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What Motivates Farmers? Tree Growing and Land Use Decisions in the Grasslands of Claveria, Philippines

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This report investigates which land use system would provide the most economic and environmental benefits to farmers of upland grassland areas in the Philippines. It analyses a number of different land use systems and focuses on the benefits that tree-based systems can bring. It also investigates the main reasons why farmers are reluctant to change from their current unsustainable cropping regimes. It finds that it would make economic and environmental sense for farmers to convert a large percentage of their farms over to tree planting. It also finds that, although this would help halt the current slide into low productivity and environmental ruin, many farmers are reluctant to make the move because of the economic risks involved. In light of this, the report suggest several policies to give farmers the assistance they need to make an environmentally-informed choice about which land use system to adopt.

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April, 2003

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EXECUTIVE SUMMARY

This study aims to quantify and analyze the environmental and economic impacts of alternative land uses of grassland areas in Claveria, Misamis Oriental, Mindanao. It is also aimed at identifying tree growing objectives and investment decisions of smallholder farmers. The study made use of interviews from 192 farmer-respondents, 86% of whom practiced tree-based farming systems and the rest planted short-term cash crops, with corn as the dominant crop.

Modeling and economic analysis showed that tree-based land use systems have significantly higher financial profitability and environmental benefits. The latter were measured in terms of higher carbon sequestration, reduced soil erosion, and higher level of soil nutrients relative to current farmers' practice of maize cropping. Despite these, the extent of tree farming remains low (<10% of land area). The risk analysis conducted indicated that while timber-based systems earned the highest net present value (NPV), they are also the most risky option as reflected by the high coefficient of variations of the NPV ranging from 164% to 205%.

The Tobit regression analysis of farmers' tree growing decision revealed that high relative price variability (timber price vis-à-vis cash crop prices) deters tree planting. Farmers' tree growing decisions also depend on: (1) current price levels, forecast price changes and relative price variability; (2) socio-economic characteristics such as household size, age, and education; (3) farm size; (4) land tenure; (5) knowledge about tree-based land use systems; and (6) membership in landcare association.

The principal component analysis showed that smallholders have multiple underlying objectives in tree growing: economic, recreation and aesthetic, and environmental protection and restoration. Of these, monetary and other economic-related objectives were found to be the primary consideration.

Since price risk appears to be the major deterrent to expansion of tree farming, measures to reduce risk or improve risk-coping mechanisms of farmers should be given the utmost importance in any upland development programs. Provision of relevant and timely price information and subsidized crop insurance for both annual and tree crops are possibilities. Tree farming produces net benefits to farmers and society in terms of carbon sequestration services. Payments to farmers for environmental services they provide should be explored to encourage expansion of tree-based land use systems.

1.0 INTRODUCTION

1.1 Background of the Study

Uplands are important geographical components of Philippine agriculture. Vast areas of the uplands in the Philippines are covered with grassland vegetation mostly dominated by *Imperata cylindrica.* Other common names for *Imperata* are alang-alang, cogon and blady grass (Sajise 1980; Turvey 1994). *Imperata* is well adapted to colonize areas cleared of forest and thrives on infertile soils. It is a fire climax vegetation type and has extensive rhizomes that sprout rapidly after burning, allowing it to maintain its dominance in the ecosystem.

Estimates of the extent of Philippine grasslands vary. The Department of Environment and Natural Resources' (DENR) estimation is only 1.5 million ha (Malvas 1995), while the Department of Agriculture (DA) has reported about 6.5 million ha (Concepcion and Samar 1995). The Forest Management Bureau estimated that about 400,000 ha are used for grazing purposes under the pasture lease agreement and the rest are utilized for agricultural purposes, mostly under traditional upland farming and shifting cultivation practices (Rañola et al. 1998).

Shifting cultivation is practised by majority of the inhabitants of grassland areas (Menz et al. 1998). It is a slash-and-burn method of farming where land is cleared from grasses, shrubs or trees by fire for crop production. The proliferation of shifting cultivation following deforestation due to increasing population pressures in the uplands has been responsible for rapid land use conversion from natural forests to grassland areas and consequently into permanent agriculture (Bandy et al. 1993; Garrity and Agustin 1995). Traditionally, shifting cultivation is sustainable with long fallow period. When fallow period shortens, soil fertility declines significantly due to increasing soil erosion, and results in degradation of grasslands that are generally acidic, with low organic matter and dry soil susceptible to soil erosion. The environmental consequences of shifting cultivation in upland areas can be severe and widespread with soil erosion recognized as the worst environmental problem in the Philippines (World Bank 1989). Total annual soil loss from the Philippines was estimated to be around 74.5 million tonnes by DENR (1992) and 80.6 million tonnes by Francisco (1994). Although soil erosion is a natural process, it is greatly accelerated by human activities. The intensive cultivation of upland areas without the adoption of appropriate soil-conservation practices produce high rates of soil loss and threaten the long-term sustainable productivity of the upland resource base (Francisco 1998; Nelson and Cramb 1998). This has serious implications on the economic welfare of a growing upland population with few feasible livelihood alternatives.

It is evident that the future of low input shifting cultivation is grim. Based on the soil quality and economic performance indicators, Menz and Grist (1998) have shown that where economic viability is still being achieved, this is not likely to last. If smallholder farmers continue to practice shifting cultivation system without the application of new technology or inputs, return to labor will fall to the point that most of these smallholder upland farms will cease to be viable (Menz and Grist 1998; Nelson et al. 1998; Magcale-Macandog et al. 1998). For most smallholder farmers, the limited land area available implies that it is not financially feasible to reduce the cropped areas sufficiently to maintain yields and soil parameters at sustainable levels. The challenge now is to facilitate the inevitable change in a manner that is positive in terms of reducing poverty at the same time improving environmental parameters of soil and carbon stocks. Thus, the focus of this study is on marginal uplands under private ownership as well as public lands previously covered by the Integrated Social Forestry Program (ISFP) of DENR, which are currently covered by grasslands or are being farmed by smallholder-farmers using shifting cultivation practices.

1.2 Statement of the Problem

One of the concerns of the Philippine government is to rehabilitate vast areas of grasslands in the country through reforestation and other tree-based plantation establishment including agroforestry. This action is aimed at providing both economic and environmental benefits. The environmental impacts consist mainly of improvement in water supply, carbon sequestration, soil erosion reduction, and biodiversity enhancement. Ultimately, this initiative is addressed at meeting the important policy objectives of poverty reduction and enviromental protection.

The vast area of grasslands as well as the potential environmental and economic impacts associated with their current use provide the imperative to examine alternative uses of this resource. On the basis of economic principles, environmental and economic policies for upland development also require that alternative uses of grasslands be examined to optimize utilization of scarce resources. Such efforts are important since a considerable portion of grasslands in the country is located in critical watershed areas that provide various environmental goods and services to smallholder farmers and the society as a whole. In the light of increasing population pressures, limited land resources, and rising expectations of the rural population, it is critical to improve the productivity of existing grasslands by converting them into more productive systems.

The conversion of *Imperata* grassland to other uses is an investment decision. Like any investment, it must be financially and/or socially profitable. This study hopes to contribute to the assessment of economic and environmental consequences of the said grassland conversion. In the Philippines, there is very limited data on the total biomass of agroforestry farms (Lasco and Pulhin 1997), and thus, the potential for C sequestration of these farms is less known. (C sequestration or carbon sequestration refers to the benefits provided by the trees for sequestering carbon dioxide through their growth process that otherwise would be added to the greenhouse gases in the atmosphere). Furthermore, previous empirical studies on carbon sequestration mostly deal with deforestation rather than reforestation while only a few dwells on smallholder agroforestry alternatives in grassland areas. In addition, most studies on land use options assumed certainty and risk neutrality, thus lacking an economic policy dimension.

1.3 Significance of the Study

Results of the study will help policy-makers and resource managers to determine optimal land use options for *Imperata* grassland and design public sector reforestation plans. The most important policy question this study hoped to answer is “under what conditions are tree crops profitable enough to provide a clear financial incentive for smallholder farmers to include these into their land use system?.” The study can also provide important inputs in formulating appropriate market-based instruments (e.g. using provider-gets-principle) for possible carbon trading between the industries and agriculture and natural resource sectors. The findings of this study will provide guidance to policy-makers and resource managers towards better and more informed decision-making for sustainable use of *Imperata* grassland to achieving the overall goal of reducing poverty in the uplands.

Tree-based farming systems are potentially profitable alternatives for improving the productivity and sustainability of marginal uplands and grassland areas. Tree growing is recognized to be effective in the control of *Imperata* and other grasses via shading (Menz and Grist 1996; Gouyon 1992). It also provides an additional public benefit by sequestering atmospheric carbon through their growth process (Nowak 1993). Tree growing is also the only known practical way of removing large volume of greenhouse gases, especially carbon dioxide (CO_2), from the atmosphere (Trexler and Haugen 1995). CO_2 is the most abundant and important greenhouse gas (GHG) under human control (Moura-Costa 1996; Houghton 1996) and it is expected to account for more than 50% of the radiative forcing of GHGs released from human activity over the next century (Houghton 1996; Houghton et al. 1990).

The important environmental benefits from tree-based land use systems are associated with long-term field experimentation and measurement. Current methodologies for most empirical analyses using single-period data are unable to provide an accurate measure of the benefits from tree-based land use systems. This is important considering that the total benefits from tree growing are realizable only over the long-term while the costs of their adoption are incurred immediately. One way of overcoming the dearth of time-series data on soil erosion and productivity including carbon sequestration would be through modeling and simulation. Results of such exercise are used to value the private and social benefits of various tree-based land use systems. Apart from knowing the profitability of tree-based farming systems, it is also important to understand smallholder farmers' attitudes and decision-making about the planting of trees. Farmers' willingness to grow trees depend on many factors, and if government or non-government organizations intend to convince farmers to invest and grow more trees, these factors must first be understood.

1.4 Scope and Limitation of the Research

The study was conducted only in one representative *Imperata* grassland site in the Philippines due to time constraint and financial considerations. In addition, modeling and simulation of alternative scenarios was done only at the farm level. Nevertheless, results from the study can be adapted to evaluate other *Imperata* grassland areas with similar socioeconomic and geographical settings. The methodology employed in the study can also be used to assess land use options in other *Imperata*-dominated uplands.

2.0 REVIEW OF LITERATURE

2.1 The Extent of Grasslands in the Philippines

Grasslands constitute more than one third of the country's land area. Satellite data analyses conducted by the Swedish Space Corporation (1988) revealed that pure grasslands occupied 1.8 million ha while another 10.1 million ha are in extensive cultivation mixed with grasses and brushes. The former are distributed throughout the archipelago in rolling to mountainous areas with a slope greater than 18% (ERDB 1989). Grassland soils are mainly oxisols and ultisols, which are essentially the red, acidic and low fertility soils. Occurences of fire and sparse cover further expose these areas to erosion. These areas are also loosely termed as "open" or "public" lands, in contrast to titled alienable and disposable land (A&D).

Grassland areas vary in topography over different localities, but they are found generally in undulating to moderately steep terrain. They are typically found at intermediate elevations below the remnant forest on steep mountains. Over the years, permanent agriculture has moved gradually upward into the grasslands, while the frontier of cultivation continually extends the grasslands even farther into the remaining forest. Grasslands have thus served as an intermediate zone. While a portion of these are continually being transformed into permanent croplands or plantations over a long period of time, new *Imperata* lands are created as forest is destroyed through logging and/or smallholder farming (Garrity et al. 1997).

2.2 Transformation Pathways for *Imperata* Grassland

The transformation pathways (Figure 1) for *Imperata* grasslands in the Philippines have been described by Rañola et al. (1998). The figure shows that conversion of *Imperata* grasslands into alternative land uses is mainly dependent on the occurrence of grassland fire. Effective fire control is a prerequisite to establishment of trees on *Imperata* grasslands as grassland fires can damage young trees. Persistent fire problem destroys trees and promotes *Imperata* establishment in the area.

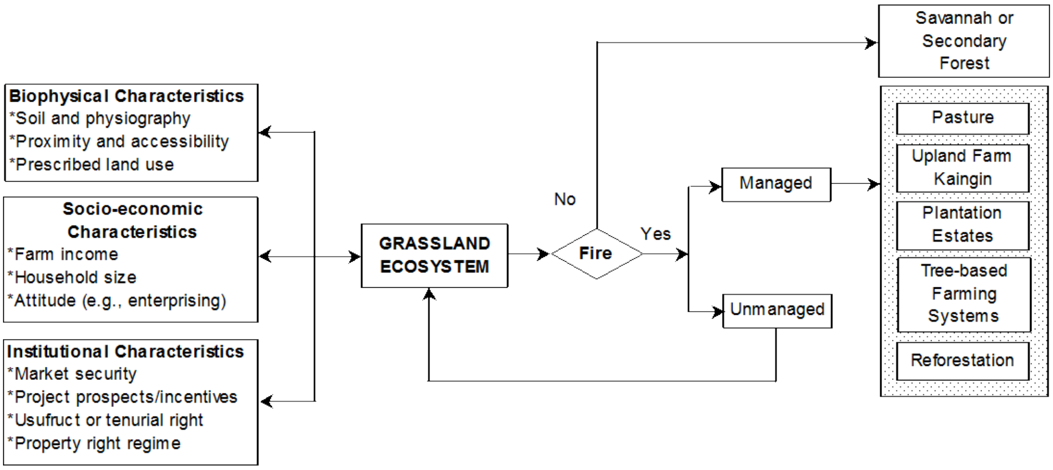


Figure 1. Transformation Pathways for *Imperata* Grasslands in the Philippines (Adapted from Rañola et al. 1998)

2.3 Determinants of Tree Growing

Shively (1999) viewed the selection of crops to be planted on a farm as analogous to the problem of an investor in choosing the combination of investments to be made considering that certain initial costs are associated with the chosen investment decision. He argued that a farmer invests assets (e.g., land) in an agricultural portfolio that consists of one or more crops. Some crops may be grown expressly for commercial sale and others may be retained and used for home consumption.

In general, choices and scales of activity are circumscribed by household needs and market opportunities (Arnold and Dewees 1995), but typically the mix of annual and perennial crops in a farmer's portfolio will be guided by both economic and non-economic considerations (Shively 1999). In the case of perennials, the important factors that influence smallholders' decision to plant timber trees might include whether: (i) markets for trees exist, (ii) planting materials are available, and (iii) the farmer is willing or able to wait for trees to mature. It was argued that within a country or region these microeconomic factors combined with physical features of the landscape determine overall patterns of perennial-crop agriculture over time. Reardon and Vosti (1995) and Scherr (1995a) discussed how poverty and economic risk also influence investment decisions of smallholders. On the other hand, Sahn and Delgado (1989) found that for low-income farmers who have no access to risk-reducing mechanisms, the movement of price variability might be as important as average prices in determining crop choice. However, from the perspective of a farmer who decides to plant trees, a key consideration is the amount of land to devote to the tree crop (Shively 1998).

2.4 Risk and its Impacts on Technology Adoption

The impact of risk and risk aversion on the choice of agricultural production techniques and input use has been a topic of extensive investigation (Feder et al. 1985; Anderson and Hazell 1994 as cited by Pandey 2000). Theoretical studies on farmer behavior under risk indicate that, in the absence of a perfect market for insurance, resource allocation for risk-averse farmers differs from that for risk-neutral farmers (Sandmo 1971; Anderson et al. 1977). Pandey (2000) argued that risk-averse farmers are likely to consider simultaneously both the level of income and risk and to reject a technology that they consider too risky.

Empirical evidence indicates that farmers in developing countries are generally risk-averse (Binswanger 1980; Walker and Ryan 1990). Poor farmers are more averse to risk and more likely to be reluctant to adopt technologies that increase risk (Pandey 2000). In addition to this direct effect, risk aversion indirectly affects technology adoption through its impact on the credit market (Binswanger and Sillers 1983). Risk-averse farmers are less likely to demand credit. Since credit is essential for the adoption of technologies that require purchased inputs, risk aversion discourages technology adoption. This indirect effect of risk is often considered to be more important than direct effect (Binswanger and Sillers 1983).

2.5 Sources of Risk

Income of farmers from agricultural production can fluctuate as a result of variations in yield, price of output, area planted, price of input, and input supply (Pandey 2000). However, the other components of risk can also be important in reducing the uncertainty of income. For example, a negative correlation between the price of rice and yield tends to stabilize the income from rice compared with a situation when these two variables are positively correlated. Hence, if the interest is in stabilizing farmers' incomes, it is necessary to evaluate the consequence of price instability and how it affects income stability (Pandey, 2000).

Pandey (2000) argued that price risk is an important component of income risk, especially in commercialized systems. When traded inputs are substituted for non-traded inputs and output is mainly for the market, fluctuations in prices of both inputs and outputs can have a major impact on farmers' welfare. Thus, a negative correlation between price and yield is an important feature of agricultural production, which helps in stabilizing farm income. Prices tend to be high when production is low and they tend to be low when production is high. Stabilizing prices in this situation can actually raise farm income instability.

3.0 CONCEPTUAL AND THEORETICAL FRAMEWORK

3.1 Conceptual Framework

A holistic understanding of smallholder farmers' resource allocation decisions as well as the associated economic and environmental effects has called for a two-pronged framework of analysis for the study. First, modeling and simulation approach was applied to evaluate and deepen the understanding on tree-based land use choices. The economic modeling and analysis quantified the economic and environmental impacts of land use conversions at the farm level. Second, the behavioral response of smallholder farmers were identified and analyzed in the context of their household and farm circumstances. The study attempted to identify underlying farmers' tree growing objectives and consequently the factors influencing the said objectives. It also analyzed the determinants of smallholder farmers' tree planting decisions. Agricultural and timber prices as well as price variability were explicitly included in the analysis to quantify and explain the effects of the changes of these variables on land use decisions of smallholder farms. It hypothesized that agricultural pricing policies have the potential to improve environmental outcomes in *Imperata*-dominated upland areas by encouraging farmers to shift their agricultural portfolios toward more sustainable crop production. All the above-mentioned analyses are expected to shed light on smallholder farmers' portfolio selection problem, especially for options involving long-term investment and substantial upfront costs as in the case of tree-based farming systems.

Figure 2 shows the summarized determinants influencing decision of farmers to invest in tree-based land use system. As shown, the decision to invest in tree-based systems may depend on household characteristics, technology, farm characteristics and asset endowment, institutional and policy factors, and invisibly by market characteristics. All the above factors are hypothesized to have differential effects on the extent of investment and ultimately may have economic and environmental impacts, which may in turn influence environmental policy. Likewise, the same or a subset of those factors in conjunction with the investment decision may also affect tree growing objectives for farmers who have invested in tree-based land use systems. Understanding tree growing objectives of smallholder farmers is important since they may influence the formulation of environmental policy to improve their economic welfare and at the same time enhance environmental benefits.

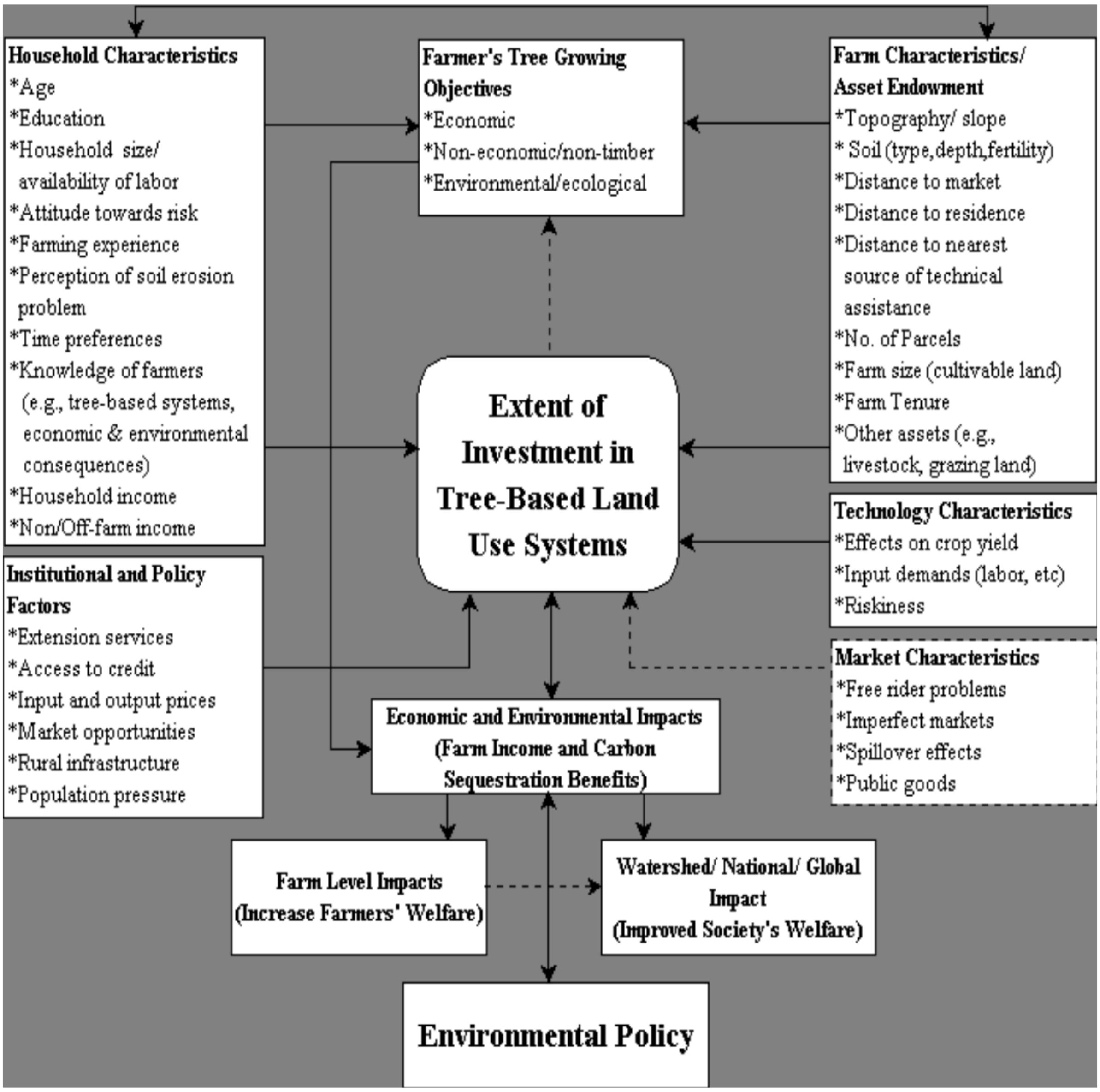


Figure 2. Conceptual Framework Showing the Determinants Affecting Decision to Invest in Tree-based Land Use Systems.

3.2 Theoretical Framework of Tree-crop Investment Model

This section presents a model that explicitly links prices to planting decisions. Consider an upland agricultural household that must choose how to allocate a parcel of land of fixed size between a food crop and a tree crop. The objective of this allocation decision problem is to maximize the net present value of expected utility of income derived from the production of selected crops over a certain period of time. This problem has characteristics of both standard portfolio choice problem (Markowitz 1959; Merton 1971) and an investment problem under uncertainty (Dixit and Pindyck 1994). To simplify the analysis, it is assumed that this portfolio-investment can be made at any time, but that the decision is made only once (Shively 1998). It is further assumed that the cost of investment is unrecoverable, and that the investment decision is irreversible[1]. Thus, there is only one choice variable at a point in time, namely the share of land to plant (if any) with trees. Following Shively (1998), the problem for the decision-maker is to choose the land share based on the cost of investing and the expected future returns from the portfolio. From the analyst's perspective, the problem is to find the minimum price at which investment will occur.

Let U represent a twice-differentiable concave utility function defined over income; δ represent a discount factor; π_t represent net income at time t; and p^i denote the price of the ith crop. The function g(t) is used to denote growth in output of the tree crop over time; and y denotes the yield of the crop. The per-hectare cost of investing in tree growing, which includes the opportunity cost of land occupied by immature trees is denoted by E. If λ represents the land planted with trees and 1-λ represents the share of land devoted to the food crop, the decision-maker's problem is to choose λ in order to maximize expected utility at time t, that is,

$$\text{Max } E\left\{\sum_{t=0}^{t=\infty}\delta_t U(\pi_t)\right\} \qquad (3.1)$$

subject to the definition of income, which is:

$$\pi_t = \lambda p_t^{tree} g(t) + (1-\lambda) p_t^{crop} y - \lambda W \qquad (3.2a)$$

if investment occurs at time t, and

$$\pi_t = \lambda p_t^{tree} g(t) + (1-\lambda) p_t^{crop} y \qquad (3.2b)$$

otherwise.

Current crop prices are known but future prices are uncertain. It is assumed that prices evolve according to a first-order vector autoregression process:

$$p_t = \alpha_0 + \alpha_1 t + \Phi p_{t-1} + \varepsilon_t \qquad (3.3)$$

The error vector ε_t is assumed to be white noise (normally and independently distributed) with $E\{\varepsilon_t\} = 0$; $E\{\varepsilon_t\varepsilon_\tau\} = \psi$ (for $t = \tau$) and $E\{\varepsilon_t\varepsilon_\tau\} = 0$ (for $t \neq \tau$).

Bellman's equation for the above problem can be written as:

$$V_m(p_m, \lambda_m) = Max\{U(\pi_m) + \delta E V_{m+1}(p_m, \lambda_m)\}. \qquad (3.4)$$

The solution to this equation would give the optimality condition:

$$u'(\pi_t) = \lambda E_t\left\{u'(\pi_{t+1})\left[p_{t+1}^{tree} g(t) - p_{t+1}^{crop} y - W\right]\right\} \qquad (3.5)$$

Equation (3.5) says that at the optimum, a decision-maker will choose land share to equate expected marginal values for each crop in the portfolio, taking into account the

[1]The assumption of irreversibility is not problematic in practice because once trees have survived after planting, farmers rarely remove them unless they die, are harvested later in future date, or unless relative prices change by a great deal more than will be considered in the analysis.

cost of investing and the current and long run impact of the tree-planting decision on expected future income. Since trees mature slowly, tree-planting decisions made in the current period have a delayed impact on revenues via $g(t)$. The decision to plant trees will be governed by three factors: (i) the cost of investing in trees; (ii) the expected prices of the trees and the food crop; and (iii) the relative riskiness of trees and the importance of this risk in the decision-makers' calculus. The relative riskiness of trees is important because when investment is costly and takes place under uncertainty, the risk associated with the investment will drive a wedge between the optimal and observed levels of investment. This is true for both risk-averse and risk-neutral decision-makers (e.g. Shively 1998 *cf* Chavas 1994).

For convenience, assume that a constant relative risk aversion utility function applies, with a risk aversion coefficient γ:

$$u(\pi_t) = \begin{cases} \dfrac{\pi_t^{1-\gamma}}{1-\gamma} \text{ for } \gamma > 0 \\ \\ \ln \pi_t \text{ for } \gamma = 1. \end{cases} \tag{3.6}$$

Using this utility function, Equation (3.5) can be rewritten as:

$$\pi_t^{-\gamma} = \lambda E_t \left\{ \pi_{t+1}^{-\gamma} \left[p_{t+1}^{tree} g(t) - p_{t+1}^{food} y - W \right] \right\} \forall i \tag{3.7}$$

Following Shively (1998), and Hansen and Singleton (1982), equation (3.6) implies that:

$$E_t \left\{ 1 - \delta \left\{ \left(\frac{\pi_{T+1}^{tree}}{\pi_t} \right)^{-\gamma} \left[p_{t+1}^{tree} g(t) - p_{t+1}^{crop} y - W \right] \right\} \middle| \Omega_t \right\} = 0. \tag{3.8}$$

Equation (3.8) indicates that portfolio allocations will be based on expectations conditional on information (Ω) available to the decision-maker at time t. This information includes price histories for each crop. As the expected price for trees rises above some "trigger price" (dependent, among other things, on the fixed cost of investing and the opportunity cost of planting trees), a decision-maker will invest in trees. Once the investment decision has been made, the share of land planted with trees will then reflect the relative importance of tradeoffs between risk and return in the portfolio. The share of trees in the portfolio may depend not only on the expected variance in return from trees (relative to the food crop) but also on the expected covariance between tree-crop and food-crop incomes. Using the time series data on prices to empirically derive the probability distribution of income from tree-crop and food-crop, a risk-averse decision-maker will choose the land use portfolio with higher net returns and at minimal risk or variability of income.

For a given a set of observed prices and land shares or intensity of tree planting expressed in terms of number of trees planted, a reduced form of equation (3.8) can be used to test econometrically the hypothesis that portfolio decisions are related to price information and other factors. Testing this hypothesis requires a reasonable forecasting rule for the expected price to be systematically related to patterns of land use.

4.0 MODELING AND ECONOMIC ANALYSIS OF LAND USE OPTIONS

4.1 Methodology

Modeling and economic analysis (Figure 3) was applied to determine the economic and environmental impacts, including carbon sequestration benefits, of tree-based farming systems vis-à-vis current cropping or land use system. The biophysical component was modeled and simulated using Soil Changes Under Agroforestry (SCUAF) version 4.0 (Young et al. 1998). SCUAF is a simple, deterministic model that can be used to predict crop yield as a function of changes in soil carbon, nitrogen and phosphorus content. These changes depend on various plant and soil processes taking place for each scenario. Data from research trials and literature survey were used in calibrating SCUAF. The major inputs or parameters in the model include soil profile/characteristics and soil erosion, plant growth, plant composition, removals or harvesting, and transfer or pruning. SCUAF determines plant growth and soil changes on a per hectare basis, hence the systems under study are modeled on a hectare of landholding. Land use systems were specified in the SCUAF model and simulation outputs[2] served as a basis in the analysis of economic and environmental outcomes. The associated economic model was implemented through the extended benefit cost analysis (BCA) framework.

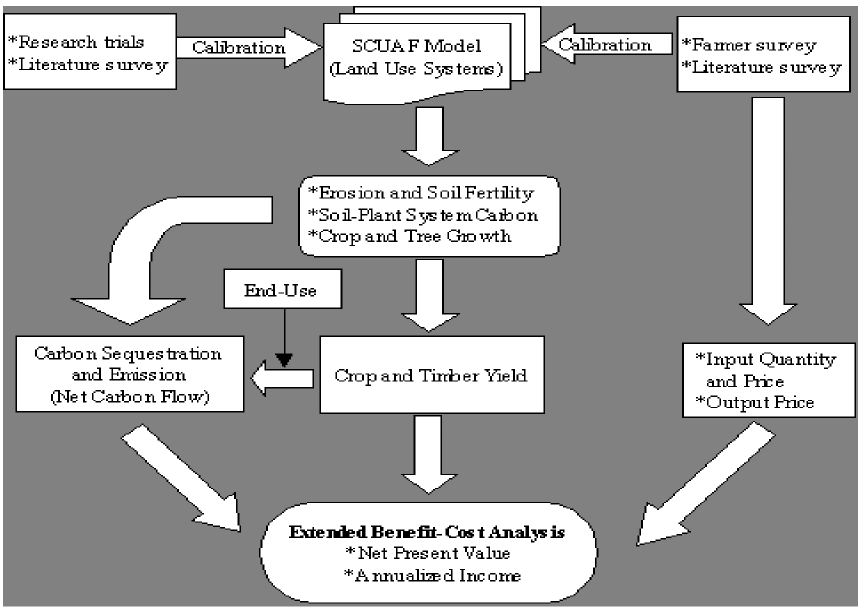


Figure 3. Economic Valuation Framework Used to Quantify the Impacts of Alternative Land Use Systems for Grassland Areas.

[2]Changes in soil carbon, nitrogen and phosphorus contents resulting from soil erosion, recycling of plant materials and mineral uptake in a specified land use system within a given environment.

4.1.1 Estimation of Carbon Sequestration

Carbon flow (as CO_2) in crop or forest production depends on two processes: fixation (assimilation) and emission processes. The former represents the biomass growth in living crop/trees (in CO_2 equivalents) due to the photosynthesis, while the latter represents the biomass decay of the wood (in CO_2 equivalents), as a consequence of natural mortality or human related removals and end-uses. For this study, the carbon flow for each land use system was estimated using SCUAF by simulating the net carbon gains/losses from plant-soil system carbon and annual emissions from decaying biomass.

The SCUAF model simulated the changes in plant-soil system carbon annually as the difference between total carbon gains and losses for each system. Gains for plant-soil system carbon are from the atmosphere, as photosynthesis or net primary production, and from additions of organic material from outside the system. Soil carbon arising from organic matter or leaf litter decomposition is accounted for in the gains from photosynthesis. Carbon losses, on the other hand, are due to harvesting, burning, erosion and oxidation.

4.1.2 Economic Analysis

The economic component of the model was linked to SCUAF with specification of production and conservation inputs and outputs for harvest, including other biophysical impacts of modeled land use systems. These outputs from SCUAF were subjected to economic analysis through the BCA framework. Two decision criteria were used in evaluating each land use system: (i) net present value (NPV) and (ii) annualized income. The discount rates used in the analysis were based on existing cost of capital to upland farmers and the social cost of capital.

Net Present Value

The NPV measures the present value of the streams of net benefits from any land use system. In order for the land use system to be acceptable, the NPV must be greater than zero (i.e., positive). With mutually exclusive land use systems, the one with the highest NPV should be preferred. The NPV of the land use systems over a period of time was computed as:

$$\text{NPV} = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t}$$

where: B_t = benefit at time t, C_t = cost at time t, r = discount rate, t = time (years) where observation is noted, and T = life span of investment (years).

In private or financial terms, B_t and C_t were calculated from all quantifiable on-site outputs and inputs valued at market prices. Private benefits were estimated by multiplying the farm gate price with marketable outputs of the system resulting from SCUAF simulation. This measure of financial profitability ignores risks and other market imperfections such as externalities and public goods, including carbon sequestration and emission.

The BCA was extended to incorporate the social benefits from carbon sequestration. Carbon sequestration benefits were derived by quantifying the value of carbon sequestration from soil and biomass accumulation over a given rotation interval. Thus, social NPV of the tree-based systems was calculated by adjusting the private NPV as follows:

$$NPV_{social} = \sum_{t=0}^{n} \frac{\left(B_t - C_t + G_t\right)}{\left(1+r\right)^t}$$

where G_t is the imputed value of carbon sequestration function of each land use system at time *t*. All other variables are similarly defined as above. Ideally, social NPV should reflect the economic value of alternative system to society. For this study however, the social profitability of each system has to incorporate only the imputed value of carbon sequestration, while the other benefits and costs were still evaluated at market prices.

The net carbon sequestration potential for each land use system was quantified following the modeling procedure outlined above. Nordhaus (1993) as cited by Tomich et al. (1997), estimated the marginal cost of carbon emissions to be between USD 5 and USD 20 per tonne of carbon (tC). The monetary value of carbon sequestered for each system was calculated using the intermediate price[3] level of USD 10/tC or PHP 510/tC.

Annualized Net Benefits

The annualized net benefit (ANB_t) indicates how much the NPV translates into yearly income over the lifespan of the investment (T). The annualized net benefit was computed as:

$$ANB_t = \frac{\text{r (NPV)} (1+r)^T}{(1+r)^T - 1}$$

Sensitivity and Risk Analysis

The parameter values and assumptions of any economic model are subject to change and error. A sensitivity and risk analysis was undertaken to quantify the impacts of policy changes or price risks on the estimates of the net benefits of the tree-based options considered in the study. Among others, sensitivity analysis helps to test the robustness of the model results, identifies critical values, thresholds or break-even values where optimal strategy changes and identifies sensitive or important variables (Pannell 1997).

While SCUAF model is a deterministic model, a stochastic component can be built into the economic decision variables of the model. The stochastic version of the model was solved through Monte Carlo analysis based on deterministic results. This analysis was implemented using the @RISK software package trial version (Palisade 2000). Following Purnamasari et al. (1999), the uncertainty specified in the output prices (i.e., historical price series from 1985-2001) of timber and crop was used as a base to produce numerical results as a probability distribution of NPV. One thousand iterations were used for each stochastic run. A 10% discount rate was used, thus the results from the risk analysis are comparable to the point estimates obtained with a 10% discount.

[3] Exchange rate: 1 USD = PHP 51.

4.1.3 Land Use Systems Modeled in the Study

The study modeled six land use systems based on the existing and potential land use transformation pathways for *Imperata* grassland (Table 1). While these systems could be a possible transformation path for *Imperata* grassland, the land use systems modeled here represent only a snapshot of the current land use mosaic in the area at any given time.

IMPLUS refers to *Imperata*-dominated grasslands that have not undergone any burning or cultivation. In the modeling exercise, 100% of one-hectare farm were devoted to *Imperata* and 95% of above-ground biomass were consumed by grazing animals (cattle) during the year while the remaining parts were allowed to regrow in the subsequent year. Meanwhile, FPLUS refers to continuous open-field maize cropping system where soil is cultivated prior to planting maize seeds. In the model, inorganic fertilizers were applied during the growing season at 60 kg/ha/cropping for nitrogen and 24 kg/ha/cropping for phosphorus. The FPLUS was modeled with 100% of the area devoted to maize production.

Table 1. Description of Land Use Systems Considered in the Study.

Land Use System	*Description*
IMPLUS	*Imperata* land use for animal pasture or grazing system
FPLUS	Farmer's current practice of annual maize cropping system
TIMPLUS	Timber trees with *Imperata* for animal pasture or silvopastoral system
TCLUS	Timber trees planted in hedgerows with annual maize cropping system at the alley areas
TCSFLUS	Social forestry model of agroforestry system where bigger area is planted to timber trees in hedgerows with annual maize cropping at the alley areas
TPLUS	Timber plantation land use system

Modeling scenario for TCLUS was based on current land use practice in the area where 85% is allocated to maize cropping at the alley areas between the hedgerows and the remaining 15% is planted with timber trees as hedgerow species. TCSFLUS, a variant of TCLUS system, is an adaptation of the social forestry agroforestry model where 40% is planted to timber trees in hedgerows while the 40% alley areas is devoted to annual cropping of maize. In the case of TIMPLUS, 85% is allocated to *Imperata* (treated as crops) and timber trees occupy only 15% of the total area. Two tree-species were modeled in the timber-based systems: (i) *Acacia mangium* (N-fixing tree – tree species that fix nitrogen from atmosphere) and (ii) *Gmelina arborea* (non N-fixing tree). Except for the TCSFLUS system, all tree-based systems allocated 60% of the tree component to *Gmelina arborea* and 40% to *Acacia mangium*. In TCSFLUS system, the tree component was planted equally (50% of 0.4 ha) with both timber tree species. Timber seedlings were planted with 3 m x 4 m spacing, yielding a density of 834 trees per hectare. A block planting method was used for timber plantation system (TPLUS). Pruning of branches and twigs of trees were done in all tree-based systems during the first two years of the rotation interval to induce straight growth of *Gmelina* and *Acacia*.

Farmers preferred to cut *Gmelina* trees at seven years (Magcale-Macandog et al., 1999). However, majority of tree growers in the survey reported the best age to harvest *Gmelina* and other fast-growing timber tree species was between 8-10 years. Thus, an optimal rotation interval of 10 years was specified in the model for timber trees. Simulations were run for two cycles of tree growth or 20 years in all land use systems. The analysis was based on a one-hectare system since SCUAF determines plant growth and soil changes on a per hectare basis.

4.1.4 The Study Site

Claveria, Misamis Oriental was chosen as the study site to calibrate the model for the following reasons: (i) it is considered a representative *Imperata*-dominated grassland area in the Philippines that meets the characteristics of interest for the study; (ii) the area has been subjected to long-term government and non-government interventions relating to soil conservation practices; (iii) there is significant adoption of soil conservation practices and transformation of *Imperata* grassland into tree-based land use systems; and (iv) availability of biophysical and economic data for model parameterization.

Claveria is located 40 km northeast of Cagayan de Oro. It lies on an undulating plateau between a coastal escarpment and mountainous interior, ranging in elevation from 200 to 500 m above mean sea level. Soil characteristics in the site are as follows: well-drained oxisol, acidic (pH between 4.5 and 5.0), depth of soil profile is more than 1 m (Garrity and Agustin 1995). The study site has an average annual rainfall of 2000 mm for a five-year period (Limbaga 1993). Wet season is from May to October while dry season occurs for the rest of the year. Major crops planted include rootcrops, tomato, and maize, being the dominant crop as source of staple food and animal feed. Tree farming of fast-growing tree species (e.g., *Gmelina arborea*, *Acacia mangium*, and *Eucalyptus deglupta*), is emerging in the area.

4.1.5 Model Parameterization and Calibration

The biophysical parameters used in the SCUAF model have been described in detail by Young et al. (1998). Default values of these parameters are based on the characteristics of the physical environment considered in the model such as climate, slope class, soil drainage, parent material, soil texture, soil reaction, and organic matter status. The physical environment used in the SCUAF model for Claveria has the following characteristics: lowland humid class of Koppen climate classification, moderate slope class, free soil drainage, intermediate parent material, clayey soil texture, strong acid soil reaction, and intermediate organic matter status.

The plant growth, nutrient composition, soil properties and erosion parameters were specified in the model for each land use system. A detailed discussion of these parameters can be found in Predo (2002) and are available upon request.

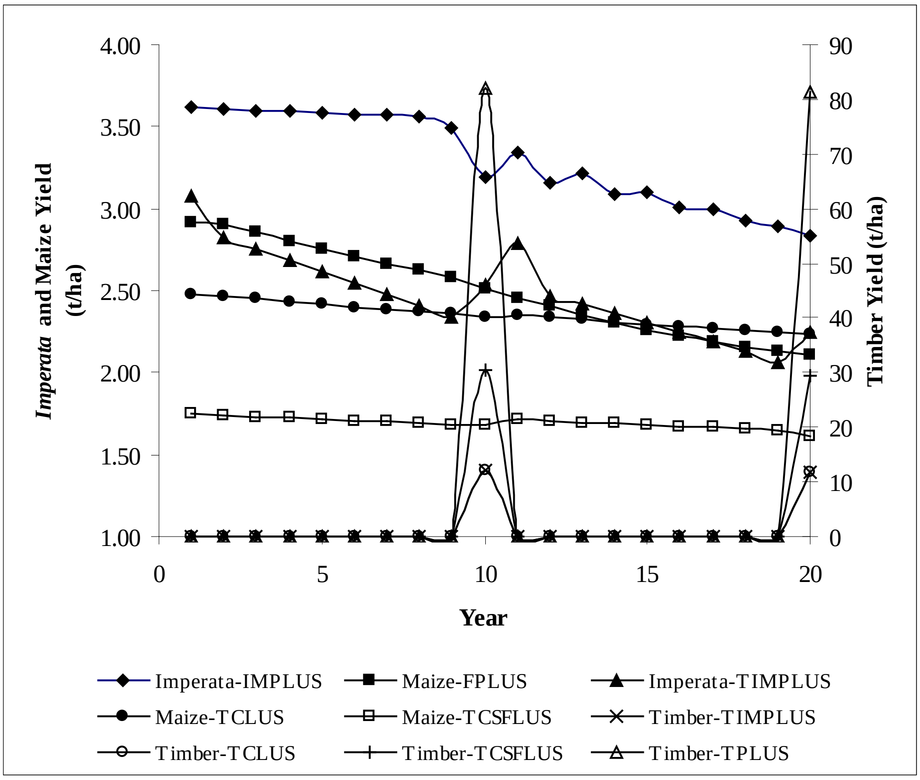
On the other hand, data and assumptions used in economic analysis were derived from SCUAF simulations, primary data (survey and key informant interviews), and secondary sources. The base parameter values used in calculating the net present value of each system are presented in Appendix Table 1. These parameters include the following economic data and assumptions: labor requirements, wage or labor cost, material input requirements, input and output prices, cost of capital and other data. A detailed description of these data can be found in Predo (2002) and are available upon request.

4.2 Economic Impacts

4.2.1 Predicted Yield of *Imperata*, Maize and Timber

The productivity of various land use systems was not directly comparable in terms of yield since each system has different outputs and/or harvested products. However, the pattern of herbage, maize and timber yields was explained by the rates of soil loss predicted and consequently the predicted soil quality in terms of carbon, nitrogen and phosphorus associated to each land use system. For instance, maize yield declined more rapidly under current practice of maize cropping without tree component (FPLUS) than the system with trees (TCLUS and TCSFLUS) throughout the simulation period (Figure 4). Relative to initial maize yield, the rate of maize reduction was about 28% under FPLUS systems while maize yield under TCLUS and TCSFLUS declined only by 10% and 8% respectively, after 20 years.

Predicted herbage yield of *Imperata* declined at a much lower rate in the *Imperata*-animal grazing system (IMPLUS) than under silvopastoral (TIMPLUS) system. This is most probably caused by the competition effect of trees and grass in terms of light capture and nutrients uptake (Figure 4). Meanwhile, all the tree-based systems exhibited a slower yield reduction over the two rotation intervals than in other land use systems but the least reduction in timber yield of 1% was observed under TPLUS system. This result could be explained by the lower rate of soil loss under this system[4].



[4] Soil erosion results are discussed in detail in the succeeding environmental impacts section.

Figure 4. Predicted Yield of the Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

4.2.2 Private Profitability of Alternative Land Use Systems

The results of the benefit cost analysis are presented in Table 2. With a discount rate of 25%, all alternative land use systems have positive NPV, which implies that they were all profitable at this level of the cost of capital. The timber plantation system (TPLUS) obtained the highest NPV [PHP 241,170 (USD 4,728.8)/ha] followed by TCSFPLUS [PHP 98,121 (USD 1,923.9)/ha] and the lowest NPV [PHP 271 (USD 5.3)/ha] was realized by the *Imperata*-grazing (IMPLUS) system. The current farmers' practice of annual maize cropping (FPLUS system) predicted a relatively higher NPV [PHP 21,161 (USD 414.9)/ha] than IMPLUS system but lower than TIMPLUS system [PHP 35,031 (USD 686.9)/ha], TCLUS system [PHP 56,074 (USD 1,099.5)/ha], and TCSFLUS system [PHP 98,121 (USD 1,923.9)/ha]. Consequently, the TPLUS system predicted the highest annualized net benefits [PHP 60,996 (USD 1,196)/ha/year] to farmers and the lowest ANB [PHP 69 (USD 1.4)/ha/yr] was from IMPLUS system. These results indicate that it was financially profitable to retain *Imperata* grassland for animal grazing purposes although it was not the most efficient type of land use. Conversion of *Imperata* grassland into tree-based systems appeared to be a more efficient land use than other systems. Among the timber-based systems, the most efficient land use was observed on TPLUS system because of the high value of harvested timber in addition to having lower predicted soil loss due to erosion and high level of soil nutrients sustained as shown in the discussion of environmental impacts in the succeeding section.

Table 2. Private Net Present Value (PHP/ha) and Annualized Income (PHP/ha/year) of Alternative Land Use Systems over 20 Years at 25% and 10% Discount Rates, Claveria, Misamis Oriental, Philippines, 2001.

Land Use System	*NPV (PHP/ha)*		*ANB (PHP/ha/year)*	
	25%	10%	25%	10%
IMPLUS	271	498	69	58
FPLUS	21,161	30,913	5,352	3,631
TIMPLUS	35,031	149,459	8,860	17,555
TCLUS	56,074	185,762	14,182	21,819
TCSFLUS	98,121	381,466	24,816	44,807
TPLUS	241,170	1,019,206	60,996	119,716

Note: ANB = annualized net benefits

1 USD = 51 PHP

Reducing the discount rate to 10% had no effect on the relative ranking of the alternative land use systems in terms of net present value and annualized income. Instead, it just reinforced the financial profitability of the tree-based systems since a lower discount rate over longer periods increased the present value of sustained future yields for both crops and timber trees. With the reduced cost of capital, the NPV of tree-based land use systems increased to a range between PHP 149,459 (USD 2,930.6)/ha and PHP 1,019,206 (USD 19,984.4)/ha. Over 20 years, the highest benefit was realized from TPLUS system and then followed by TCSFLUS system. The NPV for annual maize cropping system (FPLUS) increased only at a minimal level [PHP 30,913 (USD 606.1)/ha] due to increasing value of productivity losses of future yields resulting from high soil erosion.

It is interesting to note that while FPLUS system was not the most financially profitable option for *Imperata* grassland at current prices and technology, it is shown in succeeding chapter that farmers still continue to practice this system. In contrast, tree-based systems were found to be the most profitable option but the extent of adoption was low relative to the annual crop production. As observed, if ever adoption takes place, tree growing investments were usually done in combination with annual crops and other cash crops. Now the question is, "why are smallholders hesitant to increase investment in tree-based farming systems"? One possible reason is that smallholder farmers with limited resources and opportunities may need to have a minimum cash flow each year to sustain their families. The farmer might consider tree-based land use systems with higher NPV but a low cash flow each year as an inferior option to investing compared to annual crops that have a lower NPV over the same number of years as the tree growing but with a higher annual cash flow. This minimum cash flow consideration is a rational decision by farmers because of the risk associated with the value of one's investment tied up in a long-cycle crop such as tree crop where prices years from now may be uncertain.

Another reason is that farmers may be risk averse to trade production risk associated with subsistence crop for three other risks: yield risk for timber, price risk for the timber, and price risk for the purchased staple food. As a risk-coping mechanism, farmers may want to diversify their investments, and hence income. Diversification is simply captured in the principle of not putting "all eggs in one basket" (Pandey 2000). The risk of income shortfall is reduced by growing several crops that have negatively or weakly correlated returns. The effect of price risk on profitability of alternative land use systems is examined in the risk analysis section.

4.3 Environmental Impacts

4.3.1 Soil Erosion

The annual and cumulative soil erosion of the six land use systems, predicted over 20 years, is graphically presented in Figure 5. It was observed that predicted soil erosion has increased over time in all of the land use systems. This occurs most rapidly under FPLUS system with the highest average soil erosion of 48 tonnes (t)/ha/year over 20 years (Table 4). Predicted soil erosion under timber-based systems averaged 1-10 t/ha/year; the lowest was observed under TPLUS system and it was significantly lower than the average soil loss observed from IMPLUS and FPLUS systems. However, land use systems with *Imperata* have relatively lower soil erosion than FPLUS system. This may be because of the surface cover provided by *Imperata* grass throughout the growing period that minimizes topsoil loss since in the model not all of the biomass is consumed by the grazing animals.

The cumulative soil loss under FPLUS system in the 20th year of simulation period was about 953 t/ha compared to 241 t/ha under IMPLUS, 58 t/ha under TIMPLUS, 192 t/ha under TCLUS, 134 t/ha under TCSFLUS, and 21 t/ha under TPLUS systems (Table 3). Conversion of *Imperata* grassland to tree-based land use systems reduced the rate of soil erosion between 20 and 91%. In contrast, the rate of soil loss increased by 75% for land use change from *Imperata* grassland to current farmers practice of continuous maize cropping. The results strongly indicate that tree-based land use systems were effective in minimizing soil erosion. Incorporating timber trees in any land use would help reduce soil erosion even in the most erosive farming practice.

Table 3. Summary of Biophysical Results from SCUAF Simulation of Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

Land Use System	*Soil Erosion (t/ha)*		*Carbon (t/ha)*		*Soil Nutrients (t/ha)*		*NCF (tC/ha)*
	Annual	CSE	Biomass	Soil	ON	OP	
IMPLUS	12.06	241.25	0.00	54.19	5.99	3.93	0.00
FPLUS	47.67	953.35	0.00	48.55	5.36	3.52	0.00
TIMPLUS	2.88	57.69	4.01	53.41	5.92	3.87	1.47
TCLUS	9.60	192.00	4.59	53.11	5.89	3.85	1.96
TCSFLUS	6.70	133.97	11.58	53.23	5.90	3.86	2.98
TPLUS	1.06	21.20	23.46	54.94	6.10	3.98	5.95

CSE= cumulative soil erosion, ON= organic nitrogen, OP= organic phosphorus, NCF= net carbon flow

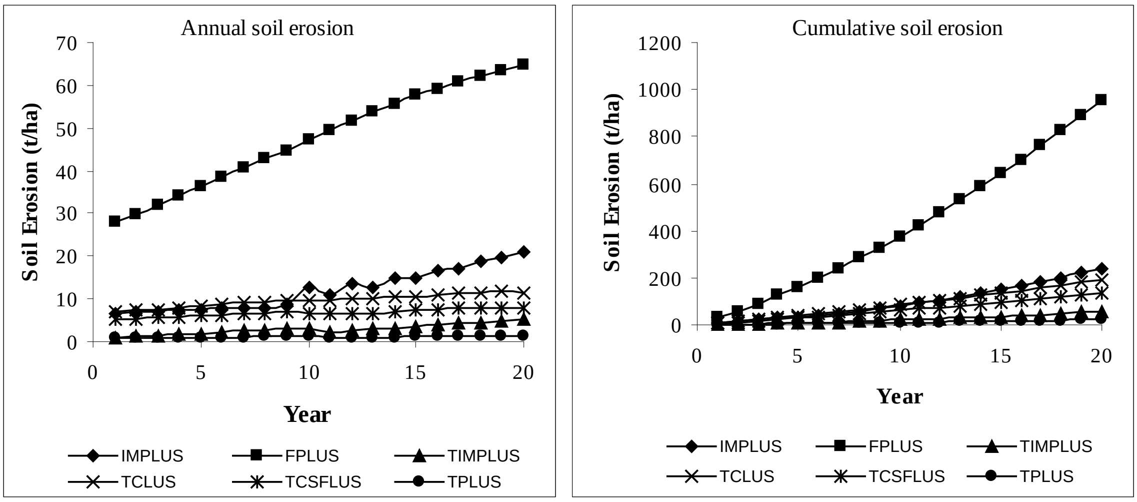


Figure 5. Predicted Annual and Cumulative Soil Erosion (t/ha) over Time of Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

4.3.2 Changes in Biomass and Soil Carbon

The time-trajectory of above-ground biomass carbon and soil carbon are presented in Figure 6. Predicted above-ground biomass carbon under tree-based land use systems (TIMPLUS, TCLUS, TCSFLUS and TPLUS) increased and accumulated during the growth period of timber trees (i.e., for the first 9 years) and then dropped to zero on the 10^{th} year, which was a cutyear or harvest time of each rotation. Among the tree-based land use systems, TPLUS system produced the highest accumulated biomass carbon because of the fast growth of timber tree species being planted and the entire system area was devoted to timber trees whereas only 40% in TCSFLUS and 15% for both

TIMPLUS and TCLUS systems (Table 3). On the other hand, predicted annual biomass carbon under IMPLUS and FPLUS systems was zero throughout the simulation period since annual harvesting of aboveground biomass has been specified on these systems and hence, plant carbon was reduced to zero at the end of each year.

Simulation results of the changes in soil carbon showed that predicted total soil carbon decreased throughout the simulation period for all land use systems (Figure 6). The rate of reduction in total soil carbon was slowest in timber plantation system (TPLUS), with only a 7% reduction over 20 years. Current farmers' practice of maize cropping (FPLUS) had the highest rate of soil carbon reduction, amounting to 26% reduction of the initial total soil carbon content. The predicted decline in total soil carbon under tree-based land use systems was influenced by the interaction of soil erosion and organic matter recycling. The level of soil carbon was sustained under TPLUS systems because soil loss was low while the amount of organic matter recycled was high.

The severe soil loss under FPLUS system could have resulted in a sharp decline in soil carbon over time. It is also interesting to note that the level of total soil carbon under TPLUS system was lower than those under IMPLUS system during the first 9 years of the simulation period. This is because systems with steadily growing trees may have had greater loss of carbon from the soil to support increasing standing biomass (Young et al. 1998). As a result, the average total soil carbon under tree-based land use systems (53.4 to 54.9 t/ha) was almost similar than those under IMPLUS system (54.2 t/ha) (Table 3).

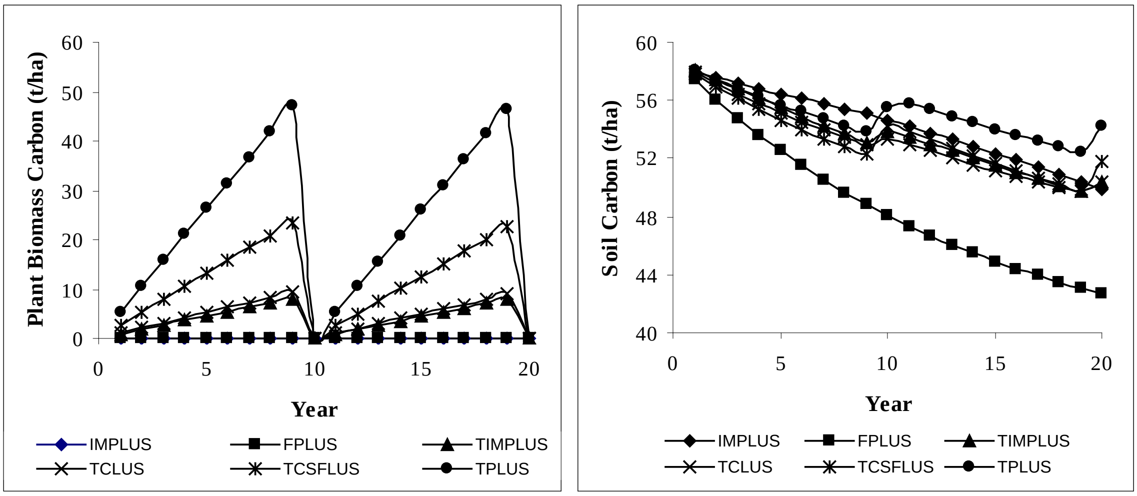


Figure 6. Predicted Carbon Stocks in aboveground Biomass and Soil (t/ha) over Time of Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

4.3.3 Changes in Soil Organic Nitrogen and Phosphorus

Predicted total soil organic nitrogen declined more slowly under the tree-based land use systems (TIMPLUS, TCLUS, and TPLUS) than under current practice of annual maize cropping (TCLUS) system (Figure 7). Predicted soil organic nitrogen was highest under TPLUS system because of the nitrogen and organic matter cycled through leaf litter and pruning during the first year of the rotation. Although there was a decline in soil organic nitrogen during tree growth, it increased at a higher level after timber harvest, though not of the same level as the initial soil nitrogen content. The soil total organic nitrogen slowly built up after harvest due to addition of organic matter from plant residues.

Similar pattern was observed under IMPLUS system but soil nitrogen slowly declined in a continuous and linear fashion throughout the simulation period and at a much slower rate compared to those under FPLUS system. The average total soil nitrogen under FPLUS system was 5.4 t/ha compared to 6.0 t/ha under IMPLUS; 5.9 t/ha under TIMPLUS, TCLUS and TCSFLUS systems; and 6.1 t/ha under TPLUS system (Table 3).

As in total soil nitrogen, the predicted total soil organic phosphorus exhibited a downward trend over the simulation period (Figure 7). The lowest decline of soil phosphorus occurred under TPLUS system while the greatest was under FPLUS system. IMPLUS system has sustained the soil phosphorus at a level similar to the systems with trees component (TIMPLUS, TCLUS and TCSFLUS systems). The average total soil phosphorus over 20 years under TPLUS (3.98 t/ha) was almost similar to those under IMPLUS (3.93 t/ha), TIMPLUS (3.87 t/ha), TCLUS (3.85 t/ha), and TCSFLUS (3.86 t/ha) systems but relatively higher than under FPLUS system (3.52 t/ha) (Table 3). The results indicate that tree-based systems would be able to sustain soil nutrients at higher levels over time than current farmers' practice of annual maize cropping.

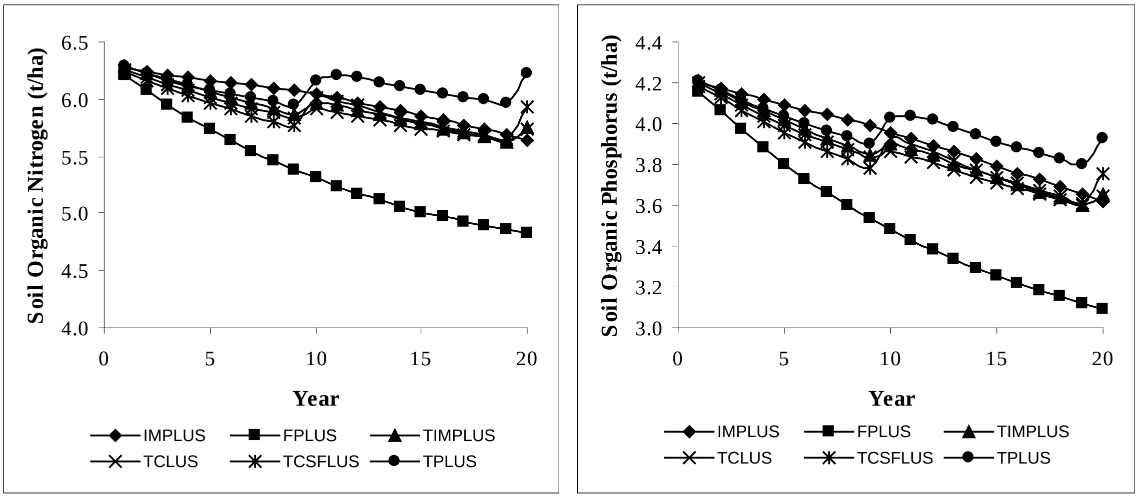


Figure 7. Predicted Soil Organic Nitrogen and Phosphorus (t/ha) over Time of Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

4.3.4 Net Carbon Flow

The annual net carbon flow (NCF) is the summation of the annual carbon flow in the plant-soil system and the amount of carbon locked up in the timber products used in durable products such as furniture less the amount of carbon emission from the gradual decay of woods in the durable products. Alternatively, NCF is the net incremental amount of carbon sequestered over time used in the analysis to impute the value of carbon sequestration for each land use alternative.

The pattern of predicted net carbon flow was similar to that of aboveground biomass carbon for all land use alternatives (Figure 8) since NCF is the incremental value of carbon accumulation in standing biomass with adjustment from erosion and oxidation losses, and emission. The average net carbon flow for 30 years under TPLUS system was about 5.95 tC/ha/year compared to 2.98 t/ha/year for TCSFLUS, 1.96 tC/ha/year for TCLUS, 1.47 tC/ha/year for TIMPLUS, and 0 tC/ha/year for both IMPLUS and FPLUS systems (Table 3). Timber plantation system (TPLUS) had the highest net carbon sequestration and fixation because of huge biomass production and higher timber yield. The *Imperata*-grazing system (IMPLUS) and current farmers' practice of annual maize cropping (FPLUS) have zero carbon sequestration because there is no accumulated standing biomass over time on these systems due to annual and seasonal harvest of grass and maize crops, respectively.

4.4 Social Profitability and the Value of Carbon Sequestration

The social profitability of each system was assessed using a social discount rate of 10% plus the imputed value of carbon sequestration but the other benefits and costs were still evaluated at market prices. When the value of carbon sequestration was accounted, the NPVs for tree-based land use systems increased but the relative ranking of alternative land use systems remain unchanged with TPLUS system realizing the highest benefit from biomass carbon payments of about PHP 42,321 (USD 829.8)/ha for a period of 20 years (Table 4).

The inclusion of soil carbon payments increased NPVs significantly relative to the biomass carbon payments only. The lowest value of biomass carbon was predicted under TIMPLUS system while zero payment was received for both IMPLUS and FPLUS systems since they do not accumulate standing biomass over time. For soil carbon payments, the TPLUS system obtained the highest NPV and the lowest was that from FPLUS system. This occurs because of high carbon losses through erosion and lower decomposing organic matter from leaf litters under FPLUS system.

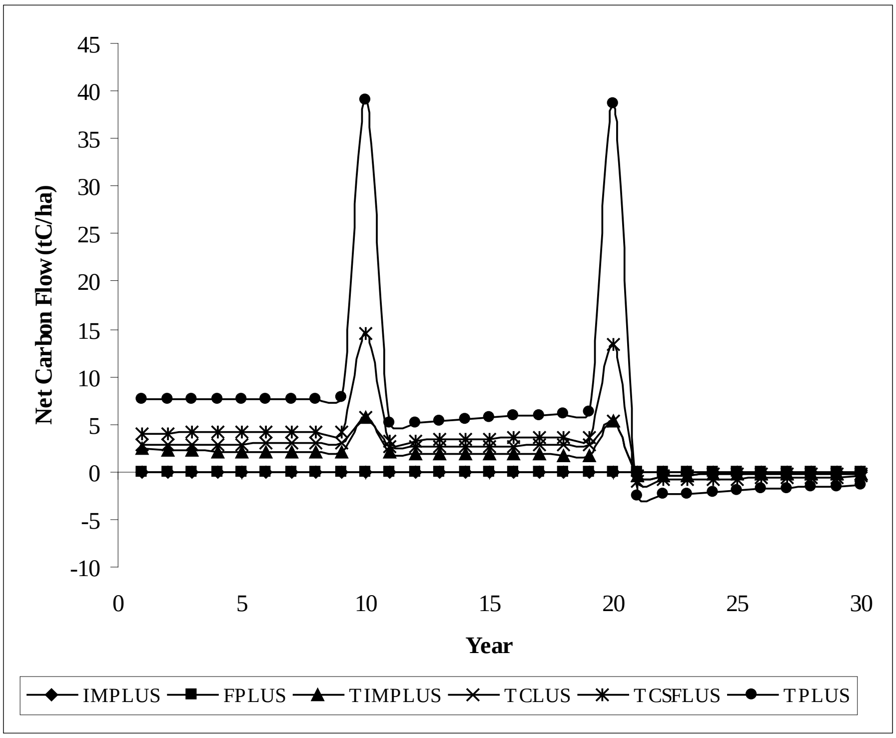


Figure 8. Net Carbon Flow (tC/ha) over Time of Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

The net present value increased further when all carbon pools were valued and accounted in the analysis. Like in the previous scenario, TPLUS system earned the highest NPV [PHP 1,327,170 (USD 26,022.9)/ha over 20 years] and annualized income [PHP 140,785 (USD 2,760.5)/ha/year]. For this system, carbon sequestration benefits helped reduce the period with negative net returns. However, the amounts were still insufficient to cover the deficit incurred from the establishment cost and maintenance costs before harvest. In the case of TIMPLUS and TCSFLUS systems, the value of sequestered carbon reduced the deficit period to only one year. The results clearly illustrate the importance of carbon payments in reducing the income risks involved in tree growing to enhance investment in timber-based systems and consequently influence the climate mitigation policy that would support smallholder farmers' provision environmental services such as carbon sequestration.

Table 4. Net Present Value (PHP/ha) with Imputed Value of Carbon Sequestration of Alternative Land Use Systems over 20 Years at 10% Discount Rate, Claveria, Misamis Oriental, Philippines, 2001.

Land Use System	*NPV without C* (a)	*ANB Without C* (b)	*NPV of Biomass C* (c)	*NPV of Soil C* (d)	*NPV with Biomass C* (e=a+c)	*ANB with Biomass C* (f)	*NPV with Biomass and Soil C* (g=a+c+d)	*ANB with Biomass and Soil C*
IMPLUS	498	58	0	264,782	498	58	265,280	31,160
FPLUS	30,913	3,631	0	243,113	30,913	3,631	274,026	32,187
TIMPLUS	149,459	17,555	10,866	261,138	160,325	17,007	421,464	44,709
TCLUS	185,762	21,819	14,282	259,660	200,043	21,220	459,703	48,765
TCSFLUS	381,466	44,807	21,472	259,291	402,938	42,743	662,230	70,249
TPLUS	1,019,206	119,716	42,321	265,643	1,061,527	112,606	1,327,170	140,785
Marginal Benefit:								
FPLUS-IMPLUS	30,415	3,573	0	-21,669	30,415	3,573	8,747	1,027
TIMPLUS-IMPLUS	148,961	17,497	10,866	-3,643	159,827	16,949	156,184	13,549
TCLUS-IMPLUS	185,264	21,761	14,282	-5,121	199,545	21,162	194,424	17,605
TCSFLUS-IMPLUS	380,968	44,748	21,472	-5,490	402,440	42,685	396,950	39,089
TPLUS-IMPLUS	1,018,708	119,657	42,321	861	1,061,029	112,547	1,061,890	109,626

Note: 1 USD = 51 PHP

The marginal benefits from switching land use would be more meaningful since the opportunity costs of existing land use are taken into account. This is particularly relevant in the imputed value of carbon sequestration since the net effect on carbon storage of implementing a tree-based system depend on the carbon content of the land use practices that are replaced. On the basis of this perspective, a switch in land use from IMPLUS system to TPLUS resulted in the highest marginal benefits of PHP 42,321 (USD 829.8)/ha from biomass carbon and PHP 861 (USD 16.9)/ha/year from soil carbon. Thus, the highest marginal NPV with biomass and soil carbon payments occurred under TPLUS system [PHP 1,061,890 (USD 20,821.4)/ha], which is equivalent to about PHP 109,626 (USD 2,149.5)/ha of annualized income.

4.5 Sensitivity Analysis Results

A sensitivity analysis (SA) was undertaken on the base case results of the BCA. Since all land use system alternatives passed the NPV criterion under the base case parameter values, the strategy employed in conducting the SA was that of changing the value of important variables at specified level and observing the impact of the change on the profitability ranking among alternatives. The sensitivity of NPVs was examined in both the benefits and costs structures of the model. An increase in labor wage rate was used for the cost side since labor is a common input among alternatives and the most important input of production in a smallholder farming system. The labor wage rate increase was taken to represent an improvement in opportunities for off-farm employment. For it to be beneficial, a decrease in the price or value of outputs was carried out in the analysis to mimic for instance trade protection removal on maize. In addition, the benefits from animal services were valued and incorporated in the analysis of the systems with animal component.

To facilitate discussion of results, the sensitivity analysis was undertaken with a 10% discount rate. The NPV of all alternative land use systems was more responsive to output price decrease compared to wage rate increase (Table 5). However, the NPV of

IMPLUS and FPLUS systems significantly decreased in both wage rate and output price changes compared to other land use systems. The greatest decline in NPV was observed under IMPLUS system in the scenario without carbon payments (-218% for wage rate increase and –468% for output price decrease). IMPLUS system even became unprofitable in either parameter change. Meanwhile, timber-based systems provided the least decline in NPV with the lowest observed under TPLUS system with either wage rate or output price change in both with and without carbon payments.

The effect of added indirect benefits from animal services for IMPLUS and TIMPLUS systems was considered to determine the profitability of these systems and whether relative ranking among alternative land uses will change. As expected, NPV of IMPLUS and TIMPLUS systems improved significantly when the value of animal services was included as indirect benefits of the system. With these added benefits, profitability of IMPLUS system exceeded that of FPLUS system while TIMPLUS system exceeded that of TCLUS system. The profitability of TCSFLUS system however, remained higher than TIMPLUS system. TPLUS system was still superior in terms of NPV compared to all other land use systems.

Table 5. Summary of Sensitivity Analysis Results, Claveria, Misamis Oriental, Philippines, 2001.

Land Use System	*WOC*		*WBC*		*WBSC*	
	NPV	% Change	NPV	% Change	NPV	% Change
	PHP		PHP		PHP	
Wage Rate Increase (10%)						
IMPLUS	-586	-217.65	-586	-217.65	264,196	-0.41
FPLUS	19,966	-35.41	19,966	-35.41	263,079	-4.00
TIMPLUS	148,237	-0.82	159,103	-0.76	420,241	-0.29
TCLUS	176,132	-5.18	190,413	-4.81	450,073	-2.09
TCSFLUS	374,032	-1.95	395,504	-1.84	654,796	-1.12
TPLUS	1,017,161	-0.20	1,059,482	-0.19	1,325,125	-0.15
Output Price/Value Decrease (10%)						
IMPLUS	-1,834	-468.31	-1,834	-468.31	236,469	-10.86
FPLUS	11,960	-61.31	11,960	-61.31	230,761	-15.79
TIMPLUS	132,160	-11.57	141,940	-11.47	376,964	-10.56
TCLUS	153,147	-17.56	166,000	-17.02	399,694	-13.05
TCSFLUS	332,342	-12.88	351,667	-12.72	585,029	-11.66
TPLUS	913,739	-10.35	951,828	-10.33	1,190,906	-10.27
Benefits from Animal Service Added						
IMPLUS	73,240	14605.61	73,240	14605.61	338,021	27.42
FPLUS	30,913	0.00	30,913	0.00	274,026	0.00
TIMPLUS	204,440	36.79	215,306	34.29	476,444	13.05
TCLUS	185,762	0.00	200,043	0.00	459,703	0.00
TCSFLUS	381,466	0.00	402,938	0.00	662,230	0.00
TPLUS	1,019,206	0.00	1,061,527	0.00	1,327,170	0.00

Note: WOC = without carbon sequestration; WBC = with biomass carbon sequestration; WBSC = with biomass and soil carbon sequestration

1 USD = 51 PHP

4.6 Risk Analysis Results

Incorporating risk into the analysis allows us to consider how variations in output price might affect the point estimates of NPV obtained above. The expected mean NPVs estimated with output price risks taken into account were slightly higher than the point estimates obtained from deterministic results except those from IMPLUS system (Table 6). The expected mean NPV estimates under tree-based systems ranged from PHP 152,352 (USD 2,987.3)/ha in TIMPLUS system to PHP 1.39 million (USD 27,254.9)/ha in TPLUS system. For FPLUS system, the expected mean NPV was about PHP 31,007 (USD 608)/ha and PHP 488 (USD 9.6)/ha for IMPLUS system. The relative ranking of alternative land use systems did not change for the stochastic results. TPLUS system obtained the highest expected NPV and the lowest was also realized under IMPLUS system.

Risk analysis not only provided mean estimates, but also the entire distribution of the NPV estimates. The NPV of various land use alternatives can lie within a wide range of values. For example, the expected NPV of TPLUS ranged from a low value of PHP -29,577 (USD –579.9)/ha to a maximum of PHP 31.4 million (USD 61,568.6)/ha. There were about 4% and 3% probability of obtaining negative NPV for IMPLUS and TPLUS system, respectively. IMPLUS system has only 1% probability of incurring a negative NPV while other land use systems have zero probability of incurring a loss.

For all tree-based systems, there were more than 70% probability of the NPV to be higher than their deterministic results while there were more than 40% probability for FPLUS and IMPLUS systems. There was also a high variation on the expected value of NPV across land use system alternatives based on the coefficient of variation (CV) results. It is interesting to note that while timber-based systems obtained the highest NPV, they seemed to be the most risky options as reflected by the high CVs that ranged from 164 to 205%.

Table 6. Expected and Probability Distribution of Net Present Value of Alternative Land Use Systems at 10% Discount Rate, Claveria, Misamis Oriental, Philippines, 2001.

Land Use System	*Expected NPV (PHP/ha)*			*Probability (%)*		*CV*
	Mean	Min	Max	NPV≤0	NPV≥Point Estimate	(%)
IMPLUS	488	-133	1,224	1.09	51.53	46
FPLUS	31,007	22,313	40,163	0.00	48.33	10
TIMPLUS	152,352	-4,959	3,724,745	3.97	76.33	205
TCLUS	188,727	28,088	3,734,460	0.00	76.24	164
TCSFLUS	388,403	12,978	8,856,102	0.00	76.26	191
TPLUS	1,038,894	-29,577	25,288,820	3.37	76.32	204

Note: 1 USD = 51 PHP

5.0 ANALYSIS OF FARMERS' TREE GROWING OBJECTIVES

5.1 Methodology

5.1.1 Sampling and Data Collection

Similar to section 4, the survey was conducted in Claveria, Misamis Oriental, Philippines. The barangays included in the survey were selected primarily based on the presence of mixed land use systems and secondly, on accessibility. From the selected barangays, a targeted selection of respondents was employed for the household survey. Households with farms contiguous to each other were selected to cover four study sites. A total of 192 farmer-respondents were interviewed, from which tree-based farming systems adopters and non-adopters were identified based on their current land use, particularly on whether or not they have planted trees on their farms. This method of classifying the respondents served as the basis in the analysis of data.

This study utilized both primary and secondary data. Primary data such as socioeconomic and farm characteristics were collected through survey using pre-tested structured interview schedule and key informant interview. Other primary data collected include landholding, land use pattern, tree growing investment objectives, and other relevant information.

5.1.2 Principal Component Analysis

The potential goals of farmers in planting trees may include economic and non-economic factors, including recreational, emotional, and aesthetic considerations. In order to capture the underlying reasons of smallholders for planting trees in their farms, 18 different objectives related to tree growing were presented to the respondents. They were asked to assess the importance of each objective being presented using a four-point likert scale (4=very important, 3=important, 2=less important, 1=not important).

With the large number of observed variables on tree growing objectives, a principal component analysis (PCA) was done to reduce the original variables into few variables that would represent the underlying tree growing objectives of farmers. PCA is a variable reduction procedure to analyze observed variable that would result in a relatively small number of (interpretable) components which account for most of the variance in a set of observed variables. Technically, a principal component is defined as a linear combination of optimally-weighted observed variables. The eigenvalue criterion and scree test were used to determine the number of extracted components from the observed data. To measure the reliability of the solution, Carmine's theta (θ) was computed for the unrotated solution as follows:

$$\theta = \frac{n}{n-1}\left(1-\frac{1}{\lambda_1}\right)$$

where n is the number of items in the total principal component analysis and λ_1 is the largest (the first) eigenvalue. Theta may be considered a maximized Cronbach's alpha coefficient (Carmines and Zeller 1979).

Orthogonal rotated solution was done to obtain uncorrelated components (and factor scores) using varimax rotation method. The general formula to compute factor scores on k^{th} component extracted (created) in a PCA is as follows:

$$C_k = b_{k1}(X_1) + b_{k2}(X_2) + \ldots + b_{kp}(X_p)$$

Where C_k = the subject's scores on k^{th} principal component extracted/created;

b_{kp} = the regression coefficient (or weight) for observed variable *p*, as used in creating principal component *k*; and

X_p = the subject's score on observed variable *p*.

The underlying tree growing objectives were determined from the loading patterns of each individual original objective in the extracted components. On the basis of statistical power of 0.80 (at n=200) in interpreting the rotated factor pattern, a variable was said to load on a given component if the factor loading was 0.40 or greater (in absolute value), and less than 0.40 for any other component (Hair et al. 1998). If a variable has high loading on more than one component, then that variable is excluded in the interpretation because it does not have pure measures of any underlying objectives. Factor scores of all meaningful components extracted were estimated and used as dependent variables in the succeeding analysis.

5.1.2 Specification of Tree Growing Objective Function

Factor scores of each extracted component were regressed to relevant household and farm characteristics to shed light on the variable that might explain the underlying tree growing objectives of smallholder farmers. The tree growing (underlying) objective function was specified as follows and estimated using ordinary least squares (OLS) regression:

$$\begin{aligned} C_k = {} & \beta_0 + \beta_1 AGE + \beta_2 SEX + \beta_3 CSTATDUM + \beta_4 EDUCYR \\ & + \beta_5 HSIZE + \beta_6 FEXPH + \beta_7 KSCORE + \beta_8 TENURDUM \\ & + \beta_9 TCASHINC + \beta_{10} PARCEL + \beta_{11} FAREA + \beta_{12} YRTREE \\ & + \beta_{13} DHOME + \beta_{14} DROAD + \beta_{15} DBRGY + \beta_{16} DTOWN + \varepsilon \end{aligned}$$

where:

C_k	=	scores of *k* principal components retained
AGE	=	age of the respondents (years)
SEX	=	dummy for sex: 1 if male, 0 otherwise
CSTATDUM	=	dummy for civil status: 1 if married, 0 otherwise
EDUCYR	=	educational attainment (years)
HSIZE	=	household size
FEXPH	=	farming experience of household head (years)

KSCORE	=	knowledge score (%) of the respondents about soil conservation and tree-based systems (see Appendix 2 for the formula in measuring knowledge score)
TENURDUM	=	dummy for tenure status: 1 if owner, 0 otherwise
TCASHINC	=	household total annual cash income (PHP)
PARCEL	=	number of farm parcels
FAREA	=	farm area (ha)
YRTREE	=	years of adopting tree-based farming systems
DHOME	=	distance of farm parcels from home (km)
DROAD	=	distance of farm parcels from nearest road (km)
DBRGY	=	distance of farm parcels from barangay road (km)
DTOWN	=	distance of farm parcels from town center (km)
β's	=	parameters to be estimated
ε	=	error term assumed to be normal and independently distributed

5.2 Results and Discussion

5.2.1 Components of Tree Growing Objectives

Based on the eigenvalue criterion and scree test results, only the first three components were retained and have meaningful interpretation to represent the underlying tree growing objectives of farmers. The reliability of the solution was good (Carmines' theta =0.88) and the explained proportion of the total variation of the original variable was 51% for the three components combined. Likewise, the Kaiser-Meyer-Olkin measure of sampling adequacy was also good to warrant interpretation of results.

The variables and the corresponding factor loadings are presented in Table 7. None of the variables have high loadings on more than one component, so all variables were included in the analysis. Ten variables were found to load on the first component. These variables described various monetary objectives, asset motives and other economic aspects of smallholder tree growing objectives. These concerned labor income and self-employment, increase income from timber sales, asset motives, security in old age, speculative motive, etc. This dimension was taken to represent "employment, economic security and asset motive" of tree growing. The second component was characterized by non-timber use of tree growing such as outdoor recreation, solitude and meditation, aesthetic value, and improved healthy residential environment. The principal component was interpreted to represent "recreation and aesthetic objective". Finally, variables relating to the objectives of restoring farm fertility and productivity, erosion control measure, nature protection, and making the environment cooler were loading high on the third component, which was subsequently labeled as "environmental protection and restoration objective."

Table 7. Principal Components of Farmers' Tree Growing Objectives, Claveria, Misamis Oriental, Philippines, 2001.

	EMPLOYMENT, ECONOMIC SECURITY & ASSET MOTIVE	*RECREATION & AESTHETIC OBJECTIVE*	*ENVIRONMENTAL PROTECTION & RESTORATION OBJECTIVE*
Outdoor recreation	0.18	0.79*	0.08
Solitude and meditation	0.14	0.86*	0.05
Aesthetic value	0.09	0.81*	0.19
Nature protection	0.07	0.06	0.63*
Healthy residential environment	-0.03	0.62*	0.16
Help make the environment cooler	0.26	0.20	0.48*
Erosion control measure	0.18	0.26	0.63*
Restore farm fertility and productivity	0.27	0.06	0.74*
Source of fuelwood	0.44*	0.34	0.07
Labor income and self-employment	0.81*	0.15	-0.20
Increase income from timber sales	0.60*	0.07	0.19
Timber for household use	0.48*	-0.06	0.18
Source of funds for investment	0.42*	0.33	0.37
Asset motive	0.69*	-0.01	0.29
Security against inflation	0.47*	0.36	0.17
Security in old age	0.71*	0.01	0.36
Speculative motive	0.65*	0.37	0.17
Bequest motive	0.59*	0.16	0.36
Variance explained (%)	21.23	17.03	12.75
Kaiser-Meyer-Olkin measure of sampling adequacy	0.86		
Carmines' theta	0.88		
n	165		

Empirical evidence from the principal component analysis indicated that smallholders' farm forestry is an investment with multi-objectives, primarily focussing on monetary and other economic objectives. This finding has significant implications on agricultural technology adoption in general, and tree farming in particular. Thus, it is likewise important to know the farmers' characteristics and conditions that would likely influence tree growing potential goals and objectives.

5.2.2 Factors Influencing Farmers' Tree Growing Objectives

The relationships between the three underlying tree growing objectives, and household and farm characteristics were examined using ordinary least squares (OLS) regressions. The goodness-of-fit of the model for each objective was considered satisfactory and significant (Table 8).

Table 8. Ordinary Least Squares (OLS) Regression Estimates for Tree Growing Objectives (Factor Scores) and Household and Farm Characteristics, Claveria, Misamis Oriental, Philippines, 2001.

VARIABLE	*EMPLOYMENT, ECONOMIC SECURITY & ASSET MOTIVE*		*RECREATION & AESTHETIC OBJECTIVE*		*ENVIRONMENTAL PROTECTION & RESTORATION OBJECTIVE*	
	Coef.	T-value	Coef.	T-value	Coef.	T-value
CONSTANT	1.45	1.65	0.24	0.28	3.05 [a]	3.53
AGE	-0.01	-0.91	0.00	0.43	0.03 [a]	3.20
SEX	-0.59 [b]	-2.13	-0.37	-1.32	0.02	0.07
CSTATDUM	-0.25	-0.68	0.66 [c]	1.75	0.34	0.93
EDUCYR	-0.05 [c]	-1.84	-0.02	-0.84	0.00	0.08
HSIZE	-0.06 [c]	-1.82	0.07 [c]	1.92	-0.05	-1.57
FEXPH	-0.01	-0.57	-0.03 [a]	-3.30	-0.02 [a]	-2.72
KS	0.00	0.30	0.00	-0.00	0.02 [a]	4.05
TENURDUM	-0.09	-0.55	-0.02	-0.10	0.04	0.23
TCASHINC	-2.9E-06 [d]	-1.58	2.9E-06 [d]	1.55	-1.6E-06	-0.90
PARCEL	0.16	1.26	0.04	0.34	-0.00	-0.02
FAREA	0.04	0.77	0.02	0.45	0.05	0.91
YRTREE	0.01	0.70	0.02	1.01	-0.00	-0.34
DHOME	0.08	0.62	-0.02	-0.14	-0.06	-0.51
DROAD	-0.50 [a]	-3.58	-0.01	-0.06	-0.22	-1.57
DBRGY	0.09 [c]	1.76	-0.05	-0.99	0.01	0.26
DTOWN	0.02	0.57	-0.03	-1.34	0.01	0.45
R^2	0.21		0.18		0.23	
F (16, 148)	2.40 [a]		2.08 [b]		2.70 [a]	
N	165		165		165	

[a, b, c, d] refer to significance at 1%, 5%, 10%, 15% level, respectively

Monetary, Economic Security and Asset Motive

Tree planting for monetary and economic objectives was found to be significantly and positively influenced by farm distance from barangay center and inversely related to the sex and education of household heads, household size, total annual cash income, and average farm distance from the nearest road (Table 8). Households whose farm parcels are located relatively far from the barangay center are more likely to consider tree growing for economic security and asset motives. This is probably because farmers consider tree growing in distant farms as the appropriate land use option for long-term investments. Farms located near the barangay center are fairly accessible that makes long-term investments like tree growing unattractive relative to food crop and other cash crop production. Further, empirical evidence was shown by the negative coefficient for the distance of farm from nearest road, which serves as proxy variable for access.

Tree farming has been considered to provide employment and economic opportunities for female than male farmers. This implies that greater participation of women in farm decision-making would likely increase adoption of tree-based farming systems since they perceive more benefits than costs. If this is the case, it is important to highlight the role of women in any upland development projects. On the other hand, the negative effect of education indicates that economic motives of tree growing diminishes as education level increases. This may be because households with higher educational attainment have relatively more economic opportunities other than tree growing. Moreover, more educated households will probably plant trees in the farm for other reasons such as recreation, environmental protection and restoration. In fact, education was positively related to environmental protection and restoration motives of tree planting, although not statistically significant.

The inverse relationship between household size and economic and asset motives implies that maybe large households do not consider tree growing to provide income for subsistence simply because they probably could not afford to compromise their immediate household needs. Further, those households with higher annual cash income have planted trees for other non-monetary motives. Similar to household size, this result suggests that households' dependence on trees for employment, economic and asset motives diminishes as total annual cash income increases. As total annual cash income increases, the primary consideration has probably shifted from monetary motive to non-timber benefits as manifested by the positive coefficient of annual cash income for recreation and aesthetic reasons.

Recreation and Aesthetic Objective

Variables associated with recreation and aesthetic objectives of tree planting were similar to the variables influencing the economic objectives of tree planting except on civil status. The sign of significant variables was however, in opposite direction (Table 8). Civil status was significant and positively related to recreation and aesthetic component, which means that married households are likely to incorporate trees in the farm primarily for leisure and relaxation purposes than unmarried farmers. In consonance with civil status, household size was positively related to recreation objective, implying that households having large families tend to use farm forests as a destination for recreation activities. It is plausible for households with relatively more family members to think in this manner since undertaking recreation activities elsewhere requires a bigger household budget.

As expected, annual cash income was positively related to the recreation objective in tree growing since farmers could afford to devote extra time for leisure instead of working in the farm. Unexpectedly, farming experience was inversely related to recreation motive, which means that more experienced farmers would value less the recreation and aesthetic benefits of tree growing. Usually experienced farmers are expected to have more time for non-farming activities. This result can probably be explained by the subsistence nature of farming households included in the survey.

Environmental Protection and Restoration Objective

Similar to recreation motive, environmental and restoration motive was negatively associated with farming experience of households (Table 8). However, it was uniquely related to the age of household heads and knowledge level (score) regarding tree-based systems. Older farmers are likely to be more concerned with the protection and restoration of the environment through their tree farming activities. This probably could be attributed to the level of awareness of older farmers than younger ones. In this light, the significant and direct relationship between knowledge level of households on tree-based systems and environmental protection motive has partly supported the above reasons.

6.0 FARMERS' TREE GROWING INVESTMENT DECISIONS

6.1 Methodology

6.1.1 Data Collection and Analysis

To capture land use decisions over time, the survey questionnaire was designed to allow elicitation of household land use decisions (using a recall technique) over the last 15 years, depending on when trees are first incorporated in the farming system. Using this strategy, a collapsed panel dataset (i.e., a historical household and land use profiles) was constructed from the cross-section survey. The constructed historical dataset included one observation for each of the sample household at each point in time that tree planting was made between 1985 and 2001.

The dependent variable used in the analysis to represent tree growing investment decision was expressed in terms of the share of total land area devoted to tree crops. This definition of dependent variables would result in a data set with a censored distribution since a value of zero is assigned for those who are not investing (non-adopters) tree-based land use systems. To fit this type of data, Tobit regression model is a more appropriate estimation technique (Tobin 1958; Greene 1998) to use considering that the degree of tree growing investment, and not just the act of adopting the technology is of interest in this analysis. Further, maximum likelihood estimation of Tobit analysis provides unbiased and consistent parameter estimates than OLS estimation when the dependent variable is censored. The Tobit model can be written as:

$$
\begin{aligned}
Y_i &= X_i\beta + \mu_i && \text{if } X_i\beta + \mu_i > 0 \\
Y_i &= 0 && \text{if } X_i\beta + \mu_i \le 0 \\
& && i = 1,2,\ldots,N
\end{aligned}
$$

where Y_i is the dependent variable; X_i is a vector of explanatory variables; β is a vector of unknown coefficients; μ_i is an independent and normally distributed error term assumed to be normal with zero mean and constant variance σ^2; N is the number of observations.

Following Tobin (1958), the expected intensity of investment on tree-based land use system technology was computed as follows:

$$E(Y) = X\beta F(z) + \sigma f(z)$$

where $F(z)$ = cumulative normal distribution of z; $f(z)$ = value of the derivative of the normal curve at a given point (i.e., unit normal density); z = Z-score for the area under the normal curve; σ = standard error term.

The marginal effect of the explanatory variable on the expected value of the dependent variable was calculated as (McDonald and Moffitt, l980):

$$\partial E(Y) / \partial X_i = F(z)\beta_i$$

6.1.2 Tree Growing Investment Decision Models

Tree-planting patterns were examined using Tobit regressions that represent a reduced-form model of the planting rule implied by equation (3.8). Tobit regression model was estimated to explain variation in tree growing investment pattern for *Gmelina arborea* only in the sample over the period 1985-2001 using the constructed panel data together with the estimated price forecasts of commodities considered in the study. Expectations on price changes, which are assumed to be based on naïve extrapolations from recent trends, were considered here to affect tree growing decisions, although it is clear that smallholders might exhibit a delayed response to changes in relative prices and that some expressions of past prices might serve as useful factor in explaining planting decisions.

Prior to estimation of tree growing decision model, time series analysis of crop and timber prices, using vector autoregression (VAR) framework, was done to forecast price changes and relative price risks[5] at planting time. Details of the estimation procedure can be found in Predo (2002) and is available upon request. The empirical model of tree growing decisions was specified as:

$$\begin{aligned} Y = {} & \beta_0 + \beta_1 AGE + \beta_2 HHSIZE + \beta_3 FAREA + \beta_4 LMR + \beta_5 OWNER \\ & + \beta_6 LUMPT + \beta_7 CORNPT + \beta_8 RICEPT + \beta_9 LUMPTCH \\ & + \beta_{10} CORPTCH + \beta_{11} PFRICCH + \beta_{12} CVCCVGL + \beta_{13} CVRCVGL + \mu \end{aligned}$$

where:

Y	=	intensity of tree growing investment (i.e., land share planted with trees, computed as land area devoted to trees divided by total farm area x 100)
AGE	=	age of household head at planting time (years)
HHSIZE	=	household size at planting time
FAREA	=	farm size at planting (ha)
LMR	=	land-man ratio or per capital land holding at planting time
OWNER	=	dummy variable for land tenure: 1 if owner, 0 otherwise
LUMPT	=	current price of *Gmelina* lumber (PHP/bdft)
CORNPT	=	current corn price (PHP/kg)
RICEPT	=	current rice price (PHP/kg)
LUMPTCH	=	one-year forecast of *Gmelina* lumber price change (%)
CORPTCH	=	one-year forecast of corn price change (%)

[5] Results of price level regression and forecast prices can be found in Predo (2002).

PFRICCH	=	one-year forecast of rice price change (%)
CVCCVGL	=	corn price forecast CV/*Gmelina* lumber price forecast CV (one-year forecast of corn price risk relative to *Gmelina* lumber price)
CVRCVGL	=	rice price forecast CV/Gmelina lumber price forecast CV (one-year forecast of rice price risk relative to *Gmelina* lumber price)
μ	=	error term assumed normal and independently distributed

Gmelina arborea was selected because it was planted by about 86% of the total respondents. On the other hand, given the widespread importance of corn (as staple) and rice (as a cash crop) in the sample, prices for both of these crops were included in the regressions.

Another Tobit regression was estimated to determine the effects of other time-independent farm and household characteristics on farmers' decision to invest in tree-crop portfolio at current period (year 2001). The model was specified as:

$$
\begin{aligned}
Y = \beta_0 &+ \beta_1 AGE + \beta_2 HHSIZE + \beta_3 EDUCYR + \beta_4 KSCORE \\
&+ \beta_5 LANDMEM + \beta_6 FAREA + \beta_7 OWNER + \beta_8 TFARMINC \\
&+ \beta_9 TNONFARM + \beta_{10} DHOME + \beta_{11} DROAD + \beta_{12} DTOWN + \mu
\end{aligned}
$$

where:

AGE	=	Age of household head at current period (years)
HHSIZE	=	Household size
EDUCYR	=	Educational attainment of household head (years)
KSCORE	=	Knowledge score (%) of respondents about soil conservation and tree-based land use systems (see Appendix 2 for the formula on measuring knowledge score)
LANDMEM	=	1 if landcare association member, 0 otherwise
TFARMINC	=	Total annual farm income (PHP)
TNONFARM	=	Total annual non-farm income (PHP)
DHOME	=	Distance of farm parcels from home (km)
DROAD	=	Distance of farm parcels from nearest road network (km)
DTOWN	=	Distance of farm parcels from town center (km)

μ = error term assumed normal and independently distributed

6.2 Results and Discussion

6.2.1 Socio-economic Characteristics of the Respondents

The mean age of total farmer-respondents was about 45 years. The mean age of tree-based system adopters ranged from 43 to 50 years while the mean age of non-adopters was about 39 years. This indicates that upland farmers who invested in tree-based farming systems were significantly older than non-adopters. In similar pattern, the average years of farming experience of adopters (20 years) was significantly longer than non-adopters (13 years).

On the average, upland farmers reached primary level, spending at least six years in school. The mean educational attainment of adopters (6.2 to 6.3 years) was not significantly different compared with the non-adopters (5.8 years). Majority (92%) of the upland farmers who make decisions about their upland farming activities were males. Both tree-based system adopters (90 to 94%) and non-adopters (93%) were predominantly males.

The household size of total upland farmers surveyed ranged from 2-11 people with an average of about six members. Comparing the average household size between adopters and non-adopters was found to be not much different, which.means that adopters and non-adopters have similar family labor resource.

The sources of annual cash income of upland farmers included farm, off-farm, and non-farm. Among these, farm income provided the highest cash income for both adopter and non-adopters while the off-farm source provided the least income for adopters, and the non-farm source for non-adopters. Farm income comprised the following sources: (i) annual crops such as corn, lowland and upland rice; (ii) perennial crops such as mango, coffee, coconut, and banana; and (iii) animal and livestock production. The average farm income over the last 12 months for tree-based system adopters ranged from PHP 32,263 (USD 632.6) to PHP 51,691 (USD 1,013.5) with an average of PHP 37,861 (USD 742.4). This was significantly higher than average farm income of non-adopters [PHP 15,379 (USD 301.5)]. This suggests that higher farm income of adopters may be due to increased farm fertility and productivity associated with the incorporation of trees into the farming system.

6.2.2 Farm Characteristics of the Respondents

Majority (92%) of the upland farmers had one to two farm parcels. On average, tree-based system adopters had slightly higher number of farm parcels (1.5) than the non-adopters (1.1). Total farm area ranged from 0.25 to 18 ha, with an average of 2.08 ha for the total respondents. Adopters of tree-based farming systems have significantly higher average farm size (2.2 ha) than the non-adopters (1.19 ha).

The respondents owned the majority (59%) of the total farm parcels they were cultivating. The tree-based system adopters owned about 52-75% of their farms but only about 26% were owned by the non-adopters. The rest of their farms were tenanted and rented/leased. The majority of non-tree growing farmers (42%) were tenants of the farm parcels they tilled while only about 13-29% of the tree-based system adopters were tenants. For farm parcels owned by farmers, majority of both adopters and non-adopters have titles to the land they cultivated (39%). The second highest proportion of land ownership was the certificate of land transfer or CLT (25%), followed by ownership with no formal document, tax declaration, certificate of stewardship contract (CSC), and mortgage.

6.2.3 Knowledge of Upland Farmers on Tree-based Farming Systems

Results from the set of multiple choice questions/statements administered to the upland farmers to obtain their knowledge level on soil conservation and tree-based farming systems show that the adopters have significantly higher mean score (84.7%) than non-adopters (45.0%) for all questions being asked (Appendix Table 2). This suggests that the adopters were more knowledgeable than the non-adopters about the economic and ecological benefits from soil conservation and tree-based farming systems.

6.2.4 Extent of Adoption of Tree-based Land Use Systems

Survey results revealed a significant adoption of smallholder farmers on tree-based land use systems. Of the total 192 farmers interviewed, about 86% have planted trees on their farms (Table 9). Majority of the adopters (49%) started to invest in tree growing about five years ago and below while about 29% and 22% planted trees in the farm between 6-10 years ago and 11 years and above, respectively (Table 10). On the average, tree-based adopters commenced planting trees on their farms about 7 years ago. The high adoption rate at later period possibly indicates that farmers' adoption of new technologies or land use systems was not automatic upon introduction of the new systems. This happens even for land use systems or technologies with high financial returns and more environmental benefits. The most probable reason is that adoption of tree-based systems may be driven also by factors other than financial considerations such as risks, particularly income risks and consequently consumption risks.

Table 9. Frequency Distribution of Smallholder Farmer-respondents, Claveria, Misamis Oriental, Philippines, 2001.

CATEGORY	*NUMBER*	*PERCENT*
Adopter	165	86
Non-adopter	27	14
Total	192	100

Table 10. Distribution of Tree-based Systems Adopters by Length of Adoption, Claveria, Misamis Oriental, Philippines, 2001.

LENGTH OF ADOPTION (YEARS)	*NUMBER*	*PERCENT*
5 & below	81	49
6-10 years	48	29
11 & above	36	22
Total	165	100
Mean (Std. Dev.)	*6.64 (5.11)*	

While the proportion of tree-based system adoption was high, the extent of adoption was considerably low. Tree-based system adopters allocated only a relatively smaller share of their farms to timber and fruit trees than to maize and other annual crops combined (Table 11). For instance, *Gmelina arborea* has been planted by about 58% of the adopters but average current land use share was only 4.8%, which is equivalent to 0.11 hectare. Average land use share for other tree species was also at minimal level (0.07% to 3.7%). Nonetheless, the average land use share reported for *Gmelina* is an underestimation of the actual land use share considering even those all tree-based adopters were included in the calculation. When only those adopters with *Gmelina* are considered, the average land use share ranged from 10 to 15%. This conforms to the findings of Nelson et al. (1996c) and Shively (1996) that an optimal share of trees or hedgerow component in a tree-crop portfolio has been found to be 10 to 20%.

In terms of annual crop production, on the average, tree-based adopters allocated a relatively smaller land use share for maize production (58%) than their non-adopter counterparts (68%). This is primarily because adopters devoted some of the farm parcels to fast-growing timber tree species (e.g., *Gmelina arborea*, *Eucalyptus deglupta* and *Acacia mangium*), fruit trees and other cash crops in combination with maize crop or upland rice. Since tree-based system adopters have relatively bigger farm size than non-adopters, the smaller percentage has translated to a larger area devoted to maize production for adopters compared with non-adopters.

Besides trees and annual crop production, banana production constituted the next highest average land use share in the whole farm portfolio for both adopters (4%) and non-adopters (10%). This was followed by the fallow system (10% for adopters and 8% for non-adopters), which is aimed at restoring soil fertility.

Table 11. Mean Current Land Use Allocation of Adopters and Non-adopters of Tree-based Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

LAND USE[a/]	*ADOPTER*		*NON-ADOPTER*		*ALL*	
	% Land Share	Area (ha)	% Land Share	Area (ha)	% Land Share	Area (ha)
Maize	58.12	1.302	67.94	0.734	59.12	1.230
Lowland rice	4.65	0.104	5.28	0.057	4.21	0.088
Upland rice	1.80	0.040	0.28	0.003	2.18	0.045
Cassava	2.32	0.052	1.94	0.021	2.48	0.052
Gmelina arborea	4.80	0.108	0.00	0.000	4.11	0.085
Eucalyptus deglupta	0.95	0.021	0.00	0.000	0.81	0.017
Acacia mangium	0.07	0.002	0.00	0.000	0.06	0.001
Sweitenia macrophylla	0.28	0.006	0.00	0.000	0.24	0.005
Fruit trees & other trees	3.66	0.082	0.00	0.000	3.82	0.079
Coconut	2.47	0.055	0.00	0.000	2.12	0.044
Coffee	0.56	0.013	0.00	0.000	0.48	0.010
Vegetables	3.96	0.089	5.96	0.064	4.54	0.094
Fallow (natural/ improved)	9.73	0.218	7.59	0.082	8.32	0.173
Pasture/Grazing	1.45	0.032	1.11	0.012	1.40	0.029
Banana	4.16	0.093	9.95	0.107	5.78	0.120
Peanut	0.18	0.004	0.00	0.000	0.16	0.003
Watermelon	1.15	0.026	0.00	0.000	0.89	0.019

[a/] Multiple response

6.2.5 Empirical Results of Tree Growing Decisions

Price and Tree Planting Patterns

The variance-covariance matrix of prices (constructed from the complete observed time series) estimated from the sample data (Table 12) shows that the variance of current price of *Gmelina* (8.0 PHP/boardfoot) was relatively higher than corn (3.2 PHP/kg) and rice (4.2 PHP/kg). Likewise, the covariance of current prices of *Gmelina* and rice (3.5 P^2/kg-bdft) was higher than *Gmelina* and corn (3.0 P^2/kg-bdft).This indicates that *Gmelina* prices were by far the most volatile over the sample period, and that corn prices were the least volatile. These patterns of price changes might help to explain planting response of smallholder farmers (Figure 9). The graph indicates that tree planting followed a cyclical pattern and it coincides with the price movements. Tree planting was most active in the early and late 1990s, periods that were accompanied by positive price changes for *Gmelina* except in year 1997 and 1999.

Table 12. Variance-covariance Matrix for Current Prices of Corn, Rice, and *Gmelina* Lumber, 1985-2001.

	CORN PRICE	*RICE PRICE*	*GMELINA PRICE*
		PHP	
CORN PRICE	3.16		
RICE PRICE	3.17	4.22	
GMELINA LUMBER PRICE	3.03	3.52	8.00

Source: Computed by the author from BAS and DENR data.

1 USD = 51 PHP

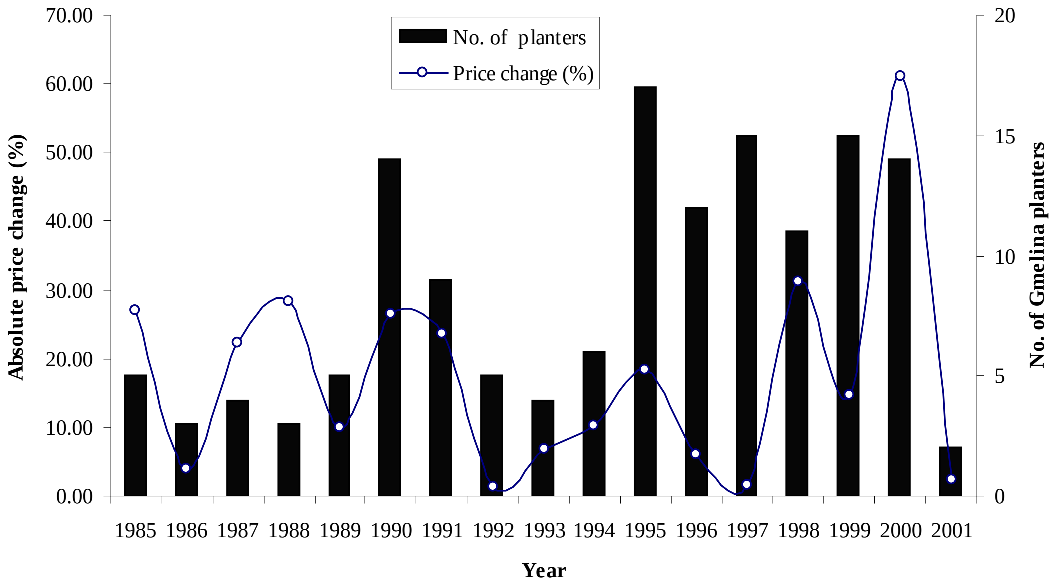


Figure 9. Annual Price Change for *Gmelina* Lumber and Number of Households Planting *Gmelina* over the Period 1985-2001.

Factors Influencing Tree Growing Decisions Over Time

Results from Tobit regression (Table 13) revealed that current and expected *Gmelina* lumber prices were positively and significantly associated with the share of land used for planting *Gmelina* trees. The land share for *Gmelina* planting was also significantly but negatively influenced by current period corn price and expected corn and rice price changes. These suggest that higher prices for *Gmelina* timber products encouraged farmers to increase tree growing and conversely, higher grain prices, particularly of corn, reduced incentives for tree planting. This is understandable because corn, being a staple food, was the dominant crop planted by majority of the farmers in Claveria for commercial and home consumption purposes. The effect of relative expected price risk for corn and rice was positive, which suggests that an increase in the expected price risk for either corn or rice (*vis-à-vis Gmelina*) is associated with an increase in the share of land devoted to *Gmelina*. The price risk for rice however, resulted in a higher marginal effect and elasticity value than corn price risk. Examination of elasticity values indicated that the decision to allocate how much land should be planted with these trees is highly responsive to prices and relative price risks. This result underscores the importance of price policy interventions for tree growing in promoting tree-based farming systems on smallholders.

Among the farm and household characteristics included in the regressions, household size significantly and positively influenced land share devoted to *Gmelina*. This indicates that larger households tend to increase *Gmelina* tree growing investment by increasing land share allocation for *Gmelina*. The impact of farm size on land share was negative, which means that as farm size increases, the share of land devoted to *Gmelina* decreases. Alternatively, large farms utilized a proportionately smaller share of land to plant *Gmelina* than did small farms. The fact that the share of land in *Gmelina* decreases as farm size increases may reflect fixed costs associated with tree planting (e.g., costs of obtaining planting materials). This pattern is consistent with the findings observed by

Shively (1998) on mango planting decision, and the observations of Scherr (1995b) for a range of commercially valuable trees in Kenya.

Table 13. Tobit Regression Estimates for Tree Growing Investment Decisions of Upland Farmers over the Period 1985-2001, Claveria, Misamis Oriental, Philippines.

Independent Variable	*Coefficient*	*Standard Error*	*Marginal Effect*	*Elasticity*
CONSTANT	-18.20 [c]	9.33		
AGE	-0.05	0.07	-0.02	-0.33
HHSIZE	0.99 [b]	0.46	0.50	0.87
FAREA	-1.70 [b]	0.82	-0.86	-0.57
LMR	4.71	3.36	2.38	0.36
OWNER	2.61 [d]	1.67	1.32	0.23
LUMPT	2.84 [a]	0.83	1.43	5.91
CORNPT	-4.93 [c]	2.97	-2.49	-4.83
RICEPT	-0.12	1.81	-0.06	-0.14
LUMPTCH	0.27 [a]	0.08	0.14	0.30
ACORPTCH	-0.24 [b]	0.11	-0.12	-0.48
APFRICCH	-0.21 [b]	0.09	-0.11	-0.50
CVC/CVGL	3.90 [b]	1.74	1.98	1.04
CVR/CVGL	5.14 [b]	2.06	2.60	1.33
σ (Sigma)	9.83 [a]	0.58		
Log-likelihood (unrestricted)	553.94			
Log-likelihood (restricted)	581.81			
Likelihood ratio	55.74 [a]			
Critical Chi-Square (df=13,α=1%)	27.69			
No. of observations	194			

[a,b,c,d] refers to significance at 1, 5, 10, and 15% levels, respectively.

In the case of land tenure, farmer-owners tend to devote more land for *Gmelina* planting than non-owners, although the level of significance was low. This suggests that farmers with secured tenure over the land they tilled or the rights to their planted trees have the incentives to increase the area devoted for *Gmelina* planting compared to farmers without secured tenure.

Factors Influencing Tree Growing Decisions at Current Period

Among the explanatory variables considered in the model at current period, knowledge score, farm size, age, education level, and membership in landcare association have positively and significantly influenced land share allocation decision of farmers for tree growing (Table 14). As upland farmers become more knowledgeable on the economic and environmental benefits of trees, they would be encouraged to increase tree growing activities in the farm. This implies the need to increase awareness level of farmers on the benefits of various tree-based systems through continued information and education campaign.

As expected, households with larger farms tend to allocate bigger share of their farms to tree growing than households with smaller farms. This is may be because farmers with larger farm area are usually not constrained in their crop production to meet immediate household needs. In other words, they can afford to trade present consumption with future higher benefits from tree growing for as long as daily subsistence needs are still satisfied. Meanwhile, older farmers tend to allocate a larger share of the farm to the tree component of the farming system than younger farmers. This may be due to the fact that older farmers might have greater environmental concerns compared to young farmers. This is consistent with the findings on tree growing objectives i.e., that older farmers are likely to be more concerned with the protection and restoration of the environment through tree farming activities.

Table 14. Tobit Regression Estimates for Tree Growing Investment Decisions of Upland Farmers for All Tree-based Systems in the Current Period (2001), Claveria, Misamis Oriental, Philippines.

Independent Variable	*Coefficient*	*Standard Error*	*Marginal Effect*	*Elasticity*
CONSTANT	-44.58 [a]	16.56		
AGE	0.39 [c]	0.20	0.25	0.76
HHSIZE	-1.31	1.02	-0.83	-0.31
EDUCYR	1.30 [d]	0.82	0.82	0.35
KSCORE	0.52 [a]	0.15	0.33	1.79
LANDMEM	8.65 [c]	4.88	5.50	0.22
FAREA	2.39 [d]	1.47	1.52	0.22
OWNER	-7.12	5.18	-4.53	-0.16
TFARMINC	-1.9E-05	5.5E-05	0.00	-0.02
TNONFARM	9.3E-05	1.3E-04	0.00	0.04
DHOME	-0.91	3.57	-0.58	-0.02
DROAD	3.99	4.21	2.54	0.06
DTOWN	-1.54 [b]	0.75	-0.98	-0.54
σ (Sigma)	29.53 [a]	1.78		
Log-likelihood (unrestricted)	-749.22			
Log-likelihood (restricted)	-766.13			
Likelihood ratio	33.82 [a]			
Critical Chi-Square (df=13,α=1%)	26.22			
No. of observations	190			

[a,b,c,d] refers to significance at 1, 5, 10, and 15% levels, respectively.

The positive and significant coefficient of the education variable implies that farmers with more education were more likely to allocate a larger share of their farms for tree growing than those with lesser educational attainment. Similar to knowledge score, this result is likewise expected since educated farmers tend to be more informed (or aware) about the economic and environmental benefits that could be derived from trees. Increasing the awareness and knowledge of farmers through non-formal education, therefore, is one way of encouraging farmers to expand tree-farming activities.

Membership in the landcare association (a farmer-related organization that promotes sustainable land use management) was positively correlated with land share devoted to tree growing. On the average, landcare-member farmers had a large share of land planted with trees than non-members. This could have been due to the fact that landcare members were priority participants in soil and water conservation related trainings and they were also recipients of planting materials and other technical assistance provided by ICRAF in the area.

Unexpectedly, the distance of farm from town center was negatively related to the share of farm area planted with trees. Treating this variable as a measure of market access, the result implies that farms located relatively far from market center are likely to allocate a smaller share of land to trees. However, land use theory suggests otherwise, i.e., that commodities that are more perishable tend to be produced closer to the market, and hence it is expected for more trees to be planted in farms located far from market center. One possible reason that might help explain this counter-intuitive result is related to biophysical circumstances of the area. It was observed that some distant farms were intensively planted with annual crops because of good soil quality, favorable climate (e.g., cooler temperature) (Mercado, 1995), and the presence of road network. Another reason is that most farm products harvested from distant farms are usually bought at the farm.

Farmers' decision to invest in tree-based farming systems was found to be highly elastic with respect to the knowledge level in soil conservation and tree-based farming systems. This suggests that a continued awareness and information campaign program for farmers is necessary in promoting tree-based farming system investment among smallholder farmers.

6.3 Implications of Farmers' Perceptions and Attitudes Towards Risks on Tree Growing Decisions

Risk analysis results above confirmed the risk perception of farmers about tree-based land use systems. It has been shown that while tree-based land use systems could provide higher income, they are associated with relatively high level of risk, as indicated by a large coefficient of variation of NPV, compared with farmers' current farming practice.

On the other hand, technology adoption also depends on farmers' attitude towards risk, even for farmers with reasonably accurate perceptions of risk associated with a particular technology. Based on the results from tree planting decision discussed earlier, the responsiveness of farmers' tree growing decision (both the number of trees planted and the share of land devoted to trees) to price and relative price risks suggests that farmers are risk-averse to output price variability. Since risk-averse farmers are likely to consider simultaneously both the level of income and risk (Pandey, 2000), one could infer from the results of tree growing decision and risk analysis that smallholder farmers in the area were highly risk-averse. This simply implies that with higher level of risk aversion, farmers were hesitant to trade income risks with higher future profitability of tree growing. The predicted attitude of farmers towards risk was consistent with their actual adoption behavior that brings about the low extent of adoption on tree-based land use systems.

7.0 CONCLUSIONS AND POLICY IMPLICATIONS

7.1 Conclusions

Modeling and economic analysis are valuable research tools that can be used to study the long-term impacts of land use change. Conversion of *Imperata* grassland into tree-based land use systems can provide significant improvements to a range of on-site and off-site benefits. Tree-based land use systems (especially timber plantation system) appear to be superior compared with the current farmers' practice of farming as well as with the existing state of being grassland. Results show that tree-based land use systems had the least cumulative soil loss, highest biomass and soil organic carbon retained in the plant-soil system, and greater amounts of nutrients conserved in the soil.

Smallholders, however, are driven by economic imperatives. For smallholders to consider changing to a significantly different land use system, the new system must be more profitable than the existing system. Benefit cost analysis has shown that, at current prices, the tree-based systems are substantially more profitable than the *Imperata* system and farmers' current farming system. In addition, there are substantially high social benefits from carbon sequestration for tree-based systems. While there is an economic incentive for smallholders to transform *Imperata* grassland to tree-based systems, the time horizon of smallholders is important. Although carbon sequestration benefits would help reduce negative returns, smallholders are less likely to adopt tree-based land use systems unless they are capable of accepting negative profitability before timber harvest. Also given the long-term nature of the investment in tree-based systems, secure land tenure is required for smallholders to invest in these systems.

Results of the study indicate that a conventional application of NPV benefit cost analysis, which typically assumes certainty and risk neutrality, to the soil conservation and atmospheric carbon reduction problems will likely prove deficient, especially when applied to poor and risk-averse farmers. Such models will tend to predict investment in tree-based land use systems when investment is unlikely. It is however, recognized that investment decision on tree planting for grassland rehabilitation and carbon payments will also depend on risk aversion behavior of farmers.

It is important to emphasize the findings that conversion of *Imperata* grassland to tree-based systems is environmentally sustainable and economically efficient (though not fully risk efficient) option to undertake either for smallholder investment or for government poverty reduction program. This clearly illustrates the case of a win-win solution for improving *Imperata* grassland productivity and agricultural sustainability, which lend strong support to the hypothesis that there is no trade-off between economic growth and poverty reduction objectives in pursuing smallholder-based strategies. A caveat for the findings of the study is that the analysis was based on the assumptions of tenure security and effective fire control.

Understanding smallholder farmers' tree growing objectives and the factors that influence such objectives are important considerations in designing rehabilitation plans for targeted development initiatives in the uplands. Results of the study show that farmers invest in tree growing for both economic and non-economic reasons. Statistical evidence lends strong support to the hypothesis that smallholders' farm forestry is a multi-objective investment initiative. The underlying tree growing objectives identified were as follows: (i) monetary, economic security and asset motive; (2) recreation and aesthetic objective; and (3) environmental protection and restoration objective. Of these, monetary and other economic-related objectives accounted the most variations among farmers, and therefore were more preferred than non-economic objectives.

Empirical results show that understanding historical price patterns at the study area helped in explaining patterns of land use. Price volatility can influence tree planting incentives for land allocation. More importantly, current price levels and forecast price changes were correlated with changes in land use allocation decision of farmers in

Claveria. Higher relative current prices for timber products (lumber) were consistently associated with expansion in the area planted with timber trees. Similarly, increased tree planting occurred during periods in which the relative prices of corn and rice were declining. The significant relationship between price variability or relative price risk and timber tree planting decision lends strong support to the hypothesis that risk influences resource allocation patterns in the uplands.

Household and farm characteristics of farmers are important determinants of tree growing investment decision over time. Among the household characteristics, only household size significantly and positively influenced land share allocation decision for tree planting. In contrast, farm size was negatively associated with the share of land devoted to tree-based system over time, which suggests that large farms utilized a proportionately smaller share of land for timber trees than did small farms. At least for *Gmelina* trees, land tenure has lesser significant effect on long-term decision of farmers to expand land share for tree planting. Tree growing decision in the current period was strongly and positively influenced by knowledge of farmers about tree-based land use systems, membership in landcare association, age and education level of farmers. Farm size also has positively influenced tree growing decision of smallholder farmers in the short run.

7.2 Policy Implications and Recommendations

Tree-based land use systems provide greater environmental and economic benefits to smallholders and the society than the current farming practice. This implies that wide promotion and adoption of these technologies in a large number of areas in the Philippines with similar settings as the study site would help reduce poverty among smallholders and sustainable resource management in the uplands.

Tree growing decision of smallholder was highly dependent on current and projected prices and price variability of timber products and cash crops. To encourage adoption of tree-based systems, there is a need to assist farmers in coping with the production and income risks associated with tree growing. One way of doing it is to provide farmers access to timely and accurate price information of relevant products. The possibility of providing smallholder tree growers with subsidized crop insurance (for both annual and tree crops) is also warranted. Furthermore, to encourage smallholders to improve their present farm management practices, particularly those that provide environmental services like carbon sequestration, a policy that will provide payments for the said environmental services is warranted. The implementation of the “Clean Development Mechanism” identified in the Kyoto protocol for carbon offset is one such mechanism for effecting environmental services payment.

The long-term nature of the investment in trees requires security of land tenure, which is consistent with the findings of other related studies. Such condition implies the need for a policy providing assurance among smallholders to reap the benefits of their tree growing investments.

Tree growing investment decision is also significantly influenced by the knowledge level of smallholders on the economic and environmental benefits of tree-based systems. This suggests the need to continue the information dissemination activities through farmers’ trainings and seminars. Knowing that membership in landcare association greatly influenced farmers’ adoption of tree-based land use systems is an indication of the need to further enhance this local initiative in other areas through extension and training support.

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APPENDIX 1 – APPENDIX TABLES

Appendix Table 1. Base Parameter Values Used in Benefit Cost Analysis of Alternative Land Use Systems, Claveria, Misamis Oriental, Philippines, 2001.

PARAMETER	*VALUE*	*UNITS*	*DESCRIPTION*	*SOURCE*
Labor requirements				
L_{MD}	103	MD/ha/yr	man-day labor requirements for maize production	c
L_{MAD}	32	MAD/ha/yr	man-animal labor requirements for maize production	c
L_{AP}[6]	22.8	MD/au/yr	labor required for tethering and caring animal	a
L_{TP}	9.6	MD/ha	labor for tree planting	d, e
L_{PW}	90.4	MD/ha	labor for pruning and ringweeding trees, twice per year for first two years	d, e
L_H	67.8	MD/ha	labor for harvesting timber and post - harvest processing	d, e
L_{HL}	13	MD/ha	man-day to layout hedgerow for timber trees component	c
L_{HA}	2	MAD/ha	man-animal day to layout hedgerow for timber trees component	c
Wage price				
W_{MD}	70	PHP/MD	labor wage for man-day	a
W_{MAD}	140	PHP/MAD	labor wage for man-animal-day	a
W_{AD}	70	PHP/AD	labor wage for animal-day	a
Material inputs				
S_M	32	kg/ha/yr	maize seeds for planting	c
S_T	834	Seedlings/ha	planting density (500 *Gmelina*; 334 *Acacia mangium*)	i
F_N	120	kg/ha/yr	nitrogen fertilizer application rate (approximately 261 kg/ha/year urea)	c
F_P	48	kg/ha/yr	phosphorus fertilizer application rate (approximately 264kg/ha/yr solophos)	c
C_{AI}	1,765	PHP/au/yr	Cost of inputs (feed supplements, veterinary drugs, ropes, etc) for animal maintenance	n
Input prices				
P_{SG}	15	PHP/seedling	price of *Gmelina* seedling	a
P_{SA}	10	PHP/seedling	price of *Acacia mangium* seedling	a
P_{SM}	10.50	PHP/kg	price of maize seeds	a, c
P_{FU}	8.30	PHP/kg	price of urea fertilizer	a
P_{FS}	10.40	PHP/kg	price of solophos fertilizer	a

Continued

Note: 1 USD = 51 PHP

[6]Animal unit (AU) was computed using the formula (Marban 1994): $AU = (HY * 0.54)/FR$, where: HY=Dry matter (DM) herbage yield (kg/ha), 0.54 = fraction of forage efficiently consumed by animals, FR= annual feed requirements (kg DM). Cattle with an average body weight of 300 kg requires 7 kg DM of feed daily (Kearl 1982), thus, FR = 2,555 kg DM.

Appendix Table 1. Continued…

PARAMETER	VALUE	UNITS	DESCRIPTION	SOURCE
Output prices/value				
P_M	6.3	PHP/kg	price of maize (grain)	a
P_C	510	PHP/tC	price of carbon	b
P_T	10	PHP/bdft	price of lumber	a
B_{AS}	10,710	PHP/au/year	animal services benefit at current wage rate	a, n
A_V	3,434	PHP/au/year	value of change in animal inventory per year	n, h
Cost of capital				
r_p	25	%	private discount rate (opportunity cost of capital)	c
r_s	10	%	social discount rate	f, g
Other data				
CPI	1.62	-	consumer price index for 2001	h
ψ_m	18	%	selling moisture content of maize	c
ψ_t	54	%	selling moisture content of lumber	e
δ	0.5	-	carbon content of biomass & wood	j, k
λ	0.07	-	decay constant of timber products based on half-life of 10 years	l
ω_G	0.35	t/m^3	wood density of *Gmelina*	e
ω_A	0.60	t/m^3	wood density of *Acacia mangium*	m

Sources: a = survey and key informant interview, b = Nordhaus (1993) cited by Tomich *et al*. (1997), c = Nelson *et al*. (1996c), d = Magcale-Macandog and Rocamora (1997/4), e = Mamicpic (1997), f = Medalla et al. (1990) as cited by Grist *et al*. (1997a), g = Menz *et al*. (eds) (1998), h = NEDA (2002), i = Magcale-Macandog et al. (1997), j = Lasco (1997), k = Young *et al*. (1998) and Schroeder (1994), l = Grist *et al*. (1997b), m = MacDicken and Brewbaker (1984), n = Magcale-Macandog *et al*. (1998b)

Appendix Table 2. Knowledge Score (%) of Adopters and Non-adopters of Tree-based Farming Systems, Claveria, Misamis Oriental, Philippines, 2001.

	ADOPTER	*NON-ADOPTER*	*ALL*
Mean*	84.7 (12.5)	45.0 (15.7)	79.1 (19.0)
Minimum	47.5	2.5	2.5
Maximum	100.0	70.0	100.0

*Significant at 99% confidence level.

Note: Figures in parenthesis are standard deviations.

APPENDIX 2 – PROCEDURE TO MEASURE KNOWLEDGE SCORE

Knowledge level of smallholder farmers on soil conservation and tree-based land use systems was assessed using a set of 20 multiple choice questions/statements answerable by yes, no or I don't know. The questions included the topics on land use management practices, tree-based systems characteristics and their economics and ecological consequences. A set of key answers was then used to evaluate farmers' knowledge score using the formula developed by Romney et al. (1986) as follows:

$$\text{Knowledge Score (KSCORE)} = \frac{(RQ_n \text{ x } n) - 1}{(n-1)}$$

where, RQ_n is the percentage of right answers to questions with n choices.

APPENDIX 3 – GLOSSARY

IMPLUS – *Imperata* land use for animal pasture or grazing system (100% of one hectare devoted to *Imperata*)

FPLUS – Farmer's current practice of annual maize cropping system (100% of one hectare planted with maize crop)

TIMPLUS – Timber trees with *Imperata* for animal pasture or otherwise known as silvopastoral system (15% timber, 85% *Imperata*)

TCLUS – Timber trees planted in hedgerows with annual maize cropping system at the alley areas (15% timber, 85% maize crop)

TCSFLUS – Social forestry model of agroforestry system where bigger area planted to timber in hedgerow with annual maize cropping at the alley areas (40% timber, 60% maize crop)

TPLUS – Timber plantation land use system (100% timber)

MD - Man-day

MAD - Man-animal day

AD - Animal day

AU - Animal unit

NPV - Net present value

Scree test – It is a graphical test or indicator to determine the number of components to be retained in principal component analysis. Component with greater eigenvalue difference between succeeding components will be retained for interpretation.

ANB – Annualized net benefit