Effect of Land Use Change on Soil Carbon Stock and Selected Soil Properties in Gobu Sayyo, Western Ethiopia

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Abstract

Background: Land-use change is one of the major factors affecting soil degradation. The pressures of the human population on land resources have increased land-use change with more negative effects on soil carbon storage and soil properties. The objective of this study was to assess the effect of land-use changes on soil organic carbon (SOC) stock and selected soil physicochemical properties in Gobu Sayyo, Western Ethiopia. Soil samples were collected from three adjacent land uses i.e., forest land, grazing land, and cultivated lands at 0-20cm and 20cm-40cm soil depths. A total of 36 composite soil samples were collected and the major soil properties and SOC storage of the area were analyzed and computed based on their standard procedures.

Results: Soil organic carbon stock was significantly ($p<0.05$) higher (43.09-81.86 tone ha^{-1}) in forest land and was significantly lower (38.08-43.09 tone ha^{-1}) in cultivated land at the of depth of 0-20cm. SOC stock decreased with dept in all land uses. Changes in land use and soil depth affected the physical and chemical properties of soil. The physical soil property such as bulk density (BD) was higher (1.62 gcm^{-3}) in the cultivated land whereas, the lowest (1.08 gcm^{-3}) was recorded in the forest at 0-20cm depth. Comparatively the moisture content was higher (25.89%) under forest land at the depth of 20-40cm and was lower (11.22%) under cultivated lands. The chemical soil properties like exchangeable Ca2+, Mg^{2+}, and K^{+} were higher in forest lands. Organic carbon, avP, TN, ex.Ca^{2+}, ex.Mg^{2+}, ex.K^{+}, and CEC were lower under cultivated lands. pH increased with depth and was higher under forest land and lower under cultivated land. Soils of the study area are in general acidic to slightly acid with pH value ranging from 4-6-6.02. The pH, SOC, TN, av. Phosphorus and CEC were higher under forest land as compared to cultivated and grazing lands.

Conclusion: It can be concluded that soil organic carbon stocks, the physical and chemical properties were affected by land-use change and depth. Therefore, reducing the intensity of cultivation, adopting integrated soil fertility management, and maintaining forest land must be practiced to save the soil of the area from degradation.

1. Introduction

1.1. Background

Organic matter is a key component of the carbon cycle and represents the largest terrestrial repository of carbon globally (Liu et al. 2012). However, the capability of the soil to store and preserve organic matter has got much attention, to develop strategies to manage soils to increase their carbon storage and reduce the atmospheric carbon dioxide (McCarl and Schneider 2001).

Soil organic matter plays a key role in ensuring the long-term conservation of soil resources (Malo et al. 2005). Adequate levels of organic matter are essential to maintain or improve soil physical properties like soil porosity, infiltration capacity, moisture retention, and resistance to water and wind erosion (Izaurralde et al. 2001) and chemical properties like soil reaction and nutrient availability (Malo et al. 2005).

Soils store two or three times more carbon than that exists in the atmosphere as CO_2 (Davidson *et al.* 2000) and 2.5 to 3 times as much as that stored in plants (Aniwek 2010). Man induced alterations affect not only the total carbon content of soils but also its distribution among the various pools (Liu et al. 2012), causing changes in the size distribution and stability of aggregates, as well as other soil properties (John et al. 2005).

Changes in land use and management have profound effects on the quantity and dynamics of soil organic matter and in turn, on the soil ecosystem functions (Liu et al. 2012). It has contributed to soil degradation and soil loss, leading to a decrease in soil carbon storage (Eaton et al. 2008). Land-use change due to deforestation in the tropics was the major contributor to CO_2 emissions in the 1990s (IPCC 2001; UNFCCC 2007). Particularly, it is well studied that converting natural forests into agricultural fields leads to a decline in organic matter (Mengistu and Fassil 2010).

The pressures of the human population on land resources have increased land-use change with more negative effects on soil properties (Islam and Weil 2000). Land use transformation can affect soil physical and chemical properties. Soil nutrient availability is greater in forest land than in the cropland and pastures that replace them (Lal 2002). Forest conversion to cropland can also decrease soil properties such as soil texture, porosity, phosphorus content, CEC but increases soil bulk density (Heluf and Wakene 2006).

Most of the land-use changes in Ethiopia are due to direct and indirect human activities. These include overpopulation, deforestation, urbanization which led to the loss of natural resources (FAO 2008). Soil resources are prone to degradation due to misuse and mismanagement (Nega 2006). Besides, intensive agriculture and long term exploitative farm practices, have led to continuous depletion of natural vegetation cover and overutilization of land resources. Lack of agricultural inputs, traditional farming methods, and overgrazing aggravated the degradation of soil physical and chemical properties in Ethiopia (Heluf and Wakene 2006). On the other hand, integrated soil fertility management maintains the physicochemical properties of soils (Yitbarek *et al.* 2013).

Ethiopia was once covered with greater than 35% forest cover in the 1940s. However, due to the increased human and livestock population, a large part of the forest is converted to farmlands and grazing lands. For sustainable utilization of natural resources, assessment of man-induced land-use change is therefore very important. Many studies have been conducted on the effect of land cover-land use change on soil properties in the country (Kiflu & Beyene 2013; Wube & Assen 2019; Aredehey *et al.* 2019). However, there is limited information on the effect of land-use change on SOC storage and soil properties in the western part of the country including Gobu Sayyo district.

Gobu Sayyo district in western Ethiopia has a large population size and shortage of farmland. The rapidly increasing population pressure in the district has led to vast changes in land use patterns mainly caused by increasing agricultural production at the expense of forest and grazing lands (GWAO 2009). Despite this problem, no research was done in the district on the effect of land-use change on soil properties. Thus, this study was undertaken to determine the effect of land-use changes on soil organic carbon stock and selected soil properties in the district.

2. Materials And Methods

2.1. Description of the study area

Gobu Sayyo is the district found in East Wollega Zone, Western Ethiopia at about 261km from Addis Ababa the capital city of Ethiopia. It is located at 8^{0}50”0’N – 9^{0}40”0’N and 36^{0}30”0’E- 37^{0}20”0’E direction (Fig. 1). Most of the land has an elevation 1500m-1960m above sea level and characterized by subtropical climatic conditions with a mean annual temperature ranging 13^{0}c-27^{0}c and mean annual rainfall of 770mm-1,657mm (GSWCCFC 2018). According to the World Reference Base soil classification, the dominant soil types in the area include Alfisol and Nitisol (WRB 2006). The area has rugged topography. The population size of the district is about 57,455, where 27,268 (47.46%) were males, whereas about 30,186 (52.53%) were females as reported by Gobu Sayyo Health Center (GSHC 2019). Mixed livestock-crop production is the major farming system in the area.

Gobu Sayyo district has good vegetation cover than the other neighboring districts. There is a natural forest having a total area of about 1,381 hectares. However, there is a very serious deforestation (GSWAO 2018). According to Gobu Sayyo Woreda Agricultural Office, out of the total land of the district, the proximate areal coverage of land used for crop cultivations is 21,640 hectares, while 6,907 hectares is pasture or grazing land (GSWAO 2018)

2.2. Sampling Technique, sample size and preparation

Gobu Sayo district has eight kebeles. From a total of 8 kebeles in the district 2 kebeles (Gambella Tare and Ago Sombo) were selected purposively for the study because of their representativeness in terms of the extensive land-use changes that happened in the district. From the two kebeles, soil samples were collected from adjacent forest land, cultivated land, and grazing land at two soil depths (0-20cm) and (20cm-40cm) in three replicates. Thirty-six (36) composite samples were collected in 2019.

The composite soil samples from representative sites of each land use were collected by auger (for disturbed soil sample) and by core sampler (for bulk density). Soil samples were packed in a plastic bowl and transported to a soil testing center for further analysis. In the laboratory samples were labeled, air dried, cleaned from contaminants and plant debris, ground by mortar and pestle, and finally sieved with a 2 mm sieve for analysis. Analysis of soil samples was carried out at Bako Research Center based on their standard laboratory procedures.

2.3. Soil lab analysis

After soil samples were well prepared, bulk density was determined by dividing dry soil by its volume after drying to constant weight at 105^{o}c. The pH was determined by potentiometrically on soil: water suspensions (soil: water ratio 1:2.5 (Guittan and Carballas 1976). The cation exchange capacity (CEC) was determined by NH4Ac extraction followed by H2SO4 titration at pH 7 (Chapman 1965). The exchangeable Ca, and Mg, by NH4 acetate extraction followed by EDTA titration. Exchangeable K was determined by NH4Ac extraction followed by a flame photometer (Jackson 1970). Soil texture was analyzed by the hydrometer method (Bouyoucos 1962). Soil moisture content was determined by the gravimetric method (Black 1965). Total N was determined by Kejeldhai (Bremner 1996). The percent of organic carbon was analyzed by wet oxidation with dichromate (Walklay and Black 1934). Available P- was determined by Bray II,1945 as the soil is acidic.

2.4. Estimation of soil organic carbon stocks

Soil organic carbon Stock was estimated up to the depth of 40 cm. The soil organic carbon stock was calculated according to Were *et.al*. (2015*)* as indicated in the following equation:

SOCst = SOC* % / 100 ** BD * D

Where SOC = Soil organic carbon (%) of a given soil depth

SOCst = soil organic carbon stock, Kg C ha^{-1}

BD (Bulk density) = soil mass per sample volume (kg m^{-3});

D = depth of soil in m

2.5. Statistical analysis

The soil property data generated through laboratory analysis were subjected to a two-way analysis of variance (ANOVA) to detect whether differences in soil attributes between the land use and soil depth using the general linear model procedure of the Statistical Analysis System (SAS Institute 2008). The least significant difference (LSD) test was employed for mean separation for the soil properties that were founded to be significantly different in statistical terms.

3. Results And Discussion

3.1. Effect of land-use change on soil organic carbon (SOC) Stock

The analysis of variance results (Table 1) indicated that the SOC stock was significantly ($p < 0.05$) affected by land-use types and by soil depth. The mean value of carbon stock under cultivated land, forest land, and grazing land at the depth of 0-20cm were 43.09 tone ha^{-1}, 81.86 tone ha$^{-1,}$ and 57.71

tone ha^{-1} respectively, whereas, at depth of 20-40cm the value of SOC stock under cultivated soil, forest soil and grazing soil were 38.08 tone ha-1, 70.31 tone ha^{-1} and 44.54 tone ha^{-1} respectively.

Forest land had the highest SOC stock and cultivated land had the lowest value. Next to the forest, grazing land had the highest SOC stock. Organic matter input and turnover rates are the drivers for the soils carbon stock. tree species strongly influence the forest floor in terms of carbon stock (Jandl et al. 2007a). The declination of SOC stock in cultivated land could be due to vegetation loss and unsustainable soil management. The present finding agreed with (Jordan *et al*. 2010; Moscatelli *et al*. 2007) who reported that the SOC loss in cultivated soil could be due to reduced OM input, as well as due to reduced physical protection of soil from erosion and the increased decomposition rate as a consequence of tillage.

Numerous studies reported decreasing soil organic carbon stocks after a land-use change from natural or semi-natural ecosystems (forest land and grassland) to cropland and a cultivation induced soil organic carbon decline of about 20–60% when forest land and grassland were converted to cropland (Guo and Gifford 2002; Murfy *et al.* 2002; Poeplau et al. 2011; Wiesmeier et al. 2012, 2015; Oberholzer et al. 2014). The carbon stocks increased by 20–50% after land-use changes from cropland to grassland or forest land (Guo and Gifford, 2002). The mean value of SOC stock of all land uses decreased significantly as depth increase, which agrees with the findings of Diekow *et al*. (2005).

Table 1
Soil organic stock under the different land uses

Soil depth (0-20cm)			
Land use	BD	% SOC	SOC stock (tone ha^{-1})
Farm land	1.62^{a}	1.33^{a}	43.09^{a}
Forest land	1.08^{c}	3.79^{c}	81.86^{b}
Grazingland	1.63^{a}	2.29^{d}	57.71^{c}
Soil depth (20-40cm)			
Farm land	1.60^{a}	1.19^{b}	38.08^{a}
Forest land	1.26^{b}	2.79^{d}	70.31^{c}
Grazing land	1.31^{b}	1.70^{ab}	44.54^{d}
p(0.05)	0.07	0.04	0.01

3.2. Effect of land-use change on selected soil properties

3.2.1. Soil Physical properties

Soil texture

As the result in Table 2 revealed, the mean value of the percentage of sand in cultivated land was 61% and that of forest land was found to be 52% at depth of 0-20cm. The highest percent of sand was found in cultivated while the lowest was found in grazing land (50%). While, at the depth of 20-40cm the percent of sand under cultivated was 58%, forestland (45%), and that of grazing lands was 54%.

The mean values of silt at depth of 0-20cm under cultivated, grazing, and forest lands were 33.5%, 38%, and 43.5% respectively. While, at the depth of 20-40cm it was 30.5%, 37%, and 44% respectively. The percentage value of clay soil at depth of 0-20cm under cultivated, grazing, and forest lands were 5.5%, 10%, and 6.5% respectively. While, at depth of 20-40cm, the clay content under cultivated, grazing, and forest lands was 11.5%, 9%, and 11% respectively. The textural class for cultivated land at depth of 0-20cm and 20-40cm were sandy clay loam and sandy loam respectively. For grazing land, the textural class at both depths (0–20 and 20-40cm) was loam soil. The textural class at depth of 0–20 and 20-40cm was sandy loam. Unlike sandy soil, clay soil was higher in forest land than both cultivated and grazing lands. Despite, slightly the higher silt content was observed in grazing land and the lower was in cultivated land which agrees with research Lechisa *et al.* (2014) who reported that the highest silt content was observed forest land and the lower was in cultivated land.

In this finding, the highest sand contents (61%) in the cultivated land was in contrast to the result of Mesgistu *et al. (*2017) who said that the highest sand and silt were found in forest land in Warandhab area, Horo Guduru Wollega Zone, Oromia, Ethiopia. However, the highest silt contents (44%) at the depth of 20-40cm in forest soil land agrees with this finding. The highest sand content in cultivated land is perhaps due to a high amount of rainfall in the area that washed away the finer soil particles (clay) leaving behind the sand fractions (Getahun et al. 2016).

Table 2
Textural Class of the land-uses

Land Use	Depth (cm)	% Sand	% Silt	% Clay	Textural class
Cultivated land	0–20	61	33.5	5.5	Sandy clay loam
	20–40	58	30.5	11.5	Sandy loam
Grazing land	0–20	52	38	10	Sandy loam
	20–40	54	37	9	Sandy loam
Forest land	0–20	50	43.5	6.5	Loam soil
	20–40	45	44	11	Loam soil
Bulk Density					

As indicated in Table 2, the bulk density (BD) values were slightly different for the land use types. The mean value of BD under forest, cultivated and grazing land at the depth of 0-20cm were 1.08 g cm^{-3}, 1.62 g cm^{-3}, and 1.63 g cm^{-3} respectively. Whereas, at depth of 20-40cm it was 1.26 g cm^{-3}, 1.60 g cm^{-3}, and 1.31 g cm^{-3} respectively. Comparatively cultivated land had significantly ($p < 0.05$) higher (1.62 g cm^{-3}) BD at depth of 0–20 cm. This is might be due to the compaction of the topsoil by cultivation or due to low organic matter. While forest land had the lowest (1.08 g cm^{-3}) bulk density which could be due to the presence of high organic matter. An increase in root penetration and biological activity might have decreased bulk density in forest soils. The result indicated that surface soil had significantly lower bulk density than subsurface soil. This could be due to the presence of higher organic matter in surface soil (Table 3). This agreed with the findings of Terefe *et al*. (2020) where the topsoil had less BD than the subsurface soil. This could also be due to overgrazing of the grazing land and the use of machinery or intensive agricultural practices in the cultivated land.

Soil Moisture

The moisture content (%) of the surface soils (0-20cm) of the study area is shown in Table 3. Accordingly, forest land, cultivated land, and grazing land have the mean value 20.6%,10.84%, and 14.76% respectively and at the depth of 20-40cm, the mean value of moisture in forest land, cultivated land, and grazing land were 25.85%, 10.86% and 15.12% respectively. The surface (0-20cm) soil had lower moisture content than that of the lower depth (20-40cm). This is might be due to solar heating at topsoil than the subsurface soil. Forest land had significantly higher moisture content, whereas cultivated land had the lowest moisture content; this implies that the soil under forest was covered by vegetation which results in low evaporation; water stays in the soil. This result agreed with (Duiker and Lal 2000; Post and Kwon 2000; Knowles and Singh, 2003; Baker, 2007) who reported soil protected by the superficial layer of organic matter improves the capture and the use of rainfall through increased water absorption and infiltration and decreased evaporation from the soil surface. This leads to reduced runoff and soil erosion with higher soil moisture throughout the season compared to the disturbed soils left unprotected (Bationo *et al*. 2007).

Table 3
Effects of land-use change on soil bulk density and soil moisture

Land uses	Depth (cm)	BD (g/cm^3)	Moisture (%)
Cultivated land	0–20	1.62^{ab}	10.84^{e}
	20–40	1.60^{b}	10.86^{e}
Grazing land	0–20	1.63^{a}	14.76d
	20–40	1.31^{c}	15.12^{c}
Forest land	0–20	1.08^{e}	20.6^{b}
	20–40	1.26^{d}	25.85^{a}
p(0.05)		0.02	0.01

3.3. Soil Chemical properties

Soil pH

Soil pH was found to be significantly ($p < 0.05$) affected by land-use change and soil depth. Forest soil has the highest mean value of pH (6.20) at the depth of 20-40cm, whereas it was significantly lower (4.63) in cultivated lands at the depth of 0-20cm. The lower pH at the cultivated land when compared with forest land and grazing lands implies that the depletion of basic cations in crop harvest and the continuous use of ammonium-based fertilizers such as diammonium phosphate $(NH_4)_2HPO_4$ in cultivated lands make the soil acidic. The oxidation of these fertilizers by soil micro-organisms produce inorganic acids. This acid releases H^+ to the soil solution that in turn lowers the pH of the soil. In general, as the depth increase, the pH value decrease (acidity increase). This is because of the larger organic matter content observed in the surface soils across the land uses and the humified organic matter can bind tightly with Al^{3+} and reduces their activity in the soil solution which raises the soil pH. The present study agreed with (Ristow *et al.* 2010) who reported as the soil pH decreases, most desirable crop nutrients become less available while others, often undesirable, become more available and can reach toxic levels. The basic cations such as Ca^{2+} and Mg^{2+} also have shown a decreasing trend with increasing depth. The adsorption of these cations on the colloidal complex gives replacement of H^+ and Al^{+3} which lowers the percentage of acid saturation which increases the soil pH.

Soil Organic Carbon

As presented in (Table 4), soil organic carbon (SOC) was significantly ($p < 0.05$) affected by land-use change and soil depth. In both soil depths (0-20cm and 20-40cm), SOC was lower in cultivated fields as compared to other land uses. The analysis of the effect of soil depth showed the highest SOC (3.79%) under forest soils at 0-20cm, While the lowest SOC (1.19%) was recorded in cultivated soils at the depth of 20-40cm. This agreed with Lal (2002) and Mengistu and Fassil (2010) who reported that soil organic carbon storage and soil nutrient availability are greater in forest land than in the cropland and pastures that replace them. Extensive deforestation and the conversion of natural forests into agricultural lands in the Ethiopia ecosystem led to a significant decline in organic matter levels. Woldeamlak and Stroonsnigder (2003) reported the conversion of forest land into grazing land and cultivated land led to a large decrease of organic matter at Chemo Watershed Ethiopia. Most cultivated soils of Ethiopia are poor in organic matter contents due to the low amount of organic materials applied to the soil and complete removal of the biomass from the field (Yihenew 2002), and due to steep relief condition, intensive cultivation, and excessive erosion hazards (Nyssen et al. 2004). In agreement with this, all agricultural fields in the study area had low organic carbon content according to the classification presented in Landon (1984). Tekalign (1991) also stated that an organic matter content of less than two (2%) as an indication of soil degradation for tropical soils involving a high risk of soil erosion.

Total nitrogen

The result presented in (Table 4) showed there were significant ($p < 0.05$) variations in total nitrogen among the land uses and soil depth. The mean value of total nitrogen at the depth of 0-20cm for cultivated land, forest land, and grazing land was 0.11%, 0.33%, and 0.20% respectively. While, at the depth of 20-40cm it is 0.10%, 0.27% and 0.15% respectively. Total nitrogen increased in the order of cultivated land < grazing land < forest land in the study area. The present finding agreed with (Nega 2006), who reported that the average total Nitrogen (N) increased from cultivated to grazing and forest land soils, which again declined with increasing depth from surface to subsurface soils. Since forest land had higher OM, higher TN was recorded in forest land than cultivated and grazing lands at both depths (Table 4). This agreed with the findings of Hazelton *et al*. (2007) where the total nitrogen was measured higher in soils with high organic matter.

Generally, cultivated soils had significantly lower TN at all depth as compared to grasslands and forest lands, which indicated continuous cultivation, ultimately reduced the total nitrogen contents in the soil. Due to land-use shifts from forest land to cultivated land, the TN content was declined, and also it was declined with increasing soil depth. This finding agreed with the findings of Nega (2006) in Senbat sub-watershed, western Ethiopia, where average TN increased from cultivated to grazing and forest soils. The minimum change of TN under cultivated land compared to forestland and grazing land shows that fertilizer applications may not have replaced the total N lost due to harvest removal, leaching, and humus losses associated with cultivation (Eyayu et al. 2009).

According to Malo et al. (2005), the lower level of nitrogen in cultivated fields compared to other land use implied that fertilizer additions have not replaced the TN lost due to harvest removal, leaching, and humus losses associated with cultivation. The continuous cultivation could have also aggravated OC oxidation and loss of N in cultivated fields resulting in the lowest contents.

Available Phosphorus

As shown in Table 4, the available P content (mg kg^{-1}) of the surface soils (0-20cm) in forest soil, cultivated soil, and grazing soil had the mean value 27.83, 12.63, and 4.17 respectively and at the depth of 20-40cm the mean value of available P in forest soil, cultivated soil and grazing land soil is 24.53, 10.43 and 2.43 respectively. The surface (0-20cm) soil has significantly ($p < 0.05$) higher available P content than that of the lower depth. The available P content of soils significantly declined due to the conversion of natural forests into grazing lands and farmland. The high content of available P in the forest land could be due to the high content of soil OM resulting in the release of organic phosphorous thereby enhance available P under forest land. Similarly, this result is in agreement with the findings of Abad et al. (2014) who reported that the available P was high in forest land as compared to pasture land and cultivated land at 0-30cm soil depth.

The higher available P content at both depths under forest land is likely the consequences of the long term litter accumulation and the associated increase in microbial activity. The results were in agreement with those of Materechera and Mkhabela (2001) who reported that organic matter influence P in soil solution by complexing P from the adsorption site in ligand exchange and increase the mobility of inorganic P, particularly in acid soils, by decreasing the chemical activity of iron and aluminum. The lack of available P in the soils limits the growth of plants. Cultivated land should be supplied with inorganic fertilizer to increase the concentration of P in the soil solution that is required by crops. Phosphorus is involved in several key plant functions, including energy transfer (Uchida 2000).

High availability of P existed in forest land and the lowest was in cultivated land. This is might be the pool of available P could be trees in the forest land with abundant microorganisms that return via litterfall to the soil (Asmamaw and Mohammed 2013). In agricultural land, available phosphorus (P) was reduced most probably due to a decline in both % SOC, CEC, and soil acidification (Achalu *et al*. 2012; Nisar et al. 2013). This finding also agrees with the result of Birhanu et al. (2016) who reported alteration of forest land to agricultural land decreased the availability of phosphorus in western Ethiopia.

In contrast to this finding, Mengistu et al. (2017) found higher available P in the soil of cultivated land as the result of crop residue left on cultivated land and later plowed in properly. In forests land, fallen vegetation cover and natural pruning of tree take time to return into the soil to decompose and increase SOM content, which lead to increases available Phosphorous content. Consequently, available P content was significantly ($P < 0.05$) different among different land-use systems (Alemayehu and Beyene 2013).

Exchangeable Cations (Ex.K, Ca and Mg)

The exchangeable K of soil under study area was significantly ($p < 0.05$) affected by land use type and depth of the soil (Table 4). Exchangeable K content at the depth of 0-20cm in forest land, cultivated land, and grazing land was 1.51 cmol(+) Kg^{-1}, 1.04 cmol(+) Kg^{-1}, and 1.13 cmol(+) Kg^{-1}respectively. At the depth of 20-40cm, Exchangeable K of forest land, cultivated land, and grazing land were 0.79, 0.88, and 0.44 cmol (+) Kg^{-1} respectively. Soils of forest land had the highest exchangeable K (1.51 cmol(+) Kg^{-1}) content than soils of cultivated and grazing lands at the surface soil (depth of 0-20cm) and exchangeable K content of the soil declined with increase in depth. This result is supported by previous findings that indicate the intensity of cultivation, and the use of acid-forming inorganic fertilizers affect the distribution of K in the soil system and enhance its depletion (Malo et al. 2005). Similarly, Yitbarek *et al*. (2013) reported that the exchangeable K of soil is higher in forest land than cultivated and grazing lands.

The analysis of variance results indicated that the exchangeable Ca was significantly ($p < 0.05$) affected by land-use types and soil depth. The presence of such significant variation on exchangeable Ca could be due to different management practices. At the depth of 0-20cm, the mean values of exchangeable Ca under forest, cultivated and grazing lands were 23.30 cmol (+) Kg^{-1}, 9.27 cmol (+) Kg^{-1}, and 14.43 cmol (+) Kg^{-1}respectively. However, at the depth of 20-40cm its mean value under forest, cultivated and grazing lands was 12.27Cmol (+) Kg^{-1}, 6.87 cmol (+) Kg^{-1}, and 8.17 cmol (+) Kg^{-1} respectively. This implies that the exchangeable Ca was higher at the surface soil depth than that of the subsurface soil depth. This could be due to the abundance of animal and plant residues at the surface layer of soil than the subsurface soil layer. This is agreed with the findings of Alemayehu and Beyene (2013) who in their results revealed that the exchangeable Ca content of the soil was higher on the surface soil layer than the subsurface soil layer due to the association of biological activity and accumulation from plant residues. In contrast, Bore and Bedadi (2015) reported that the exchangeable Ca was increasing with increasing soil depth since it is susceptible and the possibility of easily leach downward by runoff and water percolation.

The analysis of variance results indicated the exchangeable Mg was significantly ($p < 0.05$) affected by land-use types and by soil depth. The exchangeable Mg concentrations followed a similar trend as that of Ca under the land uses. The mean value of exchangeable Mg at depth of 0-20cm under forest, cultivated, and grazing land uses were 12.70, 5.83, and 6.77 cmol(+) Kg^{-1}respectively. While, at the depth of 20-40cm, the mean values of exchangeable Mg in forest land, cultivated land, and grazing land were 5.47, 4.20, and 5.83 cmol(+) Kg^{-1}respectively. The highest and lower values of exchangeable Mg were found under grazing land and cultivated land respectively. The low exchangeable Ca and Mg under cultivated land might be due to leaching, soil erosion, and crop harvest as it was reported by Negassa (2001).

Cation Exchanging Capacity (CEC)

The analysis of variance results (Table 4) revealed that the CEC of the soils was significantly ($p < 0.05$) affected by the land-use change and the depth of the soil. The mean value of CEC under forest land, cultivated land, and grazing land at the depth of 0-20cm were 37.55, 25.20, and 27.31 cmol(+) Kg^{-1} respectively. For the depth of 20-40cm, the mean values of forest land, cultivated land, and grazing land were 24.10, 24.04, and 23.86 cmol(+) Kg^{-1} respectively (Table 4). This implies that the highest CEC value was found in the surface soil layer than subsurface. The significantly higher CEC in forest land might be due to the presence of higher soil organic matter. This result is in line with the findings of Yitbarek *et al.* (2013) who reported that the CEC of soil was higher in forest land compared to that of the adjacent cultivated and grazing lands in Abobo area, Western Ethiopia. This depletion of OC in farmland could be due to intensive cultivation. These results were also in agreement with the findings of Boke (2004) in Kembata-Tembaro southern Ethiopia and Negassa (2001) in Bako area, western Ethiopia

The CEC values of the soil decreased with depth consistently from forest land to cultivated land. Similarly, Nigussie et al. (2012) reported that the CEC of soil was higher in the subsurface of the soil layer under the adjacent forest, cultivated and grazing lands. But the result of the present study is unparalleled of the findings of Alemayehu and Beyene (2013) who reported that the CEC of the soil was not significantly affected by soil depth at the depth of 0-15cm and 15-30cm under adjacent maize, Enset and grasslands in Southern Ethiopia.

Table 4
Effects of land-use change on soil chemical properties

Soil depth (0-20cm)								
Land use	pH	% SOC	%TN	AvP	Ex.Ca	Ex.Mg	Ex.K	CEC
Farm land	4.63^{c}	1.33^{e}	0.11^{e}	12.63^{c}	9.27^{d}	5.83^{c}	1.13^{b}	25.20^{b}
Forest land	6.02^{a}	3.79^{a}	0.35^{a}	27.83^{a}	23.30^{a}	12.70^{a}	1.51^{a}	37.55^{a}
Grazing land	5.14^{b}	2.29^{c}	0.20^{c}	4.17^{e}	14.43^{b}	6.77^{b}	1.04^{b}	27.31^{c}
Soil depth (20-40cm)								
Farm land	5.20^{b}	1.19^{f}	0.10^{f}	10.43^{d}	6.87^{e}	4.20^{a}	0.88^{cd}	24.04^{b}
Forest land	6.02^{a}	3.10^{a}	0.28^{b}	24.52^{b}	12.27^{c}	6.17^{b}	0.79^{c}	24.10^{c}
Grazing land	5.13^{b}	1.70^{d}	0.15^{d}	2.43^{f}	8.17^{a}	5.47^{a}	0.44^{e}	23.86^{b}
p(0.05)	0.03	0.05	0.01	0.05	0.02	0.04	0.016	0.045

Conclusion

Land-use change is one of the important factors influencing the soil properties and exerts the most significant effects on the soil. Changes in land use and management can have profound effects on the quantity and dynamics of soil organic matter and in turn, on the soil ecosystem functions. Soil organic carbon stocks, the physical and chemical properties of land uses in the study area were affected by land-use systems and depth. Soil organic carbon stock and most of the physical and chemical properties including P, CEC, K, N were significantly higher in the forest as compared to grazing land and cultivated land. While, pH and bulk density were lower in forest land as compared to cultivated and grazing lands. Thus, maintaining forest land, reducing the intensity of cultivation, and adopting integrated soil fertility management must be undertaken in the area for improving soil organic carbon stock and soil properties.

Declarations

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Authors’ contributions

MW interpreted the data and wrote the manuscript. DW collected, analyzed data. GK edited, commented, and suggested ideas in the manuscript preparation process. All authors approved the final manuscript.

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Conflict of interest

The authors declare no conflict of interest

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Figures

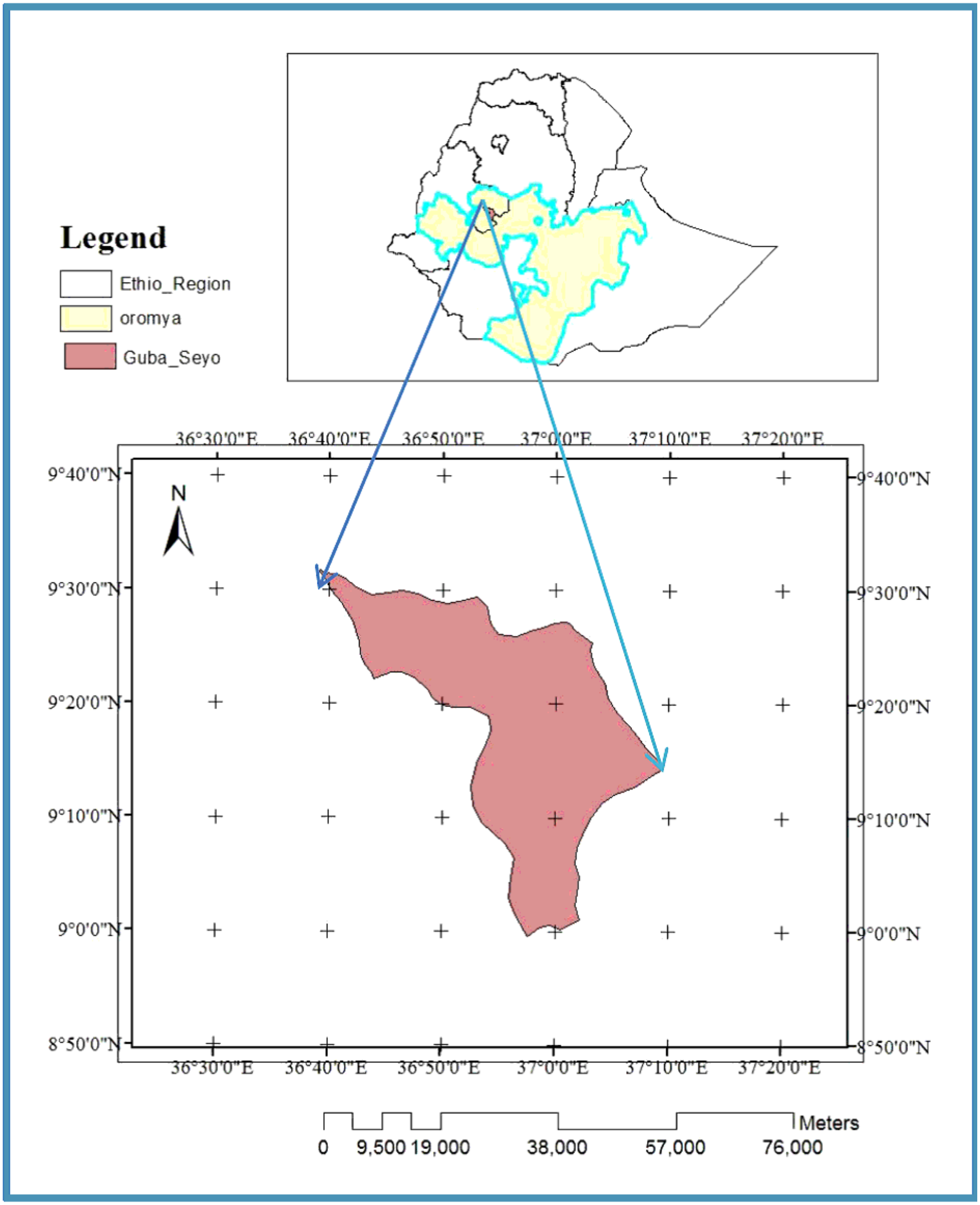

Figure 1

Map of the study area Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.