Ecological Sustainability of Land Uses in the Barobbob Watershed

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ABSTRACT

The study was conducted to assess the carbon stocks and estimate soil loss as indicators of ecological sustainability of major land uses in the watershed, and carbon footprints of farmer-occupants in the Barobbob Watershed at Bayombong, Nueva Vizcaya.

The area was subdivided into agroecological zones based on slopes, which was used as land mapping units. Assessment of sustainability was based on the ecological soundness of major land uses using tree species diversity, soil macro fauna, bacterial and fungal count, fertility level and soil loss as indicators.

The natural forest was ecologically sound due to: (1) potential soil loss was far below the soil loss tolerance; (2) diverse forest tree species; (3) bacterial and fungal populations were abundant; (4) good fertility status as nitrogen and potassium were present in sufficient amounts. However, the agroforestry areas failed to be ecologically sustainable because of higher soil loss than the soil loss tolerance and low fertility status.

The natural forest with a mean diversity index of 1.48 had a substantial amount of carbon with an average value of 323.19 tons C ha^{-1} while the agroforestry with a mean diversity index of 1.19 obtained an average carbon of 157.23 tons C ha^{-1}.

Carbon footprints of farmer-occupants in the watershed ranged from 1.34 to 3.27 t CO_2 ha^{-1}. The firewood contributed the largest share. High income farmer-occupants emitted higher carbon than low income farmers.

INTRODUCTION

Philippine watersheds have been subjected to extreme human activities especially forests. Forest trees play a significant role in maintaining the quantity and quality of water in the catchment areas. Forests generally found in watersheds areas, account for a total area of 15.88M hectares (Forest Management Bureau, 2007). The rapid rate of deforestation over the past 50 years is attributed to rampant logging activities both legal and illegal, which pave the way for forestland conversion into agricultural lands and settlement (Simbulan, 2003). Likewise, increase in land disturbances has aggravated the capability of watershed areas to control the flow of water and further elevated the rate of soil erosion (Barbosa *et al.*, 2006; Brath *et al.*, 2005). Blanco and Nadaoka (2006) mentioned that eroded soils were usually deposited in lakes, river and other water bodies resulting in the degradation of water quality and siltation of river systems which could lead to flooding.

Working on watersheds allows anticipating the impacts of climate change that intensifies extreme weather events such as floods and droughts which impacts land use. Degraded ecosystems are more sensitive to erosion and least for carbon sequestration via its low biodiversity. Management of watersheds necessitates a better understanding of the different physical factors and processes, which influence changes in watershed area. These factors, which affect the dynamics of land cover/land use change and rates of soil erosion, are critical to effective watershed management.

Awareness of the multiple environmental, economic and social benefits provided by watershed has greatly increased in recent decades especially in developing countries where the economy depends predominantly on agriculture. Most of the developing countries are experiencing degradation of land and water resources, whereas the need for these resources is vastly increasing. Sustainable use and management of land can be achieved by adopting a system based on an integrated approach to land resources development with the involvement and participation of different sectors.

The Barobbob Watershed with an estimated area of 420 hectares is jointly managed by the Local Government Unit (LGU) and the Environment and Natural Resources Office (ENRO). The community adopted agroforestry practices to get benefited with the potential of the land to produce yield. Inappropriate and unsustainable technologies of farming could lead to soil degradation and loss of biodiversity. The sustainable approach is highly regarded for the existence of farmer-occupants who will maintain the ecological balance in the watershed. Several studies have indicated the potential contribution of watersheds for carbon sequestration through its enhanced biodiversity. However, ecological sustainability is at stake under the community-based approach of management especially when resources are harvested for subsistence.

The assessment of the ecological sustainability of the Barobbob Watershed would provide basic and additional information on the potential of watershed to mitigate the effects of climate change and the benefits of agroforestry system in supporting community needs. Hence, data obtained from this study can be used as tool in developing or improving sustainable farming practices in hilly areas. Above all, this study would provide additional information to the body of knowledge on the potential of watershed to sequester carbon in the various land cover types.

METHODOLOGY

Delineation of Land Mapping Units

Slope delineated through traditional mapping in accordance with the GIS-generated map procured in the NVSU-CF Laboratory served as land mapping units (LMU) (Table 1).

Soil Sampling and Analysis

Composite soil samples were collected at a depth of 30 cm from the various land mapping units based on the standard procedure for soil sampling. Soil chemical properties

Table 1. Land Mapping Units based on slope

Land Mapping Unit	Slope Class (%)	Description
1	0 - 18	Level to undulating
2	18 - 30	Rolling
3	30 - 50	Steep
4	> 50	Very Steep

that include soil pH, organic matter, nitrogen, phosphorus, and potassium were analyzed.

The methods indicated in Table 2 were used to analyze the physical and chemical properties of soil existing in the LMUs.

Estimation of Aboveground and Belowground Biomass

Aboveground biomass. Due to DENR policy, destructive sampling was not made for large trees. The aboveground biomass of tree species was estimated using the Allometric Equation of Brown (1997) that relates tree diameter to biomass as:

$$Y\ (kg) = 2.718\ \exp\{-2.134 + 2.53 * In * D\}$$

where: Y – Biomass (kg)
In – natural log
D – diameter at breast height

Belowground biomass. The belowground biomass, which was composed of roots from tree species was estimated from the ratio of aboveground to belowground biomass of 4:1 (van Noordwijk *et al.*, 1996 and Ranmankutty *et al.*, 2007).

Estimation of Carbon Stock of Vegetation and Soil Organic Carbon

Carbon stock of above ground biomass comprising tree species in the natural forest and agroforestry areas was estimated by multiplying the carbon content conversion factor of 0.46.

The Primacs TOC Analyzer Model CS 22 which is based on dry combustion at 1050 ^{o}C was used to determine the carbon contents of vegetable crops, grasses, herbaceous plant, shrubs, and soil in each LMU.

Biodiversity Assessment

Number of tree species and number of individuals of each species were determined. For natural forest and agroforestry areas, two quadrats each measuring 5m x 40m or a total area of 200 m2 were randomly selected within a plot of at least one hectare.

The Shannon-Wiener Index was used to determine species diversity:

$$H' = \sum_{i=1}^{s} (P_i)(\log_2 P_i)$$

where: H' – diversity index
S – number of species
Pi – proportion of total sample belonging to i^{th} species

Soil Macrofauna, Bacterial and Fungal Count

Ten representative quadrats each measuring 1m x 1m were established in each the various land mapping units where a total of 50 quadrats were made. Earthworms and larvae

Table 2. Methods for soil analyses

Soil Property	Method
Soil Texture	Hydrometer Method (PCAARD)
Bulk Density	Core Method (Blake, 1965)
pH	Potentiometric Method (PCAARD)
Nitrogen	Soil Test Kit
Phosphorus	Soil Test Kit
Potassium	Soil Test Kit

of beetle were collected up to 30 cm deep by conventional digging and hand sorting method. Worms and larvae were counted and recorded.

A total of 10 composite soil samples were collected from the various land mapping units. The number of bacteria and fungi were determined using Serial Dilution Method.

Estimation of Carbon Footprint of Farmer-Occupants in the Watershed

The Slovin formula was used to get the number of respondents needed as follows:

$$n = \frac{N}{1 + Ne^2}$$

where: n – number of respondents
N – population size (margin of error of 0.01)

The Carbon Footprint was estimated using the Carbon Footprint Calculator-Philippine Version (wwf.org.ph). Key informant interview using a semi-structured questionnaire was used to draw information on the number of household, energy consumption, household activities, and daily waste generated. The contribution of firewood in the carbon footprints was included by converting the weight of wood by the conversion factor of 0.46 to get the carbon emission.

Estimation of Annual Soil Loss

Soil loss estimation in the various land mapping units, the slope classes was done. The study used the Universal Soil Loss Equation (USLE) to estimate soil loss (Wischmeier and Smith, 1978).

The formula is as follows:

$$A = (R)\ (K)\ (LS)\ (C)\ (P)$$

where: A – predicted soil loss (Mg/ha/yr)
R – rainfall and runoff factor
K – soil erodibility factor
LS – topographic factor
C – crop management factor
P – erosion control practice factor

Derivation of the factors in the equation is as follows:

Determination of Rainfall Erosivity Index (R). The R factor, sometimes called rainfall erosion index, takes into account the erosive effects of storm. The total kinetic energy of each storm (related to intensity and total rainfall) plus the average rainfall during the 30 min period of greatest intensity are considered. The sum of the indices for all storms occurring during a year provides an annual index. An average of such indices for several years is used in the USLE.

In the absence of data on maximum 30 min rainfall intensity, the R factor was calculated using two methods, the Morgan (2005) and Roose (1977). Since the R factor from both equations vary greatly, the average R value from the two methods was taken as the final R factor. The formulas for computing the R value as describe by Morgan and Roose are as follows:

$$R = [(9.28P – 8838.15) \times 75]/1000 \quad \text{(morgan, 2005)}$$

where: R – rainfall erosivity factor
P – mean annual rainfall
9.28; 8838.15; 75 - constants

$$R = P \times 0.50 \times 1.73 \quad \text{(Roose, 1977)}$$

where: R – rainfall erosivity factor
P – mean annual rainfall
0.50; 1.73 - constants

Determination of Soil Erodibility Index (K). The soil erodibility index (K) is defined as the mean annual soil loss per unit of erosivity for a standard condition of bare soil, no conservation practices, 9% slope of 22m length.

The K factor is usually evaluated using tables or nomograph. However, in this study, the K factor was evaluated using the equation described by David (1985) as:

$$K = (0.043H + 0.62/OM + 0.0082Sa - 0.0062C)Si$$

where: K – soil erodibility factor
H – soil pH
OM – organic matter
Sa – sand
Si – silt
C – clay
0.043; 0.62; 0.0082;0.0062 - constants

Determination of Slope Length and Steepness (LS). The factors of slope length (L) in meters and slope steepness (S) in percent were combined in a single index. A value of 1.0 applies to the standard 9% slope, 22m long. The value of LS was obtained from the equation (Hudson, 1981) as:

$$LS = \sqrt{\frac{L}{22.13}}\ (0.065 + 0.045S + 0.0065S^2)$$

where: L – slope length (m)
S – percent slope

Determination of Crop Factor (C). It represents the ratio of soil loss under a given crop to that from bare soil (Wischmeier and Smith, 1978). Since soil loss varied with erosivity and the morphology of the plant cover, it was necessary to take into account the changes in these during the year in arriving at an annual value. The value of C ranged from 0.001 to 1.0. However, the C values under this study were estimated based on the cropping sequence, surface residue, canopy cover, and tillage practices.

Determination of Conservation Practice Factor (P). Conservation practice factor is the ratio of soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage.

The P value used in the study was estimated from conservation measures like contouring, contouring with crop strip and terracing (Morgan, 2005). The absence of any measures is expressed by a value of 1 while 0.1 for tied ridging when applied on a gentle slope. Fifty percent of the P value for contouring was used for contour strip cropping.

RESULTS AND DISCUSSION

The watershed had a rugged terrain of which 42.38 % (178 ha) of the total land area had a steep to very steep topography. One hundred twenty two (122) hectares or 29.05% are classified as alienable and disposable (AandD) land while 120 hectares or 28.57% were rolling lands.

The A and D (Table 3) lands were situated from as low as 400 m above sea level (asl) to as high as 500 m asl. Most of the settlements were found in this land mapping unit.

Table 3. Slope classes found in the Barobbob Watershed

Slope Class (%)	Description	Area (ha)	% OCCUPIED
0 – 18	Level to undulating	122	29.05
18 – 30	Rolling	120	28.57
30 – 50	Steep	101	24.05
>50	Very steep	77	18.33
TOTAL		**420**	**100.00**

Table 4. Current land uses at Barobbob Watershed

Slope Class (%)	Land Use	Area (ha)	%Occupied
0 – 18	Agroforestry (home garden)	85.00	20.09
	Agroforestry (fallow system)	37.00	8.96
18 – 30	Agroforestry (fallow system)	120.00	28.57
30 – 50	Natural forest	101.00	24.04
>50	Natural forest	77.00	18.33
TOTAL		**420.00**	**100.00**

Major Land Uses

There were two major land uses at the Barobbob Watershed, namely: natural forest and agroforestry (Table 4).

The natural forest with a total land area of 178.00 ha is a protected ecosystem that does not require heavy input for regeneration as they spontaneously reproduced themselves. There was no distinct pattern of replanting of forest tree species on denuded portion where timber poaching is present.

The natural forest at the western side of the watershed occupied a total land area of 178.00 ha. The plant community consisted of indigenous and introduced species. The former include balobo (*Diplodiscus paniculatus*), malaikmo (*Celtis philippinensis*), white lauan (*Shorea contorta*) and tanguile (*Shorea polysperma*) which are still the dominant species that are spatially distributed within the watershed while introduced species include, yemane (*Gmelina arborea*) and narra (*Pterocarpus indicus*).

On the other hand, agroforestry areas were scattered in patches that occupy about 242 ha or 57.62 % of the total land area of the watershed. The agroforestry (home garden) had a total land area of 85.00 ha while the agroforestry (fallow system) occupied 420 ha (37.53%) of the total land area. It had distinct layers of trees/fruit trees, shrubs, herbaceous plants, and vegetable crops. Introduced species such as yemane (*Gmelina arborea*) are dominant over the indigenous species like bolobo (*Diplodiscus paniculatus*) and tanguile (*Shorea polysperma*) that constitute the uppermost layer. Trees were grown by farmers to protect the soil from the harmful effects of high intensity sunlight and rainfall, and moisture conservation. Meanwhile, fruit trees that include jack fruit (*Artocarpus heterophyllus*), mango (*Mangifera indica*), avocado (*Persea americana*) and suha (*Citrus grandis*) were also part of the uppermost layer, These are planted by farmers to provide fruits for their families. The lowermost layer was composed of vegetable crops that include snap beans (*Phaseolus vulgaris*), squash (*Cucurbita maxima*), and tomato (*Lycopersicon esculentum*).

Carbon Sequestration

The total biomass ranged from 126.70 to 275.27 tons ha^{-1} (Table 5). The agroforestry (home garden) constituted of aboveground and belowground biomass of trees and vegetable crops, with a total biomass of 126.70 tons ha^{-1} was calculated at slopes 0 – 18%. Biomass under fallow system of the same slope class was 144.53 tons ha^{-1}. Biomass of 172.01 tons ha^{-1} was obtained from slopes 18 – 30% under agroforestry (fallow system) that comes from the mixture of trees, grasses, shrubs, and herbaceous vegetation. A conspicuous difference was observed between the aboveground biomass of agroforestry (home garden) and agroforestry (fallow system) at slope 0 – 18%.

Table 5. Total biomass at different land uses in the Barobbob Watershed

Slope Class (%)	Land Use	Aboveground Biomass		Below Ground Biomass	Total (tons ha^{-1})
		Trees	Vegetation		
0 – 18	Agroforestry (home garden)	97.00	5.45	24.25	126.70
	Agroforestry (fallow system)	111.00	5.78	27.75	144.53
18 – 30	Agroforestry (fallow system)	135.72	2.36	33.93	172.01
30 – 50	Natural forest	163.96	14.98	40.99	219.93
> 50	Natural forest	207.56	15.82	51.89	275.27

The agroforestry (home garden) obtained a biomass of 97 tons ha^{-1} that increases to 111.00 tons ha^{-1} under fallow system, whereas the agroforestry (fallow system) at slopes 18 – 30% have a value of 135.72 tons ha^{-1}. Belowground biomass had similar trend as the aboveground biomass.

There was a remarkable increase of biomass of the understory vegetation of agroforestry (home garden) and agroforestry (fallow system). A value of 5.45 tons ha^{-1} was obtained at 0 – 18% slopes which increased to 5.78 tons ha^{-1} under fallow system of the same slope class. The increase was a result of a denser canopy cover provided by grasses, shrubs and herbaceous plants under the fallow system. The open space under home garden conspicuously has a lesser biomass stored.

The total biomass of the natural forest that comes from tree species, grasses, shrubs and herbaceous vegetation have a value of 219.93 tons ha^{-1} at slopes 30 – 50% and 275.27 tons ha^{-1} at slopes >50%. The understory vegetation cover obtained a value of 14.98 tons ha^{-1} at slopes 30 – 50% and 15.82 tons ha^{-1} at slopes >50%. The dense understory cover provided by grasses, shrubs, and herbaceous plants at the natural forest yielded a better biomass than any other land uses irrespective of slope classes. The aboveground biomass from trees have a value of 163.96 tons ha^{-1} at slopes 30 – 50% and 207.56 tons ha^{-1} at slopes >50%; which the belowground biomass had the same trend. The large biomass under this land use situated at higher slope classes is attributed to the size and abundance of tree species constituting the upper canopy strata.

The CO_2 fixed by photosynthesis is one of the most important components of the carbon cycle, where forests play a determinant role, being thus considered as large and persistent carbon sinks (Pan *et al.*, 2011).

The agroforestry (home garden) located at slopes 0 – 18% had a total carbon stock of 133.64 tons C ha^{-1} that increased to 158.07 tons C ha^{-1} in the agroforestry (fallow system) of the same slope class, whereas a total carbon stock of 179.99 tons C ha^{-1} was obtained at slopes 18 – 30% (Table 6). On the other hand, slopes 30 – 50% and >50% under natural forest obtained total carbon stocks of 286.17 tons C ha^{-1} and 360. 21 tons C ha^{-1}, respectively. Meanwhile, the soil provided large stocks of carbon in the various land mapping units as it ranged from 75.46 to 225.00 tons C ha^{-1}. The results of the study were consistent with the findings of Lasco and Pulhin (2003) that tropical forests contain substantial amounts of carbon up to 200 tons C ha^{-1}. The difference of SOC in all the land mapping units is attributed to plant material input and rate of decomposition. The natural forest has larger input of plant residues than agroforestry areas via its dense vegetation cover. Availability of oxygen for decomposition plays a major factor on the stored carbon in the soil. A disturbed ecosystem connotes poor carbon sink, which releases carbon in the form of CO_2 via oxidation process. Forest ecosystems, which is rated as one of the largest carbon sinks, could help mitigate the effects of climate change.

Diversity of Tree Species

Tree species found in the watershed include tanguile (*Shorea polysperma*), yemane (*Gmelina arborea*), narra (*Pterocarpus indicus*), balobo (*Diplodiscus paniculatus*), malaikmo (*Celtis philippinensis*) and white lauan (*Shorea contorta*).

Diversity indices from the different land mapping units ranged from 0.96 to 1.57 (Table 7). The natural forest at slopes 30 – 50% and >50% registered diversity indices of 1.38 and 1.57, respectively. There was a remarkable decrease of diversity indices in the agroforestry areas at slopes 0 – 18% and 18 – 30% with an average value of 1.19. The natural forest had a better diversity indices over the agroforestry due to the abundance of indigenous species (Appendix tables 1, 2 and 3).

Trees were more evenly distributed at slopes 18 – 30%, 30 – 50% and >50% with evenness values of 0.98, 0.99 and 0.98, respectively while slopes 0 – 18% had the least

Table 6. Total carbon stock at different land uses in the Barobbob watershed

Slope Class (%)	Land Use	Aboveground Carbon		Below Ground Carbon	SOC	Total (tons C ha^{-1})
		Trees	Vegetation			
0 – 18	Agroforestry (home garden)	44.62	2.40	11.16	75.46	133.64
	Agroforestry (fallow system)	51.06	2.31	12.27	92.43	158.07
18 – 30	Agroforestry (fallow system)	62.43	0.97	15.61	100.98	179.99
30 – 50	Natural forest	75.42	5.59	18.86	186.30	286.17
> 50	Natural forest	95.48	5.86	23.87	225.00	360.21

Table 7. Diversity of tree species in the Barobbob watershed

Slope Class (%)	Land Use	Area (ha)	Diversity Index (H)	Maximum Diversity (Hmax)	Evenness (E)
0 – 18	Agroforestry (home garden)	85.00	0.96	1.10	0.87
	Agroforestry (fallow system)	37.00	1.25	1.39	0.90
18 – 30	Agroforestry (fallow system)	120.00	1.36	1.39	0.98
30 – 50	Natural forest	101.00	1.38	1.39	0.99
> 50	Natural forest	77.00	1.57	1.61	0.98

with an average value of 0.89. Slopes 0 – 18% were utilized for agricultural production by the community affecting abundance and diversity of tree species. Tree species were not maintained because of competition sunlight, nutrients, water, and space. Trees were integrated with the crops to provide windbreak, control soil erosion, and as source of fruits and fodder. A high diversity index and evenness under natural forest revealed the consistency of the forest management approach in the watershed as part of the MOA between the community and provincial government.

Soil Macrofauna

Table 8 presents the number of earthworm and beetle larvae in the watershed. The natural forest (slopes 30 – 50% and >50%) obtained an average population of earthworm and beetle larvae of 17 per m^2 and 16 per m^2, respectively. A marked drop of macrofaunal population in the agroforestry areas (slopes 0 – 18% and 18 – 30%) with an average value of 9 per m^2 for earthworm and 4 per m^2 for larvae of beetle. The results of the study were not consistent with the findings of Chaudhuri *et al.,* (2007) in rubber plantations in Tripura, India where mean values for earthworm density and biomass were 108.6 m-2 and 13.1 g per m^2, respectively. Earthworms were exposed to soil temperature of 25.9 ^{o}C, moisture of 24.8%, pH of 4.85, and organic matter of 1.8%.

The low number of earthworm and beetle larvae in agroforestry areas was attributed to low organic matter content, which is a vital source of carbon and energy for soil macrofauna.

Bacterial and Fungal Count

Bacteria were dominant over fungi in all land mapping units (Table 9). Bacterial count ranged from 1.15 to 3.48 x 106 cfu per g soil. Bacterial count of 3.48 x 106 cfu per g soil was obtained in the natural forest at >50% slopes, however, there was a huge drop of population at 30 – 50% slopes with a value of 2.33 x 106 cfu per g soil.

Bacterial population of 1.15 x 106 cfu per g soil was obtained at slopes 18 – 30% under fallow system. An increased number of 3.40 x 106 cfu per g was noted under cultivation for vegetable crops.

Fungal count ranged from 1.11 to 2.20 x 106 cfu per g soil. The natural forest at slopes 30 – 50% and >50% fungal populations of 1.93 x 106 and 2.20 x 106 cfu per g soil, respectively. There was a notable drop in population at slopes 0 – 18% and 18 – 30% under agroforestry system with a mean value of 1.76 x 106 cfu per g soil. These results are consistent with the findings of Akpor *et al.,* (2005) stated that the total bacterial counts ranged from 1.2 x 106 to 8.1 x 107 cfu per g leaf litter soil, while fungal counts were at the order of 103 to 104 cfu per

Table 8. Macrofauna at different land uses in the Barobbob Watershed

Slope Class (%)	Land Use	Earthworm per m^2	Larvae of Beetle per m^2
0 – 18	Agroforestry (home garden)	6	3
	Agroforestry (fallow system)	10	6
18 – 30	Agroforestry (fallow system)	12	5
30 – 50	Natural forest	15	18
> 50	Natural forest	19	15

g leaf litter soil. In addition, Adekunle and Dafiwhare (2011) stated that in Akure forest reserve in Nigeria bacterial population ranged from 26.14 x 106 to 36 x 106 MPN g^{-1} dried soil while fungi ranged from 2.50 x 106 to 23.34 x 106 MPN g^{-1} dried soil.

The dominance of bacteria over the fungi *in situ* clearly applies the concept of microbial growth rate. Bacteria are smaller in size than fungi, which reproduce at a faster rate through binary fission (cell division) than fungi. The presence of sufficient carbon and energy sources in the watershed connotes the abundance of the two microorganisms.

Carbon Footprints of Farmer-Occupants in the Watershed

Majority of the respondents having an income ranging from Php5,001.00 to Php10,000.00 emitted 2.69 tons CO_2 per year (Table 10). Farmer-occupants having an income of Php15,001.00 to Php20,000.00 registered the highest emission of 3.27 tons CO_2 per year.

Wood consumption constituted the largest share of carbon emission ranging from 0.92 to 2.70 tons CO_2 per year. Majority of the farmers used more wood than LPG for cooking due to availability and financial reason. Waste generated by farmers posted next in rank of the amount of emitted carbon. Likewise, the yearly carbon emission of the respondents increased as their income increased. Majority of the respondents having an income ranging from Php5,001.00 to Php10,000.00 emitted 2.69 tons CO_2 per year. Meanwhile, farmer-occupants having an income of Php15,001.00 to Php20,000.00 registered the highest emission of 3.27 tons CO_2 per year. The amount of

Table 9. Bacterial and fungal count at different land uses in the Barobbob Watershed

Slope Class (%)	Land Use	Bacteria (10^6 cfu per g soil)	Fungi (10^6 cfu per g soil)
0 – 18	Agroforestry (home garden)	3.40	2.10
	Agroforestry (fallow system)	2.13	2.08
18 – 30	Agroforestry (fallow system)	1.15	1.11
30 – 50	Natural forest	2.33	1.93
> 50	Natural forest	3.48	2.20

Table 10. Carbon footprints of farmer occupants in the Barobbob Watershed

Income Category (Php)	No. of Farmer	Tran.	LPG	Wood	Elec.	Waste	Total (tons CO_2 per yr)
<5000	1	0.02	0.07	0.92	0.04	0.29	1.34
5001-10000	45	0.07	0.007	2.35	0.02	0.24	2.69
10001-15000	25	0.14	0.003	2.47	0.04	0.29	2.94
15001-20000	8	0.22	0.008	2.70	0.06	0.28	3.27
>20000	2	0.56	0.02	1.39	0.09	0.25	2.31
TOTAL	**81**						**12.55**

carbon releasd from biomass in a relatively long cycle if done naturally. Money was also a factor indirectly increased CO_2 emission in the watershed. The consumption of electricity and transportation activity was determined by the level of income a person is enjoying, thus a higher income could resort to higher contribution of greenhouse gases.

The relationship of carbon emitted by farmers and vegetation biomass had a poor positive linear relation (y = 28.965x + 114.99) at 0.13. However, the correlation coefficient (r) of 0.356622 revealed no significant differences.

Erosion Assessment

The estimated soil loss in the watershed ranged from 0.95 to 27.12 tons ha^{-1} per year (Table 11). Most of the estimated soil losses in the various land mapping units were below the soil loss tolerance of 10 tons ha^{-1} per year. A soil loss of 27.12 tons ha^{-1} per year was however estimated at slopes 0 – 18% under home garden. This decreased to 0.95 tons ha^{-1} per year under fallow system. Although soil loss of 4.92 tons ha^{-1} per year was estimated at slopes 18 – 30% under fallow system. Soil loss of 1.04 tons ha^{-1} per year was estimated in the natural forest at 30 – 50% slopes, which increased to 2.21 tons ha^{-1} per year when moving up to >50% slope.

Difference of soil loss in all the land mapping units was attributed to variability of the factors in the Universal Soil Loss Equation. The erodibility factor, crop management factor and support practice factor are integrated on how the land is utilized for a specific purpose. The agroforestry-home garden at slopes 0 – 18% had the highest C-factor of 0.2, which means that the farm lot was poorly covered with vegetation. The canopy of the agricultural crop approximately covered 80% of the total land area, which was insufficient to prevent soil loss from reaching beyond the soil loss tolerance. The fallow system having a C factor of 0.01 was attributed to grasses and herbaceous plants' canopy. The canopy cover of the said vegetation was relatively high, which was approximately more than 90% of the area covered. The dense spacing of the foliage is a critical factor in reducing raindrop impact and runoff that can cause soil erosion. The natural forest having a C factor of 0.001 connotes total protection of land from raindrop impact and runoff as the canopy could absorb 100% of the impact, hence, a very low soil loss.

Support practice factor should be treated cautiously because not all conservation measures are effective to all slope classes. Slopes 0 – 18% and 18 – 30% had the same P factor of 0.6 because they are both under contouring while P factor of 1.0 was assigned at slopes 30 – 50% and >50% because of no

Table 11. Estimated annual soil loss of land uses in Barobbob Watershed

Slope Class (%)	Land Use	R	K	LS	C	P	A (tons ha^{-1} per year)
0 – 18	Agroforestry (home garden)	1326.30	0.06	2.84	0.2	0.6	27.12
	Agroforestry (fallow system)	1326.30	0.06	2.00	0.01	0.6	0.95
18 – 30	Agroforestry (fallow system)	1326.30	0.06	10.30	0.01	0.6	4.92
30 – 50	Natural forest	1326.30	0.03	26.04	0.001	1.0	1.04
>50	Natural forest	1326.30	0.03	55.65	0.001	1.0	2.21
TOTAL							**36.24**

conservation measures done.

CONCLUSION AND RECOMMENDATION

There are two major land uses at the Barobbob watershed, namely: natural forest and agroforestry. The natural forest which was at the western side of the watershed occupied a total land area of 178.00 ha while, agroforestry areas were scattered in patches that occupyabout 242 ha or 57.62 % of the total land area of the watershed.

The test for ecological soundness used indicators on soil loss, diversity of tree species, soil macrofauna, bacterial and fungal count and fertility level. The natural forest was ecologically sound due to: (1) the potential soil loss with an average value of 1.63 tons ha^{-1} per year was far below the soil loss tolerance of 10 tons ha^{-1} per year; (2) diverse forest tree species ranged from 1.38 – 1.57 and substantial amount of carbon from the vegetation with an average value of 323.19 tons C ha^{-1}; (3) bacterial and fungal populations were abundant, and; (4) good fertility status. Agroforestry areas fail to be ecologically sustainable because of high potential soil loss with a value of 27.12 tons ha^{-1} per yearand declining soil fertility.

The relationship of carbon emitted by farmers and vegetation biomass had a poor linear relation ($y = 28.965x + 114.99$) at 0.13. However, the correlation coefficient (r) of 0.356622 revealed no significant differences.

In as much as vegetable production is the primary source of cash for farmer-occupants, there's a need to produce high yield on a sustainable basis. Alley cropping and contour strip cropping with minimum tillage should be the alternative types of farming system when agroforestry (home garden) is done on undulating to rolling topography. The existing agroforestry practices can be modified by integrating soil organic matter enhancement such as green manuring, application of organic fertilizers, and mulching.

Research study on carbon budget and land use change must be undertaken in the Barobbob watershed for a minimum of 3 years in order to establish a clear reference on the impact of land use change to the watershed's carbon stock.

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