The Effects of Agroforestry Practices on the Soil Properties of Barobbob Watershed, Nueva Vizcaya, Philippines

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Keywords:

Agroforestry, Runoff, Sediment Yield, Soil Erosion, Infiltration

ABSTRACT

The study was conducted in Barobbob Watershed, Sitio Pawac, Barangay Masoc, Bayombong, Nueva Vizcaya, Philippines. The study assessed the effects of the four dominant agroforestry practices on the condition of the soil such as physical characteristics, soil erosion and rate of infiltration. The study also assessed the relationship of the amount of rainfall that prevailed during the time of the study to the generated values of runoff, sediment yield and sheet erosion.

Experimental plots were established in the different agroforestry practices and in the residual forest to measure the amount of erosion and rate of infiltration.

Among the agroforestry practices, multistorey had better effects on the soil condition of the watershed.

INTRODUCTION

Barobbob is a small watershed that is jointly managed by the Provincial LGU of Nueva Vizcaya through the Environment and Natural Resources Office (ENRO) and the Barobbob Watershed Occupants Association (BWOA). It supports the provincial waterworks system of Nueva Vizcaya which supplies water to the municipalities of Solano and Bayombong and provide irrigation water to six barangays of these two municipalities. Based on the report of Agbayani and Tiongson (2003), the system of management of the watershed can be considered as a success story. As proof of the excellent effort towards conservation and management of the watershed, BWOA together with the local government was awarded with the Galing Pook Award being one of the ten outstanding programs in the country.

In the conducted classification of Bangloy and Rodriguez (2006), the farm lots/settlement dominates the 452.32 hectare watershed. This land use constitutes 52.60% of the whole area. The other land uses include residual forest (26.40%), grassland (14.07%) and small patches of project areas such as bamboo plantation, tree plantations, fishponds, and protected forest (6.93%).

The occupants of Barobbob watershed have adopted agroforestry as farming practice in the area. It is believed that this system would ensure production that would provide their needs, and protection in the uplands on a sustainable basis. In the study of Rodriguez (2009), there were four dominant agroforestry practices adopted in Barobbob. These findings were also verified in the study of Ngampiboonwet (2012). The four dominant practices were fallow system, the most dominant and adopted by 34.83% of the farmers, followed by trees along farm boundary (24.11%), multistorey (21.43%) and alley cropping (19.64%). The farmers have adopted more than one practice. A change from one practice to another was also evident such as fallow system to alley cropping and trees along farm boundary to multistorey. The adoption of the agroforestry practices was related to the tenure system provided. According to 87.50% of the farmerrespondents, adoption of agroforestry is in compliance with the agreement in the tenure system, while 9.82% stated that they practice agroforestry because of outside influence, i.e. extended technology and, a system recommended by farmers from other areas. The remaining 2.68% claimed that it is their own preference that they adopted such agroforestry practices.

Barobbob watershed has a terrain characterized by rugged and steep slopes that are very fragile and prone to erosion. Improper implementation of farming practices and inappropriate management systems like planting annual crops in monocultures, can diminish the carrying capacity of the land. Agroforestry is recognized as an alternative land-use to meet the needs of upland farmers and maintain the integrity of the environment as well. Different forms of agroforestry practices have been developed and promoted by government and non-government organization as approaches for sustainable upland development in the watershed.

In Barobbob watershed, agroforestry was adopted by each member of BWOA in their individual farms located in rugged topography of the watershed and in areas with high elevations and steep slopes. On this premise, the study attempted to investigate the effect of agroforestry practices on the soil properties of the watershed in general. Specifically, the study assessed the condition of the soil and determined the rate of soil erosion in the dominant agroforestry practices in the area. The study also determined the relationship of rainfall that prevailed during the period of the study to the generated amount of soil erosion in each agroforestry farm.

METHODOLOGY

The study was conducted in the area of the Barobbob Watershed co-managed by ENRO and BWOA (Figure 1). In the assessment of the soil condition in the dominant agroforestry practices, the farms representing each of the dominant practices were evaluated. Field visits and actual measurements were conducted in each farm to determine the rate of erosion. The relationship of rainfall with the rate of soil erosion was evaluated using the rainfall data from NVSU-NVPG-PAGASA AGROMET Synoptic Station and the measured soil erosion data in the farms.

Field Activities

Soil collection was conducted from selected sites in the area. Soil samples were taken before and after the conduct of the study. The composite samples that were gathered were brought to laboratory for analysis. The soil properties analyzed were bulk density, water holding capacity and soil available moisture.

In the evaluation of soil erosion, the following data were gathered in the representative farms of each dominant

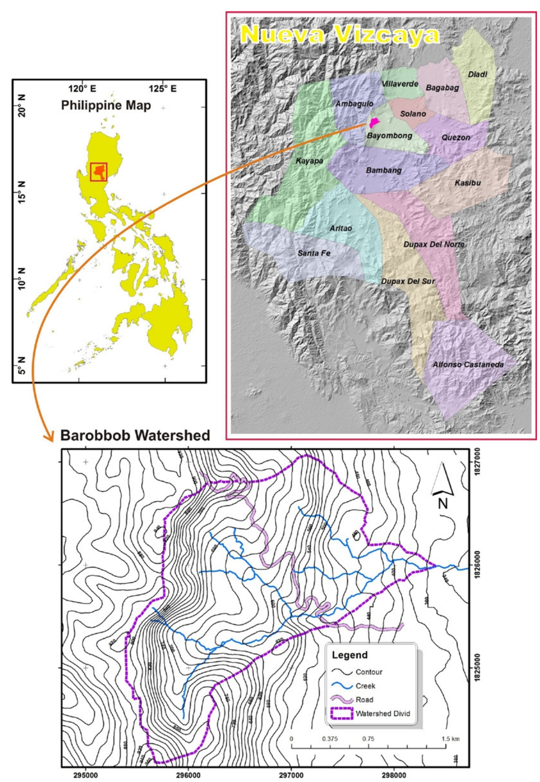

Figure 1. Location of the study area

agroforestry practices using the methodologies employed by Rodriguez (2009), Yadav (2000) and Gascon (1998):

Surface runoff. This was measured using runoff plots established in the identified study sites. Each plot has a 2 x 4 meter dimension enclosed by 25 cm wide GI sheets buried to a depth of 10 cm with a plastic container installed at one end to collect surface runoff. Runoff was measured after every rainfall event.

Sediment yield. A 500 ml water sample was collected from the runoff in the plastic container installed in every plot. The water was filtered to get the sediment. The weight of the sediment was determined using digital balance. Samples were collected after every rainfall event.

Sheet erosion. The amount of sheet erosion was assessed using modified erosion bar. This instrument that monitors the change in topsoil level is a 2.2-meter long square aluminum bar with ten holes spaced 20 centimeters apart through its opposite side. Through mathematical calculations, the sheet erosion was computed, expressed in topsoil depth and converted in tons per hectare. The total volume of soil loss per hectare was calculated by multiplying the depth of washed soil by 10,000 m2. The computed value was multiplied by the percent solid space in the soil to come up with the volume of solid particles washed in the plots. The percent solid space of the soil was computed by dividing the bulk density by particle density multiply by 100. The volume of solid particles in the washed soil was converted to its equivalent weight per hectare based on the soil separates using the conversion formula. For every 1 m3 sand = 1497 kilograms; 1 m3 silt = 1046 kilograms and 1 m3 clay = 483 kilograms.

Infiltration rate. The infiltration rate was measured using a double ring infiltrometer installed in the experimental plots during field measurements.

A similar field set up was also installed in a portion of the residual forest adjacent to the plots established in each of the dominant agroforestry practices. This set-up served as the control plots of the study. Field measurements and data collection were made in the plots established in the forest similar to the plots in each of the representative farms.

Data Analyses

The differences among treatments on surface runoff, sediment yield, sheet erosion and rate of infiltration were analyzed using Analysis of Variance (ANOVA) method in Randomized Complete Block Design (RCBD). Significant differences were further analyzed using the Least Significant Difference.

Correlation and regression analyses were also done to determine the relationship of rainfall and runoff, rainfall and sediment yield, and rainfall and sheet erosion in the different agroforestry farms and in the residual forest.

RESULTS AND DISCUSSIONS

The study was conducted from January to August 2012. Barobbob watershed has sufficient water from the rainfall received during the period of the study. This is very favorable to the farmers because it does not limit them in the choice of species for planting. With lots of water available to water the farms, there is an assurance for survival and growth of crops.

Rainfall recorded during the period of January to August 2012 from the NVSU-NVPG-PAGASA AGROMET Synoptic Station is shown in Figure 2. The total rainfall recorded in the study period was 1,290.50 mm. The lowest rainfall of 36.40 mm occurred last January 2012 while the highest rainfall occurred (385.00 mm) in July 2012.

Condition of Soils in Barobbob Watershed

Based on records, the soil in Barobbob Watershed is favorable for almost all kinds of plants. In forested areas, the soil was covered by thick litter and has high organic matter content. The soil texture ranges from loam to silt loam with an average porosity of 39.67% and bulk density of 1.2 gm/cc. In the geologic map of the province, the area is sedimentary rocks crystalline limestone origin. Erosion was found in many parts of the area (Bangloy and Rodriguez, 2006).

The study considered the physical properties of the soil to assess the soil condition of farms in the area. Table 1 shows the physical characteristics of the soil analyzed in the different agroforestry practices and in the residual forest, before and after the study.
The presence of trees in an agroforestry farm influenced soil structure by bringing organic matter to the soil and development of important root systems that explore and improve notably the deep and compacted soil layers that crop roots do not reach (Bongers *et al.,* 2013).

Water holding capacity. The ANOVA shows that the water holding capacity of the treatments was significantly different. The water holding capacity of the soil in multistorey system was very high (85.99) which is comparable to that of the residual forest. The least was trees along farm boundary system at 68.99. The water holding capacity in fallow system (84.99) was significantly different from alley cropping (83.00). The same trend was observed on the water holding capacity after the study (Table 1). Significant difference was observed among the treatments, but the water holding capacity in alley cropping and residual forest were comparable. Furthermore, the water holding capacity of the alley cropping, fallow system and multistorey increased; but, decreased in trees along farm boundary. The highest increase was observed in alley cropping (89.00); while in the trees along farm boundary, it was reduced to 66.00.

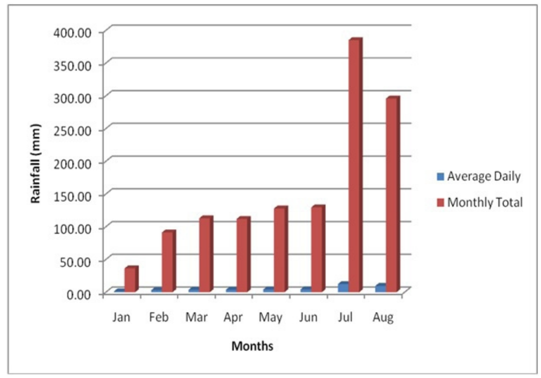

Figure 2. Amount of rainfall recorded at NVSU-NVPG- PAGASA AGROMET Synoptic Station, Bayombong, Nueva Vizcaya from January to August 2012

The presence of trees in agroforestry farm improves the soil holding capacity for water. The tree's roots permeate the soil and improve plant capacity to uptake and export water in the soil (Bongers *et al.,* 2013). Vegetated land uses such as agroforestry farms are expected to have comparatively healthy soil characteristics that may affect water holding capacities. Increases in the

Table 1. Soil physical characteristics in the dominant agroforestry practices and residual forest in Barobbob Watershed

Treatments (Agroforestry Practices and Residual Forest)	Water Holding Capacity		Moisture Content (%)		Bulk Density (g/cc)	
	Before	After	Before	After	Before	After
Tree along farm boundary	68.99a	66.00a	44.64a	43.33a	1.65c	1.68c
Alley cropping	83.00b	89.00d	43.68a	41.34a	1.49b	1.50b
Fallow system	84.99c	86.99c	38.07a	37.33a	1.69c	1.70c
Multistorey	85.99d	85.00b	45.58a	45.00a	1.31a	1.29a
Residual forest	86.00d	89.00d	51.05b	53.00b	1.22a	1.20a

Means followed by a common letter in the row are not significantly different at the 5% level by LSD

water holding capacity can be attributed to the presence of litter in the AF based Soil and Water Conservation (SWC) plots. The addition of organic matter through the litter fall from tree and shrubs had improved the soil physical conditions which in turn had increased the water holding capacity.

In the study of Gascon (1998), highest water holding capacity was also obtained in the multistorey farm of Hanunuo Mangyan in Mindoro. This result was attributed to the clay soil texture in the farm. The highest increase in observed water holding capacity in alley cropping could be attributed to the clay soil texture in the farm. Clays hold much water because they have large surface area to be covered with water.

Yamoah et al (1986) evaluated the relative potential of Cassia spectabilis hedgerows in changing soil properties. Results revealed that water holding capacity as one of the parameters observed was better in the alley cropped site.

Soil moisture. In the study, available moisture from the different agroforestry practices was not significantly different from each other before and after the study. However, the values obtained in the farms were significantly lower compared to the residual forest (Table 1). Among the agroforestry practices, the available moisture was high in the multistorey system (45.58%), followed by trees along farm boundary (44.64), alley cropping (43.68) and the lowest was in fallow system (38.07) before the conduct of the study. The same trend was observed after the study.

In the study of Masebo et al (2012), the soil moisture content differed significantly for plots of AF based SWC with 7-years residence time compared to other treatments at the upper soil layers (0-30 cm). Increases in the soil moisture can be attributed to the presence of litter in the AF based SWC plots. The addition of organic matter through the litter fall from tree and shrubs, had improved the soil physical condition which in turn had increased the water holding capacity and the soil moisture content.

Kung'u (1997) showed that application of Leucaena prunings resulted in higher soil moisture retention in a long-term trial conducted in Ibadan, Nigeria. According to Nair (1993), agroforestry systems tend to protect soil from several adverse effects and helps improve its condition in a number of ways. One beneficial effect of agroforestry system based from experimental evidence was the improvement of physical conditions such as moisture content.

Bulk density. In this study, result of the analysis of variance showed significant differences in the bulk density of the four agroforestry practices and in the residual forest (Table 1). Among the agroforestry practices, the fallow system had the highest bulk density of 1.69 g/cm3, higher than that of trees along farm boundaries but comparable to each other. This was followed by alley cropping (1.48), multistorey (1.31), and the lowest was residual forest (1.22).

The high soil bulk density indicated soil compaction which would ultimately lead to reduction of soil porosity and decrease in permeability. Higher bulk density could result in a lower soil quality. In the study of Ahmed et al (2012), the highest soil bulk density was found in sole cropping, different soil depth and the crop yield (kg/ha) was also found lowest.

The study of Masebo et al (2014) revealed no significant differences in bulk density across all treatments and depths except for the 30 to 60 cm depth in the no-SWC plots. In the study of Yamoan et al (1986), bulk density was better in alley cropped site under Cassia spectabilis hedgerows.

The values from the multistorey and residual forest decreased; while in the fallow system, alley cropping and trees along farm boundary increased. This result could be due to the higher erosion rate from the fallow system that lead to the depletion of organic matter content. The increment in bulk density in the fallow system could be due to the depletion of organic matter by sheet erosion.

More soil compaction during cultivation time could have also contributed to this result. The lowest bulk density in multistorey and residual forest could be due to the addition of organic matter.

Although no statistically significant difference in bulk density was observed between the land uses types, high bulk density value for non-SWC land use types was recorded while AF based SWC for 7 years had lowest values. This is in line with the findings which indicated bulk density decreases as organic matter increases (Masebo *et al.,* 2012)

The study of Lal (1989) contradicted the result of this study. Bulk density increased in area under contour hedgerows of *Leucaena* and *Gliricidia* with maximum value obtained from the area with no-till treatment compared to that of plow-till treatment.

The increase in bulk density in this study on areas under fallow system validated the results reported by Yadav (2000). The bulk density in Dela Paz Pulot Itaas watershed was lower in multistorey and forest compared to the BD in the fallow system and areas without hedgerow systems. Furthermore, after the rainy season, there was an increase in BD in the fallow system and without hedgerow system. Gascon (1998) had similar findings, higher bulk density was observed in the kaingin farming system (fallow system) of rice, and rice +corn based.

Volume of Surface Runoff

The study showed that the multistorey system had the lowest total runoff among the dominant agroforestry practices. The amount was significantly different from the total runoff from other agroforestry practices. In comparison with the values obtained in the residual forest, it was significantly higher (Table 2). The highest was obtained in trees along farm boundary system but this was comparable to the runoff from fallow system and alley cropping. The vegetation present in the area such as the trees help in intercepting rainfall resulting in low run off yield (Daño, 1983). The result was consistent with the findings of Gascon (1998) that less amount of runoff was found in multistorey system and forested areas.

The study showed that the month of July had the highest recorded runoff in all the agroforestry practices except for multistorey and in the residual forest (Figure 3). The runoff recorded for multistorey system was way below despite the extremely high rainfall amount during this month. This only proved that the presence of good vegetation significantly reduced runoff. The lowest runoff yield recorded was in January that was consistent with the less recorded amount of rainfall.

All the agroforestry practices recorded high amount of runoff except for multistorey. The runoff recorded for multistorey system and in the residual forest were way below despite the high rainfall recorded. This only proved that the presence of good vegetation significantly reduced runoff. In this study, the

Table 2. Total runoff (liter) in the dominant agroforestry practices and residual forest of Barobbob Watershed

Treatment	Block I	Block II	Block III	Mean
Trees along farm boundary	210.72	204.24	277.84	230.93 a
Alley cropping	195.21	194.57	260.65	216.81 a
Fallow system	194.36	193.49	267.36	218.40 a
Multistorey	86.07	86.00	117.95	96.67 b
Residual forest	22.41	22.39	30.71	22.39 c

Means followed by a common letter in the row are not significantly different at the 5% level by LSD

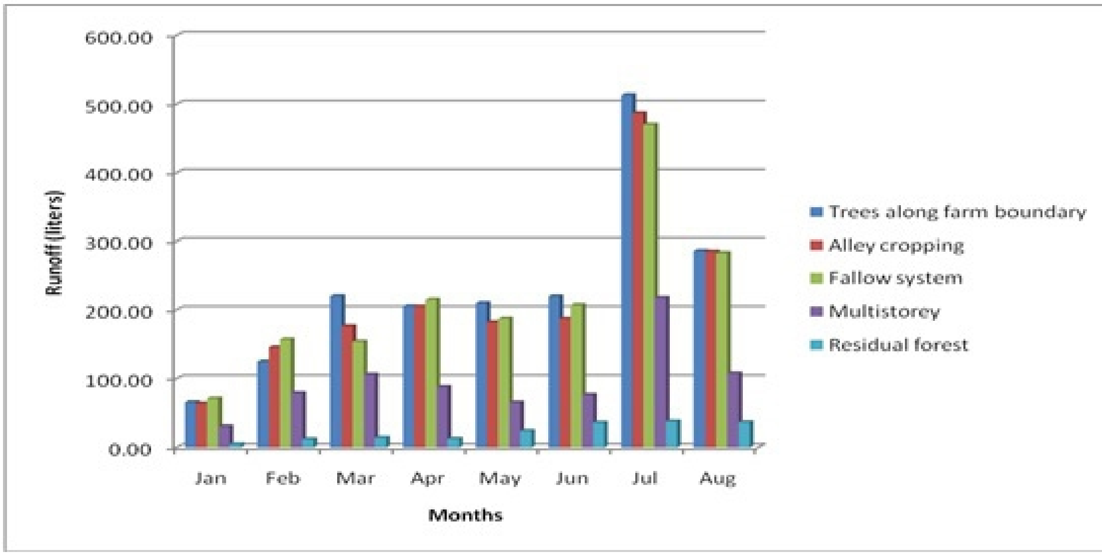

Figure 3. Monthly runoff in the four dominant agroforestry practices and in the residual forest of Barobbob watershed

high runoff yield in trees along farm boundary fallow system and alley cropping was attributed to the absence of good vegetation in the respective agroforestry practice to intercept rainfall. Likewise, the vegetation clearing and burning during land preparation and cultivation operations also contributed to the high amount of surface runoff. The exposed soil as a result of ground cover removal by fire was vulnerable to direct rainfall impact. The soil particles and ash detached in the process clogged or sealed the soil pore spaces in the surface; thus, reducing the infiltration rate and increasing surface runoff.

In the study of Udawatta et al (2002), treatments resulted in a 1 and 10% reduction in runoff during the treatment period on agroforestry and contour strip watersheds, respectively. The difference between observed and predicted losses averaged 18 and 230 m3 per hectare annually for agroforestry and contour strip treatments during the three-year treatment. The total runoff during the treatment period was lower from both treatment compared with the predicted runoff. Gascon (1998) also obtained high runoff in the rice-based and rice-corn agroforestry practices of Hanunuo Mangyan in Mindoro.

The presence of trees and woody perennials that mimics the forest was proven to be vital components in the multistorey agroforestry practice. The lower runoff values in this system showed that the vegetation present in the area helped intercept high amount of rainfall that resulted to lesser runoff yield. Similarly, the presence of vegetation not only provided continuous canopy and soil surface cover but also sufficient amount of organic matter through fallen debris.

Sediment Yield

The lowest sediment yield was obtained in the residual forest (14.56). However, the values obtained is comparable to the amount obtained in multistorey system at 23.72 tons/ha (Table 3). This value was significantly different from the sediment yield obtained from alley cropping (43.07 tons/ha), trees along farm boundary (49.24 tons/ha) and fallow system (49.61 tons/ha). The low sediment yield obtained from the residual forest and multistorey system can be attributed to the presence of trees which intercepted high amount of rainfall. However, the rate was still relatively high compared with the standard stated by Young (1989), which was 10 to 12 ton/ha/yr. This may be because of the influence of gaps, slope and high rainfall intensity.

In the study, it was noted that lowest sediment yield was obtained on the month when rainfall in the area was the lowest, and the highest sediment yield was obtained in the month when rainfall was highest. The study done by Paelmo et al (1997) in multistorey agroforestry system in Makiling showed high erosion rate at 199 to 382 tons/ha/yr.

The findings of the study are similar to Gascon (1998). The multistorey farm of Hanunuo Mangyan yielded 21.18 tons/ha sediment that is significantly lower than the rice + corn based farm (374.26 tons/ha) and rice based farm (387.47 tons/ha). The low sediment yield in the multistorey system in this study was attributed to the presence of vegetation that intercepted abundant amount of rainfall which is reflected in the lesser amount of runoff produced. The same situation

Table 3. Total sediment yield (tons/ha) in the dominant agroforestry practices and residual forest of Barobbob Watershed

Treatment	Block I	Block II	Block III	Mean
Trees along farm boundary	47.21	41.48	59.02	49.24 a
Alley cropping	37.80	39.98	51.44	43.07 a
Fallow system	44.86	43.18	60.80	49.61 a
Multistorey	23.52	23.18	24.47	23.72 b
Residual forest	14.71	15.15	13.84	14.57 b

Means followed by a common letter in the row are not significantly different at the 5% level by LSD

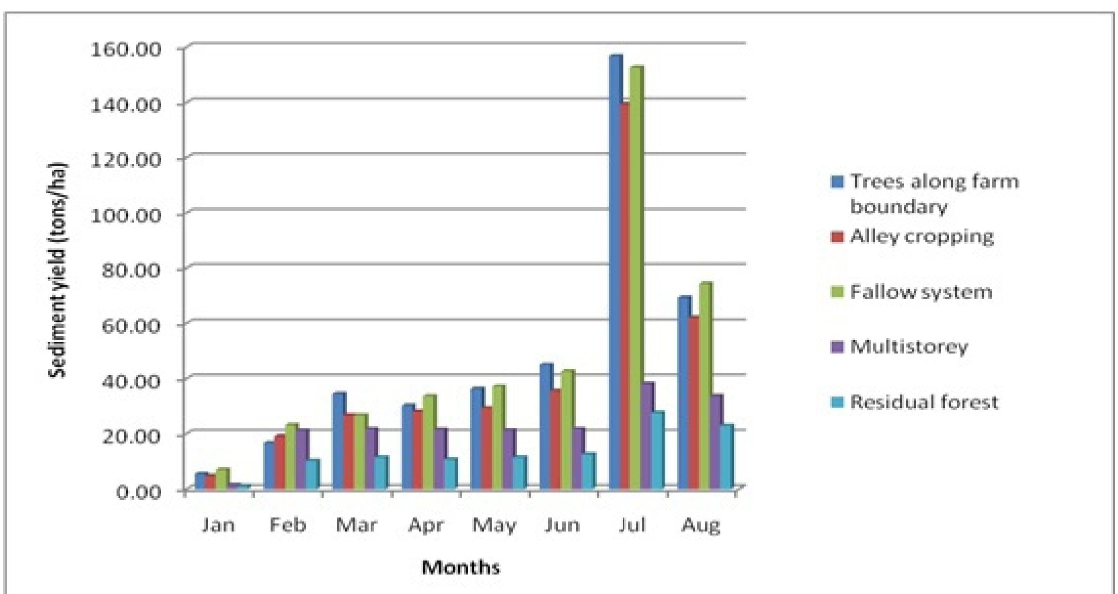

Figure 4. Monthly sediment yield in the four dominant agroforestry practices and in the residual forest of Barobbob watershed

happened in the residual forest. The net precipitate reaching the floor in the multistorey system is very low which resulted to minimal surface runoff and eventually produced low sediment yield. The presence of vegetation also contributed to the high amount of litter on the ground that enhances the soil structure. Low sediment yield in the multistorey system is also attributed to the loose soil that allows greater water infiltration that produced lower surface runoff (Rodriguez, 2009).

As regards alley cropping, the findings of this study were in contrast to the finding of other related studies. Visco (1997) observed reduced soil erosion with *Leucaena* and *Gliricidia* hedgerows by as much as four times than that of the treatment without hedgerows. Soil loss was 0.4 ton/ha under hedgerow plot and 1.6 tons/ha without hedgerow. Panigbatan (1993) also showed significant reduction in soil erosion with alley cropping. Average soil loss in the 14% slope area was 137 ton/ha in the control and 23 tons/ha with *Desmanthus* hedgerows.

Sheet Erosion

Sheet erosion or the removal of thin layer of soil is also considered as one parameter in this study. This was measured in terms of depth of soil loss using modified erosion bars. Table 4 and Table 5 show the sheet erosion in the four agroforestry practices and in the residual forest in Barobbob watershed. Sheet erosion values were lowest in the residual forest at 0.85 cm. As to the agroforestry practices, multistorey systems had the lowest (12.81 cm) soil loss which was comparable to that of residual forest but significantly different from the other systems. The depth of soil loss in trees along boundary, alley cropping and fallow system were comparable to each other. In the study of Visco (1997), the depth of soil loss in the multistorey and forest farms were comparable to the effects of a single hedgerow of *Gliricidia sepium* in an alley cropping system. The values of sheet erosion in this study were similar to the findings of Gascon (1998). In the farm of Hanunuo Mangyan, a depth of soil loss at about 10.95 mm was obtained in the multistorey farm and 22.30 mm in the rice+ corn based farm. The same trend was also observed by Yadav (2000) having the lowest sheet erosion occurred in the multistorey farm and the highest in fallow system area in Dela Paz Pulot Itaas watershed. According to Patiram and Chourdry (2003), the flow of water was arrested, reduced the soil erosion and soil remains almost undisturbed in the dense ground forest vegetation (grass, cardamom, herbs, shrubs) under large cardamom plantation. This agroforestry resembles natural forest ecosystem which made the loss of soil considerably reduced.

The sheet erosion data were converted into their equivalent weight per hectare using mathematical computation. The residual forest recorded the lowest sheet erosion at 41.16 tons/ha. This value was significantly different from multistorey and alley cropping at 58.70

Table 4. Total sheet erosion (cm) in the dominant agroforestry practices and residual forest of Barobbob Watershed

Treatment	Block I	Block II	Block III	Mean
Trees along farm boundary	2.56	2.38	2.34	2.43 b
Alley cropping	2.59	2.59	2.27	2.49 b
Fallow system	2.69	2.74	3.20	2.88 a
Multistorey	1.58	1.50	1.35	1.48 c
Residual forest (control)	0.90	0.86	0.77	0.85 d

Means followed by a common letter in the row are not significantly different at the 5% level by LSD

tons/ha and 72.62 tons/ha, respectively (Table 5). The highest was in fallow system (160.48 tons/ha) that is significant different from alley cropping, multistorey and trees along farm boundary (100.58 tons/ha). The differences in the computed values were attributed to the soil properties and characteristics like bulk density and textural class in the respective agroforestry practices. Results from other studies have shown that barrier hedges such as in alley cropping are effective in minimizing soil erosion. Ramirez (1988) reported that sheet erosion loss from pure gabi treatments were higher by as much as 38% to 200% compared to those integrated with balabag structure or napier hedge. In another study, Antolin and Veracion (1997) revealed that erosion rate with hedgerow was reduced by 48.65% compared to without hedgerow.

The result of the study supported the findings of Yadav (2000). There was significantly lower soil erosion from multistorey and forest compared to fallow system and without hedgerow treatment.

Relationship Between Rainfall and Runoff

Correlation analysis of the data gathered from the study showed a positive correlation between rainfall and runoff measured. The correlation coefficient in all the agroforestry practices and in the residual forest indicated a very strong correlation between rainfall and runoff (Table 6). Among the four agroforestry practices, correlation coefficient in the multistory system was the lowest. This could be due to the higher canopy cover compared to other agroforestry practices. This is also true with the computed values in the residual forest.

Regression analysis between average monthly rainfall and collected monthly runoff showed significant relationship in all the agroforestry practices and residual forest. Prediction equations were also generated for each agroforestry practices and residual forest; thereby, the volume of runoff can be predicted from the rainfall amount. The same results were reported by Gascon (1998) where rainfall and the corresponding runoff in the forest, multistorey and rice+corn based farm had very strong correlations. In the study of Zhang et al (2008), the regression equation for the treatment of sloping terraces with crops is remarkably different from that for the treatment of sloping terraces with grasses and trees and the conventional up-and down-slope crop system regarding equation coefficients, while regression equations are similar between sloping terraces with crops and conventional up-and down-slope crop system. Water runoff amount and runoff coefficient of slope fields increased, compared to those of sloping terraces, suggesting that terracing notably reduced the water runoff in the field.

According to Daño (1983), variation in surface run-off was due to the combined effects of rainfall depth, rainfall duration and antecedent moisture content. Rainfall was the most important factor in the variation of surface run-off. There was 85.8% variation in surface run-off attributable to rainfall amount, rainfall density and soil moisture deficiency in the secondary forest while 94.7

Table 5. Average sheet erosion (tons/ha) in the dominant agroforestry practices and residual forest of Barobbob Watershed

Treatment	Block I	Block II	Block III	Mean
Trees along farm boundary	120.38	110.53	111.62	114.17 b
Alley cropping	72.00	69.87	61.15	67.67 c
Fallow system	168.79	174.59	208.58	183.99 a
Multistorey	87.51	87.12	74.73	83.12 c
Residual forest (control)	43.33	43.14	37.00	41.16 d

Means followed by a common letter in the row are not significantly different at the 5% level by LSD

of the variation in the grassland watershed was attributable to the same variables.

Relationship Between Rainfall and Sediment Yield

The data revealed a very strong correlation between sediment yield and rainfall in all the agroforestry practices and in the residual forest (Table 7). The correlation coefficient values ranged from the lowest value at 0.9096 obtained in multistorey system to highest value at 0.9982 in fallow system. Regression analysis also showed highly significant regression values in all the agroforestry practices and residual forest. The amount of sediment in various practices could be predicted from the amount of rainfall.

Bacato (1986) reported that soil loss was positively correlated with surface run-off (r= 0.98) brought about by rainfall. In the study of Lapitan (1989), significant relationships were obtained from the sediment yield produced and the interaction between slope and rainfall amount. Based on the analysis of rainfall data and sediment yield, Orallo (1981) showed that as rainfall increased, there was a corresponding change in the soil movement. Therefore, the amount of rainfall affected the amount of sediment yield.

Gascon (1998) found very strong correlation between rainfall and sediment yield in the rice and rice+corn based farm, strong correlation in the multistory farm and moderate correlation in the forest. Prediction equations were also developed in the rice

Table 6. Correlation and regression analysis of rainfall and runoff in the four dominant agroforestry practices and residual forest of Barobbob Watershed

Variables	Total	Mean	r	R2	PROB>F	Prediction Equation
Rainfall (mm)	1290.50	161.31				
Runoff (liters)						
Trees along farm boundary	1847.45	230.93	0.9377	0.8792	0.00058**	Y= 59.76+1.06X
Alley cropping	1734.48	216.81	0.9875	0.9205	0.00016**	Y= 51.03+1.03X
Fallow system	1747.22	218.40	0.9945	0.9091	0.00024**	Y= 62.71+0.97X
Multistorey	773.39	96.67	0.9380	0.7859	0.00335**	Y= 29.64+0.42X
Residual forest	179.12	22.39	0.6093	0.6526	0.01529**	Y= 7.784+0.09X

*** Significant at 1% level of significance*

Table 7. Correlation and regression analysis of rainfall and sediment yield in the four dominant agroforestry practices and residual forest of Barobbob Watershed

Variables	Total	Mean	r	R2	PROB>F	Prediction Equation
Rainfall (mm)	1290.50	161.31				
Sediment Yield (tons/ha)						
Trees along farm boundary	393.90	49.24	0.9481	0.898944	0.00034**	Y= -12.77+0.38X
Alley cropping	344.57	43.07	0.9976	0.906889	0.00026**	Y= -12.37+0.34X
Fallow system	396.89	49.61	0.9982	0.925353	0.00013**	Y= -11.26+0.38X
Multistorey	189.78	23.72	0.9096	0.937275	0.00008**	Y= 12.33+0.07X
Residual forest	116.54	14.57	0.9158	0.966941	0.00001**	Y= 5.43+0.06X

*** Significant at 1% level of significance* and rice+corn based farm due to the high regression values.

Sediment yields on the slope fields in the normal year of rainfall distribution were notably higher in sloping terraces with crops than those on sloping terraces with grass and trees, implying that terracing also plays a significant role in the reduction in soil erosion. Terracing with crops is significantly effective for soil and water conservation in cultivated farmland, while the conventional practice of up-and down-slope cultivation creates high rates of water runoff and soil sediment transport (Zhang *et al.,* 2008).

Relationship Between Rainfall and Sheet Erosion

Table 8 showed a very strong correlation between rainfall and sheet erosion (depth of soil washed) in all the agroforestry practices. On the other hand, a strong correlation was obtained in residual forest. The statistical analysis also showed that sheet erosion in the various treatments could be predicted from the amount of rainfall as revealed by the high regression values.

In the study of Yadav (2000), poor correlation was obtained between total sheet erosion and total monthly rainfall in hedgerow, fallow system, without hedgerow and multistorey farming system. In addition, calculated probability value from all treatment showed that relationship between sheet erosion and rainfall were not linearly correlated. The same results were reported by Ramirez (1988) where sheet erosion and rainfall were not linearly correlated.

Infiltration Rate

Monthly infiltration rate measurements were conducted in the four dominant agroforestry practices and residual forest. The highest infiltration rate was found in the multistorey at 0.63 cm/min as shown in Table 9. This value was comparable to residual forest (0.83 cm/min) but significantly different from the infiltration rate obtained in alley cropping (0.34 cm/min), fallow system (0.18 cm/min) and trees along farm boundary (0.15 cm/min).

The monthly infiltration rate is shown in Figure 6. The high infiltration in residual forest and multistorey was attributed to the high organic matter content in the area provided by the vegetation through fallen debris. Decomposed litter through the action of microorganisms usually improved soil porosity and infiltration capacity. High organic matter content enhances the soil structure and aggregation making the soil loose to allow greater water infiltration (Bongers *et al.,* 2013).

Low infiltration rates were observed in agroforestry practices that also obtained high runoff. This result suggests the influence of infiltration rate on the amount of water

Table 8. Correlation and regression analysis of rainfall and sheet erosion (depth of soil washed) in the four dominant agroforestry practices in Barobbob Watershed

Variables	Total	Mean	r	R2	PROB>F	Prediction Equation
Rainfall (mm)	1290.50	161.31				
Sheet erosion (mm)						
Trees along farm boundary	19.43	2.43	0.9598	0.9213	0.00016**	Y=1.1983+0.0076X
Alley cropping	19.88	2.49	0.9422	0.9387	0.00007**	Y=1.0634+0.0088X
Fallow system	23.04	2.88	0.8427	0.5451	0.03646**	Y=1.5183+0.0084X
Multistorey	11.83	1.48	0.8164	0.6465	0.01616**	Y=1.0953+0.0024X
Residual forest	6.76	0.85	0.7211	0.4894	0.05342**	Y=0.6230+0.0013X

*** Significant at 1% level of significance* that will be formed as part of the surface runoff. Likewise, low infiltration rate can be attributed to the clearing and burning practice during land preparation activities. Since most of the humus and litter were consumed in land preparation through burning, more runoff could occur as a result of impaired soil porosity and infiltration capacity.

This study confirmed the findings of Gascon (1998) in terms of high infiltration rate in the multistorey stand and the low infiltration rate observed in the rice farm of the Hanunuo Mangyans. The high infiltration value was attributed to the high organic matter content of the soil in the multistorey farm while the low infiltration value was due to soil compaction in the rice based system that resulted to slow infiltration.

CONCLUSIONS

The four dominant agrofrestry practices in Barobbob showed different

Table 9. Average infiltration (cm/min) in the dominant agroforestry practices and residual forest of Barobbob Watershed

Treatment	Block I	Block II	Block III	Mean
Trees along farm boundary	0.16	0.15	0.15	0.15 b
Alley cropping	0.46	0.38	0.19	0.34 b
Fallow system	0.22	0.16	0.16	0.18 b
Multistorey	0.84	0.57	0.49	0.63 a
Residual forest	1.10	0.74	0.64	0.83 a

Means followed by a common letter in the row are not significantly different at the 5% level by LSD

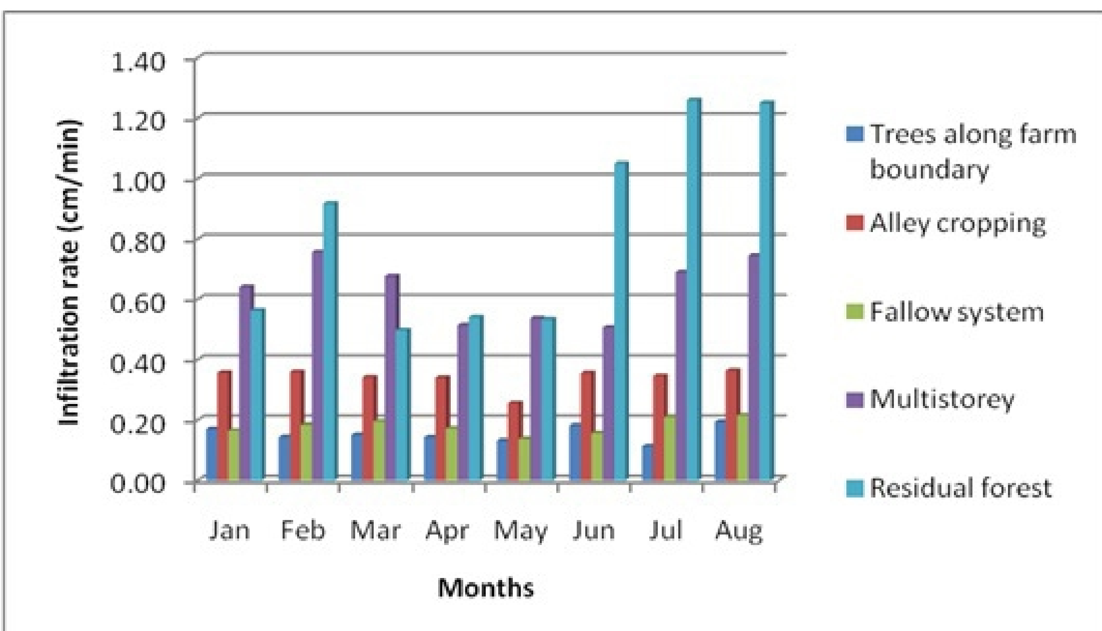

Figure 6. Monthly infiltration rate in the four dominant agroforestry practices and in the residual forest of Barobbob Watershed

effects on the soil conditions of the watershed.

The multistorey practice had better effects because of the improved soil physical condition such as availability of moisture, water holding capacity and bulk density. The infiltration rates in this agforestry practice even exceed the values obtained in the residual forest during the time of the study. Likewise, this agroforetry practice generates low erosion rates that are comparable to the rates generated in the residual forest in the area.

In the parameters used in this study, alley cropping practice had good effects on the soil condition in the area. The water holding capacity of soil under this agroforestry practice is highest among other practices. The soil moisture content is comparable to multistorey and lower soil bulk density values next to multistorey. Similarly, the alley cropping practice in Barobbob also generates lesser erosion and higher infiltration values next to multistorey practice.

Both the trees along farm boundary and fallow system caused almost similar effects on the soil condition of farms in Barobbob watershed. In terms of soil physical properties, the effect is almost comparable to the other agroforestry practices but the values were lower compared to multistorey and alley cropping. In terms of soil erosion, both produced very high amount, while in terms of infiltration both produced very low rates compared to the other agroforestry practices during the time of the study.

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