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Effects of Different Land Use Types on Soil Carbon and Nutrients in Kalaw Watershed Area, Inlay Lake

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အင်းလေးကန်ဒေသ၊ ကလောရေဝေရေလဲဧရိယာ၌ မြေအသုံးချမှုပေါ်မူတည်၍ မြေဆီလွှာအတွင်းရှိကာဗွန်ပမာဏနှင့်အာဟာရဓါတ်ပါဝင်မှုကို လေ့လာခြင်း

ဖြူဖြူဆွေ၊ သုတေသနလက်ထောက် -၂
ဆွေဆွေထွန်း၊ လက်ထောက်သုတေသနအရာရှိ
ဘီလီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ

စာတမ်းအကျဉ်းချုပ်

အင်းလေးကန်ဒေသ၊ ကလောရေဝေရေလဲ ဧရိယာအတွင်း၌ မြေအသုံးချမှု အမျိုးမျိုးတွင် မြေဆီလွှာအတွင်းရှိ ကာဗွန်ပမာဏနှင့် မြေဆီလွှာအာဟာရဓါတ်ပါဝင်များကို နှိုင်းယှဉ်ရန် ရည်ရွယ်လေ့လာခဲ့ပါသည်။ Reference area ၊ သစ်တောဧရိယာ နှင့် သီးနှံ စိုက်ပျိုးမြေများ (စိုက်ပျိုးခဲ့သည့်သက်တမ်း- ၅ နှစ်၊ ၁၅ နှစ်၊ ၁၆ နှစ်၊ ၂၀ နှစ်၊ ၃၀ နှစ် နှင့် ၄၀ နှစ်) စသည့်ဖြင့် အဓိက ၃ မျိုးခွဲ၍ မြေနမူနာစုစောင်းခြင်းနှင့် မြေဂုဏ်သတ္တိများ ဓါတ်ခွဲ စမ်းသပ်ခြင်းကို ဆောင်ရွက်ခဲ့ပါသည်။ မြေအသုံးချမှုပေါ်မူတည်၍ မြေဆီလွှာ အတွင်းရှိ ကာဗွန်ပမာဏနှင့် အာဟာရဓါတ်ပါဝင်မှုများကို ထူးခြားစွာကွာခြားခြင်းနှင့် အချင်းချင်း ဆက်သွယ်ခြင်းများ ရှိ/မရှိကို စာရင်းအင်းပညာတွက်ချက်မှုများအရ နှိုင်းယှဉ် လေ့လာထားပါသည်။ လေ့လာတွေ့ရှိချက်များအရ ဖော့စဖော်ရဓါတ်ပါဝင်မှုမှ လွဲ၍ အခြားမြေဆီလွှာရူပနှင့် ဓါတုဂုဏ်သတ္တိများသည် မြေအသုံးချခြင်း အမျိုးမျိုးပေါ်မူတည်၍ ကွဲပြားမှုရှိကြောင်း တွေ့ရှိခဲ့ပါသည်။ မြေဆီလွှာအနက်ပေါ်မူတည်၍ မြေအလွှာ အပိုင်း အခြားများကို လေ့လာခဲ့ရာ ဖော့စဖော်ရဓါတ်၊ မြေသိပ်သည်းဆ၊ မြေဆွေးဓါတ်၊ မြေဆီလွှာ ကာဗွန်၊ သဲနှင့် မြေစေး ပါဝင်မှုများသည် ကွာခြားမှုရှိ ကြောင်းလေ့လာသိရှိရပါသည်။ လျောစောက်အနေအထား ပေါ်မူတည်၍ လေ့လာမှုတွင် ၁၅ နှစ် စိုက်ပျိုးထားခဲ့သည်မြေတွင် မြေချဉ်ငံဓါတ်နှင့် မြေစေး ပါဝင်မှုများ နေသည့်မှလွဲ၍ ကျန်အာဟာရဓါတ်ပါဝင်မှုသည် ထူးခြားစွာကွာခြားခြင်း မရှိကြောင်း လေ့လာ သိရှိရ ပါသည်။

Effects of different land use types on soil carbon and nutrients in Kalaw watershed area, Inlay Lake

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ABSTRACT

This study is aimed to determine the effect of different land use on soil fertility/properties in Kalaw watershed, which is one of the sub watersheds of Inlay lake. Soil samples were collected from three major land use types: Reference area, forest area and cultivated land (age of cultivation- 5, 15, 16, 20, 30 and 40 years) and tested in laboratory for soil physio- chemical properties. The one-way ANOVA was used to determine soil properties at significant difference (p=0.05) under different land use types. Also, Pearson's correlation coefficient was used to determine the relationship between soil nutrient and land use types. Accordingly, the mean values of soil physio- chemical properties were varied among land use types but non significant difference was observed for P. The soil nutrient characteristics: P, OM & OC, BD, SOC, Sand and Clay varied in different soil depths. Similar trends were observed in different slope portions for all soil properties, expect pH and clay at the age of 15 years cultivation.

Keywords: *Soil Properties, kawlaw sub watershed*

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1. Introduction

Land use changes can affect negatively to the environment and make threats to the natural ecosystems (United Nations, 2002), especially in the hill region. In Myanmar, Inlay Lake in surrounding hillsides shows negatively environmental changes by deforestation, shifting cultivation, and permanent sloping agriculture. As a consequence, run-off and sedimentation rates increased significantly to the lake (IID 2012). Therefore, prevention from sedimentation and erosion is important for preserving the hydrological regime of the Inlay Lake watershed. A lot of data on sources of sediment are needed on the extent of the problem in Inlay lake region.

In 2015, a study was conducted by Forest Research Institute under Forest department to assess the detachment and deposit of sediment to the Inlay lake with supporting of IAEA. It was initiated to investigate which parts of sediment come to Thandaung stream (Kalaw Chaung watershed area). Because the main source of sediment to Inlay lake comes from the western mountains through the Thandaung and Inndein streams (Lwin, 2006). Therefore, this paper aims to add some information with above paper and focus on soil physical and chemical properties in relation to land use. For the environmental degradation as well as information on livelihood strategies and soil erosion risk in the Inlay region several previous studies described based on field surveys and modeling. But this paper will discuss to assess soil fertility caused by different land use with lab analyzing.

Climate and geological history are importance factors to affect soil properties. However, under small catchment scale land use may be the dominant factor of soil properties and also influence the soil nutrients (Celik, 2005). Therefore soil characteristics by the influence of land use are essential matter to estimate land productivity in long term.

2. Objectives

(a) To compare soil carbon and nutrient content under the various land use types
(b) To evaluate dynamic of soil carbon and nutrient content within the various age of cultivation

3. Literature Review

The soil has a mixture of air, water, decaying organic and inorganic material and billions of living organisms within the surrounding ecosystem (Barreto *et al.,* 2000). Land use changes such as forest clearing, crop cultivation and pasture introduction are known to result in changes of these things (Houghton *et al.,* 1999). These changes vary with land use and land management (Celik, 2005). Land use change and subsequent tillage practices resulted in significant decreases in organic matter, total porosity, total nitrogen and soil aggregates stability. There was also a significant change in bulk density among cultivated, pasture and natural forest soils. Depending upon the increasing in bulk density and disruption of pores by cultivation, total porosity decreased accordingly. Under long term continuous cultivation and natural forest soils resulted in change in both physical and chemical characteristics of soil. Because it was found that land use and land cover associated with organic matter content can alter the soil enzyme activities within the soil profile (Kizilkaya 2010).

High changes of soil physical properties are related to practice clearing methods that caused soil compaction and exposure of bare soil to the impact of high intensity rains. The resistance of the soil to compaction mainly depends on soil type and moisture content. Forest soil with higher content of organic matter is greater resistance to compaction as compare to other field crops or rangeland (Guerreo *et al.,* 1995).

Lavkulich and Rowles (1971) indicated that the clay content increased in cultivated area of Ap and B horizons and attributed by the grinding effect of cultivation on the surface horizons. Beare *et al.,* (1994) found that no tillage practices can improve and increase the soil aggregation stability of macro-aggregates and change the distribution of soil organic matter level more than conventional tillage.

4. Material and Methods

4.1 Description of Study Area

Inlay Lake, the second largest lake of Myanmar, is situated in southern Shan State. Although there is a total of 29 streams in the watershed flowing to the lake, it receives most of its run-off from four major sub watersheds containing 12 streams. Kalaw sub watershed is situated in the western part of Inlay Lake that is one of the four main sub watersheds namely: Nanlat, Negya, Kalaw and Upper Balu sub watershed.

The study was conducted at Kalaw sub-watershed and covered about 186880 acres (292 sq miles) of the whole watershed of Inlay Lake. There are five land use classes seen in Table – 1.The Kalaw sub watershed (also known as Thandaung) channels water from the western part of the watershed, reaching the lake via a complex of channels which form the 'bird foot' delta on the western coastal plain (IID- 2012).

Table- 1 land use classes in Kalaw sub watershed

Item	Area (acres)	Percentage
Water body	38.87	0.02
Close Forest	10429.58	5.58
Open Forest	11375.90	6.09
Other Wooded land	15201.37	8.13
Agriculture land	149834.27	80.18
Total	**186880**	**100**

Kalaw sub watershed lied between 20°38' N and 96°34' E at 1320 m above sea level. Topography is mountainous with steep slopes and valley. The dominant climate within the study area is monsoon. The area receives annual rainfall of approximately 1036 mm with three main seasons: dry summer (mid-February to mid-May), rainy season (mid-May to mid-October) and dry winter (mid-October to mid-February). Precipitation occurs during May to October. The dominant soil types in the Inlay Lake region are Acrisols, Red and Yellow earth, mainly in the upland area (Su and Jassby 2000, Hai et al. 2006).

4.2 Sampling Sites

This study area was selected through asking rural farmers, leader of village and others representative older cultivator about soil fertility, soil erosion, soil deterioration, depletion of topsoil and nutrients, and effects of soil erosion to define age of cultivation. In upland, cultivation practices are mostly based on mono-cultivation, shifting cultivation, terraces and agro-forestry systems. In study sites, cultivation practices are mostly mono-cultivation and rotational upland farming along slope. Selected land-use systems consisted the annual crop fields for 5years, 15 years, 16 years, 20 years, 30 years, 40 years and forest area more than 60 years and Reference area listed in table 2. Figure -1 gives the map of the Inlay Lake, its watershed and Kalaw sub-watershed with study sites.

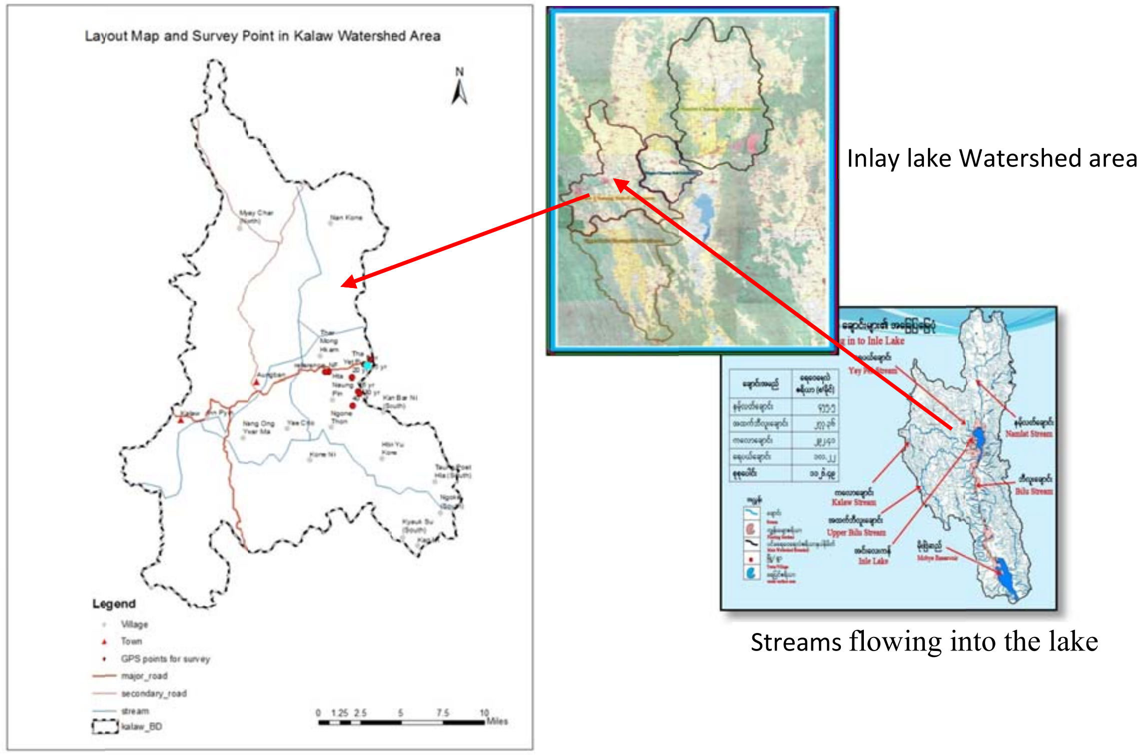


Figure-1: Location of Study Area in Kalaw sub-watershed

Table 2. Description of Sampling Sites

Items	Land use type	Reclamation history
site - 1	Upland agricultural area	Cropping period for 5 years
site - 2	Upland agricultural area	Cropping period for 15 years in Thetyetpu village
site - 3	Upland agricultural area	Cropping period for 16 years in Kantan village
site - 4	Upland agricultural area	Cropping period for 20 years in Thetyetpu village
site - 5	Upland agricultural area	Cropping period for 30 years in Kantan village
site - 6	Upland agricultural area	Cropping period for 40 years in Kantan village
site - 7	Forest area	Pine Forest area
site - 8	Reference area	Undisturbed area / natural areas (non-interventions by natural or human)

4.3 Soil Sampling and Pretreatments

The study areas is in the same slope position (14 %) and length. All soil samples were collected at different land use types with different slope portions (upper, middle and lower) and three different soil depths. The undisturbed soil samples were taken by using a steel core of a 100 cm^3 volume at 0- 10 cm and 135 cm^3volume at soil depths of 10 - 20 cm and 20 - 30 cm in each plot of the study area. A total of198 soil samples (7 land use types x 3slope portions x 3 soil pits x 3 soil depths) at different land use to analyze differences in soil properties. However, only 9 soil samples were collected at reference area.

4.4 Analyses of Soil Samples

All collected samples were air-dried, ground and passed through 2 mm sieve to separate stones, roots, and large organic residues and weight before conducting analyses for chemical and physical characteristics. The physio-chemical analyses of the soil samples were conducted at Soil Laboratory of the Forest Research Institute following standard laboratory procedures by William, L.P. &Tin Tin Ohn (1983).

Particle size distribution was determined by the pipette method after dispersion with 0.4 N sodium meta-phosphate ($NaPO_3$). Soil pH was measured on 1:2.5 soil: water suspensions with glass electrode on a pH meter. Extractable Ca and K were obtained by extracting soil with double acid with an atomic absorption spectrophotometer; total nitrogen by using Kjeldahl method and available phosphorus by extraction with double acid by spectrophotometer DR/2000 wavelength 600 nm and Organic matter by the Loss of Ignition. Bulk density was determined by measuring the wet weight of each core and converting to dry mass equivalent per unit volume of soil and the known volume of the cores. Dry mass was done by putting air dry sub-samples in oven at 105□C to get constant weight.

4.5 Statistical Analysis

A one-way analysis of variance (ANOVA) was used to test differences in soil physical and chemical properties across land use types seen in appendices. The statistical analysis of variance (ANOVA) was carried out by using the SPSS 16 program for windows. Duncan's significance test was used for mean separation when the analysis of variance showed a statistically significant difference ($p < 0.05$). Mean values found for all properties are shown in appendix-I. Different alphabet shows different significant levels at ($p < 0.05$). Pearson's correlation co-efficient was also estimated for all possible paired combinations of the variables to generate a correlation coefficient matrix.

5 Results and Discussions

5.1 Particle size distribution

The Particle size distribution (Soil texture or Sand, Silt and Clay percentages) of different horizons under the different land use types are found sand-clay loam (SCL), clay loamy (CL) and Clay (C) texture. The mean values of soil particle size distribution are mostly clay and clay loam soil in site – 1 to 4 while clay and sandy clay loam in site -5 to 8.

The particle size distribution shows an overall statistically significant variation based on land use. The highest average sand content are recorded in the site - 7 and then followed by site – 8. Lowest sand content is found in site -2. On the other hand, higher content of clay is also recorded in site-2.The trends land use types based on particle size distribution could be seen in Figure-2. The lowest clay content is presented in site-8 with statistically significance among land use. Average silt amount is significantly higher in the site – 8 in all three depth levels and then followed by site -7 (appendix-I).

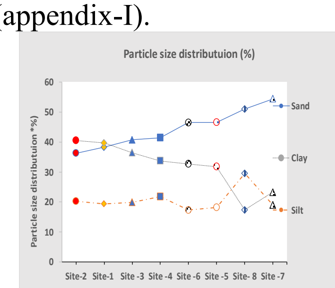


Figure - 2. Particle size distribution patterns in different land use types

Our results indicate that the different land use types have effect on the soil texture of the study area. Although texture is inherent property, the difference in soil texture is due to management of land cover (Celik, 2005) and also weathering processes on similarity in parent materials from which they developed. The characteristic of soil management is another good reason for the high proportion of sand. According to Lavkulic and Rowles (1971) the clay content increased in cultivated in A and B horizons by the grinding effect of cultivation and mixing of the A horizons with B horizons. They may become more thickness of A horizon with clay particles at cultivated area. The soil of study area is present accumulated kaolinitic clays and high erodibility as the properties of Red and Yellow earth (Acrisols). And finer soil particle than coarser soils can be a bigger problem to lose in the erosion processes because these particles let go easily with touched by water. Therefore, finer particle under insufficient soil cover will be easily lost in sheet erosion and some of the topsoil had been removed by surface flow. Even if there is sufficient soil cover soil may be eroded by geological erosion. This is another factor which leads to changes in the soil texture. The distribution patterns of soil particle based on soil depth under each land use types could be seen in figure-3 (a, b and c).

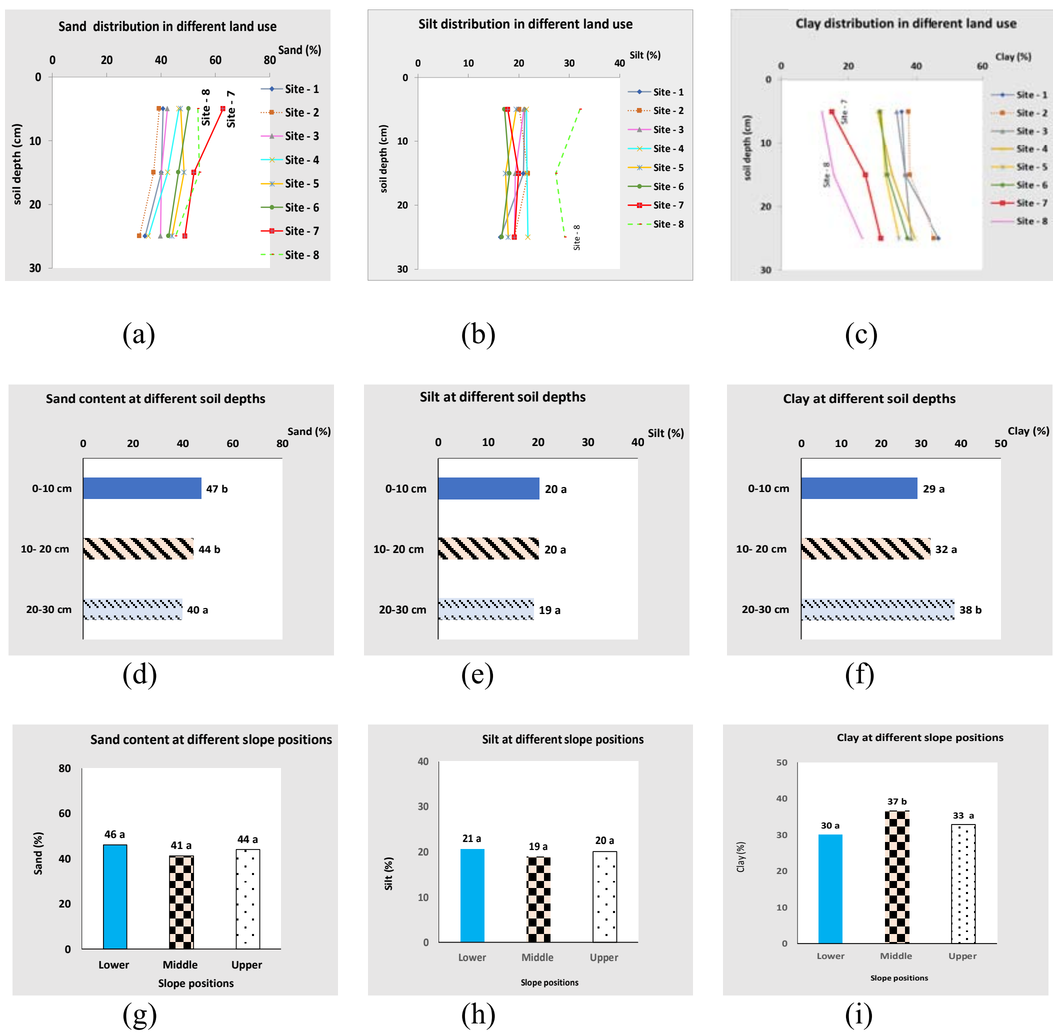


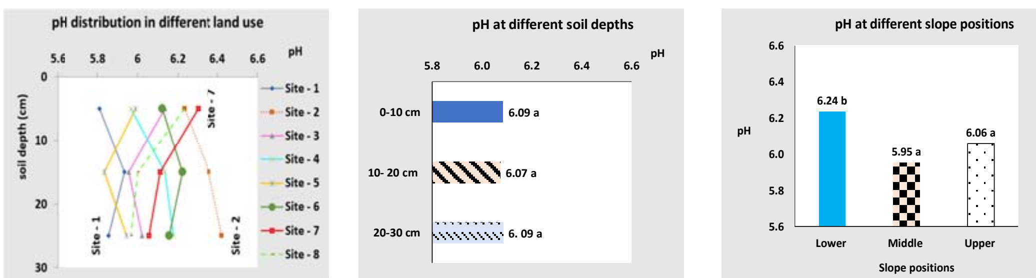
Figure3 - (a) (b) & (c) Vertical distribution of sand, silt &clay under different land use
(d), (e) & (f) Sand, silt &Clay content at different soil depths and
(g), (h)& (i) Sand, silt &Clay content at different slope portions

Within the different land use types there are no significant difference in sand and clay between 0- 10 and 10-20 cm but significantly higher in 20-30cminfigure-3 (d, e and f). This is one of the best indicators by the effect of soil compaction. Another thing indicates that soil in our study area is the types of Arcisol (Red and Yellow earths). So according to this soil properties A and massive B horizons generally have porous and weak profile differentiation but usually display a gradual increase in clay content with depth (www.Wikipedia). Among the different slope portions clay content is higher at middle portion than others seen in figure-3 (g, h and i). Because the middle portion of slope at site-2 is significant higher than others.

5.2 Soil Acidity (soil pH)

A one-way analysis of variance showed that there is an overall significant effect of land use types on soil pH values (pH 5 to 6.7). Thompson and Whitney (2000) mention that continuous cultivation for several years results in the decreasing of soil pH as compared with initial time of clearing. Declining soil pH can get from continuous cropping with inorganic fertilizer inputs. The results of our study are in contrast to that obtained by Thompson and Whitney. The lowest amount of pH is found in cultivation period for 5 years (appendix II). Therefore, the different of pH may depend on the crop removal, ploughing process, addition of green manure, crop rotation and uses of fertilizer (amount and types). The distribution patterns of pH based on soil depth under each land use types could be seen in figure-3(a).

The pH value is not significantly different with soil depth (figure-3 (b)). Among the different slope portions the pH of soil at lower slope portion is significantly higher than the others and the trend of soil pH at slope portion could be seen in figure -3(c). The result of higher pH values were found under site-2 at lower portion in 0 - 30 cm soil depth.

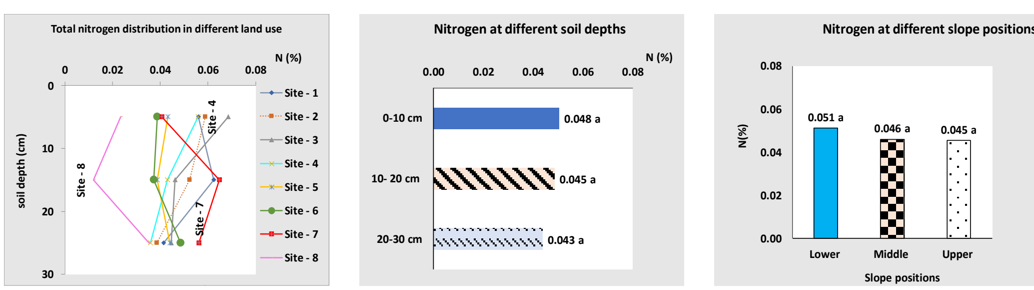


(a) (b) (c)

Figure. 4 - (a) Vertical distribution of soil pH (b) pH at different soil depths and (c) PH at different slope portions under different land use type

5.3 Total nitrogen (N)

The ANOVA results of N show that there are significant differences for different land-use. Because the N content of the soils in the site -8 is significantly lower than others. Forest and cultivated land show similar in N content (appendix-I). Each of land use shows different distribution patterns of nitrogen in figure- 4(a). The average content of N in all slope portions and among depths are not significantly different. N based on soil depth and slope portion could be seen in Figure- 4 (b & c).



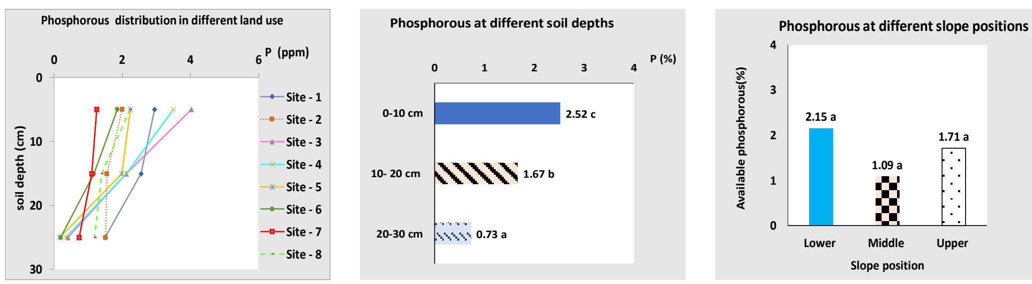
(a) (b) (c)

Figure. 5- (a) Vertical distribution of nitrogen (b) nitrogen in soil at different soil depths and (c) Nitrogen at different slope portions under different land use type

The results of higher N content (site-1 to site- 7) indicate higher content of OM or applied of inorganic fertilizer than site-8. The results show that these cultivated lands are suitable adoption in improved soil fertility management and agronomic practices for these nutrients.

5.4 Available Phosphorous (P)

Available P with lower amount are non significant in different land use types(appendix- II) and weak correlation with N and K(in appendix V). Also, the average content of P in all slope portions is not significantly different. While comparing among soil depth surface layer is significant higher than others. Available P in soil largely depends on the composition of parent rock material, inorganic or organic fertilizer inputs and a rotation of successive crop. Crop rotation system can effectively relieve by improving soil activities, and accelerating physiological and biochemical reactions within soil depths. This is one point for our results. The distribution patterns of P based on soil depth under each land use types could be seen in figure - 5 (a to c).

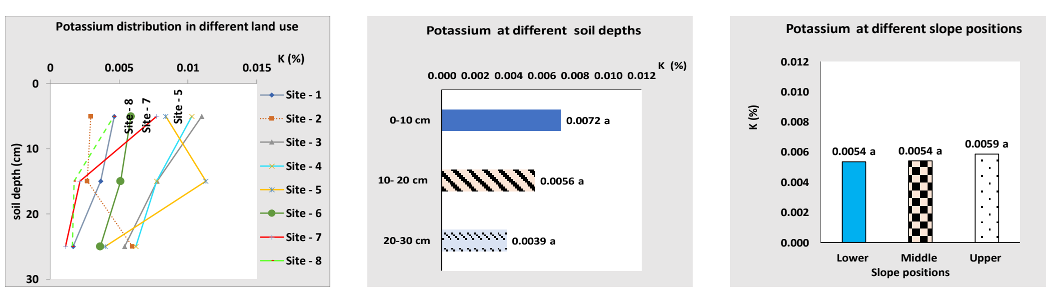


(a) (b) (c)

Figure. 6- (a) Vertical distribution of phosphorous (b) phosphorous at different soil depth sand (c) Phosphorous at different slope portions under different land use type

5.5 Extractable Potassium (K)

The ANOVA results of K show that there are significant difference for different land-use types (appendix-I). K content in the longer age of cultivated field is higher than that in forest, reference and shorter age of cultivated land. The average content of K is significant in different depths but non-significantly different in all slope portions. Each of land use shows different distribution patterns of potassium content that could be seen in figure -6 (a to c). K shows a positively correlation with soil phosphorous and calcium in these studies (r =+4 and r = +5). Usually, potassium in these study areas is found in moderately amount with little variation. K depends on the composition of parent rock material, organic and clay content and the application of wood ash and /or inorganic fertilizer inputs.

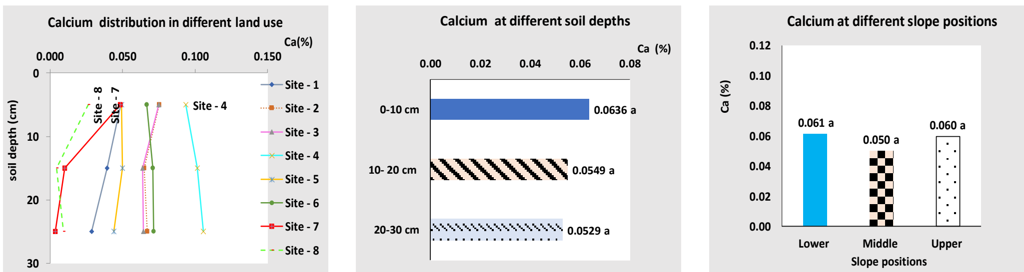


(a) (b) (c)

Figure.6- (a) Vertical distribution of soil potassium (b) potassium at different soil depths and (c) potassium at different slope portions under different land use

5.6 Extractable Calcium (Ca)

The mean Ca levels varied significantly with different land-use. The highest Ca is 0.1 % under site- 4 and followed by site-6 & site-2. Lower concentration of exchangeable Ca was found in reference area and followed by forest area seen in appendix-I. For the different land use the concentration of (Ca) are followed by the trend ofsite-4> site- 6> site- 2 > site-3> site-5>site-1>site-7 > site-8. Distribution pattern of Ca based on soil depth under each land use types could be seen in figure -7 (a to c).The results agree that of Jim Halbeisen (2017) who found calcium cation in agricultural soils flocculates clay and organic matter particles. Our results depend on the effect of compact of soil with clay particles and OM. Underlying bedrock of limestone and calcareous sandstone and siltstone in lower slope of Inlay region (Su and Jassby 2000) can get different Ca content. Among the soil depth and also slope portions there are no significantly changes of Ca in appendix-II and III.

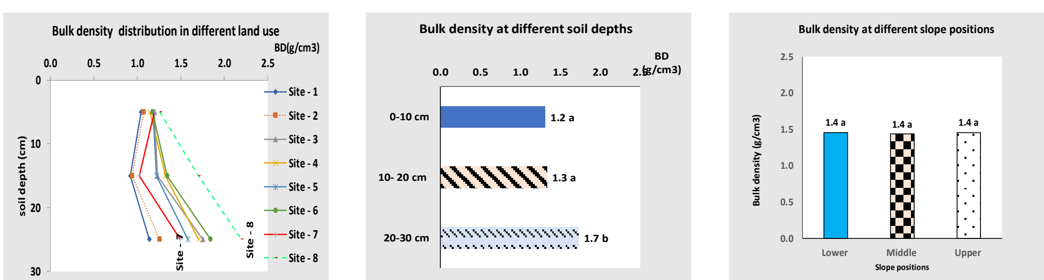


(a) (b) (c)

Figure. 7- (a) Vertical distribution of Calcium(b) calcium at different soil depths and (c) Calcium at different slope portions under different land use type

5.7 Bulk Density (BD)

The results indicate that the lowest BD (0.7 gcm^{-3}) is seen in site -1. Distribution patterns of BD have similar among different land uses that could be seen in figure-8 (a). Analysis of variance (ANOVA) shows significant variations in the bulk density values among different land use categories. It indicates that site -8 (Reference area or natural area) has the highest mean values with 1.7 gcm^{-3}. When the mean values of bulk density compared with land use types the smaller value is observed under site- 1 & 2(1.2 gcm^{-3}) in agriculture land and followed site-7 in forest land. It is subjected to intensive mulching with organic materials for the whole years in agriculture and improving soil structure process.



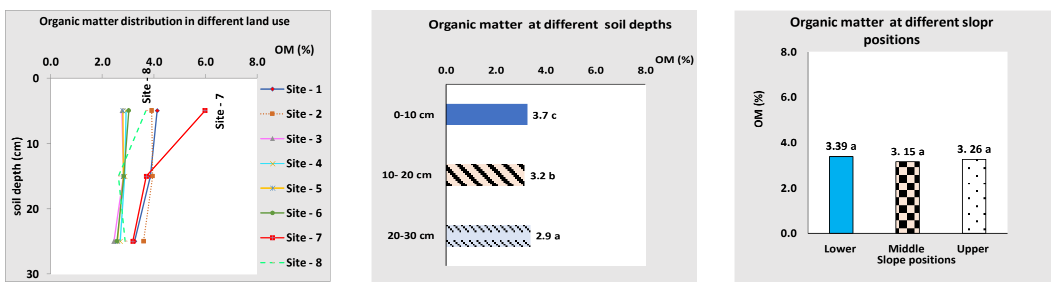
(a) (b) (c)

Figure. 8- (a) Vertical distribution fob (b) BD at different soil depths and (c) BD at different slope portions under different land use type

All surface layers have the lowest bulk density value whereas the lowest depth has the highest bulk density values at all study sites in figure-8 (b) because of greater compaction of mineral soil in lower layers. In the slope portions there are non-significant in BD seen in figure-8(c). Pearson's correlation coefficient showed that the bulk density is inversely correlated to the organic matter (r = - 0.34)that see in appendix IV.

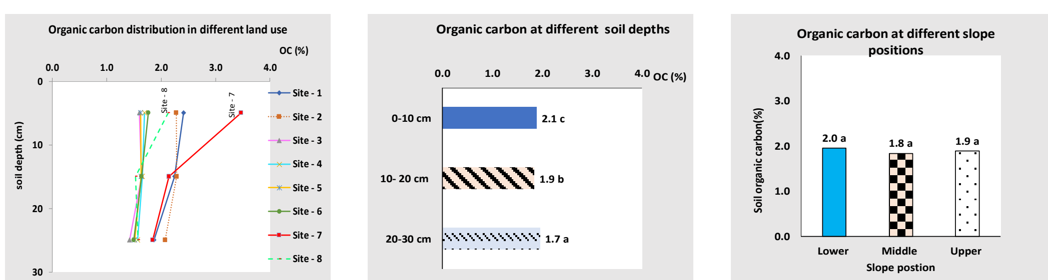
5.8 Organic Matter (OM) and Organic Carbon (OC)

Carbon (C) and nitrogen (N) in soils are the main component of organic content which known as soil fertility. In this area soil nitrogen is not significantly different. But organic matter and organic carbon are significantly different between site by site and layer by layer (Appendices -II& III). Similar distribution patterns of OM and OC are observed but a litter variation in the forest at surface layer (figure 9 and 10 (a)). Around the study region, same amount and types of fertilizers applied on same crop at different growing season. The responses are different and yield is decreasing on the same land through time. Therefore, the fertility of this soil may depend on the condition of organic matter or soil organic carbon from various vegetation that grow on the land. As mention by Liu et al., 2010, land use and type of vegetation must be taken into account relating soil organic matter with environmental conditions. Therefore, land use type has a deep effect on OM and OC storage, since it affects the amount and quality of input material, decomposition rate, and stabilization of OM and OC.



(a) (b) (c)

Figure. 9- (a) Vertical distribution of organic matter (b) organic matter at different soil depths and (c) organic matter at different slope portions under different land use type



(a) (b) (c)

Figure. 10- (a) Vertical distribution of OC (b) OC at different soil depths and (c) OC at different slope portions under different land use type

The average content of soil OM and OC are the highest in site-7 and followed by site -1 as compared to that of other agriculture land in figure -9 (a) and 10 (a). Our results agree with the amount of organic matter that is normally highest in the forest soil comparable to continuously cultivated soil. Litter fall is obviously attributed to the addition of higher biomass input on these soils. In some cultivated land, their agricultural crop with more shoot and root biomass and a shallower root system may provide more organic matter.

OM and OC content in all land use types are found to be highest in the surface horizons of the respective soil in figure -9 (b) and 10-(b). Schultz et al. (2004) pointed out the declining of OM and OC is caused by continuous cropping without nutrient inputs. And soil fertility can be reduced by the loss of topsoil in the sediment and nutrient loads in waterways. Our results are closely related the higher storage of OM and OC with the accumulation of plant materials, organic matter addition, crop rotation, reducing compaction and erosion.

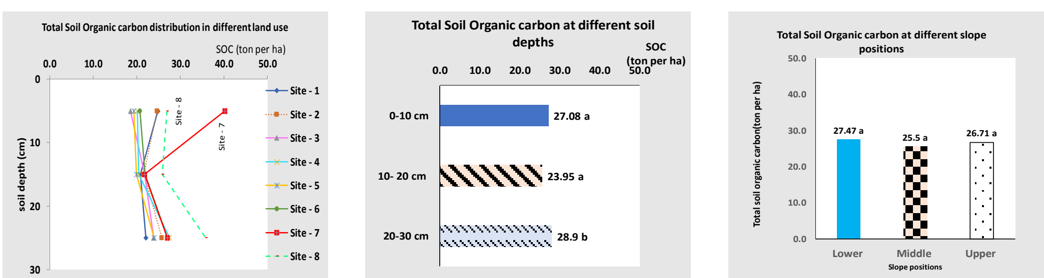
Roy C. et.al. (2006) mention that cultivation in the upland zone exhibited the highest soil erosion risk among the different cropping systems of the surveyed households in Inlay region. The majority of soil losses (77%) occurred on barren land, which is mostly situated on marginal sites along steep slopes. If soil and organic matter can be transfer down slope by erosion, soil organic matter will increase in lower parts of the slope. In our results compare among the slope position there is not significant OM and OC among land use in figure -9 (c) and 10 (c). However, the highest content of OM can be occurred in lower slope portion. Therefore it may be occurred soil erosion but not significant. Cultivators will be applied soil improvement techniques in their situations with the soil cover after cultivation.

Pearson’s coefficient of correlation indicated an overall significant positive weak correlation between OM/ OC &BD in different land-use types (r= - 0.3).

5.9 Soil Organic Carbon (SOC)

Analysis of variance has shown significant effect of land use on the distribution of SOC. Amount of SOC can result in increased in site-7 (forest area) but decreased in agricultural land use (site -1 to 6) compare with reference area (Appendix - I). The relatively high SOC in forest land is attributed to the accumulation of organic matters and soil compaction or BD to compare agricultural land use. Pearson’s coefficient of correlation indicated a significant positive correlation (r = +0.6) between OM / OC & BD and SOC in different land use types seen in appendix-V. The distributions of SOC show similar among land use types in figure -11 (a).

The mean SOC content is significantly different at soil depth in appendix- III. Because SOC is higher at surface layer in site-7(figure-11 (b)). It depends on OM and BD. The mean SOC content is not significantly different in all slope portions in appendix- IV and all depths in figure-11 (c).



(a) (b) (c)

Figure. 11- (a)Vertical distribution of soil SOC (b) SOC at different soil depths and (c) SOC at different slope portions under different land use type

6. Conclusions

Different land use systems affect significantly the distribution of sand, silt and clay. Sand content in reference area and forest area are higher than other cultivated area. In long term agricultural cultivation sand content tends to increase but silt and clay content tends to decrease. Age of cultivation effects on soil physical properties, especially particle size distribution and bulk density, in upland area. In summary, long term continuous cultivation has resulted to increase sand content and bulk density in the condition of our study.

Organic matter has the major influences on soil chemical properties in the land-use systems. SOC is higher under forest area than reference area and cultivated area. But some land use types may increase plant biomass, and cause an increase of soil organic matter. In the meantime, the soils have been gradually modified with soil improvement application during cultivation. And shifting cultivation / rotation of upland crop don't have fallow periods but sufficient use of fertilizers, manures and restorative crops by their own ways in their cultivated land. Therefore, the effect of long term cropping didn't show an undesirable condition but a decline in the soil organic matter (organic carbon) and nutrients in long term (over 15 years). There is no harm to use the agriculture on these conditions if the topography had low slope, soil deep enough for field crops, and had good agriculture management. For the long-term sustainability of agricultural systems, the decline in soil fertility in the soil could be controlled through the application of suitable inorganic or organic fertilizers and growing legumes tree crops in suitable position.

7. Recommendation

Long term cultivation with legumes or other soil improvement tree species result in soil fertilities improvement. In addition it will reduce pressure on forest and natural resources in long term. So, experimental research on soil improvement system should be supported to stabilize soil fertility and other benefits.

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Appendix- I

Physical and Chemical properties in different Study Sites

Soil properties	Locations	N	Mean	Std. Error	Minimum	Maximum
pH	Site-1	27	5.91 [a]	0.1	5	6.5
	Site-2	27	6.3 [c]	0.04	5.8	6.7
	Site -3	27	6.0 [ab]	0.1	5.2	6.7
	Site -4	27	6.1 [ab]	0.1	5	6.7
	Site -5	27	5.95 [b]	0.1	5.2	6.7
	Site -6	27	6.2 [bc]	0.1	5.2	6.5
	Site -7	27	6.2 [bc]	0.03	5.9	6.5
	Site- 8	9	6.1 [ab]	0.1	5.9	6.4
Total Nitrogen (%)	Site-1	27	0.053 [b]	0.003	0.027	0.085
	Site-2	27	0.050 [b]	0.004	0.021	0.097
	Site -3	27	0.053 [b]	0.004	0.016	0.112
	Site -4	27	0.047 [b]	0.003	0.015	0.106
	Site -5	27	0.042 [b]	0.003	0.01	0.08
	Site -6	27	0.041 [b]	0.002	0.02	0.066
	Site -7	27	0.054 [b]	0.005	0.024	0.128
	Site- 8	27	0.024 [a]	0.007	0.008	0.078
Available Phosphorous(ppm)	Site-1	27	2.31 [a]	0.32	0.21	6.33
	Site-2	27	1.69 [a]	0.30	0.09	8.26
	Site -3	27	2.19 [a]	0.44	0.04	8.37
	Site -4	27	1.76 [a]	0.42	0.02	8.28
	Site -5	27	1.45 [a]	0.31	0.02	6.64
	Site -6	27	1.08 [a]	0.18	0.02	3.18
	Site -7	27	1.04 [a]	0.19	0.02	3.68
	Site- 8	9	1.61 [a]	0.35	0.17	3.68
Extractable Potassium (%)	Site-1	27	0.003 [a]	0.000	0.001	0.009
	Site-2	27	0.004 [a]	0.001	0.0001	0.04
	Site -3	27	0.008 [b]	0.001	0.003	0.018
	Site -4	27	0.008 [b]	0.001	0.001	0.026
	Site -5	27	0.008 [b]	0.001	0.002	0.038
	Site -6	27	0.005 [ab]	0.000	0.003	0.009
	Site -7	27	0.004 [a]	0.001	0.0001	0.013
	Site- 8	9	0.003 [a]	0.001	0.001	0.007
Extractable Calcium (%)	Site-1	27	0.039 [b]	0.0031	0.01	0.074
	Site-2	27	0.069 [c]	0.0053	0.03	0.157
	Site -3	27	0.068 [b]	0.0046	0.036	0.123
	Site -4	27	0.100 [d]	0.0073	0.04	0.154
	Site -5	27	0.048 [b]	0.0052	0.016	0.119
	Site -6	27	0.070 [c]	0.0052	0.027	0.12
	Site -7	27	0.021 [a]	0.0042	0.002	0.065
	Site- 8	9	0.013 [a]	0.0039	0.002	0.033
Organic matter (%)	Site-1	27	3.7 [b]	0.11	2.5	5
	Site-2	27	3.8 [b]	0.12	2.6	5.5
	Site -3	27	2.7 [a]	0.06	1.9	3.3
	Site -4	27	2.8 [a]	0.05	2.3	3.2
	Site -5	27	2.7 [a]	0.06	2.4	3.5
	Site -6	27	2.8 [a]	0.07	2.1	3.6
	Site -7	27	4.3 [c]	0.27	2.3	7.5
	Site- 8	9	3.1 [a]	0.30	1.9	4.3

Soil properties	Locations	N	Mean	Std. Error	Minimum	Maximum
Sand (%)	Site-1	27	38 [a]	1.2	28	56
	Site-2	27	36 [a]	1.5	22	48
	Site -3	27	41 [a]	1.8	25	60
	Site -4	27	41 [a]	1.7	19	57
	Site -5	27	47 [b]	1.3	33	61
	Site -6	27	46 [b]	1.3	31	61
	Site -7	27	54 [c]	1.7	33	68
	Site- 8	9	51 [c]	2.6	37	61
Silt (%)	Site-1	27	19 [ab]	0.9	12	32
	Site-2	27	20 [ab]	0.9	8	29
	Site -3	27	20 [ab]	0.8	12	30
	Site -4	27	22 [b]	0.9	15	32
	Site -5	27	18 [a]	0.7	12	28
	Site -6	27	17 [a]	0.7	10	26
	Site -7	27	19 [ab]	1.2	8	34
	Site- 8	9	30 [c]	2.1	22	42
Clay (%)	Site-1	27	40 [d]	1.5	26	56
	Site-2	27	41 [d]	1.9	28	56
	Site -3	27	36 [cd]	1.5	22	54
	Site -4	27	34 [c]	1.6	20	47
	Site -5	27	32 [c]	1.4	18	44
	Site -6	27	33 [c]	1.1	22	42
	Site -7	27	23 [b]	1.3	11	34
	Site- 8	9	17 [a]	1.9	10	28
Bulk density (gcm3)	Site-1	27	1.2 [a]	0.04	0.7	1.7
	Site-2	27	1.2 [ab]	0.04	0.9	1.5
	Site -3	27	1.6 [de]	0.05	1.2	2.1
	Site -4	27	1.6 [de]	0.06	1.1	2.2
	Site -5	27	1.5 [cd]	0.06	1.1	2
	Site -6	27	1.7 [de]	0.07	1.2	2.4
	Site -7	27	1.4[bc]	0.06	0.8	1.9
	Site- 8	9	1.7[e]	0.15	1.2	2.5
Soil Organic Carbon (%)	Site-1	27	2.1[b]	0.06	1.4	2.7
	Site-2	27	2.2[b]	0.08	1.5	3.2
	Site -3	27	1.6[a]	0.04	1.1	1.9
	Site -4	27	1.6[a]	0.03	1.3	1.9
	Site -5	27	1.6[a]	0.03	1.4	1.9
	Site -6	27	1.6[a]	0.04	1.2	2.1
	Site -7	27	2.5[c]	0.17	1.3	4.3
	Site- 8	9	1.8[a]	0.17	1.1	2.5
Total Soil Organic Carbon(ton/ha)	Site-1	27	25.3[a]	0.93	17.8	37.9
	Site-2	27	26.9[ab]	1.03	20.7	41.1
	Site -3	27	24.2[a]	0.89	18	32.7
	Site -4	27	25.5[ab]	0.98	16.6	38.8
	Site -5	27	23.6[a]	0.89	16.6	34
	Site -6	27	26.7[ab]	1.06	15.9	38.5
	Site -7	27	33.2[c]	2.11	16.3	65
	Site- 8	9	29.5[bc]	2.90	21.5	51.4

Appendix- II

Result of the one-way analysis of variance in physical & chemical properties of the soils under the different land uses

Soil properties		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	4.097	7	0.585	5.078	0
	Within Groups	21.898	190	0.115		
	Total	25.995	197			
Total Nitrogen (%)	Between Groups	0.01	7	0.001	4.027	0
	Within Groups	0.067	190	0		
	Total	0.077	197			
Available Phosphorous (ppm)	Between Groups	204.805	7	29.258	0.941	0.476
	Within Groups	5908.71	190	31.098		
	Total	6113.515	197			
Extractable Potassium (%)	Between Groups	0.001	7	0	5.101	0
	Within Groups	0.005	190	0		
	Total	0.005	197			
Extractable Calcium (%)	Between Groups	0.126	7	0.018	26.326	0
	Within Groups	0.13	190	0.001		
	Total	0.256	197			
Organic matter (%)	Between Groups	70.249	7	10.036	21.617	0
	Within Groups	88.207	190	0.464		
	Total	158.456	197			
Sand (%)	Between Groups	6676.438	7	953.777	15.255	0
	Within Groups	11879.48	190	62.524		
	Total	18555.92	197			
Silt (%)	Between Groups	1230.532	7	175.79	8.071	0
	Within Groups	4138.296	190	21.781		
	Total	5368.828	197			
Clay (%)	Between Groups	7894.678	7	1127.811	19.401	0
	Within Groups	11045.19	190	58.133		
	Total	18939.86	197			
Bulk Density (g/cm^3)	Between Groups	5.922	7	0.846	9.758	0
	Within Groups	16.04	190	0.087		
	Total	21.962	197			
Organic Carbon (%)	Between Groups	23.167	7	3.31	20.663	0
	Within Groups	29.632	190	0.16		
	Total	52.799	197			
Total soil Organic carbon (tons/ha)	Between Groups	1730.924	7	247.275	6.395	0
	Within Groups	7153.132	190	38.666		
	Total	8884.056	197			

Appendix- III

Result of the one-way analysis of variance in physical & chemical properties of the soils under at different soil depth

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	0.006	2	0.003	0.022	0.979
	Within Groups	25.989	195	0.133		
	Total	25.995	197			
Total Nitrogen (%)	Between Groups	0.002	2	0.001	1.971	0.142
	Within Groups	0.076	195	0		
	Total	0.077	197			
Available phosphorous (ppm)	Between Groups	103.823	2	51.911	22.796	0
	Within Groups	432.676	195	2.277		
	Total	536.499	197			
Extractable potassium (%)	Between Groups	0.	2	0	6.132	0.003
	Within Groups	0.005	195	0		
	Total	0.005	197			
Extractable Calcium (%)	Between Groups	0.004	2	0.002	1.625	0.2
	Within Groups	0.252	195	0.001		
	Total	0.256	197			
Organic matter (%)	Between Groups	18.774	2	9.387	13.105	0
	Within Groups	139.681	195	0.716		
	Total	158.456	197			
Sand (%)	Between Groups	1898.071	2	949.035	11.11	0
	Within Groups	16657.85	195	85.425		
	Total	18555.92	197			
Silt (%)	Between Groups	60.374	2	30.187	1.109	0.332
	Within Groups	5308.455	195	27.223		
	Total	5368.828	197			
Clay (%)	Between Groups	2808.394	2	1404.197	16.974	0
	Within Groups	16131.47	195	82.725		
	Total	18939.86	197			
Bulk Density (g/ cm^3)	Between Groups	9.245	2	4.623	69.068	0
	Within Groups	12.717	195	0.067		
	Total	21.962	197			
Organic carbon (%)	Between Groups	7.019	2	3.51	14.566	0
	Within Groups	45.78	195	0.241		
	Total	52.799	197			
Total organic carbon (%)	Between Groups	801.019	2	400.51	9.414	0
	Within Groups	8083.036	195	42.542		
	Total	8884.056	197			

Appendix- IV

Result of the one-way analysis of variance in physical & chemical properties of the soils at different slope positions

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	2.679	2	1.34	11.203	0
	Within Groups	23.315	195	0.12		
	Total	25.995	197			
Total Nitrogen (%)	Between Groups	0.001	2	0.001	1.735	0.179
	Within Groups	0.076	195	0		
	Total	0.077	197			
Available phosphorous (ppm)	Between Groups	36.874	2	18.437	7.011	0.001
	Within Groups	499.625	195	2.63		
	Total	536.499	197			
Extractable potassium (%)	Between Groups	0	2	0	0.177	0.838
	Within Groups	0.005	195	0		
	Total	0.005	197			
Extractable calcium (%)	Between Groups	0.005	2	0.002	1.922	0.149
	Within Groups	0.251	195	0.001		
	Total	0.256	197			
Organic matter (%)	Between Groups	1.817	2	0.908	1.131	0.325
	Within Groups	156.639	195	0.803		
	Total	158.456	197			
Sand (%)	Between Groups	803.646	2	401.823	4.414	0.013
	Within Groups	17752.27	195	91.037		
	Total	18555.92	197			
Silt (%)	Between Groups	104.768	2	52.384	1.94	0.146
	Within Groups	5264.061	195	26.995		
	Total	5368.828	197			
Clay (%)	Between Groups	1450.091	2	725.045	8.084	0
	Within Groups	17489.77	195	89.691		
	Total	18939.86	197			
Bulk Density (g/ cm^3)	Between Groups	0.02	2	0.01	0.086	0.918
	Within Groups	21.942	190	0.115		
	Total	21.962	192			
Organic carbon (%)	Between Groups	0.736	2	0.368	1.344	0.263
	Within Groups	52.063	190	0.274		
	Total	52.799	192			
Total soil organic carbon (tons/ha)	Between Groups	156.748	2	78.374	1.706	0.184
	Within Groups	8727.307	190	45.933		
	Total	8884.056	192			

Appendix- V

Correlation matrix for linear relationship between selected physical and chemical soil properties

Items	pH	N	P	Ext. K	Ext. Ca	OM	Sand	Silt	Clay	BD	OC	SOC
pH	1	.04	.01	-.01	.18**	.23**	.19**	.11	-.25**	-.06	.23**	.17*
Total nitrogen (N)	.05	1	.21**	.16*	.13	.19**	.03	.11	-.08	-.19**	.18*	.03
Available phosphorous (P)	.01	.21**	1	.38**	.13	.09	.07	.10	-.12	-.12	.09	-.01
Extractable potassium (K)	-.01	.17*	.38**	1	.51**	-.01	.08	.07	-.13	-.06	-.01	-.03
Extractable Calcium (Ca)	.18**	.13	.13	.51**	1	-.12	-.10	.05	.07	-.02	-.12	-.14*
Organic matter (OM)	.23**	.19**	.09	-.01	-.12	1	.27**	.09	-.32**	-.34**	1**	.67**
Sand	.19**	.03	.07	.08	-.10	.27**	1	-.24**	-.85**	-.04	.27**	.24**
Silt	.11	.11	.10	.07	.05	.09	-.24**	1	-.28**	.09	.09	.14
Clay	-.25**	-.08	-.12	-.13	.07	-.32**	-.85**	-.28**	1	.01	-.32**	-.31**
Bulk density (BD)	-.06	-.19**	-.13	-.06	-.02	.342**	-.04	.09	.01	1	-.34**	.44**
Organic Carbon (OC)	.23**	.18*	.09	-.01	-.12	1**	.27**	.09	-.32**	-.34**	1	.67**
Total soil organic carbon (TOC)	.17*	.03	-.01	-.03	-.14*	.67**	.24**	.14	-.31**	.44**	.67**	1

**. Correlation is significant at the 0.01 level and *. Correlation is significant at the 0.05 level