Chapter 6
Agroforestry Models for Promoting Effective Risk Management and Building Sustainable Communities

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Abstract Soil erosion and environmental degradation due to the cultivation of marginal upland areas are now considered major environmental risks in the Philippines. Agroforestry may help address the situation. In agroforestry systems, the positive interactions of tree-crop combinations not only improve biophysical conditions in farms, but also enhance food security in farming households.

A combination of Participatory Rural Appraisal (PRA), a household survey, focus group discussions, field experiments, and simulation modeling was undertaken in Claveria, Misamis Oriental, Philippines. The agroforestry system adopted depended on the farmers' motivations. The adoption of agroforestry significantly increased the households' level of income by around 42–137 %, compared with that from continuous annual mono-cropping. Another beneficial feature of an agroforestry system was the enhanced nutrient inflow to the system through leaf litterfall, stemflow, and throughfall. A modeling study using the WaNuLCAS model showed that the *Eucalyptus*-maize hedgerow system provided significant improvements to a range of biophysical and economic measures of productivity and sustainability.

It is recommended that both national and local government units mainstream their policies and efforts toward promoting agroforestry adoption in the Philippine uplands.

Keywords Agroforestry • Food security • Land degradation • Leaf litterfall • Nutrient inflow • Soil erosion

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6.1 Introduction

The uplands in the Philippines are of great importance and interest because they comprise about 59 % of the country's total land area. They are dynamic and highly interactive landscape components of the rural system, and also serve as the life support for the lowlands and coastal areas. In addition, they are home to the increasing population of the "poorest of the poor," and are expected to absorb more of the expanding population (Sajise and Ganapin 1991).

The Philippine uplands are a very heterogeneous and fragile resource base (Sajise and Ganapin 1991). Most of these areas are either open grassland, degraded, or occupied by settlers (Villancio et al. 2003). More than 20 million people are estimated to have settled in the uplands, and the number is increasing at a rate of about 2.8 % annually, which is above the national average of 2.32 %.

Its geographical location has made the Philippines highly vulnerable to natural hazards, the most common of which is the occurrence of turbulent typhoons. During the decade from 2001 to 2012, the country was hit by a total of 184 typhoons, or an average of 18 typhoons per year (Israel and Briones 2012). Climate change is perceived to have increased the frequency and intensity of heavy rainfall associated with typhoons and other weather systems, resulting in flooding. From 2000 to 2010, damage to agricultural crops caused by typhoons, floods, and droughts amounted to nearly PHP 106.88 million. Rice, corn, and other high value cash crops sustained the most damage. Typhoons Ondoy (Ketsana) and Pepeng (Parma) in September and October 2009 wrought havoc in both urban and rural areas in the country, with total damage reaching PHP 36.2 billion.

In the uplands, a major problem is food insecurity, which is mainly a consequence of land degradation. There is general recognition of the serious implications of deforestation, soil erosion, declining agricultural productivity, loss of biodiversity, off-site impacts, increasing poverty, and the social costs associated with the biophysical and ecological instability in the uplands. While 53 % of the Philippines' total land area is classified as forestlands, only 17 % is adequately covered with forest vegetation. In fact, the total forest cover in the country declined by as much as 3.54 % for the period 1990–1995, the fourth highest loss rate in the world. This rapid decline in forest areas can be attributed to the large and rapid conversion of the Philippine uplands into permanent annual cropping areas to meet the food requirements of an increasingly expanding population (Domingo and Buenaseda 2000). However, the productivity of sloping lands has been diminishing at an alarming rate due to soil degradation or erosion brought about by the activities of this population as it grows. According to Escaño and Tababa (1998), the rates of soil erosion in sloping areas range from 23 to 218 ton/ha/year for bare plots on gradients of 27–29 % to 36–200 ton/ha/year on plots cultivated up and down the hill. These rates are higher than the acceptable soil loss level of 3–10 ton/ha/year (Paningbatan 1989), and the situation poses a grave threat to the productivity and sustainability of farming in the upland areas.

In summary, the uplands can be characterized as degraded and ecologically marginal for agricultural purposes with landscapes that are highly sensitive and of low resilience. The biophysical limitations of these lands affect production, income, and household food security. Diminished food access due to the degraded natural resources, higher food prices, limited income opportunities, and the impact of natural elements leave the upland population a legacy of poverty and food insecurity.

Agroforestry is a dynamic, ecologically-based, natural resource management system that, through the integration of trees into farms, diversifies and sustains smallholder production for increased social, economic, and environmental benefits (Leaky 1996). Introducing trees within the cropping system can help prevent land degradation, increase biodiversity, and at the same time allow the continued use of the land for agricultural crop production (Wise and Cacho 2002).

Mature trees in agroforestry systems can yield numerous positive effects on cropped fields (Garcia-Barrios and Ong 2004). Among these are improved soil fertility and physical properties via organic matter addition from litter; reduced soil erosion through stabilization of loose soil surface by tree roots; recovery of leached nutrients from deep soil layers inaccessible to crops; reduced soil evaporation, leaf temperature, and evaporative demand by crops via tree shade; increased soil infiltration rate; protection against wind and runoff; reduced weed population; and reduction and potential slowdown of windborne pests and diseases. In a system where nitrogen (N)-fixing trees are used as hedgerows, alternative sources of N for trees can significantly reduce competition with crops.

6.2 Agroforestry Adoption, Innovations, and Smallholder Farmers' Motivations in Claveria, Misamis Oriental

6.2.1 Description of the Study Site

Claveria is a land-locked agricultural municipality in the province of Misamis Oriental in northern Mindanao (Fig. 6.1). It is a volcanic plateau ascending abruptly from about 350 masl (meters above sea-level) in the west to about 1,200 masl in the east. Its topography is generally rugged, characterized by gently rolling hills and mountains with cliffs and escarpments. More than 68 % of Claveria's total land area has slopes greater than 18 %.

The soil in Claveria is classified as Jasaan Clay, with a deep soil profile (>1 m) and rapid drainage (Bureau of Soils 1985). The soil is generally acidic (pH 3.9–5.2), with low cation exchange capacity (CEC), and a low to moderate organic matter content (1.8 %). It also has low levels of available phosphorus and exchangeable pottasium (Magbanua and Garrity 1990).

The climate of Claveria is classified as having a rainfall distribution of 5 or 6 wet months (>200 mm/month) and 2 or 3 dry months (<100 mm/month). However, rainfall patterns throughout the municipality vary with elevation, with the upper areas having a relatively greater amount of rainfall than the lower areas.

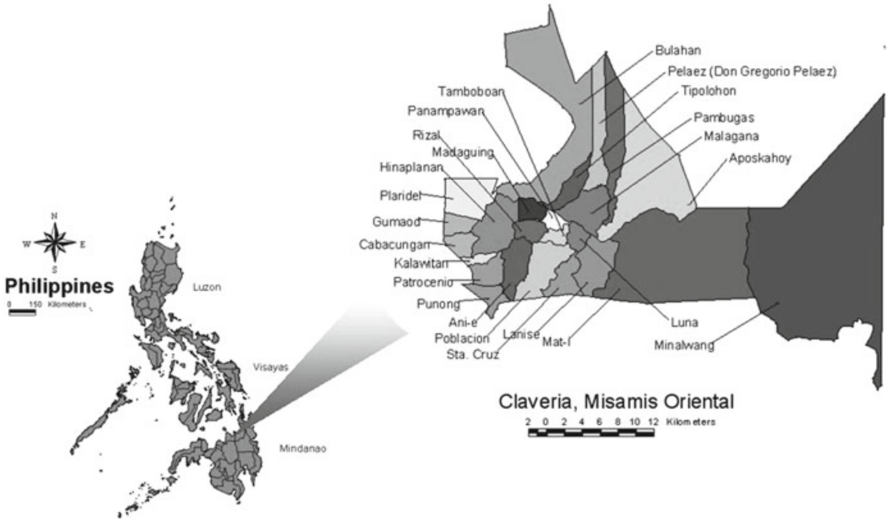

Fig. 6.1 Claveria, Misamis Oriental, Philippines, including village administrative boundaries

6.2.2 Participatory Rural Appraisal (PRA) and Household Survey

A 4-day PRA with key informants from 17 *barangays* (villages) in Claveria was conducted to obtain a preliminary assessment of the basic and universal information held by the community on the issues to be addressed (Magcale-Macandog et al. 2006). Three hundred farmer-respondents were selected for the household survey using a stratified sampling technique whereby the total population of farmers in the study area was divided into subpopulations (strata) based on elevation (Upper, Middle, and Lower Claveria) and the type of agroforestry or non-agroforestry system practiced (Magcale-Macandog et al. 2010). The number of random samples representing each stratum was proportional to the size of the subpopulation of farmers practicing the type of agroforestry system at each elevation class. Farmers practicing agroforestry systems were classified based on the spatial arrangements of trees in their systems (Fig. 6.2) as follows: (1) parkland planting (scattered trees), (2) hedgerow system (planting of trees along farm contours), (3) block planting or *taungya* system, and (4) multi-story system.

6.2.3 Drivers of Land Degradation in Claveria

Farmers identified the poor growth of plants or grasses and low crop yield as the main indicators of soil degradation. Degraded soils were also characterized by acidic or red soil, absence of earthworms, faster drying up of soil, and absence of trees.

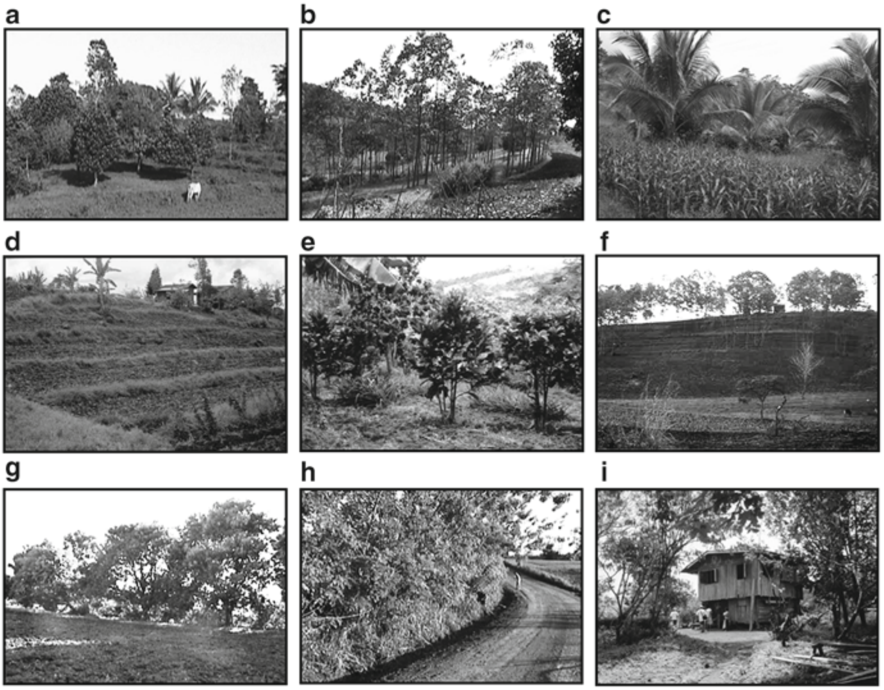

Fig. 6.2 Common farming systems adopted in Claveria, Misamis Oriental, Philippines: (**a**) parkland system; (**b**) block planting with timber trees; (**c**) block planting with fruit trees; (**d**) natural vegetative strips (NVS); (**e**) coffee-based hedgerow intercropping; (**f**) timber-based hedgerow intercropping; (**g**) border planting with fruit trees, (**h**) border planting with *Gliricidia sepium*; (**i**) home garden

In Lower Claveria, continuous land cultivation (25 %) and fertilizer application (25 %) were perceived as the main factors that led to soil degradation. In Upper Claveria, however, 67 % of the farmers said that soil erosion was the main cause of soil degradation. In both areas, farmers associated soil degradation with plowing along the contour, not observing proper soil conservation, burning farm waste, and pesticide application.

Farmers thought that contouring was the primary strategy to address soil degradation. Planting trees or agroforestry was cited as the second strategy, since it improves the environment due to the capacity of trees to retain soil nutrients and water, and prevent severe flooding.

6.2.4 Introduction and Adoption of Tree-Based Systems in Claveria

At the turn of the century, 18 % of the municipality was forested by species of *Shorea*, *Pterocarpus*, and other hardwoods. In the 1930s, indigenous people or

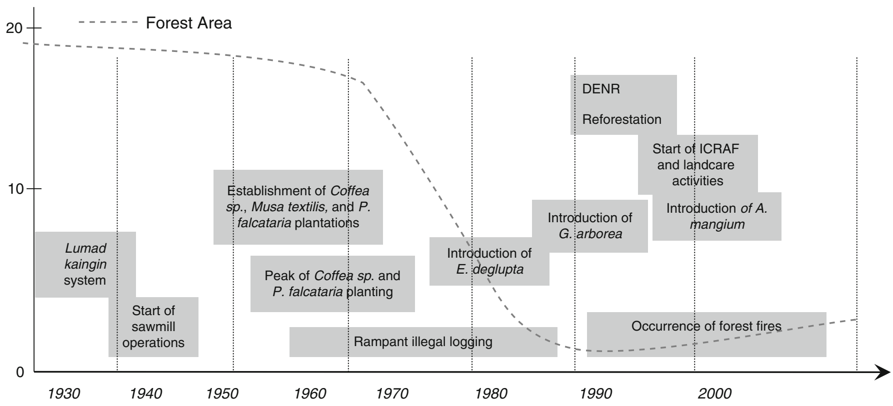

Fig. 6.3 Change in forest area and forestry-related events in Claveria, Misamis Oriental

lumads practiced *kaingin* (slash-and-burn) to clear forest areas and plant annual crops (Fig. 6.3). A marked decrease in the forest area was noted in 1965 due to rampant illegal logging by both large timber concessionaires and small-scale loggers (Garrity and Agustin 1995).

Trees domesticated by farmers included coffee (*Coffea robusta*, *C. excelsa, C. Arabica*), gmelina (*Gmelina arborea*), falcata (*Paraserianthes falcataria*), mangium (*Acacia mangium*), mahogany (*Swietenia macrophylla*) and bagras (*Eucalyptus deglupta*). In the 1950s, coffee growing under falcata stands was popular in the area. Falcata was favored by farmers because it provides good shading for coffee, wood for box construction, and pulp for paper.

The Department of Environment and Natural Resources (DENR) introduced gmelina in the 1980s to encourage tree growing as part of its reforestation program. With the establishment of the International Center for Research in Agroforestry (ICRAF) in 1993, agroforestry practices were introduced to farmers. ICRAF initiated the planting of mangium and bagras as agroforestry species.

6.2.5 Innovative Agroforestry Practices in Claveria

Tree-based systems commonly used among the respondents were parkland, block planting, border, and hedgerow (Fig. 6.4). These systems could be found in all *barangays* and elevation classes. Originally starting from a simple combination of trees in crop areas, the Claveria farmers developed innovations in the agroforestry systems they practiced.

Out of the 300 households surveyed, 72 % adopted agroforestry in their farms. The parkland system was the most widely practiced (30 %), followed distantly by the hedgerow system or natural vegetative strips (NVS) (18 %), and block planting (16 %). Only 8 % of the respondents adopted border planting.

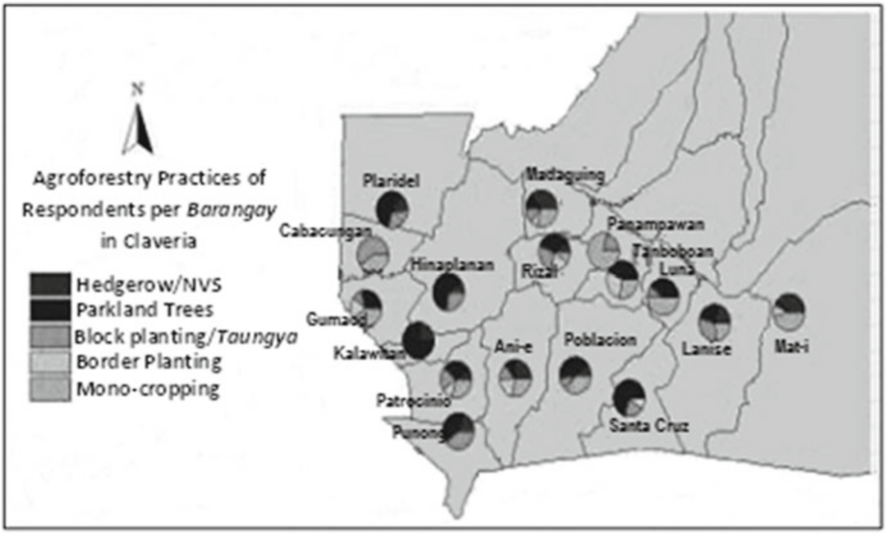

Fig. 6.4 Map showing agroforestry practices of respondents in the study site

Table 6.1 Reasons or motivations of farmers in adopting certain agroforestry systems in Claveria, Misamis Oriental, Philippines

Reasons	Block planting (%)	Parkland (%)	NVS/hedgerows (%)	Border planting (%)
Income	48	37	21	27
Soil conservation	17	13	55	17
Fruit/diversity of harvest	6	–	14	14
Use of rolling lands	4	12	–	–
Nature restoration	–	8	–	–
Construction materials	9	5	–	10
Optimal use of land	–	–	4	–
Wind break	–	–	–	8
Trend-following/curiosity	–	–	4	–

6.2.6 Farmers' Motivations for Planting Trees

In all the agroforestry systems, the common reasons given by farmers for planting trees were for additional income, soil conservation, future procurement of construction materials for their houses and furniture, harvest of fruits for home consumption and sale, and to maximize use of their rolling lands (Table 6.1).

6.3 Tree Growth, Crop Productivity, and Water and Nutrient Flows in *Gmelina arborea–Zea mays* Hedgerow Systems in Claveria, Misamis Oriental

Miole et al. (2011) evaluated the nutrient flows in *G. arborea–Zea mays* agroforestry systems in Claveria. Experimental plots (18 m upslope × 10 m across) with narrow (1 × 3 m) and wide (1 × 9 m) hedgerow spacing were established. Maize was planted in the alley areas in between hedgerows planted with *Gmelina* trees. Soil profile was characterized following standard procedure for soil profile description. Bulk soil samples were collected and analyzed for routine soil analysis. Tree height and diameter at breast height were measured, while maize plant height, biomass, and nutrient content were determined. Monthly tree leaf litterfalls were collected using 1 m^2 litter traps. Incident precipitation, stemflow, and throughfall were measured at each rain event. The collected rain water was analyzed for NO_3^-, P, and K contents. A soil erosion plot (6 × 4 m) was established within each experimental plot for sediment and surface run-off measurements. Run-off volume was determined using a water meter installed in a plastic container. Nutrient contents of sediment load and run-off water were analyzed following standard methods.

6.3.1 Water Dynamics in Agroforestry Systems

Stemflow, throughfall, crop biomass residues, and litterfall were classified as processes contributing to nutrient inflows, while soil erosion, surface run-off, and crop harvest represented processes for nutrient outflows. Tree leaf litterfall was the major source of N input in both hedgerow spacing treatments. Maize crop residue was another source of N input for wide hedgerow spacing. The major avenue for N loss in narrow hedgerow spacing was soil erosion. In wide hedgerow spacing, N was lost mainly via crop harvest.

About 54 % of the incoming rainfall landed in the hedgerow system as throughfall, and only 1 % as stemflow, in both spacing treatments. Depths of stemflow and throughfall were slightly higher in the narrow spacing treatment, while depth of surface run-off was higher in the wide spacing treatment. Water passing through stems and barks of trees had higher K content than throughfall. Throughfall, however, showed higher NH_4^+ and NO_3^- contents.

6.3.2 Growth Performance of Trees and Maize

The growth performance of trees along the hedgerows and maize crop in the alley areas was better in wide hedgerow spacing than in narrow spacing. Nutrient contents of maize biomass and *Gmelina* leaf litterfall, particularly N, were likewise higher in the former. Providing wider spacing for hedgerow trees would give greater opportunity for a crop to grow well, and consequently, higher maize biomass and yield, with correspondingly higher levels of NPK nutrients.

6.4 Enhancing the Food Security of Upland Farming Households Through Agroforestry in Claveria, Misamis Oriental, Philippines

A combination of techniques was used to gather information on the food security situation of farmers in Claveria, including a household survey, focus group discussions, field experiments, bioeconomic modeling using the Water, Nutrient, and Light Capture in Agroforestry Systems (WaNuLCAS) model, and investment and profitability analysis (Magcale-Macandog et al. 2010).

An investment analysis was undertaken to determine the financial viability of investing in agroforestry systems over a 25-year period given a 10 % discount rate. A sensitivity analysis was also performed to compare the economic benefits derived from agroforestry and annual cropping given varying costs of capital ranging from 5 to 30 %.

6.4.1 Agroforestry and Improved Access to Food

The adoption of the agroforestry system has improved food supply and helped address food insecurity among the farmers in Claveria. Fruit-bearing trees combined with crops increase the households' access to food. In any combination, whether planted along the borders, on hedgerows or blocks, or scattered on the farm, they provide additional harvest for marketing, as well as food for farm families.

Usually scattered or planted along borders of farms, fruit trees such as jackfruit, coconut, marang, mango, and avocado serve as additional sources of nutrients or alternative sources of food during the lean months of supply (Brown 2003). While waiting to harvest their main crops, farming households rely on fruits for their nutrition.

6.4.2 Increasing Food Access Through Augmentation of Income

The farmers in Claveria are primarily driven to agroforestry because of the additional income it can provide (Table 6.1). Agroforestry increases income levels and builds assets that improve purchasing power (Garrity 2004). The profitability analysis showed that agroforestry systems were more efficient in utilizing scarce resources and provided higher returns on farmers' investments than annual cropping. Among the different agroforestry systems, the most profitable was the hedgerow system with a net present value (NPV) of PHP 100,817 ha and annualized net income of PHP 11,107 ha. This was an increase of 137 % compared to the income of farmers practicing annual cropping.

The second most profitable agroforestry system was block planting with NPV of PHP 97,013 ha. Under this system, farmers with only one parcel of land would usually allocate 50–65 % of the total farm area to trees and 35 % to crops. Farmers optimized the use of the land for food crop production by growing annual crops under the timber trees during the first three years of tree growth when sunlight could still penetrate the tree canopy (Dalmacio and Visco 2000). The least profitable among the agroforestry systems was parkland planting, with NPV of PHP 60,216 ha. This could be attributed to the small number of trees planted on the farm. Only about 20–25 % of the area could be allocated for timber and fruit trees that were dispersed around the farm, hence the main crops contributed the greater portion of the total income.

It is worth noting that, while timber trees provided income for the households, about 23–56 % of the total benefits from agroforestry were obtained from fruit trees. When corn was not available for consumption and for market, farmers sold bananas and coconuts to generate income with which to purchase rice and other foods. Hence, farmers preferred fruit trees to timber trees.

6.5 Predicting the Long-Term Productivity, Economic Feasibility, and Sustainability of the Smallholder Hedgerow Agroforestry System Using the WaNuLCAS Model

This study aimed to predict and assess the long-term productivity, economic feasibility, and sustainability of a *Eucalyptus*-maize hedgerow agroforestry system using the WaNuLCAS model. The results of simulation here were compared with those obtained from simulation of a continuous maize mono-cropping system (Magcale-Macandog and Abucay 2012).

6.5.1 Bioeconomic Modeling Using WaNuLCAS

The WaNuLCAS model was used to determine the complementary effects of trees and crops in the agroforestry systems to improve crop yields. The parameterization of the model used primary data from field experiments as well as secondary data.

WaNuLCAS is a process-based model of the water, nutrient, and light capture in agroforestry systems developed by van Noordwijk et al. (2004). It enables evaluation of the choice of tree species, their spacing and pattern, and possible intercrop.

Parameter values for the model were gathered through field measurements, literature survey, and interviews with farmers. The parameters were used as inputs into the WaNuLCAS model, either directly or indirectly, through sub-routines including Functional Branch Analysis (FBA), Pedotransfer, and WOFOST.

6.5.1.1 Tree and Crop Database

A survey form to describe trees (Treeparam) was designed together with the WaNuLCAS model for parameterization of the tree component (van Noordwijk and Mulia 2002). Default values for the various parameters of the maize crop were available in the crop database of the model. The tree and crop parameters in the databases were part of the input parameters required in the simulation using the WaNuLCAS model.

6.5.1.2 WaNuLCAS Parameterization

The land-use scenarios modeled were the continuous maize (*Z. mays*) cropping system and the bagras (*E. deglupta*) and maize hedgerow agroforestry system. A seven year-old bagras hedgerow with a spacing of 1 × 10 m intercropped with maize was selected for the simulation. N and P fertilizers were applied at rates of 15.65 and 16.65 g/m^2, respectively, for all plots. P was applied at planting, while N was applied 30 days after emergence. Climatic data were collected from the field site and the Misamis Oriental State College of Agriculture and Technology (MOSCAT) Agromet station. Soil samples were collected from the field and analyzed for chemical and physical properties.

6.5.2 Water Balance

In both the *Eucalyptus*-maize system and maize mono-cropping, subsurface flow and water draining into the different zones and layers accounted for more than half of the water balance in the systems. Water loss through soil evaporation was higher in maize mono-cropping. However, canopy evaporation was higher in the hedgerow system than in the maize system. Water uptake by maize was higher than by the trees in the *Eucalyptus*-maize hedgerow system.

6.5.3 Soil Loss

Continuous maize cropping resulted in greater cumulative soil loss (>100 ton/ha) than the *Eucalyptus*-maize hedgerow system (60 ton/ha) (Fig. 6.5). The greater

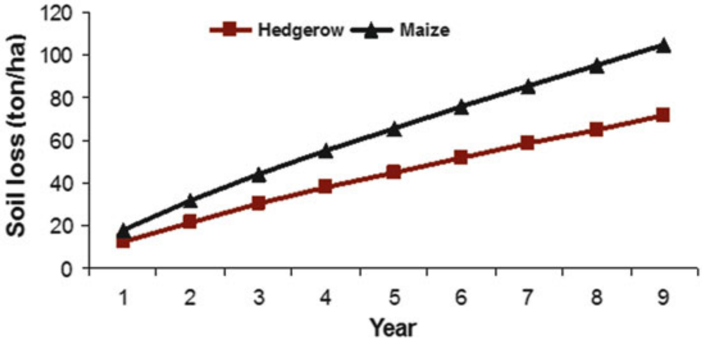

Fig. 6.5 Simulated cumulative soil loss in *E. deglupta*-maize hedgerow and maize mono-cropping systems

cumulative soil loss in the former was due to cultivation of soil for raising maize. On the other hand, *E. deglupta* hedgerows served as barriers to minimize loss of eroded soil from the system.

6.5.4 Crop Yield and Biomass

Simulation results using the WaNuLCAS model showed that maize yield was initially higher in the continuous annual cropping system (2.4 ton/ha) than in the *Eucalyptus*-maize hedgerow system (1.5 ton/ha). This indicates significant competition for light between trees and crops under the latter, as reflected in the low crop yield (Fig. 6.6).

However, yields of maize under both systems declined through the years. Yield from the mono-cropping system exhibited steeper decline than in the *Eucalyptus-maize* hedgerow system. This could be attributed to the greater loss of rich topsoil due to erosion in maize mono-cropping. Tree biomass, on the other hand, increased as the trees grew during the simulation period (Fig. 6.6).

6.5.5 Private Benefits of the Two Land Use Systems

The benefits obtained were grain yield from the maize mono-cropping, and grain yield and timber from the *Eucalyptus*-maize hedgerow system. Cost benefit analysis showed the *Eucalyptus*-maize hedgerow system having higher NPV after 9 years of simulation than the continuous maize (PHP 304,323 vs. PHP 20,872).

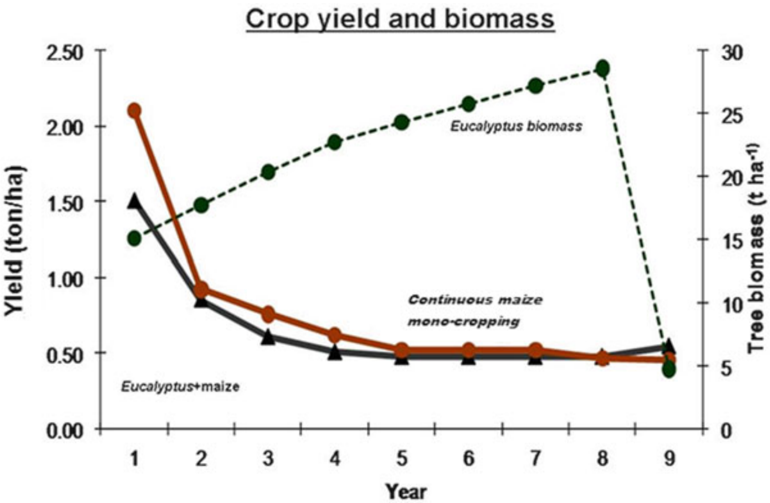

Fig. 6.6 Simulation results using the WaNuLCAS model showing crop yield under the *Eucalyptus* hedgerow system and annual mono-cropping system as well as *Eucalyptus* biomass in Claveria, Misamis Oriental, Philippines, after running for a 9-year continuous cropping period

6.6 Conclusion

Farmers in Claveria develop innovations in the type of agroforestry systems they adopt. The agroforestry system chosen by farmers varies with their motivations. If the primary motive is to obtain additional income, they adopt block planting, border planting, or a parkland system. For soil conservation, farmers prefer the hedgerow system or natural vegetative strips.

The results of the present study have shown that tree spacing affects the nutrient and water dynamics of hedgerow agroforestry systems. Wide hedgerow spacing had higher nutrient inflows and outflows while narrow hedgerow spacing resulted in higher depths of stemflow and throughfall.

The introduction and adoption of an agroforestry system among upland farmers has enhanced their earning capacity and food security. Agroforestry is an essential part of the effort to feed the hungry people in the uplands. While agroforestry efforts cannot substantially alter the social, economic, and political factors that cause food supply inequalities, they can help build up household food security. The integration of trees in agroforestry systems can also help prevent land degradation, increase biodiversity, and at the same time allow the continued use of the land for agricultural crop production.

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