Assessing the profitability and sustainability of upland farming systems in Cambantoc subwatershed, Philippines

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Abstract. Deforestation, forest and land degradation affect the provision of ecosystem services in the watersheds of Laguna Lake. The study site, Cambantoc Subwatershed, experiences unsustainable upland farming practices that worsen the flooding situation in the downstream areas. This study analyzed rice monocropping and agroforestry farming systems upstream based on measures of profitability, sustainability, and soil quality using the Benefit-Cost Analysis and Soil Changes Under Agroforestry (SCUAF) model. Data on the costs and benefits of the farming systems and the parameters used in calibrating the model were acquired through interviews and secondary data collection. The study found that monocropping is more profitable while agroforestry has better environmental benefits because it can minimize soil erosion and soil nutrient loss through time. Agroforestry is an ideal example of Nature-Based Solution to achieve sustainable farming and enhance the delivery of ecosystem services such as soil nutrient enrichment in the upstream farms and flood mitigation in the downstream areas. The results of this study can serve as a decision support for the policy makers to consider developing and implementing market-based instruments to capture the total benefits of agroforestry to both upland farmers and downstream communities.

1. Introduction

In the Philippines, roughly 24 million people or a third of its population lived in upland areas in 2000 [1] and a great proportion of them depend on farming as their only source of income [2]. Upland areas in the country occupy approximately 50% of the land surface where 6 million ha of public forestland are under agricultural cultivation [3].

Farming systems in the uplands are primarily oriented towards subsistence production and shifting cultivation, permanent cultivation, home gardens, grazing, and any combination of these [3]. However, as the population increases in the uplands, agricultural extensification also increases - transforming forest lands to agriculture in order to address increasing food demand. Moreover, portions of the upland areas are increasingly being converted to permanent and intensive cultivation, oftentimes using monocropping of high valued crops. Intensive cultivation without adopting suitable soil conservation practices will contribute to high soil loss rates and nutrient leaching that pose risks on the long-term sustainability and productivity of the soil upland resource base [4].

Agroforestry system can be a viable response to agricultural extensification and intensification problem as it exemplifies Nature-based solution that has the potential to improve soil health and provide economic benefits [5]. Agroforestry in the Philippines can be classified according to their dominant component, that is, agricultural crops, forest trees, and animals [6]. However, despite the benefits of agroforestry in securing food supply, reducing poverty, protecting upland environment, and enhancing biodiversity [6], many upland farmers still continue practicing monocropping and other harmful agricultural practices because of lack of awareness of benefits of and incentives to practice agroforestry and other sustainable farming systems.
The study focused on the upstream area of the Cambantoc subwatershed in the Mount Makiling Forest Reserve, a government forest reservation which is being administered by the University of the Philippines Los Baños for use in forestry education and information. The specific study area covers portions of the upland barangays of Cambantoc Subwatershed, which includes the barangays (villages) of Bagong Silang in Los Baños; and Bitin, Masaya, Paciano Rizal, Sta. Cruz and Tranca in Bay, Laguna, Philippines. Because of the prevailing land uses, parts of this 1,618 ha sub-watershed are degraded and highly eroded [7] and pose flooding risks in the downstream areas [8].

The general objective of this study was to assess the profitability and environmental sustainability of the monocropping and agroforestry farming systems in the Cambantoc Sub-watershed in order to inform government agricultural and land use policy. The specific objectives were to: 1) compare the profitability of the monocropping and agroforestry farming systems using Benefit Cost Analysis and Net Present Value (NPV) criterion, 2) evaluate the soil changes (fertility and erosion) associated with the two farming systems, and 3) recommend appropriate policy support to incentivize sustainable farming systems.

2. Materials and methods

2.1. Data collection

The study selected six upland barangays that were implementing the two farming systems being studied: monocropping (rice) and agroforestry. Based on the list and profile of community members given by each of the barangays, twenty-three (23) farmers representing the two farming systems were randomly selected for interview on May 23-27 in 2019 using a structured pre-tested questionnaire. The number of samples is justifiable as the data acquired was used for statistical analysis, with the typical farmers representing the two farming systems analyzed. The profitability analysis (BCA, NPV) made use of the data acquired from the farmers’ interview. The analysis of soil changes (as a proxy of environmental sustainability) focused on soil erosion and analysis of soil nitrogen (N), carbon (C), and phosphorus (P) contents. Both soil erosion and chemical analyses made use of secondary data obtained from the Municipal Planning and Development Office (MPDO). The information gathered is supplemented by unstructured interviews with the Municipal Agrarian Office and barangay officials.

Secondary data derived from the Comprehensive Land Use Plan and other literature were used for the calibration of SCUAF 5 to model the soil impact of the farming systems in terms of both erosion and fertility parameters.

2.2. Data analysis

Data acquired from the survey interviews such as labor, materials inputs, output prices, and input prices were summarized and used in the financial Benefit-Cost Analysis (BCA). The study used the net present value (NPV) indicator as a measure of profitability for the two farming systems. The NPV for each farming system was computed as follows:

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

where: \( B_t = \) benefits of farming system (yield market value) i at time t; \( C_t = \) cost of farming system (inputs, labor cost, fertilizers used, etc) i at time t; \( T = \) time horizon considered in the analysis; \( r = \) discount rate (%).

The NPV was deemed to be a suitable indicator in measuring financial viability of farming investments as supported by literature. Components of NPV will be mentioned in Section 2.3.

The current social discount rate (10%) set by the National Economic and Development Authority (NEDA) [9] was used and the time horizon was set to 30 years. Possible economic risks on the profitability of the farming systems were determined using sensitivity analysis using these scenarios: (a) 5% discount rate; (b) 10% discount rate and 10% increased cost of labor and material inputs; (c) 10% discount rate and lowered price of outputs at 10%; (d) 15% discount rate; (e) 20% discount rate. Sensitivity analysis was deemed to be fit for examining the results from the BCA indicators, as measures of profitability, particularly on determining the risk factors at varying inputs and discount rates [10].

In terms of the soil impact of the farming systems, Soil Changes Under Agriculture, Agroforestry, and Forestry (SCUAF 5) [11] was used. SCUAF is a computer model which predicts the effects on soils of specific land-use systems given environmental conditions. It is a process-response model wherein
the user specifies the physical environment of the area, the land-use system, initial rates of plant growth, and the rates of operation of soil. This model was deemed to be fit for the assessment for it is able to predict changes of soil conditions including the nitrogen, phosphorus and potassium (NPK) content, carbon, and soil depth changes under the biophysical and land use parameters [12,13]. Policy recommendations were identified based on the results of the study.

2.3. Data sources and variables in BCA
Data on costs acquired from each farmer in 2019 include: labor costs (depend upon number of man-days, man-animal/ machine-days and machine/animal days and corresponding labor price) for establishment until the harvesting phases; and material inputs (planting material, fertilizer, herbicide, pesticide, pole). Price of crops and each respective yield obtained from the interview were used to calculate each of the farmer’s gross revenue per crop. Values of costs and gross revenues per farmer were for the whole year depending on the cropping cycle per year stated by the farmers. These were checked if these matches the standardized yield and input price based on article sources. The values were then divided into the corresponding farm size (ha) per individual farmer. From these, mean values were generated for gross revenue (USD/ha/year), labor cost (USD 578/ha/year), material inputs cost (USD 433/ha/year) and net revenue (USD/ha/year) which were analyzed for the BCA and sensitivity analysis. To estimate the EAB of the farming system, the annuity factors were calculated for the respective discount rates.

2.4. Model parameterization in SCUAF 5
The values set for the physical parameters in SCUAF 5 are: lowland humid (climate), gentle slope of the farming systems, medium soil texture, free drainage, acidic soil reaction, and intermediate soil fertility status, which were acquired based on the descriptions from the CLUP of Bay and articles related to Mt. Makiling Forest Reserve [14]. Fraction of tree and crop for agroforestry was set based on the mean fractions from the respondents (Table 1). Likewise, mean kg per hectare per year was used for the inorganic fertilizer (4.636) for both land-use systems. Information for the years input on the SCUAF 5 model was set into 10 years for 3 periods, resulting in 30 years, supposing that the average maximum productivity of the perennial species for agroforestry is 10 years [15]. Period was set into 3 to visualize the trends in the long-run for sustainability assessment.

Table 1. Description and average size of farming systems and fractions of agricultural crops and fruit trees

| Farming system | Average Size (ha) | Description |
|----------------|------------------|-------------|
| Monocrop (rice) | 1                | Rice plantation (100% of the area devoted to rice), chemical fertilization, basic land operations for rice production (includes tilling, plowing, etc.), irrigated Farmer’s current practice of annual cropping system with fruit trees |
| Agroforestry   | 1.37             | (80 of area devoted to annual crops and 20 % of area devoted to fruit trees), fertilization for agricultural crops, basic land operations for fruit trees (tilling, composting), rainfed |

3. Results and discussions

3.1. Profitability and sensitivity analysis
Generated values of economic indicators of the two farming systems at the baseline scenario (social discount rate at 10% [7]), imply that these farming systems are profitable as both have positive NPVs ($). Monocropping of rice is more profitable than the agroforestry system as it has higher NPV in all the different discount rates (5, *10, 15 and 20%) as shown in Table 2. This is brought about by the limited fruiting season and amount of harvest of tree species from the agroforestry system that varies on a monthly basis as affected by typhoons [16]. Moreover, middlemen buy most of the agroforestry fruits at a very low price according to the interviews and as supported by literature [17]. These reflect the opportunity cost of the agroforestry system compared to monocropping of rice crop.
**Table 2.** 30-year cash flow of monocropping and agroforestry at different discount rates (DR)

| Scenarios     | Farming systems NPV (USD) |
|---------------|----------------------------|
|               | Monocropping | Agroforestry |
| 5% DR         | 23,314.22    | 2,840.43     |
| *10% DR       | 14,297.08    | 4,993.97     |
| 15% DR        | 9,958.12     | 1,821.34     |
| 20% DR        | 7,551.17     | 1,268.77     |

Note: $1 = ₱50; * Baseline scenario (Social Discount Rate [7])

Monocropping and agroforestry systems were subjected to sensitivity analysis using varying economic scenarios (Table 3). Economic indicator NPV is also presented to show the profitability of each farming system over a 30-year time period.

In Table 3, monocropping of rice was deemed more profitable under the scenario where the cost of materials and labor is increased at 10% at a social discount rate of 10%. Agroforestry, like monocropping, has positive NPVs under the scenario where there is a lowered price of output at 10% at a 10% social discount rate. It was indicated by their positive net present values. Although both were profitable, monocropping still outperformed agroforestry.

**Table 3.** 30-year cash flow of monocropping and agroforestry at different scenarios

| Scenarios                             | Farming systems NPV ($)  |
|---------------------------------------|--------------------------|
|                                       | Monocropping | Agroforestry |
| 10% DR and cost increased at 10%      | 11,153.52    | 2,155.49     |
| 10% DR; low PRICE output at 10%       | 9,723.82     | 1,476.51     |

Note: USD1 = PHP50

Despite the uncertainties from the changing discount rates, the values obtained suggest that both farming systems are still profitable at all discount rates and other concomitant scenarios on lower price and increased cost, with monocropping of rice being more profitable and efficient compared to the values of agroforestry system. The scenario on lower price of output at 10% discount rate implies the worst-case results for the farming systems among any other scenarios as the economic indicators are on their lowest values. Agroforestry declined at around 62% from its NPV baseline whereas monocrop decreased at around 32%.

3.2. Soil quality modeling

SCUAF 5 was used to further assess the two land systems according to their soil erosion, nutrient deficiency and recycling properties. The projection was set to thirty (30) years as shown in Figures 2 and 3.

3.2.1. Soil erosion. The annual erosion and soil depth of the two farming systems projected over 30 years are graphically shown in Figure 2. Both farming systems experienced soil loss and declining soil depth over time. However, soil loss appeared greater and steeper under the monocrop system until year three at the rate of 30,878 kg/ha/yr, afterwards a constant amount of around 48 kg/ha/yr was observed until year 30 (Figure 2 left).

The agroforestry system, in contrast, experienced a much slower rate for soil loss of an average of 2,747 kg/ha/year (Figure 2 left). The decline in soil depth was also more conspicuous under the monocrop system than under the agroforestry system (Figure 2 right). This implies that the agroforestry system is comparably more protective of soil cover than the monocrop system which can also provide flood mitigation and climate change amelioration, among other ecosystem services [18].
Figure 1. Thirty (30) years projection of the rate of soil loss (left) and soil depth (right) after soil erosion in the two farming systems.

3.2.2. Carbon, nitrogen and phosphorus content in soil

The SCUAF model simulated changes in soil organic carbon and plant nutrients (Nitrogen and Phosphorus) under the monocrop and agroforestry systems. The results project that the soil’s Carbon (C), Nitrogen (N), and Phosphorus (P) will decrease over time due to erosion under both farming systems (Figure 3). However, the quantity, timing, and rate of loss of C and nutrients for both farming systems differed. To illustrate, in terms of soil carbon content, the monocropping system exhibited much higher C content (blue line) than the agroforestry system (orange line). However, while the C content under agroforestry was increasing at slow but steady rate up to year 27 when it appeared to stabilize, the C content under the monocropping system exhibited a much rapidly rising C content until year 23, when a drastic decline was projected. This observation may be attributed to the ability of agroforestry systems to store up more carbon in the soil as organic matter in the soil accumulates over time, trees and shrubs can store greater amounts of carbon in belowground biomass [19]. The abrupt loss of C under the monocropping system at the later stage of cultivation may be attributed to the loss of soil organic matter over time. Therefore, incorporating trees and shrubs into agroforestry systems can increase carbon sequestration compared to monoculture pastures [18].

Both the monocrop and agroforestry systems registered a slightly increasing soil N content over time, with the latter containing more. However, the N content under the monocrop system started to decline at year 23 while that for the agroforestry continued to increase, stabilizing only at year 27. The P content and decline trend in both the agroforestry and monocrop systems are similar. These results (C, N, P) suggest the tendency of soil carbon and soil fertility to decline over time under the monocropping system, i.e. agroforestry being more protective.

Figure 2. Thirty (30) years projection of the Carbon (C), Nitrogen (N), and Phosphorus (P) content in soil of the two farming systems
3.2.3. Nutrient deficiency and recycling

The Total Nitrogen (TN) content in soil of the two farming systems presented in Figure 4 shows that under the monocropping system, the TN needed by the crop exceeds the TN available in the soil. In contrast, the agroforestry farming system’s TN available overshoots the TN needed by crop. Also, under the 30-year projection, the model shows that the agroforestry farming system can provide for the TN needed by existing crops over a longer period.

The Total Phosphorus (TP) content in soil of the two farming systems is presented in Figure 5. For the two farming systems, there are enough available TP to meet the required TP of the crop over a 30-year period. One would note, however, that the agroforestry system offers more allowance in terms of available compared to the required amount of P. This shows the ability of the agroforestry system to provide major nutrients required of crops for a longer time period.

According to a study, forest, soil depth, and their interactions significantly affect the SOC, TN, and TP concentrations and storage, indicating that forest types and soil depth are important factors affecting the soil nutrient distribution [20]. Competition for nutrients is maximized in simultaneous agroforestry systems, particularly short-duration systems such as alley cropping [21,22].

![Figure 3. Thirty (30) years projection of the Total Nitrogen Content (TN) in the two farming systems](image_url)

![Figure 4. Thirty (30) years projection of the Total Phosphorus Content (TP) in the two farming systems](image_url)

4. Conclusions

The study suggests that both the monocropping and agroforestry farming systems are profitable in view of their positive NPVs under all the tested scenarios. Monocropping rice is more desirable in terms of profitability and efficiency and has higher values generated using financial indicators than the agroforestry farming system. The study suggests that the profitability of monocropping systems will be difficult to sustain in the long run due to soil loss, declining soil condition and fertility. In contrast, the agroforestry system can be more profitable and economically and environmentally sustainable in the long run.

From these analyses, it can be deduced that it is crucial to consider the association between the economic, environmental and social elements in sustainable agriculture. Although agroforestry is being promoted as an ideal example of Nature-Based Solution, it may not be as profitable as the monocropping system over a shorter time period. However, if the long-term environmental impacts of monoculture are considered and translated into monetary terms, the agroforestry system may prove to be more
This study can serve as a baseline that can be suggested for policymakers for the improvement of the agroforestry system, as a Nature-Based Solution, through the adoption of a PES (Payments for Ecosystems Services) scheme that will incentivize upland agroforestry farmers to continue their sustainable farming to sustain the ecosystem services needed by the downstream communities. Implementation of the Clean Development Mechanism (CDM) from the Kyoto Protocol is one great example of a PES for carbon sequestration.

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