



Research article

Soil organic carbon and its' stock potential in different land-use types along slope position in Coka watershed, Southern Ethiopia

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ABSTRACT

Understanding organic carbon accumulations in soils is crucially essential concerning carbon sequestration, fighting climate change, increasing land productivity, improving soil properties, providing energy to the microbial community, enhancing ecological restoration, and reversing global environmental damage. This study was aimed at assessing the effects of land-use-cover change (LULC) on soil organic carbon (SOC), its' stock potential, and bulk-density (BD) along slope position in the Coka watershed. Replicated soil samples had been collected and composited from 30 cm depth topsoil of five major land use types and three slope positions. This result showed that significantly ($P < 0.001$) lowest and highest mean of soil organic carbon stock (SOCS) was observed under bare lands ($37.835 \text{ Mg ha}^{-1}$) and bushlands ($144.582 \text{ Mg ha}^{-1}$), respectively which was the same for SOC concentration. Barelands lose 3.82 times (3.82x) higher SOCS than bushland and 2.68x more SOCS than forestland. Both SOC-stock and SOC showed significant ($P < 0.001$) differences among slope positions, which were the highest in lower-slope followed by middle-slope, which had 1.8 and 2.6x higher than in middle-slope and upper-slope positions, respectively. Thus, the multivariate-test result divulges that LULC along slope positions has a strongly significant ($P < 0.05$) main and interaction effect on SOCS in the area. Therefore, the potential contribution of bushland and forestland uses should be improved for SOC sequestration, soil productivity improvement, and environmental protection.

1. Introduction

Soil organic carbon (SOC) stock is considered to be among the largest carbon reservoirs of the earthly ecosystems and also plays an essential role in the worldwide carbon cycle [1] and [2]. The effect of land-use changes on organic matter has impacted soil fertility, agricultural productivity, food security, terrestrial and global carbon cycle, and climate change [3]. Soils store higher organic carbon than the aboveground vegetation and the atmosphere together [4]. As reported by [5], soils play a vigorous role in regulating global climate and store two-thirds of carbon storage. As argued by [6] that soil organic carbon is threefold more than in plants and twofold than in the atmosphere. Soils might be among the largest carbon sinks to lead to atmospheric CO_2 concentrations. Thus, changes in SOCS might have significant influences on the global carbon cycle. SOC improves soil properties by retaining a vital soil nutrient for the growth of plants and providing energy to the microbial community. It could be affected by various factors such as vegetation [7],

altitude and climate [8], land-use-cover changes (LULC) [9], topographic factor [10], and loss of topsoil by erosion [11, 12, 13], and fire [14].

The land-use type is a vital element in controlling carbon stock in the soil. Numerous studies have revealed significant variation in SOC concerning LULC [11]. As reported by [15], LULC type influences the quantity of residue input and decomposition rate in soil. Similarly, both SOCS and Carbon content was decreased by cultivation [16]. LULC changes may support soil property degradation and deterioration [17]. Organic carbon depletion could reduce soil and land productivity fertility by influencing soil nutrient retention, physical structure, and water storage [18]. Thus, SOC depletion might affect the livelihoods of households. Commonly, forest-cover changes to cultivated-land decreased soil fertility by increasing erosion rates [19].

LULC dynamics are affected by human actions, which decline available water, vegetation, animal feed, and soil fertility at the landscape level. Land-use changes have remarkable effects on soil properties, including soil-organic-carbon-stock. The soil carbon accumulation is composed of decaying fungal, bacterial matter, plant and animal stored,

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and soil organic matter. Vegetation removal and soil erosion due to land-use changes can accelerate SOCS loss [20]. Moreover, addressing the LULC in diverse land utilization types may give a clue on carbon sequestration in soil [21]. Conversion and modifying one land use for another may result in the loss of natural resources and agro-biodiversity [22]. Forest clearing and continuous cultivation caused a high risk of SOC depletion for nearly half of the total landmass in Ethiopia [23]. LULC is the leading anthropogenic carbon source in the atmosphere [24].

Topographic factors (e.g. slope and altitude) positively or negatively influence soil properties by varying vegetation cover, rainfall, and temperature. Typically precipitation rises, and temperature becomes colder with increasing altitude, resulting in changes in vegetation distribution, affecting SOC stock [25]. Slope position is a main topographic factor affecting the pattern of SOC along the topo-sequences [26]. Similarly, slope position contributes to the spatial unevenness of SOC [27]. It can alter both the hydrological processes and the solar radiation intensity [28], which is a significant factor governing the residue decomposition rate and organic matter.

Moreover, a foot slope tends to receive less solar radiation and more water, which can create more favorable conditions for vegetation growth [29]. Climatic, hydrological, and ecological conditions can be reshaped by this topographic factor which can modify the spatial arrangements of SOC at both a regional and a hill-slope scale [30] and [31]. In regions, slope position varies SOC fate through the rate of decomposition and soil erosion [32]. As reported by [33] SOCS on the foot slope were 2.5 times greater than other slope classes along an eroding hill slope located on cultivated land in Belgium, and that of [34] found similar outcomes in a quiet environment in Australia. The slope gradient is the key factor affecting SOC dynamics and soil quality [11, 12, 13], while topsoil losses and soil erosion are highly correlated with slope steepness [14]. SOC concentrations at the 0–60 cm soil depth in terraces were the highest when compared to forestland, grassland, and sloping cropland [35]. Soil erosion and cropping contributed to variations in SOC and TN losses along the sloping terrace [36]. The most serious problems for the farmer in tropical highlands are land degradation due to misuse of land resources and land cover changes which result in decreasing soil fertility and crop yield losses [37].

Thus, the Coka watershed faced food insecurity problems, climate change (uncommon rainfall, hotness, and coldness), the occurrence of drought, lack of crop productivity, and population growth from the last 30 years to the present [38, 39], which is a 56.3% increment of population growth with the requirement of construction, crops for food security, firewood and charcoal for fuel or income, and grazing. These all anthropogenic activities have significant impacts on the environment and ecology of natural resource management and assurance of food security. Food security depends on soil productivity whereas soil fertility and productivity depend on soil organic matter, which is a reservoir of essential nutrients and plays an important role in cycling essential nutrients. The investigation in and surrounding the study area is limited to soil organic carbon content and stock, but the study area faced uncommon weather conditions and extended food insecurity periods. The findings from the study may provide scientific information for the scientific community, government and non-government organizations, and local area people to fill the gap and effective decision-making to mitigate environmental and ecological problems in the area. This study was aimed to assess the effects of LULC along with slope positions on SOC stock's potential and provide information for effective land use planning, and to mitigate the change in climate in the Coka watershed.

2. Material and method

2.1. Study area

Coka watershed is located in geographical boundaries 7°12'10"N - 7°18'20"N and 37°31'0"E - 37°34'25"E in Tembaro woreda, Kembata Tembaro Zone, Southern Ethiopia (Figure 1). The watershed area is 3731

ha, and the altitude ranges between 771m in plains to 2524 m.a.s.l. in the plateaus (Figure 1). The district slope gradient ranges from gently (2–5%) to very steep (above 30%) (Figure 1).

Coka watershed has bimodal rainfall distribution small (*belg*) and major (*Kiremt*). The long-term mean average rainfall is 1267.13 mm, and the mean max and min temperature are 30.0 °C and 9.9 °C, respectively [40] and (Figure 2). The trend rainfall showed unsystematically decreasing from 198 to 2021 years periods (Figure 2). The trend of temperature in the area revealed an unsystematic increment for max. temperature and decrement for min. temperature (Figure 2). Rains in kiremt season are intensive, which is used for economic and food crop production and causes soil erosion during this time at different parts of this watershed. According to [41] the agro-climatic classification of the study watershed can be kola or warm semiarid (500–1500/1800 m), woinadega, or cool sub-humid (1500/1800–2300/2400 m), and dega or cool-humid (2300/2400–3200 m).

The study watershed drains to the Coka stream, forming a tributary of the Omo River that flows into L. Turkana, bordering with Kenya. Geologically, the area is covered by trap series volcanics of the tertiary period that are characterized by acidic rocks such as rhyolites, ignimbrites and trachetis covering the basemen complex of the Precambrian rocks [42]. Moderate to deeper and shallower soils are found on plains slopes and steeper slopes, respectively. The total population of the study watershed was 12,493 in 1994, 14,303 in 1998, 17,486 in 2008, and 22,194 in 2021 [39] showing a population increase of 56.3% in the last 30 years. The reason why Coka watershed was selected for this study is the food insecurity problem that existed in the area and the dramatic increment in population growth.

2.2. Analysis of land-use-cover

The people within the Coka watershed are involved in mixed agriculture and crop-livestock farming. The land-use-cover (LULC) within area was classified into seven classes which includes forestland (23%), bush-land (18.3%), cultivated-settlement-land (38.5%), grassland (16.9%), bare-land (1.8%), built-up-area (0.6%) and water-body (0.9%) [43]. LULC current data were assessed by using remote-sensing data from satellite images (Landsat-8 OLI-TIRS) with 30 m*30 m spatial resolution and path/row of 169/55. LULC change is the largest anthropogenic carbon source in the atmosphere [44].

2.3. Soil-sample-collection and laboratory-test

Soil samples were composed using offseason, which was appropriate for sampling in Coka watershed. Slope and climate variability and land-use type and its adjacent area were considered to minimize differences in soil sampling; because of this, the method used was purposive sampling. Soil data for soil carbon content and bulk density were collected from five LULC types (forestland, cultivated-land, grassland, bushland, and bare-land) and three slope positions (lower-slope (0–10%), middle-slope (10–30%), and upper-slope (>30%)) within 30 cm soil depth. The soil sample was collected from 0–30 cm soil depth because this soil depth might be the most biologically active portion of the soil profile and root ability zone for most plants. The reason for the classification of LULC change types and slope classes is their existence in the area. Soil samples from each slope position and land-use types were collected from randomly selected points with 5–8 replications based on a sampling plot size and replicated soils mixed together to form a composite for organic carbon-content analysis. Samples were gathered by using the core ring method (100 cm³ core volume) for soil bulk density (BD) analysis. Totally 60 soil samples (5 LULC types x 3 slope positions x 4 plots) were collected for analysis of SOC and BD in the Coka watershed. Soil bulk densities and carbon contents had been analyzed in Hawassa University soil test laboratory.

BD was taken from undisturbed samples with a known volume of core ring samplers and measured. The BD samples were dried for 12 h at 105

°C and weighed. The bulk density (BD) (g cm^{-3}) was calculated as the dry soil weight divided by the volume of the soil as shown in Eq. (1).

$$BD = \text{Dry weight of soil/volume of soil} \quad (1)$$

where BD-bulk density.

Sixty composite samples of soil were brought to the laboratory for organic-carbon estimation. The soils were dried, ground, and sieved (<2 mm) for SOC analysis before occurring the laboratory process to remove the debris and roots. The total carbon concentrations were analyzed at 1100 °C by dry combustion. Organic carbon (OC) in soil was estimated using the [45] wet digestion method, which is a widely used procedure [46] for soil organic carbon estimation. In Walkley and Black methods, about 60–86% of SOC is oxidized; therefore, a common correction factor (1.32) was used to get the corrected SOC values [47]. This analysis was executed for original samples and those treated with 6 M HCl to remove carbonate carbon. The results presented in this document represent carbon contained in organic matter, remaining in the soil after the HCl treatment. Carbon stocks (Mg ha^{-1}) were primarily calculated by multiplying the concentrations (%) of organic carbon in soil by the bulk density (g cm^{-3}) and depth of sampled soil (30 cm) (Eq. (2)). Soil organic carbon stocks (SOCS) were calculated using [46], which is:-

$$\text{SOCS} = BD \cdot D \cdot \% C \quad (2)$$

where, SOCS(Mg ha^{-1}) is Soil organic carbon stock, BD (g cm^{-3}), D (cm) is soil depth, and %C is soil organic carbon concentration in percent.

2.4. Data analysis

Soil data on SOCS were subjected to Factorial design following the general linear model (GLM) procedure using IBM-SPSS statistics 26 version statistical software. Multivariate-test was conducted to identify the statistical significance of main effects and interaction effects between LULC-types and slope positions. A one-way analysis of variance (ANOVA) showed significant differences ($p \leq 0.05$) among the various land-use and slope position for each parameter.

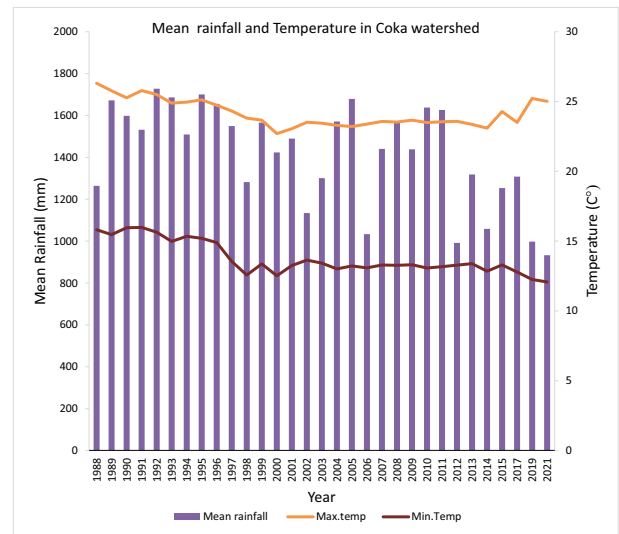


Figure 2. Mean Rainfall and Temperature in the Coka watershed.

3. Result and discussion

3.1. Main and interaction effects of LULC types along with slope positions

All multivariate tests (Wilks' Lambda) showed that the multivariate main effects of LULC types were statistically significant ($P < 0.001$), indicating SOC stocks were significantly affected by LULC types (Table 2). The main effects of slope positions showed a significant ($P < 0.01$) difference between the subject's effects on BD (g/cm^3), SOC (%), and SOCS (Mg ha^{-1}) (Table 1). The main effects of all multivariate tests for slope classes have revealed statistically significant ($P < 0.001$) differences even in the same selected soil properties in the LULC types in different slope positions (Table 2). Interaction effects of LULC types along

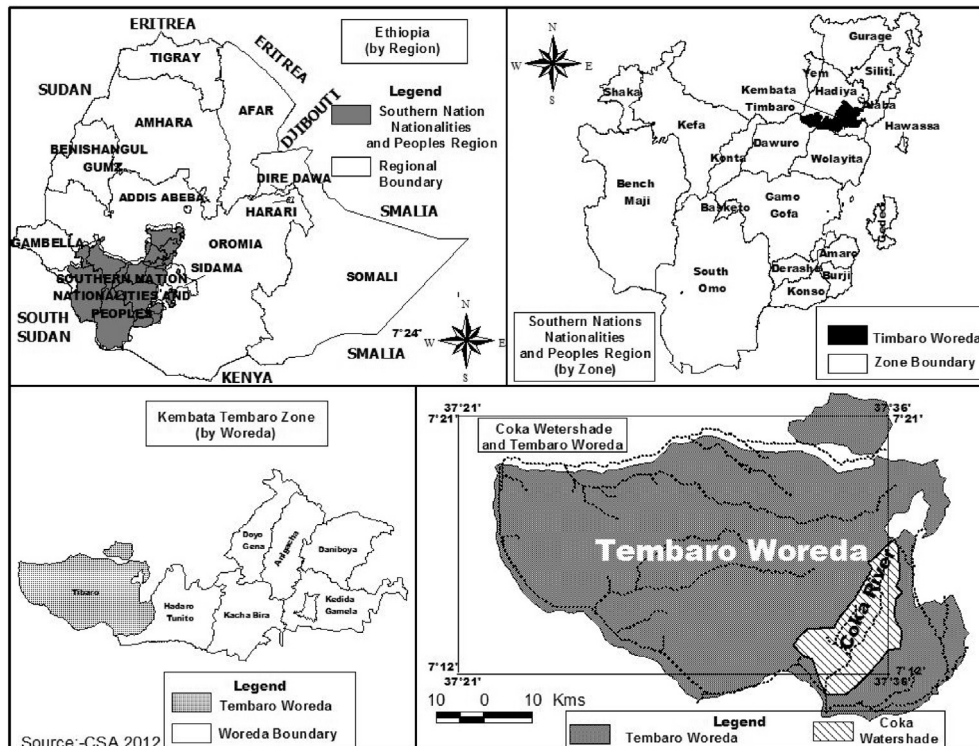


Figure 1. Map of the study watershed, Southern Ethiopia.

Table 1. Multivariate tests between-subjects effects on soil organic carbon stock in Coka watershed.

Variables	Soil properties	Mean Square	F	Sig.
LULC-Type	BD (g/cm ³)	0.485	79.074	0.000
	SOC (%)	20.549	54.073	0.000
	SOCS(Mg ha ⁻¹)	22,054.801	44.663	0.000
Slope-position	BD (g/cm ³)	0.379	61.677	0.000
	SOC (%)	39.261	103.314	0.000
	SOCS(Mg ha ⁻¹)	31,970.478	64.744	0.000
LULC Type * slope position	BD (g/cm ³)	0.016	2.671	0.017
	SOC (%)	2.867	7.545	0.000
	SOCS(Mg ha ⁻¹)	2327.993	4.714	0.000

slope positions for analysis of all multivariate tests were statistically significant ($P < 0.05$), and tests' between-subjects effects on SOCS were statistically substantial ($P = 0.000$) (Tables 1 and 2). A statistically significant correlation ($R = 0.981$) has occurred between (SOC (%)) and (SOCS (Mg ha⁻¹)) but negative correlation with BD. This divulges that SOCS at 0–30 cm depth varied significantly ($P < 0.001$) in LULC changes and slope position in this specified area which is in agreement with the study conducted by [48].

3.2. Effects LULC types

Soil bulk density (BD) varied statistically significantly ($P < 0.001$) from highest in bare land and lowest in forestland (Table 3). According to Hillel (1980), more OM content in the topsoil makes soils loose, porous, and well aggregated, thereby reducing BD, a good range for agricultural soils from 1g cm⁻³ to 1.7 g cm⁻³. This implies that the soils of the study area have no excessive compaction, no restriction to root development, and are within the average range for good agricultural productivity, which is in line with the study [49].

SOC stock at 0–30 cm depth showed a statistically significant difference ($P < 0.001$) in LULC changes in the Coka watershed. According to ANOVA test analysis (Table 3, Figure 3) indicated that LULC types had statistically significant ($P < 0.001$) effects on soil organic carbon content (SOC (%)) and soil organic carbon stock and (SOCS (Mg ha⁻¹)). The overall mean of SOC and SOCS in the bushland (3.95%) and 144.58 (Mg ha⁻¹) followed by forest land (3.33% and 101.52 Mg ha⁻¹) was significantly ($P = 0.000$) higher than in bare land (0.81% and 37.84 Mg ha⁻¹), respectively (Table 3, Figure 3). The increasing trend of SOCS was shown at a depth of 30 cm in the following order: bushland > forestland > grassland > cultivated-land > bare-land. A significant correlation ($R = 0.98$) was detected between SOC content and SOC stock. SOCS in bushland was 2.93 and 3.82 folds greater than in cultivated land and bare land, respectively. The result showed that the presence of the highest SOCS in bushland could be because the types of bushes presented in the study area were large in amount and faster for decomposition. Forestland contained 2.01 and 2.68 times more SOCS than cultivated land and bare land in 30 cm soil depth. This indicates that the identified soil depth is appropriate for SOCS evaluation, primarily for cropland productivity and improvement of carbon sequestration. The finding is confirmed by [50]; SOCS observed in the topsoil (0–10 cm) was 60% of the total. As reported by [9] soils converted to cropland lost 13–18% of their SOC for the top layer of 20 cm. Similarly, the amount of SOC is approximately double

Table 2. Main effects and interaction effects of LULC types and Slope position in Coka watershed.

Variables	Multivariate Tests	Value	F	Df	Error df	Sig.
LULC-Type	Wilks' Lambda	0.020	31.892	12.000	114.059	0.000
Slope-position	Wilks' Lambda	0.108	29.283 ^b	6.000	86.000	0.000
LULC-Type * slope position	Wilks' Lambda	0.180	4.203	24.000	125.314	0.000

Table 3. Mean effects of LULC types on soil organic carbon stock.

LULC Type	BD (g/cm ³)	SOC (%)	SOCS(Mg ha ⁻¹)
Forestland	1.048	3.329	101.521
Cultivated-land	1.244	1.384	49.347
Grassland	1.251	2.224	75.883
Bare-land	1.606	0.808	37.835
Bush-land	1.278	3.952	144.582
Mean Square	0.485	20.549	22,054.801
F	22.923	9.533	11.576
Sig.	0.000	0.000	0.000

(2x) the amount of C in atmospheric carbon dioxide (CO₂) and threefold that in aboveground vegetation globally in the 30 cm surface layer [51]. This result showed lower SOC stock than the same soil depth at a global level. This finding agrees with those studied by [52], the SOC global stock of soil has been calculated to be in the range of 684–724 Pg to the soil depths of 30 cm. This critical severity indicates that ecological and environmental restoration is required in the study watershed. Moreover, this discovery is within the range of earlier findings by [53] who reported that SOC stock ranging (42.9–234.6 Mg ha⁻¹) for different soil types for 0–60cm depth, Southern Ethiopia.

LULC changes have considerable contributions toward the SOC-storage and/or CO₂ emission. Observably, LULC changes can influence soil properties, including SOC stock and SOC content, because of anthropogenic activities (agricultural intensifications, overgrazing, fertilizer application, harvesting, planting, etc.). This result, approved by [47] reported that organic carbon was lowest in cultivated than forestland, bushland, and grassland. This finding is maintained by [54] who argued that a significant difference in SOCS is due to LULC changes in Western and Central Ethiopia. Similarly, the study by [55] cropland expansion typically reduces SOC stocks. The highest area was covered by cultivation with low organic carbon stock which is directly connected with low soil agricultural productivity. As reported by [56] that SOC-stocks are sensitive to land-use-cover change. Soil-carbon can improve the soil's physical and chemical properties. Cultivated land and bare land have lower organic carbon stocks and contents than other land-uses ecosystems since cultivated-land increases the soil's aeration, microbial-mobility, enhances decomposition, removal with crop residues, and bare land might be exposed to removal of organic carbon with topsoil by erosion and evaporation from soil surface due to lack of land cover.

The lowest SOCS and SOC content in the study area were recorded in bare land followed by cultivated land which may cause land degradation and environmental pollution. Besides, LULC and widespread poor agricultural practice might be among the reason for soil quality deterioration and low crop productivity. This finding is in line with the study by [57], the human factors of poverty, insecure land tenure, and high population pressure as driving forces for land degradation. Similarly [58], investigated the impact of LULC on concentrations of SOC sequestration. The land conversion from natural forests to plantations, croplands, and unsustainable land uses negatively influenced the SOC pool in soils across Ethiopia [59]. In contrast [60], found no significant differences in soil chemical properties among land uses, including SOCS, but found a significant difference in physical properties of Andosol in Ethiopia's Southern part.

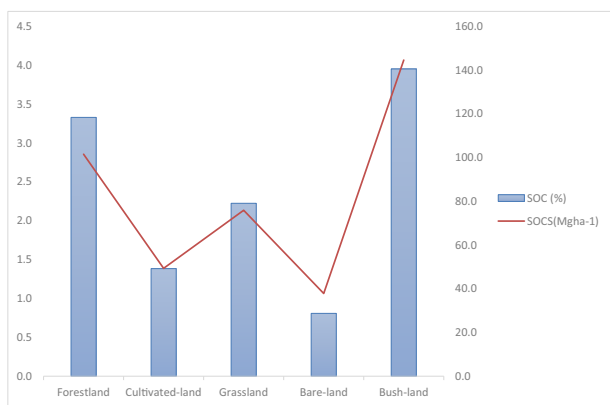


Figure 3. Effect of land-use-cover change on soil organic carbon stock and content.

This study revealed that the transformation of natural vegetation to anthropogenic land uses (grassland, cultivated land, and bare land) could cause a deterioration effect on SOC stock. This result is in line with a study by [61] that reported that alteration of natural forests into human-managed land uses (cropland, grazing land, and eucalyptus plantation) had more harmful effects on SOC in Northwestern Ethiopia. Another study by [62] also found a comparable higher SOC under grassland than in cereal farms in Southern Ethiopia.

The SOCS increment showed from bare land to bushland by 3.82 times, indicating the need for improving and restoring SOCS by converting bare land and farm-land to forestland and bushland. The findings agree with studies conducted by [63] that reported that improvements in SOCS have been documented with the change of cultivated-land and grazing-land to the forest in different parts of Ethiopia. As reported by [44], revegetation and afforestation have been suggested as effective approaches to ensure SOCS in soils [2]. Converted that the transformation of degraded grazing land into protected areas significantly increased SOCS in the topsoil layer (0–10 cm) by 42%. The increment of SOC and ecosystem improvement have been achieved by converting degraded lands to protected areas across different agro-ecological zones in Ethiopia [48]. Correspondingly [64], confirmed that SOCS increased by community-based water and soil conservation practices. This indicates that enhancing SOC-stock is possible in the area by converting degraded land to forest or protected land. Thus, approaches that enhance SOC increment in farming ecosystems systematically improve atmospheric CO₂ sequestration and organic-matter pools restoration, which is critical to soil quality and health.

3.3. Effect of slope position on soil organic carbon stock

The result revealed that statistically significant ($P < 0.001$) difference in SOC (%) and SOCS (Mg ha⁻¹) in all slope positions (Upper,

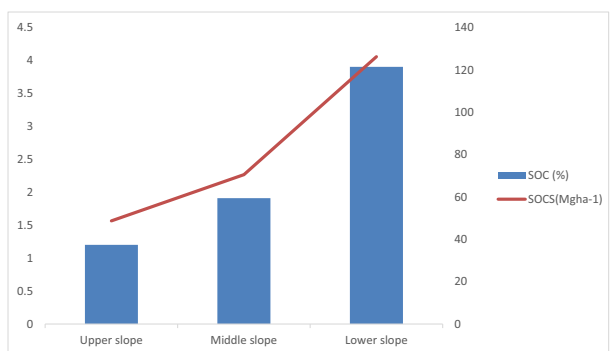


Figure 4. Effect of slope position on soil organic carbon stock and content.

Table 4. Mean effects of slope position on soil organic carbon stock in the Coka watershed.

Slope position	BD (g/cm3)	SOC (%)	SOCS(Mg ha ⁻¹)
Upper slope	1.420	1.202	48.714
Middle slope	1.292	1.911	70.540
Lower slope	1.145	3.904	126.247
Mean Square	0.379	39.261	31,970.478
F	9.187	18.308	14.119
Sig.	0.000	0.000	0.000

Middle, and lower slopes) (Table 3, Figure 4). The significantly highest mean difference between SOCS and SOC was observed in the lower slope position (mean = 126.247 Mg ha⁻¹ and 3.904%) followed by the middle slope position (70.540 Mg ha⁻¹ and 1.911%), respectively (Table 4, Figure 4). The lowest significant ($P < 0.001$) mean difference for SOCS and SOC was recorded in the upper slope (48.714 Mg ha⁻¹ and 1.202%), respectively (Table 4, Figure 4). In the overall mean, the increasing trend of SOCS in slope position was observed within the depth of 30 cm in the order: lower slope > middle slope > upper slope. This is the same trend for soil organic carbon content in the study area. SOCS in lower-slope positions had 1.8 and 2.6 times higher than in middle-slope and upper-slope positions, respectively. The result revealed that SOCS was higher on the lower slope than in other slope classes in the study area due to might be the removal of topsoil from upper and middle slope classes and deposited in the lower slope position, the presence of more vegetation on the lower slope, and less exposed for sunlight. This result is verified by [33] that the foot slope was 2.5 times higher SOCS than other slope positions in Belgium. Similarly, organic carbon content decreased from the lower slope to the upper slope position in the Kabe watershed, Southern Ethiopia [47]. This study demonstrated that the SOCS varied significantly ($P = 0.000$) in slope positions (lower, middle, and upper classes) at 30 cm depth in the Coka watershed.

In most land uses, middle-slope and upper-slope classes have lower SOCS and SOC content than lower slope positions in the Coka watershed. This could be caused by a decrease in upper and middle slope position due to the removal of topsoil by accelerated erosion. This finding is confirmed by [65] that the SOCS of the grassland and forestland were higher on the lower slope than on the upper hill slope. This might be the occurrence of increased evaporation and removal of topsoil due to upper and middle slope land uses exposed to temperature and water erosion. This result is in agreement with conducted [66], that SOC content and SOCS might be affected by topographic factors. Correspondingly, the slope positions are supported to force distribution patterns of plant types and aboveground biomass [67]. According to [68], afforestation on sloping cultivated lands increases SOCS. As argued by [66] in Ethiopia's northern highlands, an impact of different land uses along slope positions showed the apparent changes in soil properties, including SOC content. This reveals that the slope position has shown a statistically significant ($P = 0.000$) difference in SOC stock.

4. Conclusion

Exploring the effects of land-use-cover changes (LULC) along slope-position on carbon stock under global warming is fundamental to global climate change and land-productivity investigation. The LULC-change showed significant ($P < 0.001$) variation in SOC content and SOCS (soil organic carbon stock) with the range of bushland (144.582 Mg ha⁻¹) to bare land (37.835 Mg ha⁻¹) and with slope position range of upper-slope (48.714 Mg ha⁻¹) to lower-slope (126.247 Mg ha⁻¹) in the Coka watershed, Southern Ethiopia. These findings revealed massive losses of SOCS and SOC content due to the transformation of forestland and bushland to grassland, cultivated land, bare land, and lower slope to upper slope positions. This loss indicates that it might be caused by the decrement in agricultural productivity in the study area. ANOVA and a

multivariate test showed that all LULC-changes and slope positions revealed a significant ($P < 0.001$) effect on SOC and SOCS, and the interaction effect of LULC-types with topographic position also showed a statistically significant ($P < 0.001$) difference. The SOC and SOCS are varied in the shift of LULC types within 0–30 cm soil depth because this soil depth might be the most biologically active portion of the soil profile and root ability zone for most plants. The highest BD in bare-land and upper-slope and lowest BD in forestland and lower-slope were observed. Generally, this study implies the presence of a positive relationship between SOCS and LULC types along with the topographic position. However, the overall SOCS status in all land-use types and slope positions was found to be low. Thus, appropriate LULC and management practice should be required to add inputs and reduce losses of the SOCS has to be designed and implemented to increase the content and stock of soil organic carbon in the Coka watershed. These could increase soil productivity, recover the soil potential to sequester more SOC, protect the environment and lessen the effect of climate change for long periods of sustainability.

Declarations

Author contribution statement

Tadele Buraka: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Eyasu Elias & Alemu Lelago: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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