0 \; e^{\alpha 1 \lambda} e^{\alpha t T} P_y^{\alpha p y} P_x^{\alpha p x} Z_{pv}^{\alpha p v} Z_{ex}^{\alpha e x} \neq 0$.

Since W enters the log-linear part of the profit equation (Eq. (6)) as a continuous variable, the estimated coefficient, $\hat{\alpha}_w$, is the percentage effect of soil conservation on estimated profits, Π.

For incremental values, the analysis proceeds in two steps. First, because soil conservation is attributed to agroforestry practices, parameters from the estimated soils equation (Eq. (4)) are used to simulate two levels of soil conservation, W_0 and W_1, describing the absence and presence of agroforestry practice. Adoption, implies moving from W_0 and W_1, and results in quasi-rents, $V_i^w = \Pi_1 - \Pi_0$. Thus, in the second step, path independence is assumed in the integration of the marginal value (calculated above) over the range W_1 to W_0 to obtain the value of soil conservation, V_i^w, in Eq. (8).

Incremental Value

$$V_{W_i} = \int_{\hat{W}_0}^{\hat{W}_1} v_i dW = \hat{\alpha}_w \hat{\Pi}_i^{\oplus} \int_{\hat{W}_0}^{\hat{W}_1} e^{\hat{\alpha}_w W} dW$$

$$= \hat{\Pi}_i^{\oplus} \left[e^{\hat{\alpha}_w \hat{W}_1} - e^{\hat{\alpha}_w \hat{W}_0} \right]$$

$$\text{where: } \hat{\Pi}_i^{\oplus} = \frac{\hat{\Pi}_i'}{e^{\hat{\alpha}_w \hat{W}}}$$

3. Data

The data for this study were collected through an extensive socio-economic survey, in 1993 and 1994, of 277 agricultural households, sampled from lists of both adopters and nonadopters of agroforestry technology in two villages, Visares and Cagnocot, on the island of Leyte, Eastern Visayas, Philippines. Two field pre-tested questionnaires, relating to socio-economic and agronomic characteristics, and farm budgets, were administered to each household through direct interviews to obtain the following data: (1) household socio-economic characteristics: age, farming experience, sex, education, family size, membership in community organizations, and years of residency, (2) farm production budgets: outputs of subsistence and commercial crops, timber, fuel, fodder, and livestock; inputs of labor, land, agricultural capital, and other material inputs, gross revenues from sale, cost of production, remittances, wage–income and other sources of income, and (3) agro-ecological profile: slope, type of land (upland or lowland), soil attributes of thickness, fertility and texture, and water quality. See Francisco and Mercer (1995) for additional information related to field logistics and data gathering.

Both sites are hilly and subject to significant erosion. Visares has a pronounced maximum rainy period in December but no dry season, while Cagnocot receives even rainfall throughout the year except for the dry months of February to April. The soils are acidic, varying from sandy loam to clay in Visares and extremely clayey in Cagnocot. Both sites have schools, health centers, flea markets and village halls. Visares is on the main highway and receives some irrigation water. Farming is the main source of income in both sites with corn and banana the dominant subsistence and fruit crop, respectively. Ipil-ipil

Table 1
Variables used in probit model of agroforestry adoption (descriptive statistics)

Description	Variable name	Mean	Std. dev.
Made contour hedgerows on your farm? (Yes = 1, No = 0)	*DMAKE*	0.314	0.465
Ever planted trees on farm? (Yes = 1, No = 0)	*PLTREE*	0.657	0.476
Slope of farmland (%)	*SLOPE*	28.56	15.75
Percent of income from farm agriculture	*AGRI*	57.75	33.97
Heard of contour hedgerow farming? (Yes = 1, No = 0)	*DHEARD*	0.769	0.422
Extent of assistance from project official[a]	*ASISTNC*	0.099	0.203
Length of residency in the village (years)	*REZ*	33.04	15.50
Tenant? (Yes = 1, No = 0)	*TENANT*	0.377	0.421
Household head's years of education	*HEDU*	1.484	1.339

[a]The extent of assistance is measured as the normalized sum of dummy variables where each dummy measures the receipt of one of four types of assistance (cash, technical information, labor, and seeds) from project staff.

Table 2
Soil quality variables (descriptive statistics)

	Description	Mean	Std. dev.
s_1	Improvement in color (grey–yellow range to brown–black range): Yes = 1, No = 0	0.26	0.44
s_2	Improvement in texture (fine to coarse): Yes = 1, No = 0	0.23	0.42
s_3	Increase in thickness of top soil (inches)	0.87	2.1
s_4	Improvement in fertility? (Yes = 1, No = 0)	0.27	0.44
W	Soil conservation index	0.30	0.53

(*Luecaena leucocephala*) and kakawate (*Gliricidia sepium*) are the two primary tree species used as hedgerows. Chicken is the primary livestock. Both communities engage in fishing, carpentry and other nonfarm activities, and Visares has a rudimentary rattan furniture industry introduced by the USAID project.

3.1. Agroforestry adoption data

Summary statistics for data used to estimate the adoption Eq. (4) are presented in Table 1. The first variable in Table 1, *DMAKE*, distinguishes contour hedgerow agroforestry adopters (31% of sample) from nonadopters (69%). *PLTREE* describes respondents' experience with growing trees on their farm land; 66% had previously planted trees on their farms. *SLOPE* provides a measure of the household's need for contour hedgerows to counter soil erosion; the average farm parcel is situated on a 29% slope. *AGRI* measures the household dependence on agricultural production with the average respondent relying on farm production for 58% of household income. External technical assistance levels, *ASISTNC*, is measured as the normalized sum of dummy variables where each dummy measures the receipt of one of four types of assistance (cash, technical information, labor, and seeds) from project staff. Finally, respondent characteristics are represented by the length of residency (*REZ*), farm ownership (*TENANT*), and education of head of the household (*HEDU*). On average, respondents have resided in their village for 33 yrs and have 1.5 yrs of formal education. About 38% of the respondents are tenants.

3.2. Soil quality / conservation data

In order to avoid likely multi-collinearity problems, a soil conservation index, W, was constructed as a weighted combination of changes in four soil attributes: color (s_1), texture (s_2), thickness (s_3), and fertility (s_4). Households were asked to rate changes in a variety of environmental variables, including, soil fertility and water quality, on a Likert Scale ranging from 1 (= significantly improve), via 3 (= no change), to 5 (= significantly deteriorate). The

Table 3
Variables used in soil equation (descriptive statistics)

Description	Variable name	Mean	Std. dev.
Tenant? (Yes = 1, No = 0)	*TENANT*	0.377	0.421
Site (Visares = 1, Cognacot = 0)	*SITE*	0.396	0.490
Simpson's index for land fragmentation[a]	*SIMPSON*	0.351	0.271
Upland (= 1) or lowland (= 0)	*UPLAND*	0.822	0.310
Water quality improvement (Yes = 1, No = 0)	*WQUAL*	0.329	0.471
Length of farming experience (years)	*USE*	15.55	11.64
Ever planted trees on farm? (Yes = 1, No = 0)	*PLTREE*	0.657	0.476
Frequency of mulching activities (times/yr)	*FRQMUL*	3.913	31.53
Index of agroforestry (T)	*HEDGE*	1.253	2.659

[a]The Simpson Index (SI) for land fragmentation is such that 1 = completely fragmented, 0 = completely consolidated. It is calculated by the following: $SI = 1 - \Sigma A_i^2/(\Sigma A_i)^2$ where A_i is the size of each land parcel.

Table 4
Correlation between the five agroforestry activities[a]

	T_1	T_2	T_3	T_4	T_5
T_1	1.00				
T_2	0.65	1.00			
T_3	0.52	0.71	1.00		
T_4	0.31	0.46	0.49	1.00	
T_5	0.05	0.07	0.13	0.23	1.00

[a] T_1 = the portion of farm area with contour hedgerows at the time of installment, T_2 = the number of years of agroforestry practice, T_3 = the rank assigned by respondents to soil conservation, as the reason for adopting hedgerows, T_4 = the number of years that households have engaged in other soil conservation practices, and T_5 = the frequency of mulching activities.

soil fertility and water quality data are consolidated as binary variables representing improvements if respondents provided values 1 or 2. Descriptive statistics for the four soil attributes are presented in Table 2. Previous studies used a product of five soil attributes (water holding capacity, aeration, bulk density, pH, and electrical conductivity) in a 'productivity index' to aggregate soil quality (Larson et al., 1983). Since W is defined as an increment, we use a sum rather than the product to combine the four soil characteristics. The summation suggests that incremental improvements in thickness, texture, color and fertility are substitutes. Eq. (9) describes the method for constructing the soil conservation index, W. [4]

$$W = \sum_{i}^{4} \omega_i \Delta s_i$$

$\omega_i \subseteq (0.3, 0.3, 0.1, 0.3)$

Δs_i = reported change in soil attributes

Table 3 presents the descriptive statistics for the variables used in the soils equation (Eq. (4)). Approximately 38% of the respondents were tenants and about 40% live in Visares. The *SIMPSON* variable represents the amount of land fragmentation as

[4] The authors' confidence in the differential quality of data is perhaps the only a priori reason to use the particular combination of weights specified in Eq. (9); the literature does not offer much guidance in this matter. Our estimates are fairly robust under different combinations. The first principal components, (0.25, 0.25, 0.25, and 0.25) and (0.2, 0.2, 0.4, and 0.2) were the other combinations tested.

Table 5
Prices and incomes (descriptive statistics)[a]

Description	Variable name	Mean	Std. dev.
Banana price (pesos/piece)	*PBNANA*	0.13	0.1
Corn price (pesos/sack)	*PCORN*	133.2	132.3
Chicken price (pesos/animal)	*PCHIKEN*	116.0	269.1
Labor price (pesos/man-day)	*PLABOR*	31.3	10.8
Corn seed price (pesos/sack)	*PCORNSD*	22.2	8.1
Agricultural profits (pesos)	*PI*	9774	13291
Household income (pesos)	*TOTINC*	24709	33645

[a] US$1 = 27 pesos.

measured by the Simpson Index (SI), which stipulates that 1 = completely fragmented and 0 = completely consolidated. SI is calculated as follows: $SI = 1 - \sum A_i^2/(\sum A_i)^2$ where A_i is the size of each land parcel. As indicated by the *UPLAND* variable, 82% of all farm parcels were in upland areas. *USE* describes the household's farming experience; respondents had farmed for an average of 15.5 yrs.

As noted earlier, the index of agroforestry activities (*HEDGE* in Table 3 and T in Eqs. (4) and (6)), is a weighted index of the following: (1) the portion of farm area with contour hedgerows at the time of installment, (2) the number of years of agroforestry practice, (3) the rank assigned by respondents to soil conservation as the reason for adopting hedgerows, (4) the number of years that households have engaged in other soil conservation practices, and (5) the frequency of mulching activities. Table 4 presents the correlation matrix for these five variables. The first four variables are highly correlated; their individual contribution in regression analysis is unidentifiable due to multi-collinearity. Therefore, following Kennedy (1993), the first principal component of the first four variables in this vector is used as a weighted index of agroforestry activities (*HEDGE* in Table 3). [5]

[5] Principal components are weighted averages of the collinear variables in which the weights are chosen to maximize the variation present in the data. The weights for the first principal component are comprised of the elements of the first characteristic (eigen) vector of a matrix comprised of the standardized deviations of all collinear variables. Such a composite index is credible only if the grouping of variables has some useful economic interpretation. In this case it is a behavioral index of household agroforestry practice.

Table 6
Non-price variables used in profit equation (descriptive statistics)

Description	Variable name	Mean	Std. dev.
Index of social affiliations	*SOCAFF*	1.2	1.2
Household experience with farming in the village (years)	*USE*	15.4	11.6
Number of adults in the household	*ADULT*	3.64	1.84
Amount of land area under crops (hectares)	*PLNTAREA*	2.6	3.5
Average education of household members (years)	*EDU*	5.7	3.3
Site (Visares = 1, Cognacot 0)	*SITE*	0.396	0.490
Upland (= 1) or lowland (= 0)	*UPLAND*	0.822	0.310
Index of agroforestry activities	*HEDGE*	1.253	2.659
Soil conservation index	*SOIL*	0.30	0.53

3.3. Production data

Descriptive statistics for production variables for the profit function equation (Eq. (6)) are presented in Tables 5 and 6. Table 5 presents the sample mean and standard deviation of agricultural profits, *PI*, the dependent variable in the profit equation. Using data from the farming and household labor budgets, household profits are calculated as the difference between revenues and cost. Farm profits averaged 9774 pesos/yr (US$362/yr) while total household income (*TOTINC*) averaged 24 709 pesos/yr (US$915/yr). The profit function includes prices of three primary outputs and two inputs. The output prices include corn (*PCORN*), banana (*PBNANA*) and chicken (*PCHIKEN*), input prices are labor (*PLABOR*) and corn seed (*PCORNSD*).

Two types of fixed inputs, private and public, are evaluated. The first set of private fixed inputs (Z_{pv} in Eq. (6)), include human capital inputs such as participation in community organizations and farming cooperatives (*SOCAFF*), local farming experience (*USE*), education levels (*EDU*), and number of adults (*ADULT*), and conventional fixed inputs such as farm size (*PLNTAREA*). Most of the household attributes, listed in Table 6, enter the profit function like inputs that are fixed in the short run. *SOCAFF*, the index of social affiliations, measures the extent of participation in village-level community organizations and is the normalized sum of the number of community organization to which household belongs. On average, each household contained 3.6 adult members (*ADULT*) with an average of 5.7 yrs of educations (*EDU*), and had 2.6 hectares under crop production (*PLNTAREA*).

Investments in agroforestry, *T*, and soil conservation, *W*, are other fixed inputs. Because agroforestry practices may impose labor, land, and resource costs, as well as generate benefits that are independent from soil conservation, it is included as the separate explanatory variable *HEDGE*. The second set of fixed inputs are exogenous public inputs, Z_{ex} in Eq. (6), and include the dummy for site (*SITE*) and land type (*UPLAND*).

4. Results

4.1. Adoption equation

The results of the first stage probit analysis for contour hedgerow adoption are presented in Table 7. The dependent variable is the probability of adopting agroforestry contour hedgerows. The overall model fit the data well as indicated by the χ^2 statistic, 240, and the percentage of correct predictions, 94%.

The signs of statistically significant regressors have theoretical and intuitive appeal. Those households who have historically planted trees on their own farms (*PLTREE*) and were familiar with agroforestry in terms of having some information about it (although *DHEARD* is insignificant) were more likely to adopt. Economic and agro-ecological needs influenced the adoption choice, as households with a greater percent of their income from agriculture (*AGRI*) and with steeper farms (*SLOPE*) were more likely to adopt. As in many rural development projects, the extent of project assistance (*ASISTNC*) appears to have a substantial impact on the adoption of agroforestry technology. The length of residency

Table 7
Probit model of agroforestry adoption (dependent variable is probability of adopting agroforestry)

Variable name	Coefficient	Std. error	*P*-value
CONSTANT *	−3.44	0.90	0.000
PLTREE *	1.19	0.49	0.015
SLOPE **	0.02	0.01	0.048
AGRI ***	0.008	0.005	0.101
DHEARD	0.57	0.48	0.238
ASISTNC *	16.85	2.84	0.000
REZ **	−0.02	0.01	0.069
TENANT	−0.24	0.37	0.511
HEDU	0.11	0.12	0.350
χ^2 (8)	240	% Correct prediction 94	
N	268 ****		

* Significant at 0.01 level.
** Significant at 0.05 level.
*** Significant at 0.10 level.
**** Based on the Belsley et al. (1980) studentized residual diagnostic, 8 outliers were identified and excluded from the sample.

(*REZ*) indicates that older households are less likely to adopt. Analyses of the Conservation Reserve Program in the US Mid-west found similar results and hypothesized that this may reflect increasing cynicism toward government sponsored technologies (Gould et al., 1989; Lohr and Park, 1994). The tenure variable (*TENANCY*), insignificant but with the expected sign, is negatively correlated with the assistance index (*ASISTNC*). Estimating the model without *ASISTNC*, the tenancy variable becomes significant and negative. Tenants are less likely to make long term soil conservation investments and/or project managers may have been more willing to assist landowners. Finally, the education variable (*HEDU*), though insignificant, is positively related with adoption.

4.2. Soils equation

Table 8 presents the results of estimating the soils equation (Eq. (4)). The dependent variable is the index of soil quality, *W* in Eq. (4). Model 1 is a generalized least squares model with no cross equation correlation. Model 2 is the SUR model that allows for contemporaneous correlation across the soil and profit equations. The overall 'goodness of fit' of both models is indicated by the adjusted R^2 (0.53) and *F*-statistic (30.57) as well as several

Table 8
Effects of agroforestry on soil conservation

	Model 1 Generalized least squares		Model 2 Seemingly unrelated regression (SUR)	
Variable name	Coefficient	*P*-value	Coefficient	*P*-value
CONSTANT	−0.25	0.006 *	−0.25	0.005 *
TENANT ***	−0.10	0.086 ***	−0.10	0.063 ***
SITE	0.12	0.010 *	0.12	0.009 *
SIMPSON	0.41	0.000 *	0.40	0.000 *
UPLAND	0.11	0.158	0.11	0.152
WQUAL	0.18	0.000 *	0.18	0.000 *
USE	0.002	0.327	0.002	0.336
PLTREE	0.18	0.001 *	0.18	0.001 *
FRQMUL *	0.002	0.057 ***	0.002	0.045 **
HEDGE	0.08	0.000 *	0.08	0.000 *
λ	0.29	0.000 *	0.29	0.000 *
Adj. R^2	0.53		0.53	
F [10, 257]	30.57			
χ^2 (8)	121.00			
ρ(selection)	0.77			
ρ(SUR)			0.084	
N	268			

* Significant at 0.01 level.
** Significant at 0.05 level.
*** Significant at 0.10 level.

statistically significant variables that have intuitively expected signs.

Tenants (*TENANT*) are less likely to realize soil conservation. The higher levels of soil conservation at the Visares site (*SITE*) may be attributed to the more even rainfall pattern, access to irrigation water and less clayey parent soil. Farm households with more fragmented farm holdings (*SIMPSON*) achieve higher levels of conservation. Soil conservation appears to benefit those households with a greater percentage of upland farms (*UPLAND*) that are more susceptible to erosion, although the variable is statistically significant only at 15% confidence levels. The positive coefficient on the water quality variable (*WQUAL*) indicates that water and soil quality are covariates and that contour hedgerows may improve the overall hydrologic system. The coefficient on the local farming experience (*USE*), though statistically insignificant, has the intuitively expected sign. Farmers with a history of tree planting (*PLTREE*) achieve higher levels of soil conservation. Higher frequency of mulching (*FRQMUL*) of the soils with prunings from the contour hedges results in better soil conservation. Finally, the index of agroforestry (*HEDGE*) is significant and positive, validating the hypothesis that conservation oriented land uses can induce improved quality of soil assets.

The inverse mill ratio, λ, is statistically significant and the high cross-equation (adoption and soil) correlation, suggests that adoption of a technology and the perception of its benefits are positively correlated. Inclusion of λ in the specification corrects for the selection bias and the significance of the other regressors. Table 8 also reveals that the cross-equation correlation, ρ(SUR), is low (0.08). Moreover, there are scant gains in statistical efficiency by using a SUR specification as Models 1 and 2 are similar with respect to significance of all regressors.

Table 9
Cobb–Douglas profit function: least square estimates

Variable name	Generalized least squares				Seemingly unrelated regressions (SUR)			
	Model 1		Model 2 (restricted)		Model 3		Model 4 (restricted)	
	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
CONST.	6.85	0.001*	7.88	0.000*	6.75	0.001*	7.62	0.000*
PLABOR	−0.31	0.378	−0.45	0.091	−0.31	0.306	−0.39	0.121
PBNANA	0.54	0.000*	0.54	0.000*	0.51	0.000*	0.50	0.000*
PCORN	0.23	0.009*	0.19	0.004*	0.23	0.015*	0.20	0.005*
PCORNSD	0.87	0.017**	0.71	0.004*	0.86	0.045**	0.69	0.009*
PCHIKEN	0.02	0.854	0.01	0.933	0.02	0.853	0.01	0.929
SOCAFF	0.19	0.204	0.19	0.212	0.18	0.163	0.18	0.158
USE	0.35	0.025**	0.34	0.035**	0.35	0.011*	0.35	0.012*
ADULT	0.12	0.750	0.18	0.624	0.03	0.941	0.05	0.904
PLNTAREA	0.33	0.067***	0.32	0.085***	0.31	0.054**	0.31	0.054**
EDU	0.62	0.028**	0.61	0.038**	0.62	0.029**	0.60	0.033**
SITE	0.57	0.145	0.54	0.180	0.60	0.134	0.58	0.147
UPLAND	−1.87	0.001*	−1.77	0.002*	−1.88	0.001*	−1.85	0.001*
HEDGE	−0.10	0.077***	−0.11	0.076***	−0.19	0.053**	−0.20	0.009*
SOIL	0.84	0.001*	0.84	0.001*	1.78	0.027**	1.81	0.024**
λ	0.03	0.921	0.04	0.902	−0.22	0.620	−0.22	0.627
Adj. R^2	0.25		0.26		0.25		0.25	
F [15, 252]	7.04	0.00	7.53	0.000				
F [1, 252]			0.35	0.557	χ^2 (1)		0.25	0.618
ρ(selection)	0.12							
ρ(SUR)					0.084		0.086	
N	268		268		268		268	

* Significant at 0.01 level.
** Significant at 0.05 level.
*** Significant at 0.10 level.

4.3. Profit equation

Table 9 presents the results of the second stage of valuation, the profit function equation (Eq. (6)). Models 1 and 2 do not account for contemporaneous correlation between the soil and profit equations. Model 2 is a restricted version of Model 1; the restriction is for linear homogeneity in prices such that the coefficients on all price variables add up to one. [6] Models 3 and 4 are the unrestricted and restricted counterparts in a SUR system that accounts for contemporaneous cross-equation correlation. As noted in the discussion of the soils equation results, the cross-equation correlation in the SUR models (3 and 4) is low and there are no substantial gains in statistical efficiency nor markedly different conclusions compared to the Models 1 and 2. The size of the *SOIL* coefficient is puzzling, moreover, and could be attributed to an inappropriate choice of instrument for the *SOIL* variable in the profit equation; an alternative instrument variable is not apparent. Other than this coefficient, the significance and size of rest of the parameters do not markedly differ between the four models. Thus, because of the lack of statistical efficiency gains and low cross-equation correlation, subsequent discussion is limited only to Models 1 and 2.

The unrestricted Model 1 differs from the restricted Model 2 essentially in terms of the size and significance of the coefficients on the price variables. Profit is increasing in output prices (*PCORN* and *PBNANA*) and decreasing in input prices (*PLABOR*). The coefficient on the price of labor is significant in Model 2. The sign on the coefficient for the price of corn seed (*PCORNSD*) is an exception to the theoretical performance of this model. Perhaps it is a mistake to categorize seeds as traditional inputs like mechanized tools and commercial fertilizers. Because corn seed is often the residue from corn production, high prices for seed can induce a positive supply, net of own-farm use. Just like conventionally marketed produce such as corn and bananas, in response to high prices corn seed may behave like an output.

In conjunction with the negative sign on the wage coefficient (*PLABOR*) in the restricted model, the statistical insignificance of the coefficient on number of adults (*ADULT*) suggests that market substitutes for own labor are available. This is consistent with the findings of Benjamin (1992) and Pitt and Rosenzweig (1986) who use similar tests to determine the completeness of market based on the separability of production and consumption allocations. Moreover, it allows us to exploit analytical separability in specifying our valuation approach in terms of changes in producer surplus.

Profit is increasing in both the private and exogenous fixed inputs. Quasi-fixed inputs such as farm size (*PLNTAREA*) and human capital, measured in terms of farming experience (*USE*) and educational attainments (*EDU*), are correlated with higher profits. Farmers in Cognacot fare no differently than their counterparts in Visares (*SITE*). Farming on steeper uplands (*UPLAND*) results in lower profits. These results are supported by previous studies of agroforestry adoption in Leyte in which higher education levels, larger farm size, participation in public institutions and flat (as opposed to steep) parcels were the foremost explanatory variables for higher net household incomes (Armenia et al., 1990; Cruz et al., 1987). Participation in community organizations (*SOCAFF*) does not appear influence profits.

For the self-selection effect, a low across-equations (adoption and profit) correlation of 0.122, and insignificant coefficient on the inverse mill ratio, suggest that adopting households do not possess innate pioneering capabilities (separate from the characteristics used as independent regressors) that puts them at comparative advantage over non-adopters. Another interpretation is that adoption by itself does not induce special effort that would result in statistically higher levels of profit.

The emphasis of this empirical study is the soil conservation variable (*SOIL*), and all models show that households with greater levels of soil conservation produce higher profits. This suggests that natural assets can produce positive economic benefit streams. Nevertheless, the extent of agroforestry practice (*HEDGE*) is associated with lower profits. This is

[6] Linear specification for the profit function is rejected on the basis of a high χ^2 test statistic (788) in a Box–Cox regression. The Busch–Pagan test statistic for heteroskedasticity is 87.05 for Models 1 and 2. White's estimator is used to correct for heteroskedasticity (Greene, 1993).

Table 10
Marginal and total value of soil conservation in pesos[a] ($N = 87$: summary statistics are for the sample of adopting household

	Mean	Median	Std. deviation
Marginal values (v^W)			
Model 1	9780	4970	13420
Model 2	9410	5450	12150
Total Values (V^W)			
Model 1	1380	790	2640
Model 2	1330	820	2440

[a]US$1 = 27 pesos.

likely due to increasing net opportunity costs of labor, land and other resources necessary for establishing the agroforestry system. In Section 4.4, we examine whether or not the positive soil conservation effect on profits is large enough to outweigh the negative impacts from adopting agroforestry.

4.4. Value of soil conservation

Eqs. (5) and (6) and the estimated coefficients from Tables 8 and 9 are used to calculate marginal and incremental values of soil conservation for each adopting household. As discussed above, only Models 1 and 2 were used to calculate the values presented in Table 10. For the sample of adopters, the average marginal value of soil conservation is 9410 pesos/yr (US$348) from Model 2 and 9780 pesos/yr (US$362) using Model 1. [7] Because the mean numerical value for the soil conservation variable is 0.96, the marginal value (an increase by 1) measures an approximately 100% increase in soil conservation. More realistic changes at the 10% level would produce commensurably smaller and credible numbers equal to 941 pesos/yr (Model 2) and 978 pesos/yr (Model 1). A somewhat different interpretation of first derivatives is an elasticity measure, evaluated at sample mean, of 0.81.

For the sample of adopters, the average incremental value of soil conservation is 1330 pesos/yr (US$49) from Model 2 and 1380 pesos/yr (US$51) from Model 1. Because total values measure changes in profits associated with changes in W within its realized range, they do not face caveats on interpretation such as those applied to the marginal values. Given that the mean total and agricultural incomes for the sample are 25 000 pesos (US$926) and 11 000 pesos (US$407), respectively, the calculated values suggest that soil conservation generated productivity benefits in the range of 5 to 10% of current incomes (the range reflects the choice between total or agricultural incomes as the denominator).

The positive signs and statistical significance of the coefficient of the agroforestry index (*HEDGE*) in the soils equation (Table 8) and the soil conservation index (*SOIL*) in the profit equation (Table 9) indicate that agroforestry-related soil conservation is economically beneficial to the farmer. Moreover, the calculated incremental value associated with soil conservation, a quasi-rent measure, is positive. This in itself, however, is insufficient incentive for farmers to invest in agroforestry. As indicated by the negative co-efficient on the agroforestry index (*HEDGE*) in the profit equation, other aspects of agroforestry adoption appear to impose direct opportunity costs on the agricultural households. [8] Farmers will voluntarily participate in agroforestry practices only if the net benefits are positive. For the 'average' household the total net benefit, a sum of the direct (*HEDGE*) and indirect (*SOIL*) effects on profits, are 2420 pesos (US$89) and 2570 pesos (US$95) for Models 1 and 2, respectively. This suggests, that without some form of financial, material, and technical assistance the 'average' farmer lacks the incentive to adopt agroforestry.

There are some caveats to this result. First, the specific soil conservation benefits calculated here are edaphic. These estimates do not account for several, possibly significant off-site and on-site benefits that

[7] The average is taken over a sample comprised only of adopters.

[8] The quasi rents associated directly with agroforestry practice are calculated by using *HEDGE* instead of the *SOIL* variable in Eq. (6). While individual farmers fare differently, for the sample of adopters, the mean quasi-rents are 3800 pesos (US$141) and 3900 pesos (US$144) associated with Models 1 and 2, respectively. The elasticity of profits with respect to agroforestry is 0.75.

are external to the individual households.[9] Therefore even if the net contribution of agroforestry to individual household profits is negative, net benefits to society, including the external benefits and project related costs, are likely to be positive. Thus, there may be good reason for society to implement an incentive system, through subsidies or extension services, for the farmers to practice agroforestry that would conserve the soil and enhance overall societal welfare. Second, all 'long run' soil conservation benefits, and particularly improvements in the agro-ecological profile, may not have been realized in the short ten yr period since the initiation of the agroforestry project. Third, by ignoring other on-farm, nonprice benefits of agroforestry such as fuelwood and fodder in the calculation of farm income budgets, the analysis may significantly underestimate benefits. These caveats imply that the analysis is conservative in spirit and has generated lower bounds for agroforestry related soil conservation values.

5. Conclusions

In this study, we develop and estimate a three stage conceptual framework for valuing the on-site soil conservation benefits farmers receive from adopting contour hedgerow agroforestry systems in the Philippines. Two methodological observations are noteworthy. First, even though the survey was designed to elicit information on the chronology of adoption, there was insufficient time series 'length' to detect trends or to determine if the survey year was typical. Future evaluations are advised to either conduct repeat surveys with a time lag, or to maintain regular annual records for a sub-sample of the surveyed households. Second, the agro-ecological variables are self-reported. 'Ground truthing' by engaging the soil conservation service to obtain precise scientific measurements for a sub-sample of the households may have improved the reliability of the results.

Estimated soil conservation benefits associated with agroforestry (as measured by increase in farm profits) ranged from 5–10% increases in current income. However, the additional opportunity costs associated with adopting the agroforestry systems appear to outweigh the soil conservation benefits received by the farmers. These results explain in large part the low adoption rates of contour hedgerow agroforestry systems in the Philippines despite substantial efforts by donor agencies, nongovernmental organizations, and the Government of the Philippines (Nelson et al., 1997). Additional studies are required to measure both the off-site external benefits and on-site nonsoil benefits associated with agroforestry adoption to help evaluate additional subsidies or other incentives for encouraging agroforestry adoption in the Philippines.

[9] There are three broad categories of soil conservation benefits: on-site, off-site–in-stream, off-stream (Brooks et al., 1992). The major on-site benefits are the sustenance of agricultural productivity and general on-site ecosystem productivity; also described in the text as 'edaphic'. The off-site benefits are typically categorized as in-stream and off-stream. In-stream benefits includes habitat protection for aquatic life, recreational values, water storage in lakes, and navigation. Off-stream benefits are associated with flood and drought mitigation, improved water conveyance, decreased water treatment requirements, and increased quality and quantity of water.

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