Soil Physicochemical and Macrobiota Diversity Dynamics Under Enclosed Areas of Central Rift Valley of Ethiopia

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Abstract

Background Area enclosures have been implemented for many decades to restore degraded areas. The objective of this study was to evaluate its contribution to the enhancement of soil physicochemical and macrobiata diversity.

Results Among the soil physicochemical parameters, the overall mean BD (0.002*), soil-MC (0.000*), % sand (0.011*), % clay (0.038*), pH (p = 0.022*), SOM (p = 0.005*), and Exch. Ca (p = 0.000*), and exch. K (p = 0.000*) exhibited a significant mean difference across the different land-use while % silt, EC, ava. K, ava. P, TN, CEC, and exch. Mg was insignificant at α-0.05. Although the whole study area was dominated by sandy, the result of ANOVA indicated that there was a significant mean difference in %sand (p = 0.011*) fraction across the land uses. The SOM also varied significantly and it is very high in the CA1, followed by CA2, PA, and OA, respectively. Though the result of Tukey's HSDa and homogeneity test showed that there is no statistically significant mean difference in the amount of available soil nutrients across the study sites, there was a slight variation in their magnitude, and PA was characterized by having high ava. P (9.70 ± 3.261a) and TN (0.28 ± 0.064a) while ava. K is very low (1062.29 ± 110.018a) compared to other land uses. In terms of the soil macrofauna, the CA1 had higher species diversity (1.90), abundance (32.69%), and richness (30.95%), and the species were evenly distributed. Followed by CA1, PA has a good species diversity (1.30), richness (26.19%), and abundance (24.16%), although the soil macrofauna was less evenly distributed compared to other land uses.

Conclusion Generally, the enclosed area contributed to the improvement of soil physicochemical and biological components, and hence, expanding such measures in consultation with concerned bodies of the study area and proper follow-up mechanisms have a crucial role in rehabilitating degraded areas.

1. Background

Globally, over the last two to four decades, more than half of the earth's land surface has been affected by anthropogenic activities, which was associated with increasing population number, land use and land cover change, expansion of agriculture, and other development activities (Ward et al., 2014). Soil plays significant multitude roles (regulating, provisioning, cultural, and supporting services) to humans and the environment (Schwilch et al., 2016). Nonetheless, interference with the increasing world population for pursuing different socio-economic benefits contributed to extensive land degradation that disturbed the entire earth system and its overall services to society over century (Brevik et al., 2015; Khaledian et al., 2017).

Similarly, in Sub-Saharan Africa, land and other environmental resources degradation is becoming a serious challenge (Lemma et al., 2015) and major threatening factor to development activities (Erkossa *et al.*,2015). Ethiopia is also one of the developing countries and its major portion of the communities (83%) depends on agriculture, which has facing recurrent drought since the 1970's (Mohammed et al., 2018) and land degradation. This poses a potential impact on the physicochemical quality of soil (Zhang et al., 2015; Fernandez et al., 2014), soil productivity (Wu et al., 2007), and socio-economic impacts like food insecurity, price hick of market commodities, and social instability(Abeje et al., 2019; Mekonnen, et al., 2019). On top of these, several studies concluded that land degradation was also leading to the current global headache which associated with global warming. All these complicated and pressing challenges were either directly or indirectly related to land degradation, and drew the attention of the national government and the continent to desk discussions on the rehabilitation of degraded lands and combating desertification using different techniques. Among these, area enclosures, which have been practiced particularly around churches and religious areas for centuries, was reconsidered as the most preferred and affordable system that is widely implemented in most regions of the country, particularly in the study area. However, their contributions to the improvement of soil physicochemical and biological diversity were not exhaustively investigated, which was very difficult to provide information for the communities around the study area so that they will fill the sense of ownership and strengthen their protection and management of closed areas. Accordingly, this particular study was initiated with the objective of investigating the contribution of enclosed area for soil organic carbon and biota diversity improvement.

2. Material And Methods

2.1. Description of the study area

Arsi-Negele district is located in the West Arsi zone of the Oromia Region State about 225 km south of the capital Addis Ababa. Geographically, it is situated in the Ethiopian central rift valley system of 7^{0} 09'-7^{0}41' N and 38^{0} 25'-38^{0}54' E. It is bordered in the south by Shashamene district, in the southwest by Bulbula woreda, which separates it from Seraro, on the west of the Southern Nations, Nationalities and Peoples Region, on the north by Adami Tullu and Jido Kombolcha with which it shares the shores of lakes Abijatta and Langano, and on the east by the Arsi Zone (ORS, 2004). The area has an altitude that ranges from 1500-2300m above sea level (ICRA, 2002), and mean annual temperature varies from 10–25 ^{o}c while annual rainfall varies between 500–1000 mm (ORS, 2004).

The vegetation of the area is predominantly woody acacia, while the soil types are andosols and nitosols. Abijata, Shalla and Langano are large water bodies that covers most part of the study area (ORS, 2004).The total population of Woreda is estimated to be 260,129, of which 80.2% is rural, with an average density of 105.4 persons per km2 (CSA, 2007). Rain-fed agriculture, mainly cereal cropping, and livestock raring, are the major sources of food and income for maintaining livelihoods. If area encounter agricultural failure, the community depends on the production and selling of charcoal (Biazen, 2014), and this has its own contribution for natural forest degradation.

2.2. Data Collection

The soil samples were collected from quadrats that had been developed following a transect line. Accordingly, the soil samples were collected from different depths of 0–15, 15–30, and 30-45cm and immediately placed in a polythen bag and transported to Wondo Genet College of Forestry for preparation and analysis. As for soil sampling, collection of soil biotas were held following the transect line developed for soil sampling but different quadrats were developed, and collection was conducted by digging the land up to a depth of 0-20cm. This is because most soil biota colonize the top profile of the soil due to the high availability of nutrients.

2.3. Data Analysis

Bulk density, pH, moisture content, available phosphorus, available potassium, total nitrogen, and electrical conductivity were determined using core sampling (in gm/cm^3), pH meter (Model no. 361), oven drying, spectrophotometer (Model no. 166), flame photometer (Model no. 130), and conductivity meter (Model no. 304) method.

Accordingly, organic carbon stock inventory in mineral or organic soil was determined after measuring the depth, bulk density (calculated using core sampling method in gm/cm^3), and the concentrations of organic carbon within the sample (Pearson *et al.*, 2005). A 100 g of composite subsamples was taken at each corner and at the center for the determination of soil organic carbon using soil auger, whereas the core sample was used for bulk density determination. In other words, the carbon concentration in the soil was determined by following Walkley-Black (1934) method and core sampling method (using soil cores of 5 cm in diameter and 10 cm length) for bulk density. Soil samples was oven dried for 24 hours at constant temperature of 105^{o}C until constant weight was obtained to determine the soil bulk density (Eq. 1). The total of the carbon stock density of soil organic carbon was estimated using the Pearson *et al.* (2005) method (Eq. 2).

Soil bulk density (g/m^3) = $\frac{\text{ovendrymass}(g)}{\text{corevolum}(m3)}$ …………………………………………..Eq. 1

$SOC = OrganicCarbonContent(\%C)*Soilbulkdencity(gm/m3)*soildepth(cm)$ ……equation2

Finally, the overall data of the study area was analyzed using the Statistical Package for Social Science (SPSS) software (Version 18) and Microsoft Excel.

3. Result And Discussion

3.1. Soil physical Properties

Most of the soil physical properties (bulk density, soil moisture content, and sand and clay textural class) under investigation exhibited a significant mean difference (P = 0.002*) across the different land use of the study sites, as indicated in Table 1. Among these, the mean bulk density of the open area is much higher than the other land uses. This might be due to higher compaction by livestock and human disturbance. This is in line with the finding of Endale (2016) Lemma, Menfes and Fantaw (2015), Demelash and Stahr (2010), which states that open areas experience significantly higher bulk density across compared to different land use due to differential treatment and management practices. In contrast, the finding of Abdelkadir and Yimer (2011) stated that bulk density does not vary under different land uses and does not show a significant mean difference.

From the soil particle size point of view, the overall percentage of sand (p = 0.011*) and clay (p = 0.038*) shows a significant difference across the different land uses at 0.05 level of significance respectively (Table 1). In view of this, the whole study area is dominated by sandy fractions followed by silt. However, comparatively there is a great difference in the mean percentage of soil minerals among the land uses. The soil of the protected area was dominated by sand (63.333 ± 5.993), followed by silt (18.667 ± 4.372^a) and clay (18.000 ± 2.633^b). Even though the results of multiple comparisons categorized statistically in a similar group, numerically, the mean percentage fraction of sand in open areas (50.000 ± 3.759^a) is relatively very higher than that of closed are one (43 ± 2.113) and closed area two (41.333 ± 5.258). The relative dominance of the sandy fraction might be the result of selective removal of the fine fraction by runoff and deposition of sandy from the upper slope of area and from adjacent open area. This is consistent with the study of Brady and Weil (2002), Woldamlak (2003), and Sandor *et al.* (1986), who stated that pedagogical processes like erosion and deposition of soil particles affect the soil particle size.

Table 1
Mean value (+ standard error) of selected soil physical parameters across the study area.

Study Sites	Soil Parameter				
	BD (%)	MC (%)	% Sand	% Clay	% Silt
Closed Area1	0.950 ± 0.026^a	26.855 ± 1.382^a	43.000 ± 2.113^a	26.333 ± 2.275^a	30.667 ± 0.989^a
Closed Area2	0.973 ± 0.037^a	26.583 ± 1.568^a	41.333 ± 5.258^a	28.333 ± 1.745^a	30.333 ± 3.947^a
Protected Area	0.955 ± 0.030^a	17.798 ± 1.915^c	63.333 ± 5.993^b	18.000 ± 2.633^b	18.667 ± 4.372^a
Open Area	1.145 ± 0.047^b	7.770 ± 2.127^b	50.000 ± 3.759^a	24.000 ± 2.921^b	26.000 ± 2.309^a
P-value	0.002*	0.000*	0.011*	0.038*	**0.053**
* The mean difference is significant at the 0.05 level					

In other words, the protected area, closed area one, and two have comparable mean of bulk density, which is the result of relatively low disturbance by livestock and human activity.

The soil moisture content is another physical parameter under investigation, which varies and exhibits significant mean difference (p = 0.000*) across the land uses. Accordingly, open area has lower moisture (7.770 ± 2.127^b) followed by protected area, closed area two, and one, respectively. This is probably due to low soil organic matter content, lower vegetation cover, and dominance of sandy soil, which is consistent with the findings of Abdelkadir and Yimer (2011).

The overall result of correlation analysis (indicated in Table 2 below) showed that there is a strong positive relationship (r = 0.563**) between bulk density and pH at 0.01 significance level, while it showed a strong negative relationship with total nitrogen (r = -0.502*), organic carbon/soil organic matter (r = − 0.518**), and a very strong negative relationship with moisture content (r = -0.759**) at 0.01 and 0.05 significance levels, respectively. This was also in line with the findings of Pravin et al. (2013) and Ahad et al. (2015).

The result of one-way ANOVA also shows that the soil moisture of the closed area one (26.855 ± 1.382) and two (26.583 ± 1.568) were statistically homogenous and difficult to differentiate, while the difference was recognizable across protected area (17.798 ± 1.915) and open area (7.770 ± 2.127). However, numerically, there is a distinct difference in moisture content between closed area one and two. The high soil moisture content of closed area one and two is the result of high vegetation diversity, which has the potential to trap runoff as a result of infiltration through the help of their root system and low evaporation rate as a result of high canopy cover. The open area has relatively very low moisture content compared to other land uses. This is probably due to differences in organic matter content, high bulk density, overgrazing, and unsustainable land use and management (Maitima *et al.*, 2009), which have great influence on the amount of water infiltrated and added to the soil profile.

Table 2

The results of binary correlation among the different physicochemical parameters under investigation in the study area

		pH	EC	OC	SOC	Ava_P	Ava_K	TN	CEC	Ex_Ca	Ex_Mg	Ex_K	% sand	% clay
pH	Pearson Corr.	1	0.054	− .545**	− .545**	− .748**	-0.264	-0.305	-0.191	.447*	-0.286	-0.202	-0.355	.499*
	p-value		0.803	0.006	0.006	0	0.213	0.147	0.372	0.028	0.176	0.345	0.089	0.013
EC	Pearson Corr.		1	-0.12	-0.12	-0.113	.424*	0.078	0.033	-0.083	0.396	-0.194	-0.077	0.039
	p-value			0.577	0.577	0.599	0.039	0.719	0.878	0.701	0.055	0.364	0.722	0.855
OC	Pearson Corr.			1	1.000**	0.216	0.088	0.265	.429*	0.212	.436*	0.167	-0.234	0.166
	p-value				0	0.311	0.681	0.211	0.036	0.32	0.033	0.435	0.272	0.437
SOM	Pearson Corr.				1	0.216	0.088	0.265	.429*	0.212	.436*	0.167	-0.234	0.166
	p-value					0.311	0.681	0.211	0.036	0.32	0.033	0.435	0.272	0.437
Ava_P	Pearson Corr.					1	0.127	0.262	0.037	− .599**	0.083	0.104	0.357	− .479*
	p-value						0.554	0.215	0.865	0.002	0.7	0.628	0.087	0.018
Ava_K	Pearson Corr.						1	.419*	0.23	0.023	0.113	-0.152	-0.127	-0.006
	p-value							0.041	0.279	0.916	0.599	0.478	0.555	0.976
TN	Pearson Corr.							1	0.385	-0.095	-0.056	0.02	0.095	0.014
	p-value								0.063	0.659	0.793	0.928	0.66	0.949
CEC	Pearson Corr.								1	0.337	0.314	-0.026	0.002	0.018
	p-value									0.107	0.136	0.904	0.992	0.932
Ex_Ca	Pearson Corr.									1	-0.047	− .465*	− .619**	.628**
	p-value										0.829	0.022	0.001	0.001
Ex_Mg	Pearson Corr.										1	0.079	0.067	0.03
	p-value											0.715	0.756	0.889
Ex_K	Pearson Corr.											1	.418*	-0.292
	p-value												0.042	0.166
% sand	Pearson Corr.												1	− .829**
	p-value													0
% clay	Pearson Corr.													1
	p-value													
% silt	Pearson Corr.													
	p-value													
Moisture	Pearson Corr.													
	p-value													
Bulk density	Pearson Corr.													
	p-value													

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

The result of ANOVA analysis also shows that the mean percentage fraction of clay across the area of investigation is significantly different (p = 0.038*). However, the silt fraction across land use is not significantly different (0.053), although numerically they differ (Table 2). Closed area two recorded the highest clay fraction followed by closed area one, open, and protected area, respectively.

3.2. Soil chemical properties

Among the selected parameters for analysis of soil chemical dynamics, pH (p = 0.022*), soil organic matter (p = 0.005*), and exchangeable calcium (p = 0.000*), and potassium (p = 0.000*) showed significant mean differences across the different land uses of the study area, while electric conductivity, available potassium, available phosphorus, total nitrogen, cation exchange capacity, and exchangeable magnesium were insignificant (Table 3). The mean pH value of the open area (8.04 ± 0.034^{b}) was significantly very higher than that of the enclosed area two (7.94 ± 0.058^{ab}), closed area one (7.79 ± 0.059^{ab}), and protected area (7.75 ± 0.100^{a}). The higher mean value of pH in open area might be related to the relatively higher leaching of nutrients and lower soil organic matter content, which is in line with the findings of Umer and Sinore (2019).

The mean value of soil organic matter is significantly varied across the study area, and it was very high in the closed area one followed by the closed area two, although Tukey's homogeneity test shows there is no mean difference between the two areas. This is the result of several factors, such as vegetation (Yimer, 2007; Finzi et al., 1998), and management (Yang and Wander, 1999). The findings of this research are also complementary to the aforementioned studies. According to the study of Buschiazzo et al. (2004), soil organic matter highly depends on clay and silt content when vegetation is dense and uniform, and the coverage is sparse and heterogeneous. The protected area also has higher soil organic matter than the open area. The reason for this variation may be the result of differences in vegetation diversity and composition, and the intensity of disturbance they face from the external environment, mainly livestock and charcoal burning activity carried out by the local community.

The result of multiple comparisons using Tukey's HSD^{a} and homogeneity test showed that there was no statistically significant mean difference in available soil nutrients across the four study sites. However, there is a slight variation in terms of available soil nutrients in the area. Accordingly, the protected area was characterized by having high available phosphorus (9.70 ± 3.261^{a}) and total nitrogen (0.28 ± 0.064^{a}), while available potassium was very low (1062.29 ± 110.018$^{a)}$ compared to other land uses. Followed by protected area, the closed area revealed a high concentration of phosphorus (5.88 ± 1.374^{a}), potassium (2806.46 ± 1478.592^{a}), and total nitrogen (0.27 ± 0.091^{a}).

Table 3
The mean (+ standard error) value of selected soil chemical parameters across the study area

study sites	Soil chemical parameters							
	pH	**EC**	**SOC**	**Av. P**	**Av. K**	**TN**	**CEC**	**Ex. Ca**
Closed Area 1	**7.79 ± 0.059^{ab}**	**494.17 + 87.270^{a}**	**3.153 + 0.185^{b}**	**5.88 + 1.374^{a}**	**2806.46 + 1478.592^{a}**	**0.27 + 0.091^{a}**	**22.50 + 1.647^{a}**	**37.33 + 2.404**
Closed Area 2	**7.94 ± 0.058^{ab}**	**357.83 ± 23.913^{a}**	**2.68 ± 0.507^{b}**	**3.87 ± 0.909^{a}**	**1159.69 ± 131.934^{a}**	**0.26 ± 0.051^{a}**	**19.23 ± 1.522^{a}**	**40.50 ± 1.408**
Protected Area	**7.75 ± 0.100^{a}**	**314.50 ± 13.873^{a}**	**2.41 ± 0.418^{ab}**	**9.70 ± 3.261^{a}**	**1062.29 ± 110.018^{a}**	**0.28 ± 0.064^{a}**	**17.73 ± 2.056^{a}**	**22.83 ± 2.626**
Open area	**8.04 ± 0.034^{b}**	**484.17 ± 99.993^{a}**	**1.19 ± 0.106^{a}**	**3.07 ± 1.949^{a}**	**1203.02 ± 191.899^{a}**	**0.13 ± 0.070^{a}**	**18.23 ± 1.982^{a}**	**34.83 ± 2.330**
P - value	**0.022***	**0.185**	**0.005***	**0.140**	**0.323**	**0.432**	**0.274**	**0.000***

* the mean difference is statistically significant at 0.05 level; Electrical conductivity (EC in μS/cm), Soil Organic Matter (SOM) in %, Available phosphorus (Av. (Av. K) in ppm, Total Nitrogen (TN) in %, Cation exchange capacity (CEC) in meq/100 g, Exchangeable calcium in meq/100 g, exchangeable magnesium (ex. I exchangeable potassium (Ex. K) in meq/100 g

3.3. Soil Macrofauna Diversity and Biomass distribution

Macrofauna diversity analysis was conducted across the different land uses (protected area, open area, closed area one, and two). The results of the diversity index showed that the closed area one have a higher diversity of soil organisms compared to other land uses, as indicated in Table 4 below. On top of this, the abundance (32.69%) and species richness (30.95%) were also higher in the closed area one followed by closed area two, which have species richness and abundance of 26.19%, and 24.16%, respectively. These were probably the result of the difference in age of establishment of closed area (i.e., 15 and 12 years for closed area one and two, respectively), its management, and low carbon to nitrogen ratio recoded in the area. Furthermore, flooding of their burrows by excessive rainfall during the seasons of data collection. The distribution pattern of soil organisms was also more even (0.74) in the closed area one (Table 4), followed by closed area two and protected areas.

Table 4
The diversity, evenness, abundance and species richness of soil organisms across the different land use.

study area	*H′*	Evenness (E)	Abundance	richness
Closed Area one	1.90	0.74	303	13
Closed Area two	1.14	0.49	187	10
Protected Area	1.30	0.54	224	11
Open Land	0.89	0.43	213	8
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The lowest diversity and species richness of soil organisms was documented in closed area two (0.89) and open area (1.14), which had more species richness and abundance compared to closed area two.

The analysis of the biomass of soil organisms was also performed across the different land uses of the study area. Accordingly, the highest record of biomass per meter square (11.4) of soil organisms was obtained in Open followed by the protected area (6.18).Even though the mean difference of biomass across the land uses was observable from Table 7 below, it was not statistically significant at alpha of 0.05 and 0.01. A possible reason for the higher biomass of soil organisms in protected area than others was the availability of high total nitrogen, low pH (7.75), and low carbon to nitrogen ratio (5.04) relative to the other land uses.

Table 3
Biomass of soil organisms across the different land uses in the study area

Common names of Soil Organisms	Biomass of soil organisms in gram/m^2			
	PA	CA1	CA2	OA
Nairobi fly	0.10	0.10	0.10	0.00
Ant	0.00	0.10	0.13	0.13
Beetles	0.10	0.00	0.00	0.00
Butterfly larvae	0.30	0.00	0.00	0.00
Centipede	0.30	0.00	0.00	0.00
Cockroach	0.00	0.30	0.00	0.00
Earthworm 1	0.52	0.25	0.13	0.10
Earthworm 2	1.00	2.58	3.78	7.70
Earthworm 3	0.55	0.17	0.17	0.73
Insect larvae	0.30	0.20	0.00	0.25
Millipede	0.98	0.00	0.00	0.00
Soil bug	1.63	0.54	0.62	0.13
spider	0.20	0.10	0.00	0.10
larvae (arthropod)	0.00	0.10	0.20	0.00
Termite	0.10	0.00	0.00	0.00
Grasshopper	0.00	0.00	0.00	0.30
Earthworm 4	0.00	0.00	0.00	1.90
Unidentified	0.10	0.30	0.10	0.10
Total biomass	6.18	4.74	5.22	11.44
Where: PA- protected area CA1 – Closed area one CA2 – Closed area two OA - Open area				

Table 5
Biomass of soil organisms across the different land use in the study area

Common names of Soil Organisms	Biomass of soil organisms in gram/m^2				Total Biomass
	PA	CA1	CA2	OA	
Nairobi fly	0.10	0.10	0.10	0.00	0.30
Ant	0.00	0.10	0.13	0.13	0.36
Beetles	0.10	0.00	0.00	0.00	0.10
Butterfly larvae	0.30	0.00	0.00	0.00	0.30
Centipede	0.30	0.00	0.00	0.00	0.30
Cockroach	0.00	0.30	0.00	0.00	0.30
Earthworm 1	0.52	0.25	0.13	0.10	1.00
Earthworm 2	1.00	2.58	3.78	7.70	**15.06**
Earthworm 3	0.55	0.17	0.17	0.73	**1.62**
Earthworm 4	0.00	0.00	0.00	1.90	**1.90**
Insect larvae	0.30	0.20	0.00	0.25	0.75
Millipede	0.98	0.00	0.00	0.00	0.98
Soil bug	1.63	0.54	0.62	0.13	**2.92**
spider	0.20	0.10	0.00	0.10	0.40
larvae (arthropod)	0.00	0.10	0.20	0.00	0.30
Termite	0.10	0.00	0.00	0.00	0.10
Grasshopper	0.00	0.00	0.00	0.30	0.30
Unidentified	0.10	0.30	0.10	0.10	0.60
Total biomass	6.18	4.74	5.22	11.44	27.58

Where: PA- protected area CA1 – Closed area one CA2 – Closed area two OA - Open area

4. Conclusion And Recommendations

Soil, which is a precious natural resource that provides a multitude of benefits to socio-economic development and other biological services, has been affected for many decades by anthropogenic activity, and its quality and productivity have deteriorated. On the basis of the findings, although there are slight differences in the figures of the result for parameters that are associated with differences in age of establishment, management practice, and extent of disturbance, the enclosed area contributed to the improvement of soil physicochemical and biological components. Hence, expanding the enclosure area through consultation with the concerned bodies of the study area and proper follow-up mechanisms has to be considered in order to maintain environmental resource management.

Abbreviations

ANOVA
Analysis of Variance; BD = Bulk density; CA1 = Closed area one; CA2 = Closed area two; Ca = Calcium; CEC = Cation Exchange Capacity; CSA = Central Statistical Agency;
EC
Exchange Capacity; K = Potassium; MC = Moisture Content; OA = Open Area; OC = Organic Carbon; ^{o}C=degree Celsius; ORS = Oromia Regional State; PA = Protected Area; P = Phosphorus; SOC = Soil Organic Carbon; SOM = Soil Organic Matter; TN = Total Nitrogen

Declarations

Ethical Declaration

This research is not associated with humans or part of human's participation/involvement. In other words, it is not applicable

Consent of Publication:

All authors declare that they don't have any conflict of interest (i.e., agreed) to submit their manuscript to Environment Science Europe for publication.

Availability of data and materials

The datasets obtained and analyzed in the current study are available from the corresponding author on reasonable request.

Conflicting interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author's contribution

Both the first (GD) and second authors (AD) involved in the inception of research ideas, data collection, and analysis. Moreover, the first author (corresponding author) involved in report generation, manuscript development, and editing.

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Figures

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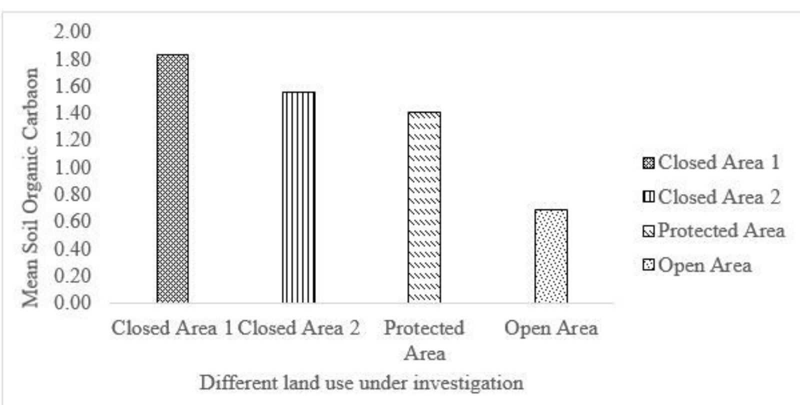

Figure 1

The mean soil organic carbon across different land uses under investigation in the study area