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Effect of Land Use on Plant Nutrient Availability and Soil Carbon Stock of Mokonisa Machi Watershade, Dugda Dawa Woreda, West Guji Zone, Southern Ethiopia

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ABSTRACT

Background: Various land use practices have a different influence on soil degradation on both physical and chemical property of soil as well as on soil carbon sequestration capacity. A small number of studies have studied the effects of land use on plant nutrient availability and soil carbon sequestration in Ethiopia. Therefore, current study was to explore the effects of land use on vegetation nutrient accessibility and soil carbon restoration.

Methods: Further definitely the study pointed out the difference between various land use category on soil texture, soil pH, available phosphorus and exchangeable potassium and the implication the farming practices on soil carbon sequestration. Soil sample were collected from the upper 0-40 cm depth of forest land, cultivated land and grazing land. The soil texture was primarily clay and heavy clay textural class.

Result: Along soil depth, bulk density (BD) increasing ranges from (1.12 to 1.27 g/cm in all sampling sites. Slight increase in pH was recorded with increase in soil depth in all land use system. The average total soil organic carbon stock forest, grazing and farm land was ranged between 95.2, 88.45 and 65.5 t/ha, respectively for surface soil and 93.3, 73.75, 62.5 respectively for sub surface soil. Soil organic carbon concentration and bulk density improvement are the most important management interventions to increase soil organic carbon storage capacity.

Key words: Land use, Plant nutrient, Soil carbon stock, Soil depth.

INTRODUCTION

The forest resource is very limited, its demand remains high. According to the Wakene (2001) the national demand for woody biomass was estimated at 50 million m^3, of which 90% is in the form of fuel wood. The supply was estimated to be only 14.4 million m^3, indicating a deficit of some 35.6 million m^3 or 71% of the demand. Different forest biomes have differed in soil organic carbon/soil organic matter storage capacity. And soil is the largest terrestrial pool of organic carbon (Lal, 2004). In total, soil contains about 3 times more carbon than the atmosphere and 4.5 times more than in living organisms (Alfred and Tom, 2008). Due to relatively large size and long residence time of carbon in soil, soils are potentially important natural sink for carbon (Barua and Haque, 2013).

Soil management practices play a significant role in sustainable agriculture and environmental quality. Land controlling practices have larger consequence on the course and degree of alterations in soil properties. Conversions of an area from native ecosystem to cultivated land may be the reason of soil degradation and decreases of quality. Soil management practices such as soil tillage, fertilizers and extreme irrigation often create unsuitable changes in soil quality (Gebeyaw, 2006).

Rapid population growth and long history of sedentary agriculture has changed the land use/land cover system and has been a major cause of environmental degradation on most parts of the world including Ethiopia (Gupta, 2004).

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In Ethiopia, where agriculture is the back bone of the economy (approximately 50% of GDP, 90% of foreign exchange earnings) (EEA, 2002), it was estimated that half of the Ethiopian highlands' arable lands are moderately to severely degraded and nutritionally depleted due to over cultivation, over grazing, primitive production techniques and over dependent on rainfall (ADF, 2001). Agricultural activities change the soil chemical, physical and biological properties and play the major role for soil degradation primarily due to soil fertility decline as a result of absence of nutrient inputs (Lal, 2004).

Hence, soil fertility depletion is considered as the fundamental biophysical causes for declining per capita food

production in sub-Saharan African countries in (Ahmed, 2002) and in particular Ethiopia. The problems of land degradation and low agricultural productivity in the country, resulting in food insecurity and poverty, are particularly severe in the rural highlands (Hagos, 2003). Soil losses from crop and grazing lands have been reported as 42 and 5 tons/ha/year respectively (Mitiku, 2000). The severity of land degradation in some parts of highlands is estimated to reach as high as to offset the gains from technical change. Finding solutions to these problems require identifying the farming system and the environment (Abayneh, 2001).

Numerous approaches can be justified to alleviate soil degradation problems. These include private incentives, integrated watershed management approach and focus on farming systems approach in research and development (Ahmed, 2002). Private incentive is provided for individuals in order to manage resources efficiently from the society point of view (Barua and Haque, 2013). On the other hand, focusing on farming systems approach as well as watershed development approach to research and development are also a vital element to understand and implement environmentally friendly, economically feasible and socially acceptable options. However, to implement appropriate management choices the essential element is to identifying different land use patterns as well as recent management trends and effects on soil physical and chemical property (ADF, 2001).

The problems of land degradation and low agricultural productivity in Ethiopia, resulting in food insecurity and poverty, are predominantly severe in the rural low and highland area. Despite climate and geological history which affects soil properties on regional and continental scales, land use and its management practices may be the dominant factors affecting soil properties and plant nutrient under small catchment scale. Land use and soil management practices affect the soil nutrients and related soil processes, such as erosion, oxidation, mineralization and leaching, *etc.* As a result, it can modify the processes of transport and re-distribution of nutrients. In non-cultivated land, the type of vegetative cover is a factor influencing the soil organic carbon content. Moreover, soils through land use change also produce considerable alterations and usually soil quality diminishes after the cultivation of previously untilled soils.

Thus, land use and type of vegetation must be taken into account when relating soil nutrients with environmental conditions. The particular nature of the typical rugged relief with slopes subjected to cultivation for many years in the study area had led to decline in soil fertility. Therefore, there is special need for the analyses of soil nutrients in relation to land use due to different land use practices have a varied influence on soil degradation on both physical and chemical property of soil as well as on soil carbon sequestration capacity. Such a local analysis is necessary to estimate nutrient storage in semi-natural and cultivated ecosystems; few studies have observed the effects of land use on plant nutrient availability and soil carbon sequestration in Ethiopia (Mitiku, 2000). Gebeyaw, (2006) reported that increasing population pressure and shortage of land, deforestation and cultivation activities are being carried out on steep slopes, practice of fallowing and crop rotation being eliminated. Besides this, shortage of grasslands has forced the farmers to remove crop residues for animal feed and firewood rather than doing it as manure for maintenance of soil fertility and productivity, therefore this research will be initiated to investigate the influence of different land use type and its management practices on plant nutrient availability and soil carbon sequestration of the soil in Dugda Dawaa Woreda. The main objective of study was to assess the effects of land use on plant nutrient availability and soil carbon sequestration in the study area and the specific objectives were: to figure out the difference between different land use types based on their OM, pH, CEC, OC, TN, available P, exchangeable K and Na in the study area,to evaluate the effect of soil depth on selected soil physicochemical properties of soils and to quantify, soil carbon sequestration capacity of different land use in the study area.

MATERIALS AND METHODS

Description of the study site

The topography of the area is characterized by steep slope, gentle slope and flat slope. The steep slopes were dominated by forest, whereas gentle and flat slope is used for cultivation and grazing land. The dominant tree species important for various socio-economic value are *Juniperus procera*, *Lantana camara* (Barkarkate) and *Carissa edulis (*Agamsa), *Olea europe*, *Acacia albida*, *Acacia synic* (Wangayo*)* and others are found in scattered manner. Local people cultivate different crops such as teef, coffee, maize, wheat enset *etc.* The forest is mostly used for browsing, fire wood and also as sources of construction wood by the local people.

Astronomically, the area is found between 5°38 N and 38°14 E, at average elevation of 1825 m.a.s.l. The temperature of town is from 20°C to 25°C and receives mean annual rainfalls relatively not less than 700 mm with main rains in spring and small rain in autumn. Regarding the moisture of town, it is drying sub-humid (CSA, 2007).

Sampling method

Soil sampling sites were selected based on land use type of the landscape and vegetation types (tree, shrubs and herbs). The steady area was divided into three sampling sites, namely: forest, cultivated and grazing land.

The investigator was gather a total of 24 combination samples (eight composite samples per land use type form grassland, farm land and forest land) of soil from the surface (upper 0-15 cm) and sub-surface (15-30 cm) of soil by using auger. Each composite sample was made from a pool of five samples. Before sampling, forest litter, grass and any other materials on the soil surface were removed. Every sampling point was Geo referenced and GPS readings of

the coordinates system was taken from where soil samples were collected. In general, for the sake of simplicity the researcher was made a boundary for each composite sample location.

As shown on Fig 1, soil sample is taken from 20 m by 30 m size with 5 m × 5 m from four corner and 1 m by 1 m from the center. Disturbed soil samples were collected from each site at the depth of 0-15 cm and 15-30 cm. Similarly, undisturbed soil samples were collected from each site at the respective depth for bulk density determination. The disturbed samples were air dried and crushed to pass through 2 mm sieve for determination of soil texture, CEC and pH. Sub samples from each disturbed soil sample were ground to the size of 0.5 mm for the determination of soil organic carbon, OM and nitrogen contents. All the samples were made ready for the analysis of soil physico-chemical properties and for the determination of study area soil organic carbon stock.

Laboratory method

Air dried soil was pounded with pestle and mortal and then the soil was sieved through 2 mm sieve. Only soil that passed the sieve was analyzed. pH was measured potentio-metrically in the supernatant suspension of 1:2.5 ratio of soil to a 1 M KCl solution. CEC was determined by measuring the total amount of a given cation needed to replace all the cation from a soil exchange site and it is expressed in centimoles per 100 gram soil (cmol/100 g soil). To do this, saturated sample was prepared followed by an extraction of the saturation cations adsorbed on the exchangeable complex and measuring its amount. Since CEC was highly affected by pH values, it was done at a known pH value and using ammonium acetate method.

Soil texture was determined by standard hydrometer method as described by Wakene, (2001). Bulk density of the soil was determined following (White, 1997) method. Titration method was followed to calculated percentage organic carbon. Soil organic matter is oxidized under standard conditions with Potassium dichromate in Sulfuric acid solution. A measured amount of $k_2Cr_2O_7$ was used in excess of the needed to destroy the organic matter and the excess was determined by titration with Ferrous sulfate solution, using Diphenylamine indicator to detect the first appearance of oxidized ferrous iron.

To estimate the total organic matter content of soil from OC measurements the following equation was used:

% Organic matter = % Organic carbon × 1.78

(http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/aesa1861). The kjeldahl procedure was used to calculated percentage total nitrogen. The basic principle is that the organic matter is oxidized treating soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation. The acid NH4+ ion in the soil was liberated by distilling with NaOH. The liberated NH4+ was absorbed by boric acid and back titrated with standards H_2SO_4. Potassium sulfate was added to raise the boiling point of the mixture during digestion and copper sulfate and selenium powder mixture are added as catalyst. The procedure determines all the soil nitrogen (including adsorbed NH4+) except that in nitrate form.

Olsen method was used to determine available phosphorous content of the soil. The sample was extracted with sodium bicarbonate solution at pH 8.5. Phosphate in the extract was determined calorimetrically after treating it with Ammonium Molyb date- Sulfuric acid reagent with Ascorbic acid as reducing agent. The high pH of the extracting solution renders the method suitable for calcareous, alkaline or neutral soils containing Ca-phosphates because the Ca concentration in solution is suppressed by precipitation of $CaCO_3$, as a result the phosphate concentration in the solution will increase. Finally, to determine the amount of exchangeable potassium and sodium, flame photometer method was used.

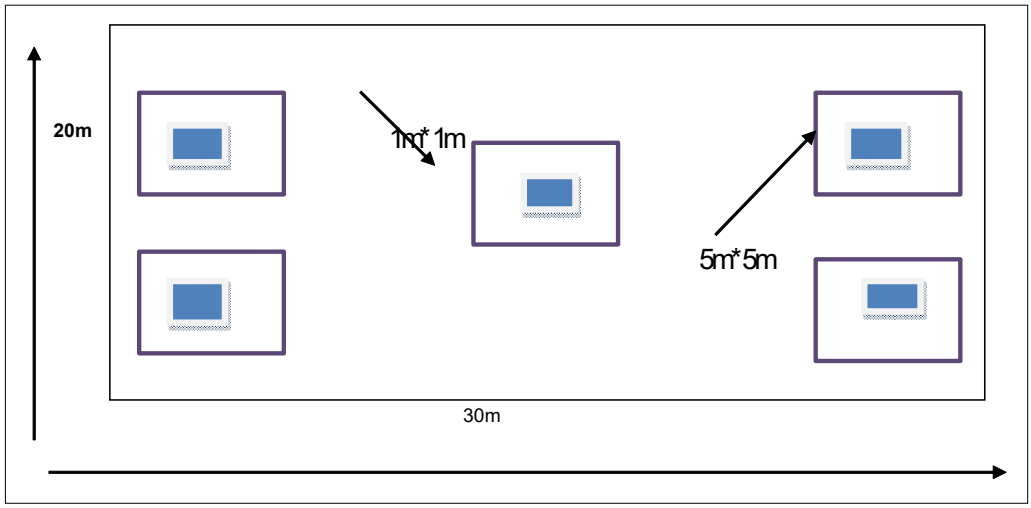

Fig 1: Soil sample preparation.

Total SOC at the respective depth was calculate and be summed up to determine soil organic carbon storage.

$$\text{Mass SOC (t/ha}^{-1}) = OC \times BD \times D$$

Where
OC = Organic carbon concentration (g C kg^{-1}).
BD = Bulk density of soil (g cm^{-3}).
D = Depth (cm) of profile.

Statistical analysis

Statistical package for the Social Sciences (SPSS) version 20 was used to analyze soil data (by descriptive procedures and a Pearson correlation matrix).

Plan for the quality of the study

The investigators of this study was report the progress and the finding of this study to research and publication office of Bule Hora University publish the finding and present on different seminars and symposium.

RESULTS AND DISCUSSION

The effect of land use and soil depth on plant nutrient availability

Soil organic carbon

The recorded per cent organic carbon contents of the soils indicated decreasing with soil depth in all sample pits at all land use system (Table 1). Slight decreases in percent organic carbon contents were recorded with depth in farm land as compared with other. Per cent organic carbon content for surface soil 0-15 cm depth in the study area ranged from 4.25 to 2.66, while its content varied from 3.93 to 2.46% for subsurface soil (15-30 cm) at the respective land use system. According to the rating of (Yuand, 2014) soil organic carbon content of soil of the study area was in the medium to low range. Per cent organic carbon was higher in the surface layer (0-15 cm) than its content in subsurface (15-30 cm). Higher soil organic carbon content in the surface soil might be due to higher clay content and rapid organic matter input. Similar trend was reported by Bot and Benites, (2005) that the level of soil organic carbon was higher in the surface layer, dropping with an increase in soil depth. The reduction of soil organic carbon along depth could be linked to higher accumulation of plant debris and clay on surface soil than sub surface soil.

Soil organic matter

Soil organic matter (SOM) showed significant variation with respect to un-conserved and the conserved land. The lowest mean soil organic matter was occurred in non-conserved area (2.26%), while soil OM showed the highest (3.59%) in conserved area with soil bund. This might show that SC practices have a positive role in improving soil OM. The result agrees with the findings of Bot and Benites, (2005) who reported that soil organic matter in soils under the well conserved site were higher compared to the un-conserved sites of similar slopes and depths. Gupta, (2004) also reported that the non-conserved fields had significantly lower

Table 1: Average soil testing laboratory analysis result at the respective land use type and depth.

Sample code (Al)	Depth	%OC	%OM	pH	%T	CEC (meq/100 gm soil)	BD	Available P (mg/l)	Exchangable K (meq/100 gm soil)	% sand	% clay	% silt	Textural class
Forest land	0-15	4.25	4.75	6.12	0.2	10.4	1.12	11.22	0.43	6	76	18	Clay
	15-30	3.92	3.31	6.62	0.18	10.13	1.19	10.79	0.39	20	62	18	Clay
Grazing land	0-15	3.51	4.48	5.95	0.17	8.31	1.26	18.12	0.28	52	36	12	Clay
	15-30	2.95	3.36	6.01	0.16	7.4	1.25	17.71	0.29	28	48	24	Clay
Farm land	0-15	2.66	3.79	6.9	0.14	9.16	1.24	25.1	0.72	36	40	22	Clay
	15-30	2.46	3.52	6.92	0.12	9.37	1.27	24.48	0.67	18	64	18	Clay

*OC = Organic carbon, OM = Organic matter, TN = Total nitrogen, CEC = Cation exchange capacity, TC = Textural class, BD = Bulk density, Available P = Available phosphorus, Exchangeable, K = Exchangeable potassium.

SOM as compared to the conserved fields. This might be because of the decomposition of different plant biomasses on the soil of conserved land. According to Landon (1991) the overall mean SOM value of the study site ranges between (3.59-2.26); which is categorized under the rating of medium to low.

Soil reaction (pH)

Soil reaction (pH) in the study area showed increasing trends with soil depth in all land use system. There were slight changes in the pH of soils with soil depth at the respective land use. Soil pH values at surface layer (0-15 cm) ranged from 5.95 to 6.9. According to the rating of Benton *et al*. (2003) for pH ranges, the soil reaction for surface soil at all land use was slightly acidic and the pH values for subsurface (15-30 cm) soil ranged from 6.01 to 6.92, which varies from neutral to slightly acidic reaction (Table 2). Amundson (2001) reported that the pH range of most productive soils is between 5.5 and 7.5. Amundson (2001) indicated that soil organisms grow best at neutral pH.

Soil cation exchange capacity

As indicated in Table 1, a decreasing trend of average soil cation exchange capacity (CEC) was observed with increasing soil depths in all sample pits at forest, grazing and farm land in the study area. Cation exchange capacity was highest in the surface layer (0-15 cm) and lowest in subsurface depth (15-30 cm). The value of CEC is high as compared with grazing and farm land. This may be due to availability of relatively high organic matter content in the forest land than other land use system which has low organic matter. The higher value of CEC at the surface in the study area might be due to highly decomposition of litters due to favorable environment and high organic matter input which responsible to increase the value of CEC. Similar finding was reported by Ahmed, (2002) who found that soils with large amounts of clay and OM have higher CEC than sandy soils with low OM. In surface horizons of forest soils, higher OM and clay contents significantly contribute to the CEC.

Total nitrogen

A decreasing trend in average total nitrogen (TN) content was observed with soil depth in all sample pits at respective land use system. This decrease in total nitrogen content could be due to decreasing in soil organic carbon content with depth. Relatively, higher nitrogen content in the surface (0-15 cm) is the result of accumulation of plant debris on the soil surface. Similar finding was reported by Yuand (2014) that TN and SOC storage increased significantly with plantation age, but there were different changes as with soil depth. With respect to land use, there were slight differences in the percent total nitrogen content of the soil. The results showed slight change between forest and grazing land.

Bulk density

The average bulk density values showed increasing trend with soil depth in all samples at the respective land use system. There is also variation in average bulk density value of soil along depth with in same land use system of the study area. Relatively, changes in bulk density values of soil with respective depth were higher for soils forest land. The change or variation of bulk density in different land use and depth may be due to soil texture and organic matter, in area. As Table 3 below, lower bulk density values for soils of surface layers (0-15 cm) relative to its values for that of subsurface layers (15-30 cm) in all pits at respective land use might be due to higher organic carbon, contents of the surface layer soils. In line with this Bot and Benites, (2005) reported that soil bulk density declines with an increase in soil organic matter content of surface soil.

Soil particle size distribution

The average results of particle size distribution in Table 1 indicate relatively similar in the textural classes of the soils

Table 2: Soil pH, soil organic matter and total nitrogen analysis result.

Land type	Variables (Soil chemical properties)		
	pH	SOM (%)	TN (%)
Conserved land	5.93[a]	3.59[a]	0.17[a]
Non-conserved land	5.56[b]	2.26[b]	0.11[a]
CV (%)	5.11	11.42	16.15
LSD (0.05)	0.29	1.27	0.06
Significance at (p<0.05)	**	**	Ns

Note: (**) - sign shows that there is a significance difference at 95% probability or with the consideration of 5% error, LSD = Least significant difference, CV = Coefficient of variation, (Ns) - shows that there is no significance difference at 95% probability.

Table 3: Soil bulk density and soil moisture content analysis result.

Land type	Variables (Soil physical properties)	
	BD (g/cm^3)	SMC (%)
Conserved land	0.85[a]	6.04[a]
Non-conserved Land	1.34[b]	3.94[b]
LSD (0.05)	7.91	8.14
CV (%)	0.20	3.55
Significance at (p<0.05)	**	**

Note: (**) - sign shows that there is a significance difference at 95% probability or with the consideration of 5% error, LSD = Least significant difference, CV = Coefficient of variation.

Table 4: Average soil organic carbon stock against depth of land use system.

Altitude	Depth (cm)	TSOC (t/ha)
Forest land	0-15	95.2
	15-30	93.3
Grazing land	0-15	88.45
	15-30	73.75
Farm land	0-15	65.97
	15-30	62.5

*TSOC = Total soil organic carbon, t = Ton, ha = Hectare.

in different land use system within soil depth of 0-15 cm and 15-30 cm. The textural class of surface and subsurface soil (0-30 cm) in the study area was medium to heavy clay for all land use system. Most of the textural classes of soil in the study area were classified under heavy clay soil. The percentage of clay composition of soil was dominant as compared to silt and sand in the study area. This might be due to the degree of weathering, parent material and the greater shielding effect of the canopy formed by the mature shrubs and understory vegetation from the erosive energy of the falling raindrops improve the texture of the soil. In line with this, Bot and Benites, (2005) reported that the composition percentage of clay was the highest for soils taken from shrub or bush followed by cultivation land. Similar finding was reported by Gupta, (2004), clay was the dominant soil particle in Pengkalan Chepa Industrial Park and southwest of Kota Bharu Township shrub and or forest soil. Sand contents showed increasing trends with soil depth. There were slight changes in the clay content of sample pits with a given soil depth at the respective altitudes.

Available phosphorus (P)

The average total soil available phosphorus in the study area was high for farm land than forest and grazing land. Available P decrease with the respective depth in all land use system. As indicated in Table 1 available phosphorus content in the study area was in the range of 10.79 to 25.1 (mg/l). According to the rating of Holford and Cullis (1985) the average value of available phosphorus of soil in the study area was high.

Average soil organic carbon stock of different land system

The average total soil organic carbon stock recorded for forest land was 95.2 and 93.3 t/ha for the depths of 0-15 cm and 15-30 cm, respectively. As indicated in Table 4 average soil organic carbon stocks showed a slight decreasing trend in the forest land with soil depth. In grazing land, average total soil organic carbon stock showed between 88.45 and 73.75 t/ha at soil depth of (0-15 cm) and (15-30 cm), respectively. In farm land, the levels of average soil organic carbon stock ranged from 65.97 to 62.5 t/ha for the respective depth of (0-15 cm) to (15-30 cm). In all land use system, the average total soil organic carbon stock was higher in the surface soil (0-15 cm) than in subsurface soil (15-30 cm). This higher soil organic carbon stock in the surface soil might be due to addition and decomposition of litter at favorable environmental condition at the surface. Similar trend was reported by (Azlan *et al.,* 2012) who found that *Pinusroxburghii shrub/*forest, where organic carbon was the highest in the surface layer (0-15 cm) compared to its content in subsurface layer (15-30 cm). In *Quercusleucotrichophora shrub/* forest, the level of soil organic carbon ranged from 24.3±1.9 g kg^{-1} to 21.9±3.1 g kg^{-1} and was higher in the surface layer, dropping with an increase in depth.

Changes in the average soil organic carbon stock with soil depth (1.9 t/ha) was the lower at the forest land relative to its changes (14.7 and 3.47 t/ha) with soil depth at grazing and farm land, respectively. There was drastic change in average soil organic carbon stock (SOC) between the two depths in the grazing land in the study area. This variation in average organic carbon stock with depth is due to texture of soil and vegetation type/cover that affect organic carbon content of the soil.

The average total soil organic carbon stock at forest land was the highest in the study area as compared to grazing and farm land (Fig 2). According to above Fig 2 soil carbon stock in forest land 90-95% which is the highest and the carbon stocks of 70-80% for grazing land and carbon stock for farm land is about 50-70. Lower soil organic carbon stock at farm land and grazing land, compared to forest land in the study area might be due to decrease in total tree density and basal area, slope of the land, cutting of tree for construction material and low litter input and decomposition due to unfavorable environmental condition.

The forest land is covered with vegetation of different species composition natural and manmade forest such as *Podocarpus falcatus, Cupressus lusitannica, Junporous procera, Olea africana, Cordia africana, Croton macrostachyus* and *Carissa edulis (*Agamsa) were dominant, *Olea europe, Acacia albida, Acacia synic* (*Wangayo), Eucalyptus falcatus* (Bahar zaf) and others are found in scattered manner and forest land is mostly used

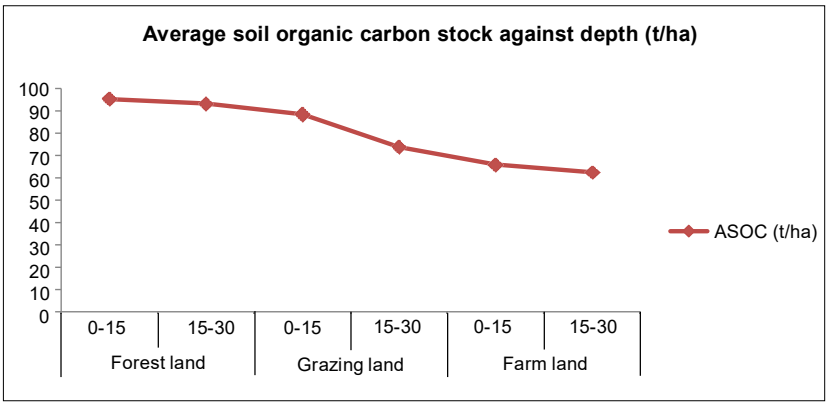

Fig 2: Graph of average soil organic carbon stock against depth of land use system.

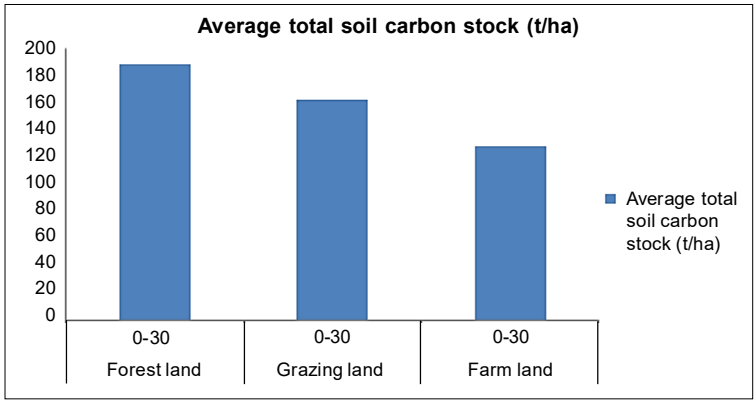

Fig 3: Average total soil organic carbon stock along land use system.

for browsing, fire wood and construction purpose. Forest land was under less human impact relative to other land use system. Thus, more soil organic carbon stock at forest land might be due to dense canopy, high vegetation residues like litter drop, root exudates, root mortality, which can be converted into soil organic carbon through decomposition. Similar finding was reported by Gebeyaw, (2006) that soil organic carbon stock (SOC) increased with density of trees per hectare and decreased with other anthropogenic activities. In addition, Bot and Benites, (2005) reported, greater SOC stocks are due to greater accumulation of plant litter (increased C inputs), which resulted in relatively higher soil organic matter.

In the study area, the average total soil organic carbon stock forest, grazing and farm land were 188.5, 162.2 and 128.47 t/ha, to depth of 0-30 cm respectively as showed in (Fig 3). According to Fig 3 below soil carbon Stock per hectare for different types of land use indicate that forest land, grass land and farm land accounts about 180, 160 and 120 respectively. There was drastic change in total soil organic carbon stock between the three land use systems.

SUMMARY AND CONCLUSION

In order to understand the effect of land use on plant nutrient and soil carbon visual field survey and appropriate sampling was carried out to have a general trend of the variations among and within land use and soil depth. Following this, three representative land uses were selected from each land use type (cultivated, forest and grass lands). Finally, 24 total composite soil samples and separate soil core sample for bulk density determination were prepared for laboratory analysis of selected physicochemical parameters of the soils. The amount of organic carbon in soil at a particular site indicates the potential of an ecosystem to provide services in terms of biogeochemical processes such as carbon sequestration, plant nutrient and buffering activities. Thus, losses of organic carbon from soil have large impact on ecosystem services and the global carbon cycle.

Considering the effects of land use and soil depth, on OM, pH, CEC, OC, TN, available P, exchangeable K and BD in the steady area, the highest average OC, OM, CEC and TN contents were recorded at the surface layer of forest land than cultivated land and grass land. In contrast, the lowest was recorded at the subsurface layer of the farmland. There was lightly decrease in available P and exchangeable K with soil depth in all land use system in the study area. But when we compare the three land use system i.e forest land, grazing land and grassland in the study area farm land contain high level of available P and exchangeable K.

The average total soil organic carbon stock at forest land was the highest in the study area as compared to grazing and farm land. The minimum soil organic carbon was registered in cultivated and grazing land. Sustainable farming and improper handling of yield residue as well as decline in whole tree thickness and basal area, cutting of plants for building material and low litter input for the lower values contributed for crop land and grazing land.

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