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Soil erosion assessment of the various vegetation cover in Mt. Musuan, Philippines

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Abstract

Soil erosion is one of the main causes of land degradation. This is very prominent in developing countries where large tracts of forest land are converted to other land uses. Mt. Musuan, a land mark of Central Mindanao University in Bukidnon, is not spared in this phenomenon. This study is conducted to assess and quantify soil erosion rates of the various land cover across the landscape of the mountain. These include the forest area, grassland and the agro-ecosystem components. Soil erosion plots were established in various slope gradients of the three vegetative/land cover. Erosion bar method was used in measuring the soil erosion rates and the micro-infiltrometer was used to determine infiltration rates. Findings show that agro-ecosystem had the highest soil losses at 41.43 ton ha^{-1} yr^{-1} followed by grassland with 26.39 ton ha^{-1} yr^{-1} while the forest area had the least with 13.98 ton ha^{-1} yr^{-1}. In terms of slope gradient, though non-significant, the slope greater than 20 % had the highest soil loss of 35.37 ton ha^{-1} yr^{-1} followed slope gradient between 10% to 20% with 29.17 ton ha^{-1} yr^{-1}. The slope less than 10 % had the least soil losses with 17.35 ton ha^{-1} yr^{-1}. In terms of infiltration rate, the forest area is highest with 94.67 mm hr^{-1}. Agro-ecosystem and grassland ecosystem had infiltration rates of 52.44 mm $hr^{-1}$and 54.89 mm hr^{-1}, respectively. The soil erosion rates of Mt. Musuan are beyond the tolerable limit and need immediate actions particularly in the agro-ecosystem. Rehabilitation like planting of perennial crops in these areas needs to be prioritized.

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Introduction

Soil degradation by accelerated erosion is considered as a serious problem especially in developing countries of the tropics and subtropics. In fact, its extent, severity, and economic and environmental impacts are debatable in present times (Lal, 2001). Soil erosion is a naturally occurring process that affects all landforms. In various land uses, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage (Ritter, 2012).

Soil erosion can happen in a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinisation and soil acidity problems are other serious soil degradation conditions that can accelerate the soil erosion process (Ritter, 2012). This may result to abandonment of arable land due to declining productivity (Bakker *et al*., 2005).

Upland and rolling areas are prone to soil erosion occurrences. Extents of erosion in these areas are influenced by the activities done by the communities. Lal and Stewart (1990) reported that erosion rates are high especially on marginal and steep lands that are being converted from forests to agricultural use to replace the already eroded, unproductive cropland. On the other hand, Pimentel *et al.* (1995) revealed that the impacts of erosion are intensified on sloping land, where more than half of the soil contained in the splashes is carried downhill to valleys and waterways.

Musuan which is classified as an active volcano is not spared from this phenomenon. Its entire landscape has varied slope ranging from 0 to over 50 %. It has an elevation of 646 meters asl (summit), and a base diameter of 3 km. PCAARRD (2009) reported that plant diversity of this mountain varies considerably on all parts. Most of the tree species are found in the northern and southwestern portion of Mt. Musuan, while grasses are distributed in the central and southeastern portions. The majestic landscape of the Mt. Musuan is very potential for ecotourism The lowland areas surrounding this mountain areas are agricultural land, settlements, and the Pulangi River that supports the hydroelectric plant of the National Power Corporation, thus, sediments coming from the upland of this mountain has tremendous effect to its surrounding land-uses.

In order to preserve the beauty of the mountain and its surrounding landscape, policy and governance needs to be carried out. However, basic information on the mountain needs to be generated in support to whatever local ordinances will be implemented. Hence this study was conducted to evaluate the extent of soil erosion in Mt. Musuan with consideration to the various vegetation cover of the area.

Methodology

Location of the study

The study was conducted within the landscape of Mt. Musuan. This is located in the North-eastern part of Central Mindanao University that divides the two Municipalities of Maramag and Valencia. It has an elevation of 646 meters on the summit and with an approximate diameter at the base of 3 kilometers. It is geographically located with coordinates 070° 52’ 51”N 1250 03’ 48”E. Major land cover of the mountain include grassland, shrubland, lowland residual forest and agro-ecosystem (Fig. 1).

Establishment of Plots

There were three (3) land uses/cover that were considered in this study. These include Lowland residual forest, grassland ecosystem and Agroecosystem (Sugar cane plantation). For each land-uses/cover, there were three (3) slopes that were considered: greater than 20%, 11 to 20%, and less than 10%. For each slope, there were three erosion plots that were established which were distributed at the upper, middle and lower side slope. Design of the study.

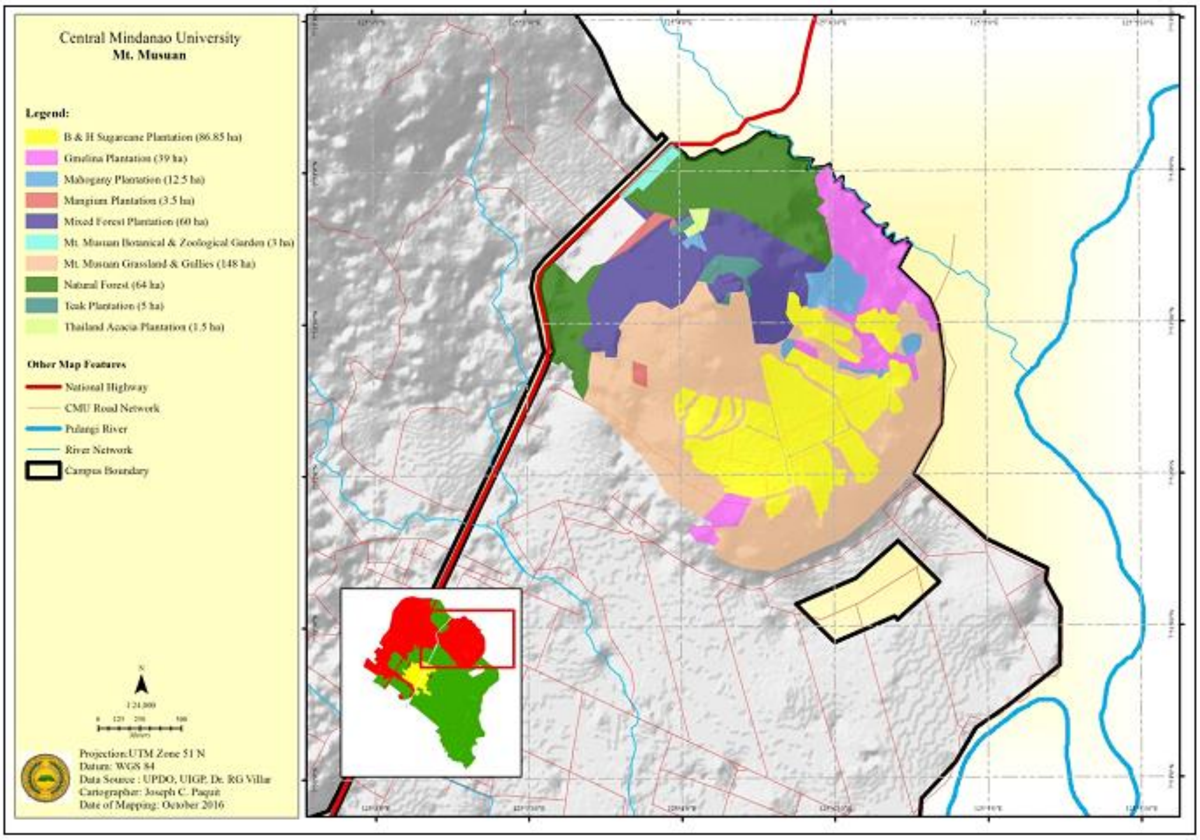

Fig. 1. Land Cover of Mt. Musuan.

The experimental design of the study was factorial experiment in Randomized Complete Block Design replicated three times. The treatments were as follows:

Factor A Land Uses/Cover

1. Lowland residual forest
2. Grassland ecosystem
3. Agro-ecosystem (Sugarcane Plantation)

Factor B Slope

1. Greater than 20 % slope
2. 10 to 20 % slope
3. Less than 10% slope

Data Collection/measurement

Soil erosion was measured using a modified erosion bar used by Ramirez (1988). The method made use of a modified 1.5-meter long aluminum bar with 10 holes spaced at 15 cm apart throughout the whole length of the bar. During the data gathering, the bar was laid on predetermined points and rested on top of the GI sheet bordering on each plots. Measuring pins of identical size and length (1-foot) were inserted in the holes of the bar. These pins were kept lightly rested on the soil surface during measurement by a measuring device.

In determining the soil loss, measurements were made once a month for ten months. The difference between each measurement served as the amount of soil loss.

The data on soil loss were converted into tons per hectare by first determining the volume using the formula:

Vplot= (depth of soil washed) x (length of plot) x (width of plot)

The value of soil particle density and bulk density per treatment plot were used to determine the percent solid space. This percent solid space was multiplied by the computed soil volume loss giving the value of solid space (m^3). Using the conversion figures formulated by the Range and Management Division of the Ecosystems Research and Development Bureau (ERDB), the volume of solid particles was computed to its equivalent according to the particle size distribution. The ERDB conversion values were follows:

1 cu. m of clay= 483 kilograms
1 cu. m of silt= 1,046 kilograms
1 cu. m of sand= 1,497 kilograms

Total erosion in tons per hectare was determined by adding the computed soil loss (tons/ha) of the three particle size distribution (Clay, Silt, and Sand).

The infiltration rates of the three sites were obtained using a micro-infiltrometer. This was done in every treatment slopes. The data were recorded once every quarter of the year. The information obtained from this measurement was used in support to the extent of soil erosion per treatment of the study.

Data analysis

The data in this study were analysed through the Analysis of Variance to determine the level of significance among treatments. Treatment means were subjected to DMRT. The Statistical Package for the Social Sciences (SPSS) version 16 was used in the data analyses.

Results and discussions

Soil Properties of the three Land Cover in Mt. Musuan

Table 1 shows the soil properties of the three land cover in Mt. Musuan. For pH, the forest area is highest with 5.89 and is significantly different from the agro-ecosystem (sugarcane plantation) with 4.24.

The difference between grassland and forest area is not significant. In terms of the soil organic matter (OM) and total Nitrogen, no significant difference was observed among the three land cover.

Table 1. Soil features of the three land cover in Mt. Musuan.

Land Cover	pH	Organic Matter	Total Nitrogen	Extractable Phosphorus	Exchangeable Potassium	Particle Density (PD)	Bulk Density (BD)	water holding capacity
Forest	5.89	4.46	0.27	1.49	276.00	2.40	1.13	75.71
Grassland	5.72	3.45	0.21	10.83	117.00	2.29	1.24	59.35
Sugarcane	4.24	4.18	0.19	11.21	80.00	2.47	1.20	56.66

Means of the same letter are not significantly difference at 5% level of significance using Duncan.

The extractable phosphorus shows that sugarcane plantation had the highest with 11.2. This can be attributed to the application of commercial fertilizer in the area to improve crop yield. For the exchangeable potassium, the forest area had the highest value with 276 but this is not significantly different from the grassland and agro-ecosystem (sugarcane). In terms of soil particle density, significant difference was shown with agroecosystem having the highest with 2.47 g/ml while grassland had the least with 2.29 g/ml. For bulk density, no significant difference among the land cover but the forest area had the least with 1.13 g/ml. In term of water holding capacity, forest area had the highest with 75.71 %. This is significantly different from the agro-ecosystem, the least among the three with only 56.66%.

The high water holding capacity of the forest area can be attributed to its high in soil OM. The forest litters accumulated in the soil surface can have contributed to the high WHC in the site.

Soil Erosion and Infiltration Rates in Mt. Musuan

Rates of soil erosion and infiltration in Mt. Musuan are presented in Table 2. For the three land cover, soil erosion rates and infiltration presented significant differences. In slope gradients, both parameters did not show significant difference. In terms of interactions of the two factors, no significant differences were also observed. However, the pattern shows that the agroecosystem had higher erosion rates and those combined with steeper slopes (more than 20%) also exhibited higher soil losses.

This findings conforms with the study of Marin and Jamis (2016) which showed high erosion rate in Maapag subwatershed in Bukidnon Province with 184.70 ton ha-1 yr-1. It was noted that this watershed has wide area of cropland and soil compaction to grazing animals. On the other hand, the infiltration rates of agroecosystem and grasslands have lower values than that of the forest areas.

Table 2. Soil erosion and infiltration rates among the three land cover and various slopes in Mt. Musuan.

Land Cover	Soil Erosion Rate (Ton $Ha^{-1}Yr^{-1}$)	Infiltration Rate (mm Hr^{-1})
Forest (F)	-13.98^{a}	94.67^{a}
Grassland (G)	-26.39^{ab}	29.33^{c}
Agro-ecosystem (A)	-41.43^{b}	45.11^{b}
Slope		
> 20 % (1)	-35.27^{a}	52.44^{a}
11 – 20 % (2)	-29.17^{a}	61.78^{a}
< 10 % (3)	-17.35^{a}	54.89^{a}
Land Cover × Slope		
F × 1	-37.81^{a}	96.33^{a}
F × 2	-11.29^{a}	89.67^{a}
F × 3	-2.83^{a}	98.00^{a}
G × 1	-28.81^{a}	24.33^{a}
G × 2	-27.45^{a}	32.00^{a}
G × 3	-22.91^{a}	31.67^{a}
A × 1	-49.20^{a}	36.67^{a}
A × 2	-48.77^{a}	63.67^{a}
A × 3	-26.32^{a}	35.00^{a}

Means of the same letter are not significantly difference at 5% level of significance using Duncan.

Rainfall

Total rainfall for the entire duration of the study is 949.9 mm but this has basically influence to the erosion rates across the landscape of Mt. Musuan. Ziadat and Taimeh (2013) reported that rainfall intensity was the most important factor affecting soil erosion and that erosion could occur at a relatively small intensity on wet soils as a result of subsequent rainfall events. Very low rainfall was observed from December 2015 to May of 2016 due to the *elniño* phenomenon. The peak of the rainfall was observed to be in June and July 2016 (Fig. 2).

Soil Erosion

Figure 3 presents the erosion rates of the three land cover at Mt. Musuan. Significant difference was shown among the three land cover with the agro-ecosystem having the highest soil loss at 41.43 ton ha^{-1} yr^{-1}. This is significantly different from the forest area while with the grassland ecosystem is not significant at 5% level. Grassland and forest, however, did not also show significant difference.

High infiltration of the forest area might have influence to its low erosion rates. Surface run-off is minimized if infiltration rate is maximized and usually it is surface run-off that causes erosion to occur.

This is consistent with the study presented by Mohammad and Adam (2010) that forest and natural vegetation dominated by *S. spinosum* treatments exhibited the lowest amounts of runoff, with averages of 2.02 and 1.08 mm, respectively, in comparison to deforested sites with 4.03 mm. The authors further revealed that the greatest amount of sedimentation was observed in cultivated land and with deforestation.

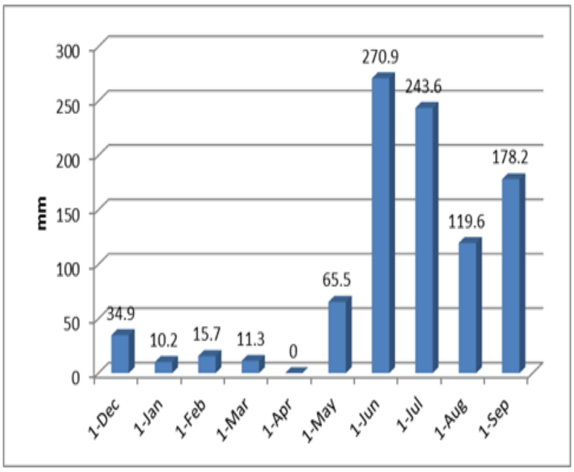

Fig. 2. Monthly rainfall of the study site.

On the other hand, the study of Loch (2000) on the role of vegetative cover in reducing runoff and erosion from rehabilitated mined land found out that erosion was greatly reduced by vegetative cover, declining from 30–35 t/ha at 0% vegetative cover to 0.5 t/ha at 47% cover. On the other hand, the high soil losses of the agro-ecosystem can be attributed to the soil disturbances due to cultivation activities. The study of Sanchez *et al.*(2002) conforms to this where they foundout that highest soil erosion rate corresponded to horticultural crops in rotation: reaching a value of 22 ton ha^{-1} yr^{-1} while in the natural forest with less disturbances had only 0.54 ton ha^{-1} yr^{-1}.

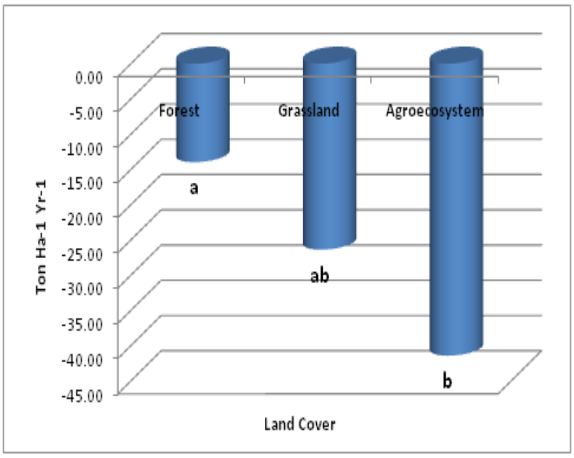

Fig. 3. Soil erosion rates within the three land cover at Mt. Musuan ($P < 0.05$: significant).

Figure 4 below presents the monthly graphical data of the three land covers in Mt. Musuan. Generally, the dropping of the curve are observed among the land uses which indicates soil losses.

Agro-ecosystem is the most disturbed sites where dropping and rising of the curve can be highly observed. Disturbances can be due to the frequent cultivation of the farm as part of the maintenance operation conducted by the farm operator. This finding is parallel to that of the study conducted by Wei *et al.* (2007) that for 14 years of observation, the order from highest to lowest of mean runoff coefficient and erosion modulus among the five land use types were cropland > pastureland > woodland > grassland > shrubland.

On the other hand, the litters and root systems of the perennial vegetation such as trees regulated soil movement. This is supported by the investigation of Gyssels and Poesen (2003) who revealed that both an increase in shoot density as well as an increase in root density resulted in an exponential decrease of concentrated flow erosion rates.

They added that the protection of the soil surface in the early plant growth stages is crucial with respect to the reduction of water erosion rates and increasing the plant root density in the topsoil could be a viable erosion control strategy.

Figure 5 presents the graphical presentation of the soil losses in the various slopes within Mt. Musuan. Though no significant differences were observed among the three slope brackets, the slope greater than 20% exhibited the highest soil loss at 35.27 ton ha^{-1} yr^{-1}. This was followed by the slope range from 10 % to 20 % while the least soil losses was with slope less than 10 % at 17.35 ton ha^{-1} yr^{-1}.Though non-significant, but it is very evident that steeper slopes had higher soil losses.

This phenomenon is supported by Koulouri and Giourga (2007) where they stressed that when slope gradient is steep, soil erosion is increasing significantly. Furthermore, the study of Shi *et al.* (2012) on revealed that bed-load transport by rolling of medium to large-sized sediment particles (coarser than 0.152 mm) was enhanced by increased slope.

Among the three land covers in Mt. Musuan, the forest area had the greatest infiltration rates with 94.67 mm hr^{-1}.

This is significantly different compared with the grassland and agro-ecosystem (Fig. 6). The agro-ecosystem had 45.11 mm hr^{-1} and is also significantly different from grassland having the least with 29.33 mm hr^{-1}. The high infiltration rate of the forest area can be attributed to the existence of the vegetation litters in the forest floor. This is parallel to the findings of the study conducted by Loch (2000) where they found out that infiltration totals and rates increased strongly with increasing vegetative cover. Jimenez *et al.* (2006) also found out in their study that infiltration rates in the natural soils were very high and in all cases were greater than 130 mm hr^{-1} (5.1 in hr^{-1}).

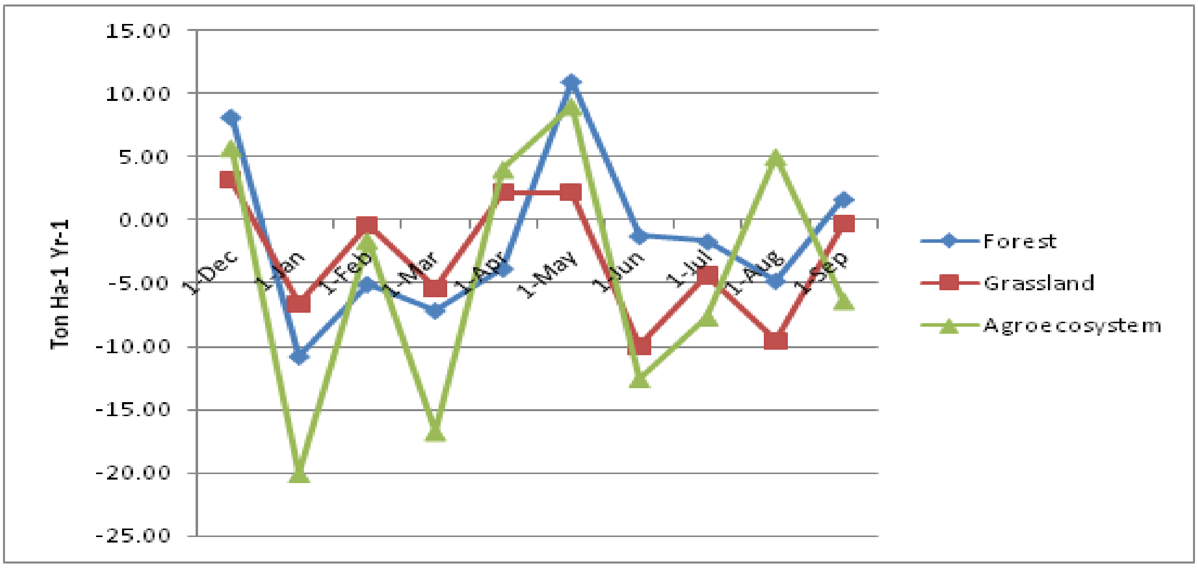

Fig. 4. Monthly graphical presentation of the soil erosion rates of the three land cover in Mt. Musuan.

They added that harvesting the natural vegetation appeared to increase the bulk density, while also reducing organic matter and the apparent saturated hydraulic conductivity values.

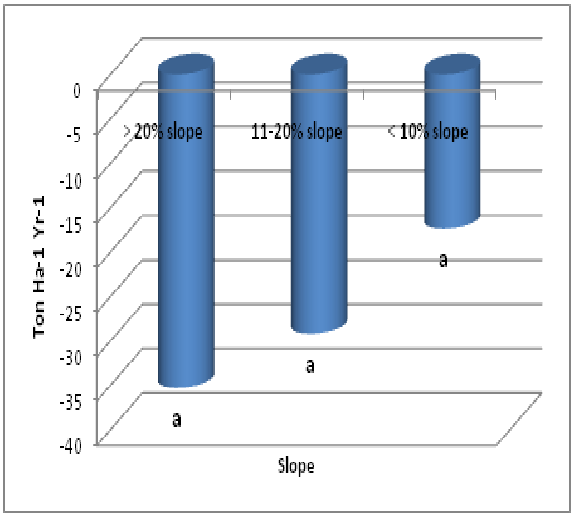

Fig. 5. Soil erosion rates across the various slopes of Mt. Musuan Infiltration rates.

The agro-ecosystem was higher in infiltration than grassland ecosystems maybe because of the cultivation that was made in the former. Cerda (1997) stressed that cultivation promotes infiltration of rainfall.

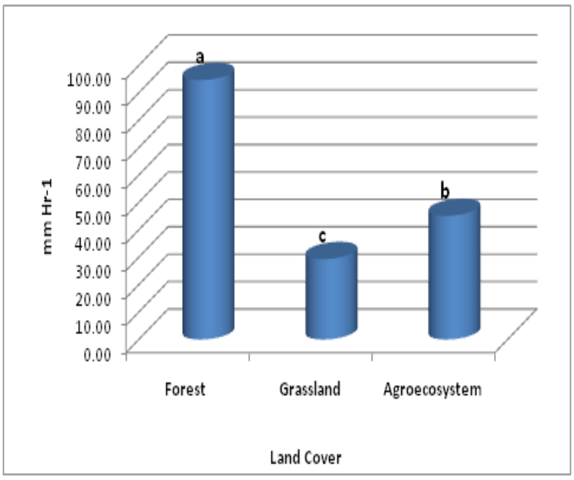

Fig. 6. Infiltration rates within the three land cover at Mt. Musuan ($P < 0.05$: significant).

On slope gradients, no significant difference was shown among treatments. However, the gradient ranging 10% to 20% is slightly higher (61.78 mm hr-1) than > 20% and < 10% (Fig. 7). The least among the three is the slope gradient > 20 % with 52.44 mm hr^{-1}.

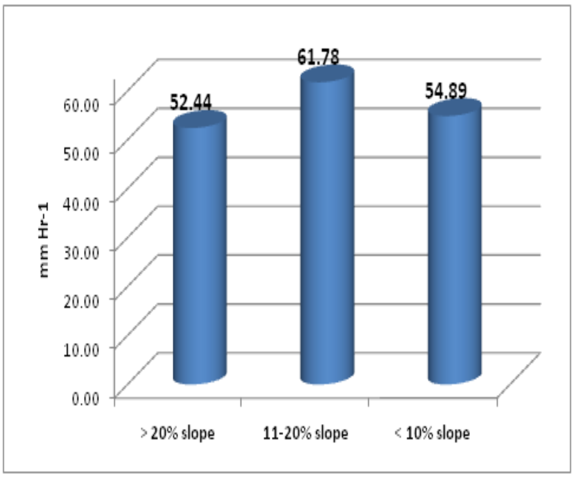

Fig. 7. Infiltration rates across the various slopes of Mt. Musuan.

Conclusions

Various vegetation covers exhibit different soil erosion data in Mt. Musuan. Agro-ecosystems had the highest soil loss among the three land covers at 41.43 ton ha^{-1} yr^{-1}. Grassland ecosystem was second highest with 26. 39 ton ha^{-1} yr^{-1} while the forest area had the least soil loss with 13.98 ton ha^{-1} yr^{-1}.On slope gradient across the land cape of Mt. Musuan, slope greater than 20% exhibited the highest erosion rates with 35.37 ton ha^{-1} yr^{-1}.

The slope less than 10% had the least with 17.35 ton ha^{-1} yr^{-1}.Infiltration rates influenced the extent of soil erosion in Mt. Musuan. The higher the infiltration rate, the lesser is the soil losses. In this study, the infiltration rate of the forest area is 94.67 mm hr-1, the highest among the three land cover. The soil erosion rates of the three vegetation/land covers are beyond the tolerable limit of 10 ton ha^{-1} yr^{-1} with agro-ecosystem on critical level. The information generated in the study implies that there is a need to preserve the landscape of Mt. Musuan by dis-allowing activities that promotes soil/land disturbances. Planting of more perennial vegetation must be expanded in the whole landscape to minimize soil erosion and sedimentation problems.

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