Vol. 13(24), pp. 1248-1256, 14 June, 2018
DOI: 10.5897/AJAR2018.13190
Article Number: 808F22457420
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Soil organic carbon stock under different land use types in Kersa Sub Watershed, Eastern Ethiopia

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Received 15 April, 2018; Accepted 21 May, 2018

Understanding and assessing soil organic carbon stock (SOCS) within the framework of greenhouse gas emissions and land degradation is so crucial in combating climate change and enhancing ecological restoration. The goal of this study was to quantify the current SOCS in major land use types in Kersa sub watershed, eastern Ethiopia. Replicated soil samples from 0 to 20, 20 to 40, and 40 to 60 cm depth were collected from three major land uses types: grazing, cultivated, and fallow lands. Analysis of variance (ANOVA) was used to compare means and Pearson correlation analysis was used to see relationships between selected soil parameters. The results of the study revealed significant difference in soil organic carbon stock under the different land use types (P≤ 0.05). Soil under grazing land use type had significantly higher values of SOCS (42.9 t/ha and 32.9 t/ha) than cultivated land use type (32.6 t/ha and 26.3 t/ha) and fallow land use type (23 t/ha and 12.5 t/ha) in surface and sub surface layers, respectively. Similarly, SOCS decreased with soil depth in all the land use types and showed positive and significant correlation (P≤ 0.05) with clay content while negatively and significantly correlated with bulk density. The results show potential contribution of vegetation cover in land use to enhance soil organic carbon sequestration and environmental protection.

Key words: Land use, organic carbon, soil organic carbon stock, carbon sequestration.

INTRODUCTION

In the presence of climate change, land degradation and biodiversity loss, soils have become one of the most vulnerable resources in the world (FAO, 2017). Soil plays crucial role in combating climate change and ecological restoration through controlling the global carbon cycle.

Managing soil organic carbon (SOC) through sustainable agricultural practices has become a widely recognized strategy for restoring vulnerable soil resources. This is because soils are a major carbon reservoir in terrestrial ecosystems. The SOC pool stores an estimated amount of 1500 petagram of carbon (Pg C) in the first meter of soil which is more carbon than what is

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contained in the atmosphere (roughly 800 Pg C) and terrestrial vegetation (500 Pg C) combined (Batjes,1996). Therefore, a relatively small change in the soil C pool can considerably mitigate or enhance CO_2 concentrations in the atmosphere.

The distribution of SOC varies spatially and temporally. This is because SOC can be influenced by various factors such as soil type, land use types, land use change, climate, landscape, and soil management practices. As a result, soils in different geographic areas have different potential as carbon sources and sinks. However, vegetation is the major source of soil organic matter hence land uses are known to play a major role in SOC stock build up through organic matter input. That is the reason after the burning of fossil fuels land use and land cover change is the largest anthropogenic source of carbon into the atmosphere (Houghton et al., 2012; IPCC, 2014).

Many studies have suggested that land use type is the main factor determining SOC content by directly altering soil properties and supply of soil nutrients (Woldeamlak and Stroonsnijder, 2003; Lemenih and Itanna, 2004; Li et al., 2012; Yan et al., 2012). The impact of land use change varies according to the land use types. Land use change from natural forest to agricultural land and plantation result in lowering of SOC through intensive soil disturbance of soil structure and oxidation of soil organic matter. For example, conversion of forest to crop land invariably results in a loss of 20 to 50% of soil carbon (Post and Mann, 1990).

Similarly, 59% carbon lose through the conversion of pasture to cropland has been reported (Guo and Gifford, 2002; Murty et al., 2002). However, the conversion of forest to pasture did not results in significant loss of soil carbon (Murty et al., 2002). Similarly, when cropland is converted into natural vegetation, SOC will accumulate (Kwon, 2000; Zhang et al., 2010). Moreover, in the surface soil degradation in the form of deforestation and erosion results in significant loss of soil organic carbon in top soil (Sombroek et al., 1993; Lal, 2002). As a result, SOC is expected to vary along with soil depths in addition to land use types. Ingram and Fernandes (2001) reported that apart from land use, the level of SOC is determined by soil attributes including soil depth, texture and climate factors.

Currently, sequestering carbon in agricultural soils is seen as one way of decreasing atmospheric carbon dioxide (CO_2) concentrations and mitigating climate change. The potential increases in soil organic carbon associated with land use could be achieved through improved retention of plant/animal residues and greater inputs (Hoyle, 2013). As a result, identifying land uses that increase net plant/animal organic carbon inputs to the soil and then understanding how these changes will impact soil function is so indispensable (Murphy et al., 2011).

Land use change is the main primary net C release in Africa, much of it released through burning of forests (Williams et al., 2007). In sub-Saharan Africa, the increasing demand for food can encourage farmers to reduce the length of fallow periods, cultivate continuously, overgraze fields, or remove much of the above ground biomass through fuel collection or for building materials. Such practices can result in the reduction of SOC, water holding capacity, nutrients, as well as enhance soil erosion (Lal, 2004).

In Ethiopia, rural population is currently growing rapidly, resulting in massive conversions of land use and land cover with negative impacts (Woldeamlak and Stroosnijder, 2003). Similarly, the highlands of Eastern Ethiopia, due to continuous intensive cultivation for many years, are highly degraded, being degraded, and prone to degradation (Kibebew, 2014). The Kersa sub watershed which is part of Eastern Hararghe highland is facing a similar problem. It is clearly observed that the study area is characterized by high population pressure and intensive cultivation for many years. The increase in population has resulted in encroachment of crop production to the marginal and steeper slopes. This conversion of land use is likely to result in loss of CO_2 through vegetation removal and rapid oxidation of SOC following intensive cultivation.

Therefore, understanding the influence of land use types on soil organic carbon is an important step in line with the United Nations Framework Convention on Climate Change (UNFCCC) plan to reduce the effect of climate change and greenhouse gases (GHG) emission and developing potential future CO_2 mitigation strategies. However, little is known about the impact of different land use types on SOC stocks in Eastern Ethiopia. Therefore obtaining information on the SOC stocks of adjacent land use types is essential and imperative. Hence, this study was aimed at generating data to build scientific evidence that could be available to land managers and policy makers based on hypothesis that different land use types affect the soil organic carbon stock in Kersa sub watershed. Therefore, the objective of this study was to quantify the soil organic carbon stock and assess the relationship between SOC and land use types.

MATERIALS AND METHODS

Description of the study area

Geographically, the study area, Kersa sub watershed, is located in Kersa District, Eastern Harerghe zone of Oromia National Regional State between 9° 26' 28" N to 9°27' 50"N, and 41°52' 0 "E to 41°53'50"E (Figure 1). The total area of the watershed is 622 ha.

Climate

Based on 19 years (1995 to 2014) data obtained from Ethiopian National Meteorology Authority, the study area receives a mean annual rainfall of 732 mm. The rainfall pattern in the area is bi-modal with high amount of rainfall occurring during the main rainy

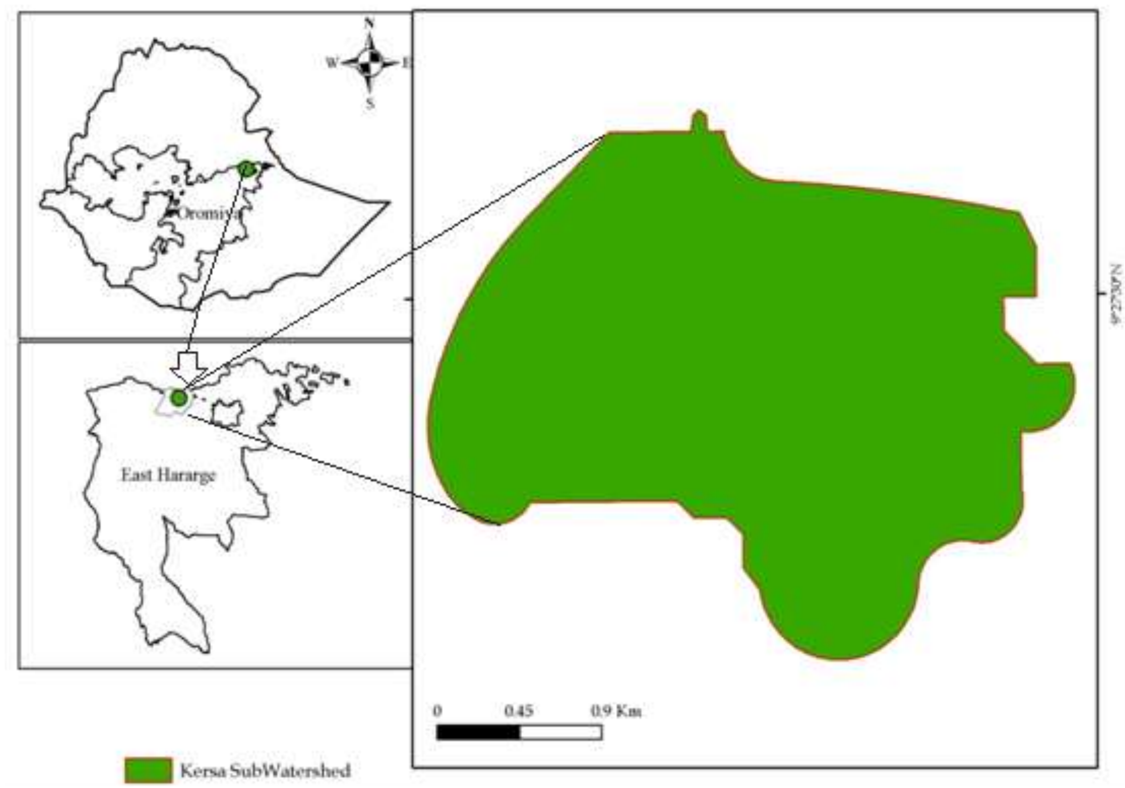

Figure 1. Map of the Kersa sub watershed.

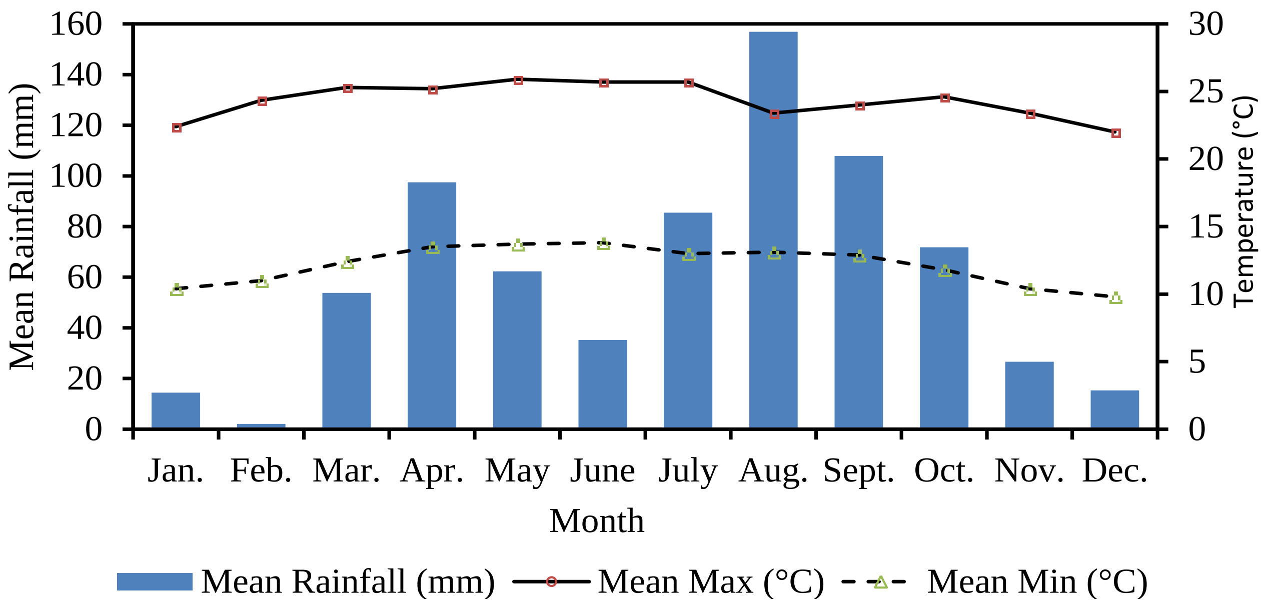

Figure 2. Mean monthly rainfall and mean monthly minimum and maximum temperatures in Kersa sub watershed.

season between July to September and the short rainy season stretching from March to June (Figure 2). The highest mean rainfall is received in August. Based on 17 years climate data (1997 to 2014), the mean minimum and maximum annual air temperatures of the area are 12 and 24°C, respectively, with mean annual air temperature of 18°C.

Table 1. Description of land use within the Kersa sub watershed in Eastern Ethiopia.

Land use	Description
Grazing	Land used as communal grazing land for cattle and it is managed through controlled system whereby livestock is confined in a stall and fed with cut and carry system
Cultivated	This includes land used for cultivation of crops under rainfed conditions. The main cropping system is mixed cropping where khat (*Catha edulis*) is intercropped with sorghum. Small amount of organic matter is returned to the soil because no crop residue is returned to the soil due to its use for other purposes, such as animal feed, fuel wood, source of cash, and construction material
Fallowing	This includes land that has been once under intensive cultivation and is now relieved from use for crop production since 2012

Geology and soil

According to the geological map of Ethiopia, first published in 1973 at a scale of 1:2000, 000, the geology of the Kersa district is covered by Adigrat formation constituted by sandstones and shell. Hamanlei series formation that contains Oxfordian limestone covers the lower part of the landscape and lower complex undifferentiated pre Camberian rock cover the upper part of the landscape. Moreover, Mohr (1964) indicated that Hararghe highlands lie over the crystalline bed rock composed mainly of granitic rock and gneiss material. According to FAO/WRB (2014) classification, the soils of the study area consist of Luvisols, Cambisols, Vertisols, Leptosols, and Regosols. Altitude of the watershed ranges from 1968 to 2127 meters above sea level.

Land use and farming systems

The study area encompasses different land use types and the dominant land uses are grazing, cultivated, and fallow land (Table 1). The farming system of the area is predominantly subsistence farming based on mixed crop-livestock production. Livestock are integral part to the farming system, supplying draught power for cultivation, food and income to households. The major rainfed field crops grown are sorghum and maize intercropped with common bean and Khat. Besides these, around homesteads, the vegetation is dominated by *Eucalyptus globules and Eucalyptus camaldulensis* trees.

Land use selection and soil sampling

Before soil sample collection, field observation and a reconnaissance soil survey was carried out, and informal group discussions with agricultural experts was made to identify representative land use types. Accordingly, three adjacent land use types: fallow, cultivated, and grazing lands were selected. Purposive sampling method was employed and selection for sampling considered adjacent land use types in order to minimize differences in climate, slope and soil type. Soil samples were taken from cultivated, fallow and grazing land use types with three replications based on a sampling plot size of 10 m by 10 m. In each plot, an auger was used to collect soil samples from the corners and in the centre of the square plots at three depths, at 0 to 20, 20 to 40, and 40 to 60 cm , and mixed to form a composite sample.

Analysis of soil physical and chemical properties

Determination of particle size distribution was carried out by the Bouyoucos hydrometer method (Bouyoucos, 1962) using sodium hexametaphosphate as dispersing agent as described in Sahlemedhin and Taye (2000). Bulk density was determined from undisturbed (core) soil samples collected using core sampling method (Black and Hartge, 1986). The bulk density was then calculated by dividing the mass of oven dry soil by volume as it exists naturally under field conditions. Measurement of soil pH was conducted using pH meter in the supernatant suspension of a 1:2.5 soil to water ratio as described by Van Reeuwijk (1993). Organic carbon of the soils was determined using the Walkley and Black wet oxidation method (Walkley and Black, 1934). Coarse fraction was determined during sample preparation after crushing of clods by hand and mechanical grinding and sieving until the sample was passed through a 2 mm sieve. Subsequently, coarse fraction was weighted and its proportion was determined using the following formula as described in Zhang et al. (2008):

$$\text{Coarse fraction (\%)} = \left(\frac{\text{Total weight} - \text{weight of fraction} < 2\text{mm}}{\text{Total weight}}\right) \times 100 \quad (1)$$

Soil carbon stock calculation

Soil carbon density (kg C m^{-2}) for each sample and depth was computed using the following equation (Zhang et al., 2008):

$$\mathrm{SOCD_i} = \frac{\mathrm{L_i} \times \mathrm{SOC_i} \times \rho \mathrm{b_i}\left(1 - \frac{\mathrm{F_i}}{100}\right)}{100} \quad (2)$$

where, $SOCD_i$ is the total amount of soil organic carbon between the soil surface and depth of i^{th} layer per unit area (kg C m^{-2}); i is the i^{th} layer and L_i, SOC_i, ρbi and F_i are thickness (cm),SOC concentration (g kg^{-1}), bulk density (g cm^{-3}), and the proportion (%) of coarse (> 2mm) fragments in the i^{th} layer, respectively and 100 conversion factor. Carbon stock for each layer of the dominant land use was calculated by multiplying the C stock obtained by Equation 1 by the total area covered by a particular land use. Subsequently, C stock in each soil layer thickness was summed up to determine total C stock contained up to 60 cm depth for each land use type.

Data analysis

Measured data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure in which land use types and depth were considered as independent variables (factors) and the selected soil properties as dependent variables. Mean separation was done using LSD at $P < 0.05$ level. Furthermore, correlation analysis was used to check the degree and magnitude of relationships between soil organic carbon and selected soil properties using SAS 9.2 software.

Table 2. Selected soils physical and chemical properties Kersa sub watershed, Eastern Ethiopia.

Variable	Depth cm	Land use			LSD	CV (%)
		Grazing	Cultivated	Fallow		
Sand %	0-20	54^{a}	54^{a}	51^{ab}	5.13	6.1
	20-40	52^{a}	$50a^{b}$	46^{bc}		
	40-60	53.3^{a}	40.6^{d}	42^{cd}		
Silt%	0-20	17^{ab}	16.7^{ab}	16.66^{ab}	2.6	9.33
	20-40	17.7^{a}	14.67^{bc}	13.66^{c}		
	40-60	17.33^{a}	18^{a}	13.66^{c}		
Clay%	0-20	29^{b}	29.3^{b}	28^{b}	5.33	9.22
	20-40	30^{b}	32^{b}	40.33^{a}		
	40-60	29.33^{b}	41.33^{a}	44^{a}		
pH($H_2$0)	0-20	7.17^{ab}	7.29^{a}	6.72^{d}	0.2	2.18
	20-40	6.95^{cd}	6.98^{bc}	6.96^{cd}		
	40-60	6.89^{cd}	6.81^{cd}	7.0^{bc}		
BD g/c^3	0-20	1.18^{d}	1.30^{cb}	1.33^{ab}	0.09	4.22
	20-40	$1.21d^{c}$	1.32^{b}	1.38^{ab}		
	40-60	1.32^{b}	1.38^{ab}	1.42^{a}		
Textural class	0-20	Sandy clay loam	Sandy clay loam	Sandy clay loam		
	20-40	Sandy clay loam	Sandy clay loam	Sandy clay		
	40-60	Sandy clay loam	clay	clay		

Means followed by the same letter(s) across columns and rows are not significantly different (p > 0.05) with respect to land uses and depth.

RESULTS AND DISCUSSION

Physical and chemical properties of the soils

Particle size distribution

Across the land uses and depth sandy clay loam is the dominant textural class in all the land use types (Table 2). However, cultivated and fallow land use types revealed sandy clay and clay textural class in their sub surface soils. This could be related to intensive cultivation in cultivated and fallow land uses.

ANOVA (Table 2) showed that both land use and soil depth (p<0.05) had a significant effect on sand and clay content but the interaction effect between the two factors was not significant (p > 0.05). Across the land use types, mean particle size distributions of clay (44%) and sand (54%) were the highest in fallow and grazing lands respectively. The silt fraction was also highest in cultivated soils. The more clay content recorded under continuous cropping might be due to cultivation which might have enhances physical and chemical weathering in addition to mixing soils from the subsurface layers. Similar results were reported by Awdenegest (2013) in which higher clay fraction was recorded in soils under farm land use types

However, the clay percentage increased while the sand percentage decreased from the surface to the subsurface layers in almost all land use types (Table 2). The relatively higher clay content in sub surface layer might be due to movement of clay from upper to lower layer. These results are in conformity with the findings of Atofarati et al. (2012) and Desalegn et al. (2015) who found vertical clay migration content with depth and high sand content in topsoil. In addition, the highest (r=-0.94, p<0.01) negative and significant correlation between clay and sand in Table 5 indicates that removal of clay results in a relative increase of sand. Moreover, according to particle size distribution rating proposed by Hazelton and Murphy (2007), the soils of the sub watershed are characterized by moderate to high clay, low level of silt and high to very high level of sand.

Soil bulk density

Bulk density (BD) varied significantly with land use types and depth ($p < 0.05$), but the interaction effect between the two factors was not significant ($p > 0.05$). The bulk density of soils under different land uses ranged between 1.18 g cm^{-3} in grazing land (0-20) to1.42 g cm^{-3} in fallow land (40-60) (Table 2). On average in the surface soil, cultivated and fallow land had 2.25 and 11.3% higher BD than grazing land. The smallest value of bulk density recorded in grazing land use type could be related to less soil disturbance and relatively higher organic matter (OM) content.

By contrast, study by Woldeamlak and Stroosnijder (2003) reported that bulk density was the highest in grazing land. On the other hand, the higher bulk density value in fallow land could be related with less aggregation of soil as result of organic matter degradation which in turn affects pore space and water holding capacity. This result is in consonance with Teshome (2016) and Zhang et al. (2009) who stated that the highest BD in the fallow land is due to organic matter degradation, animal tracking and human activity.

In all the land uses, the lowest bulk density values were found at the surface layers. This could be ascribed to high organic matter, better aggregation, particle size distribution, and root penetration in the surface layers. The results are in agreement with the findings of Ahmed (2002) and Bessah et al. (2016) who reported that bulk density values revealed increasing trend with depth in all land uses. Moreover, the critical values of bulk density for plant growth at which root penetration is likely to be severely restricted in clay loam soil is 1.6 g/cm^3 (Jones, 1983). In reference to this critical value of bulk density, all the surface and sub surface bulk density values of the soils were below the critical values. This implies that no excessive compaction and restriction of root development occurred in the soils of the study area.

Furthermore, the correlation analysis revealed SOC (%) and SOCS (t/h) had a significant negative relationship with bulk density (Table 5). These result evidenced that the lower bulk density the higher will be the SOC and SOCS in the study area. Similar finding (Lal and Kimble, 2001; Murty et al., 2002; Don et al., 2011) indicated the inverse relationship between SOC and SOCS with bulk density (Table 2).

Soil pH

ANOVA results indicated that there was no significant difference ($p> 0.05$) in soil pH value among land uses and depth but their interaction effect showed significant ($p < 0.05$) difference. Continuous cultivation practices, leaching of bases from the bare surfaces and application of inorganic fertilizers could be some of the factors which are responsible for the variation in pH in the soil. These results are in consonance with Aweke et al. (2013) who explained that intensive farming over a number of years with nitrogen fertilizers resulted in decline of soil pH more rapidly. The result, however, contradicts with previous study by Kaleem (2005) who found the lowest pH under grass because of presence of high OM. In addition, the soil pH of different land use types ranged between 6.72 to 7.29 and 6.82 to 7.00 in surface and sub surface soils respectively. It revealed decreasing trend with depth. This was supported by a negative correlation between OC and pH for the 20-40 and 40-60 cm depth (Table 5). According to soil pH (H_2O) ratings of Tekalign (1991), the overall pH (H_2O) range of the studied soils fall under the neutral (6.72-7.29) soil reaction range, which is favourable range for availability of most nutrients and activities of microorganisms.

Effect of land use on soil organic carbon content and soil organic carbon stock

The data pertaining to soil organic carbon (SOC) content (g kg^{-1}) and soil carbon stock (SOCS) (t/ha) in Tables 3 and 4 showed significant variations with respect to both land use type and depth ($p < 0.05$). However, the interaction effect of land use type and depth was not significant ($p > 0.05$). In the surface soils, the mean SOC and SOCS in the grazing land (18.5 g kg^{-1}, 42.9 t/h) was significantly higher than cultivated (13 g kg^{-1}, 32.6 t/h) and was the lowest in fallow land (9.7 g kg^{-1}, 23.0 t/ha) respectively. SOC and SOCS consistently declined with depth in all the land uses.

The highest SOC and SOCS in the grazing land use could be related to the high amount roots of grass and high grass root biomass turnover rate, which is important as protection from erosion and lack of tillage. In addition, the controlled grazing management practice where livestock is confined in a stall and fed with cut and carried fodder might have contributed to the high SOC and SOCS in Kersa sub watershed. In relation to this high total organic carbon stock under grazing land due to high grass root biomass turnover rate and also lack of tillage was reported (Guo and Gifford, 2002; Urioste et al., 2006; Qi et al., 2012; Yoseph et al., 2017). Similarly, Girmay and Singh (2012) reported higher mean SOCS in northern Ethiopia due to animal excrement. Our result clearly shows that in the study area controlled grazing land use types accrue significantly higher soil organic carbon stock than cultivated and fallow land use types.

Conversely, SOC and SOCS were significantly lower in the cultivated land compared to the grazing land use type, in which the cultivated lands accumulated 28 and 27% less SOC and SOCS than the grazing land, respectively. These could be due to fast decomposition and mineralization as continuous cultivation affect the soil

Table 3. Effect of land use types and depth on soil organic carbon content in Kersa sub watershed.

Land use types	SOC (g kg^{-1})		
	0-20cm	20-40 cm	40-60cm
Grazing	18.5^{a}	13.9^{b}	11.6^{b}
Cultivated	13.0^{b}	10.6^{cd}	07.8^{e}
fallow	09.7^{d}	05.2^{f}	03.8^{f}
Overall mean	10.5	-	-
LSD (0.05)	0.15	-	-
CV (%)	8.40	-	-

Means followed by the same letter(s) across columns and rows are not significantly different (p > 0.05) with respect to land uses and depth.

Table 4. Effect of land use types on soil organic carbon stock (t/ha) in Kersa watershed.

Land use types	SOCS (t/h)		
	0-20cm	20-40 cm	40-60cm
Grazing	42.9^{a}	32.9 ^{b}	32.6^{bc}
Cultivated	32.6^{bc}	26.3^{dc}	20.3^{f}
fallow	23.0^{ef}	12.5^{g}	09.5^{g}
Overall mean	25.5	-	-
LSD(0.05)	0.039	-	-
CV (%)	8.85	-	-

Means followed by the same letter(s) across columns and rows are not significantly different (p > 0.05) with respect to land uses and depth.

moisture and aeration which in turn results in oxidation of soil organic matter and less accumulation of organic matter through harvesting plant as well as plant residues. The continuously removed plant residues from fields for various purposes like source of fuel wood and livestock feed ultimately result in low organic carbon stock besides increasing surface runoff and removal of other essential nutrients from the soil. The results indicate that cultivation causes SOC loss, which is in conformity with other studies (Post and Kwon, 2000; Yimer et al., 2006; Wang et al., 2008; Don et al., 2011; Itanna et al., 2011) who reported that cultivation reduced soil organic carbon through high decomposition and minimum protection of SOC.

Similarly, the lowest SOC and SOCS found in fallow land could be related to the fact that the fallow land is situated on a relatively steep slope area which is prone to high soil erosion and soil degradation as well as the process of succession was slow and the fallow time was short. In line with this, Yoseph et al. (2017) indicated that soil organic matter plays significant roles in soil aggregate stability and nutrient availability which subsequently contributes to enhanced soil quality. As a result, low soil organic carbon in fallow land can lead to severity of soil degradation in terms of nutrient availability and water holding capacity.

SOC and SOCS also showed variability with depth. SOC and SOCS decreased consistently with depth for each land use types. The highest SOC and SOCS were observed in the top layer (0 to 20 cm) than in the middle layer (20 to 40 cm) and in the bottom layer (40 to 60 cm).The difference in SOC and SOCS between different land use types narrowed with soil depth. In the study area about 42.3 and 43% of SOCS and SOC was found in the top 0-20 cm layer, while 30.8 and 31.56% was in the 20 to 40 cm layer and 26.8 and 24.4% in the 40 to 60 cm layer respectively. The finding revealed that not only land use but soil depth also significantly affected the level of SOC and SOCS in the study area. The high SOC and SOCS in surface soil could be due to incessant addition of undecayed and partially decomposed plant and animal remains in the surface soils. This finding is in consonance with the results of studies (Yimer et al., 2007; Awdenegest et al., 2013; Nega and Heluf, 2013).

In addition, the correlation analysis in the surface layer showed significant (p < 0.05) and negative relationship between soil organic carbon stock (SOCS) and sand, while positive and significant relation with clay was recorded (Table 5). This indicates that the amount of SOC in soil increased with the amount of clay. This could be related to SOC coating around clay minerals and protected against weathering and microbial degradation which helps the SOC to stay in the soil for long periods.

In consistent with Plante et al. (2006) and Hoyle et al. (2011) report clay content increase the amount of SOC through physical protection from microbial breakdown.

Despite a significant difference in SOC and SOCS content among the major land use types in Kersa sub watershed, according to the OC content rating criteria established by Tekalign (1991), the overall OC content of the soils was in the range of very low to low. The low amount of organic carbon in the study area could be related with inadequate application of organic input and intensive cultivation. Similarly, Tegbaru et al. (2014) and Okubay et al. (2015) reported intensive cultivation and low application of organic inputs were the factors which reduced soil OC in Ethiopian soils respectively.

Conclusion

Based on the result of the study grazing, cultivated and fallow land use showed significant differences in their soil organic carbon and soil organic carbon stock content. SOC stock in grazing land was significantly higher than those of cultivated and fallow land use types. Similarly, the surface layer (0 to 20 cm) stored significantly higher SOC in all land use types. However, the soil organic carbon status in all land use types was found to be low. This indicates the presence of a good potential to

Table 5. Correlation matrix for selected soil parameters in Kersa sub watershed.

Variable	Depth (cm)	Sand	Silt	clay	pH	BD	OC	SOCS
	0-20	1.00	-	-	-	-	-	-
Sand	20-40	1.00	-	-	-	-	-	-
	40-60	1.00	-	-	-	-	-	-
	0-20	0.368	1.00	-	-	-	-	-
Silt	20-40	0.571	1.00	-	-	-	-	-
	40-60	0.292	1.00	-	-	-	-	-
	0-20	-0.86***	-0.50	1.00	-	-	-	-
Clay	20-40	-0.93**	-0.72**	1.00	-	-	-	-
	40-60	-0.94**	-0.582	1.00	-	-	-	-
	0-20	0.548	0.276	-0.392	1.00	-	-	-
pH	20-40	0.410	-0.218	-0.246	1.00	-	-	-
	40-60	0.006	-0.605	0.196	1.00	-	-	-
	0-20	0.187	0.31	-0.453	-0.184	1.00	-	-
BD	20-40	-0.033	-0.67**	0.242	0.406	1.00	-	-
	40-60	- 0.69**	-0.79**	0.85**	0.369	1.00	-	-
	0-20	0.21	0.1	0.08	0.48	-0.76**	1.00	-
OC	20-40	0.35	0.56	-0.52	-0.11	-0.80**	1.00	-
	40-60	0.76**	0.74**	-.89**	-0.47	-0.86**	1.00	-
	0-20	-0.27**	-0.24	0.6*	0.23	-0.80**	0.82**	1.00
SOCS	20-40	-0.25	-0.15	0.11	-0.14	-0.60*	0.54 **	1.00
	40-60	0.15	0.58	-0.33	-0.63	-0.39	0.69**	1.00

sequester carbon in soils of the study area. Therefore, appropriate farming and management practice which increase inputs and reduces losses of the soil organic carbon should be designed and implemented in the study area. These improve the soil potential to sequester more SOC and minimize the effect of climate change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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