Soil Property and Carbon Storage Variations Affected by Land Use Type in the Semi-Arid Ethiopian Rift Valley

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Abstract

This study examined the variations in soil properties, and carbon and nutrient storages under different land use types in the flood plains of Metehara, upper part of the Main Ethiopian Rift Valley. The study considered four land use types: cane plantation (CP), free grazing lands (FG), traditional maize farming (MF), and restored pasture (RP). The study established four transects with typical land use types and selected three soil sampling sites with 50m intervals from the upper-slope and the lower-slope position under each land use type. In each slope position, a 10m x 10m plot was established to collect the soil samples. A total of 24 distributed soil samples (3 land uses, and 3 replications) from 0 to 30 cm depth were collected using soil auger. The results indicate that the land use types significantly affected the soil parameters ($P<0.001$) whereas the slope position did not. The land use type explained the variations in soil carbon (R^2 =0.77, $P<0.001$, df = 23), and total nitrogen (R^2 =0.39, $P<0.05$). However, the results indicate insignificant effects on soil carbon and nitrogen variations when combining the soil properties covariate with land use factor in statistical model than the variation explained by land use type. The result also reveals that soil carbon (C) and total nitrogen (N) contents under the RP were significantly higher than the FG and MF sites. This study generally suggests how land use change has increasingly affected the semi-arid ecosystems and highlights the need to improve awareness about how human land use and land management decision impacts in the semi- arid areas of Ethiopian Rift Valley.

Keywords: Grazing, Exclosure, Management, Restored pasture, RiftValley

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1. Introduction

Soil degradation is a global threat, and a serious challenge in Ethiopia (Hurni, 1993; Daniel *et al.*, 2015). Soil degradation associated with inappropriate land use and management practices influences soil quality; particularly soil organic matter (Lemenih, et al., 2005; Solomon and Mohammed, 2016). The adverse effects of the land use changes on soil organic carbon and nutrient losses are more severe in arid and semi-arid regions, and are exacerbated by human inappropriate management practices. For example, deforestation associated with farming practices, overgrazing and forest fire was reported to reduce the soil organic carbon (SOC) by about 60-70% in the central Rift valley of Ethiopia (Fisseha, et al., 2011). The rate is significantly higher than the average loss of soil carbon recorded in tropical humid regions (Rhoades, *et al.,* 2000; Anderson-Teixeria, et al*.,* 2009).

Ecological restoration has been an important approach globally to mitigate human pressures on natural ecosystems, and reversing degraded ecosystems (Lal, 2001; Mekuria, et al., 2013). The approach improves soil quality through increasing a net primary productivity and biomass return to the soil, and is scientifically proven by some of the long-term experiments conducted in different regions including Ethiopia (Descheemaeker *et al.,* 2006; Bongers and Tennigkeit, 2010; Mekuria, et al., 2011). Although there are different restoration approaches, area exclosure is one of the commenest land managment options that has been adopted in Ethiopia over decades (Descheemaecker, et al., 2006; Mekuria, et al., 2007; Mekuria and Aynekulu, 2011). For instance, Mekuria et al. (2007) indicated 1.1 % of organic matter, 0.1 % of total soil nitrogen, and 1.8 mg kg^{-1} of available P increases after exclosure of degraded communal grazing lands in the semi-arid region of northern Ethiopia. Area exclosure also improved the soil organic carbon and nitrogen levels in semi-arid rangeland of Kenya though the effects vary under private and communal management systems (Mureithi *et al.,* 2014). In several other studies (Mengistu, et al., 2005; Tsetargachew, 2008; Tesfaye, 2011; Mekuria, et al., 2013), the adoption of long term area exclosure was found to improve the soil quality and vegetation cover of the degraded area.

Conversion of native ecosystem to agricultural land use affects the storage of soil carbon and nutrients cycling depending upon human management measures following the changes such as tillage methods, farming systems (intensity and crop types), soil fertility management techniques and others (Brye, et al., 2002; Wu, et al., 2003; Ogle, et al., 2005; Liu. et al., 2005). For instance, agricultural management practice that involves maize cultivation with legume based rotation can restore as much as 20 tones C ha^{-1} when compared to maize monoculture in India (West *et al.,*2002). Similarly, fertilizer application significantly increased the concentrations of N, P, K and SOC in the plough layer of Chinese Mollisols (Liu, et al*,* 2005). In other studies, Delgado *et al. (*2011) indicated that retaining crop residues into soil to improve SOC and nutrient levels since most agricultural crop residues constitute nearly 40 to 50% of C. Similar conclusion was also made by Zeleke*et al.* (2004) who found 67% increases in SOC concentration in Andosols due to retaining maize (*Zea mays L.*) residue in farming system in South Central Rift Valley of Ethiopia.

In recent decades, human interventions on communal grazing land have put an increasing pressure on ecosystems and challenged the traditional resource use patterns in the semi-arid region of Ethiopian Rift Valley (Ayalew, 2001). These interventions were state-driven primarly focused on expansion of large-scale agriculure and establishment of protected area, and aimed to increase agricultural productivity and sustainability of the natural biodiversity at national level. While the traditional grazing land has catered for new land use functions, human pressure on an ever-decreasing grazing land may lead to unsustainable land use practice. One of the potential impacts of the land use change is the risk effect it poses on SOC and nutrient movements in the ecosystem. In this study, we used restored site that retired from grazing in the late 1960s, historically grazed site, and two agricultural land use sites that followed different management regimes. All the land use types were once under similar management condition used for communal grazing. The objective of the present study, therefore, was to identify the differences in carbon and nutrient storages under different land use types; and examine the effect of restoration on the level of soil carbon in the semi-arid Ethiopian Rift Valley.

2. Description of the study area

The study site is located south of Fentale Mountain that covered the Metehara plain, upper part of the Main Ethiopian Rift Valley (Figure 1).The area is characterized by the flat topography with an average elevation of 960 meter above sea level, and which increases towards north, south and southwest directions (Abule, et al., 2005). Geologically, it is a zone of different tectonic and volcanic activities that transformed the overall structure of the physiography (Mohr, 1971). The dominant soil types are Vitric Andosols, Eutric Fluvisols, Lithosols, Eutric Cambisols and Vertic Cambisols (FAO, 1984). The Vitric Andosols evolved from volcanic ash of quaternary origin and overlaid by alluvium deposition derived from erosion of volcanic materials from the surrounding highlands (Gibson, 1969).

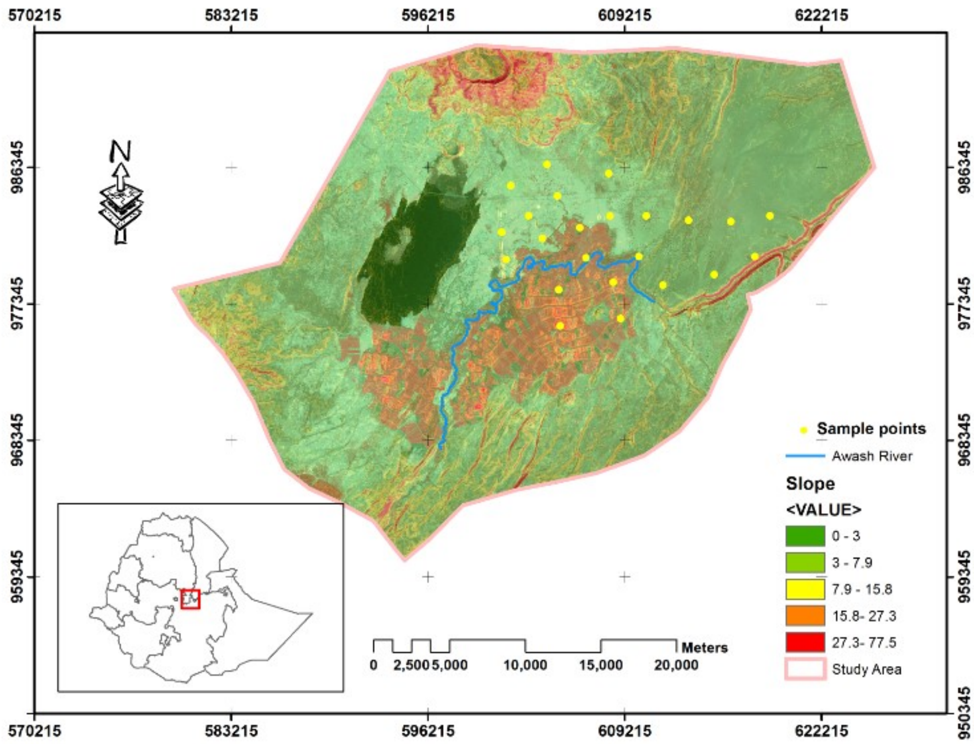


Figure 1 Map of the study site

Based on agro-climatic zonal classification, the area is described as semi-arid climatic zone (Daniel, 1977). Average annual precipitation recorded by meteorological station located on the plantation site is 531.7 mm (NMA, 2012). The temperature is generally high throughout the year wherein the mean maximum temperature of the three hottest months, and mean minimum temperature of the three coldest months are $34.6^{0}C$ and $13.8^{0}C$, respectively. Ecologically, the area has been described as open savanna, a mixture of grasses and acacia species, together with patches of woody vegetation and riverine forest. It was predominantly used as dry-season grazing land before the introduction of alternative land use functions in recent decades (Jacobs and Schloeder, 1993).

2.1. Land use sequences

Communal grazing lands used to occupy a vast area of the Metehara plain where the local pastoralists have managed and controlled the resource regime in customary way for a century. However, extensive grazing land as land use system has been challenged over time with the introduction of alternative land use functions in recent decades. Currently, four land use and managment practices have dominated the area. These include the restored pasture (RP), sugarcane plantation (CP), free grazing land (FG) and subsistance maize farming (MF).

The restored pasture (RP) was designated as Awash National Park (ANP) from exclosure made the communal grazing lands in 1969 (Solomon *et al.,* 2012). It was the first national park in the country to conserve the wild life resources, covering a total area estimated about 756 km^2 (Hailu, 1975). The restored pasture consists of various native vegetation dominated by acacia and perennial grass communities such as *A. tortilis*, *A. senegal*, *Chrysopogonplumulosus* and *Cymbopogon commutatus* (Jacobs and Schroeder, 1993; Abule *et al.,* 2005). Sugarcane (*saccharum sp.*) plantation (CP) also forms significant proportion of the present land use catagory. The practice of sugarcane growing dates back to 1960s conciding with the establishment of the ANP. The cane plantation has occupied more than 13,000 ha of land under eleven major fields with varied cultivation age ranging from nine to fifty-five years (Ayalew, 2001). The management of sugarcane growing has been undertaken using irrigation system and N-based fertilizer, averaging to 130 kg N $h^{-1}yr^{-1}$ (Ambachew, 2005).

Free grazing lands occupied the area outside the buffer zones of the sugarcane plantation and the ANP. Despite the current grazing regime started from a remote past, human pressures have intensified on use of the resource following the introduction of new land use functions, and resulted to change the customary way of resource management system and emerge the adoption of subsistence farming (Ayalew, 2001). Maize (*Zea mays*) was a major crop being produced with a roatation of sorghum (*Sorghum bicolor L.*), and finger millet (*Eleusinecoracana*) in some cases. Maize was grown based on seasonal rainfall without N-fertilizer application, and its residuals were harvested for fodder and fire wood.

3. Research Methodology

3.1. Soil sampling and analysis

The study used four land use and management sites for soil sampling namely cane plantation (CP), free grazing lands (FG), subsistence maize farming (MF), and restored pasture (RP). FG, CP and RP sites form a spatially contiguous series of land use cover types, whereas the MF site exists in small patches interspersed within free grazing lands. The sites are characterized by the flat topography where the slope position slighltly increases (2-10%) as far away along the river both in the left and in the right directions. Accordingly, the FG, MF and RP sites were located to the left side of the river whereas the CP land use site was to right side of the river. From each land use category, four transects were drawn from the upper and lower slope positions. In each slope position, we selected three soil sampling sites at 100m interval and established 10 m x 10m plots to take the soil samples. To this end, small pits were dug to represent down to 30 cm depth at four corners and center of the plots to obtain composite soil samples. The study considered only the upper 30cm soil depth since the impact of cultivation on soil is significantly higher in the plough layer. A total of 24 evenly distributed soil samples (4 land use types, 2 slope positions and 3 replications) were collected for soil laboratory analysis. We also took equal numbers of undisturbed soil samples from each small pit located in the plots using a core sampler of known volume.

The samples were air-dried, ground, and passed through a 2-mm sieve to analze soil texture, soil pH, soil salinity (EC_e, dS m^{-1}), bulk density (BD), soil moisture content (MC), soil organic carbon (SOC), total nitrogen (TN) and available phosphorous (P). Percent in sand, silt and clay fractions was determined by the hydrometer method (Bouyoucos, 1962). Soil pH was determined in a 1:2.5 soil to water ratio suspension. Soil electrical conductivity (EC) was measured in saturation extracts and determined the degree of salinization (EC_e, dS m^{-1}), following the procedure illustrated by USSLS (1954). Soil bulk density (BD) was determined from the dry weigh per unit of known volume following the removal of the moisture content at 105^0C. Volumetric soil moisture content was determined as the ratio of the weight of the wet soil to the weight of the dry soil and multiplied by 100. Soil organic matter (SOM) was determined by loss on ignition method. Since the SOM contains 58% of C (Brady, 1985), the estimated SOM was further divided by a factor of 1.72 to determine SOC concentration for a given soil sample. Total nitrogen (TN) was measured by the Kjeldahl digestion procedure applying distillation and titration method. Available P was analyzed using Olsen extraction method (Olsen, et al., 1954). Soil organic carbon, nitrogen and Olsen- P stocks were determined for upper 30 cm soil depth using C, N and P concentrations, bulk density and conversion factors as follow:

$$SOC\ stock\ = \frac{C}{100} \times Bd\ \times D \times 10^4 m^2 ha^{-1}$$

$$N\ stock\ = \frac{N}{100} \times Bd \times D\ \times 10^4 m^2 ha^{-1}$$

$$Olsen\ P\ stock\ = \frac{P}{10^6} \times Bd \times D \times 10^4 m^2 ha^{-1}$$

Where: soil organic C (SOC), N and Olsen- Pstocks are in unit of (Mg m^{-3}), soil C and N concentrations are in unit of (%), Olsen-P concentration is in unit of (ppm), *BD* is soil bulk density (Mg m^{-3}), *D* is the soil depth (cm) and 10^4 m² $ha^{-1}$is a conversion factor.

3.2. Statistical analysis

The study employed multivariate analysis of variance (MANOVA) to analze soil texture, soil pH, soil salinity (EC_e, dS m^{-1}), bulk density, soil moisture content, soil organic carbon, total nitrogen and available phosphorous. The statistical analyses were considered with the design that included land use site (CP, FG, MF, and RP) and slope position (upper-slope and lower-slope) as main effect variables. In first analysis of a one-way MANOVA model, the study considered the overall effect of land use site and slope position on soil attributes using Wilks' lambda approximation test. Next to this, the study conducted a univariate F test (ANOVA) for all soil variables using land use site and slope position as the treatments. Fisher's protected least significant difference (LSD) test was applied for multiple comparison of the mean differences in soil attributes among land use sites and slope positions. All statistical analyses were performed using SPSS version 20.

4. Results and Discussion

The multivariate analysis of variance indicated that slope position did not significantly influence on the soil attributes (Wilks' lambda =0.166, F= 1.93, P=0.067). However, land use types had a significant effect (Wilks' lambda =0.009, F= 5.44, P<0.001) to control the soil attributes considered in the present study.

4.1 Physico-chemical soil properties under different land use types

Table 1 indicates results for physico-chemical properties for upper 30 cm soil layer among the land use types and within land use site. The proportions of sand and silt contents were similar among the land use types (CP, FG, MF and RP) though there was a non-significant trend towards higher sand content in FG site (Table 1). Relatively higher level of sand content in the FG site is more likely due to the impact of livestock grazing. The fraction of clay content varied among the land use types (P<0.01, F=5.03), and the CP site had higher clay content compared to the FG, MF and RP sites. However, this value was lower to that of Zeleke and Kibebew (2009) who conducted their study on the whole plantation site. The results also indicated variation in soil texture particularly in sand contents within land use sites, and this variation was very high for FG (SD=11.5) and MF (SD= 10.5) sites. This variation might be due to differences in material distribution as the study site historically has experienced water flooding. In their studies, Chaneton and Lavado (1996) also identified differences in soil texture distribution along flooding plain of Pampa's grass land due to the exposure of the site to a frequent and long duration of water logging.

Table 1 Mean values ofphysico-chemical soil properties under four different land uses

Land use Types	Soil Texture Content (%)						
	Sand	Silt	Clay	Bulk density (g/cm^3)	Soil water content (%)	pH (H_2O)	EC_e (dSm^{-1})
CP	30.38± 3.9	33.5± 9.7	36.12±8.4	1.34±0.11	24.84±1.43	8.3±0.22	2.86±1.48
FG	42.48±11.5	30.27±6.1	27.25±5.45	1.35±0.08	19.78±1.33	8.34±0.29	1.85±0.39
MF	38.88±10.5	31.62±5.4	29.5± 6.2	1.30±0.05	18.76±2.16	8.46±0.36	2.44±0.83
RP	38.25±5.9	29.03±6.9	32.09±6.7	1.23±0.06	21.67±2.11	8.64±0.61	1.55±0.58

CP-cane plantation, FG - free grazing land, MF- subsistence maize farming, RP- restored pasture. Values are represented as mean ± Standard Deviation (n = 3).

Bulk soil properties varied among the land use types ($P<0.001$, $F=9.82$). On average, the bulk density ranged from 1.23 g/cm^3 in the RP to 1.35g/cm^3in the FG site (Table 1). Soil bulk density is affected by the land use and human management practices. Bulk density often increases with grazing intensity or from hoof traffic of grazing animals. Fantaw et al. (2015) in central part of the Ethiopian Rift Valley found higher bulk density levels in open communal grazing lands than sites under long period of exclosure, which are very comparable to the results identified in the present study. Commonly, a soil bulk density ranges from 1.2-1.4 g/cm^3in native vegetation cover (Walker and Desanker, 2004). Conversion of native vegetation to agricultural cultivation, however, increases the bulk density due to plowing effects on soil aggregates. The lower level of bulk density in the MF site than that of the CP site in the present study was probably due to the lower effect of hand plowing in traditional maize farming compared to plowing with heavy machinery where the effect on soil bulk density is often rapid. Despite large differences in sand fraction distribution between the CP and FG sites towards higher value in FG sites, our result surprisingly showed non-significant differences in soil bulk density between the two sites.

This may appear a little bit biased underestimating the value of bulk density in the FG site. On the contrary, the presence of extreme value (outlier) in our sample data of the sand particle distribution may partially exaggerate our results of the bulk density as well as particle size distribution in the FG.

Analysis of variance of soil salinity (EC_edS m^{-1}) indicated that there were significant differences (*P*<0.01, *F*=5.89) in salinity levels among the land use types. Generally, the level soil EC_ein agricultural land use types (CP and MF) were higher than the soil EC_ein the non-agricultural (FG and RP) land use types. Soil salinity is generally a concern in the study site due to underground water runoff discharged from the adjacent saline Lake Beseka. High EC_e values in some of the measured samples in the present study also indicated the presence of significant amounts of soluble salts, and relatively higher in lower slope than the upper slope of the site position. Despite this fact, our results generally showed lower soil salinity EC than reported previously in alkaline soils such as (Rietz *et al.,* 2001) in semi-arid area.

The lower accumulation of soluble salts found in this study might be associated with the frequent and prolonged flooding over the sites because soil water logging events could lead to leach the accumulated salts (Chaneton and Lavado, 1996). The soil salinity less than 2 dS m^{-1} was also reported in alkaline soils of semi-arid Kenya (Mureithi *et al.,* 2014) at swampy and seasonally flooded site. Our results, however, showed higher levels of soil salinity in the CP site compared to other sites, suggesting human cultural practices related to water and soil management practices to increase the level of salinity in irrigation based agricultural practice. Continuous grazing increases salt content by reducing aerial plant and litter cover, which lead to higher soil temperatures and evaporation rates in arid and semi-arid environments (Chaneton and Lavado 1996). In spite of this, our findings rather did not show a significant difference in soil ECe between grazing (FG) and restored pasture (RP) sites.

4.2. Soil carbon and total nitrogen contents under different land use types

There were significant differences in concentrations soil carbon (*P*<0.001, *F*=54.03) and soil total nitrogen (*P*<0.001, *F*=17.71) among the land use types (Table 2).

Table 2 Soil carbon, total nitrogen and available P concentrations at four land use types.

Land use types	% C	%N	C: N	Av. P	C density (g/cm^3)	N density (g/cm^3)	P density (g/cm^3)
CP	1.14a	0.085a	14.02a	9.37a	0.0153a	0.00114a	0.000013a
FG	0.98b	0.096a	10.59b	5.69a, b	0.0132b	0.00131a, b	0.000008a, b
MF	0.82c	0.068b	12.05b	3.46b	0.0105c	0.00088b	0.000005b
RP	1.36d	0.121c	11.33b	5.93a, b	0.0162a	0.00144a, b	0.000007a, b

CP- cane plantation; FG- free grazing land; MF- subsistence maize farming, and RP, - restored pasture. Means with different lowercase letters within a column are significantly different for $P < 0.05$ using the LSD test.

The concentrations of soil carbon, total nitrogen and available phosphorus identified in this study generally very low values according Landon's (1991) classification. However, the land use types considered un this study had varying levels of soil carbon, nitrogen, and available phosphorus contents due to differences in land management that have been practiced over decades. Accordingly, the amount of soil carbon and nitrogen contents in restored pasture (RP) was much higher than observed in CP, FG and MF sites. This might be attributed due to the effect of area exclosure since retirement of pasture land from grazing improves vegetation cover and organic matter input. This was proven by Mekuria et al. (2009) who found an increase of soil carbon from 36% - 50% due to the exclosure of communal grazing lands in the semi-arid land of northern Ethiopia. In similar study, Tsetargachew (2008) indicated increases of OM and TN at 2.3 % and 0.08%, respectively, after 20 years of exclosure of pasture land in Central Rift Valley of Ethiopia.

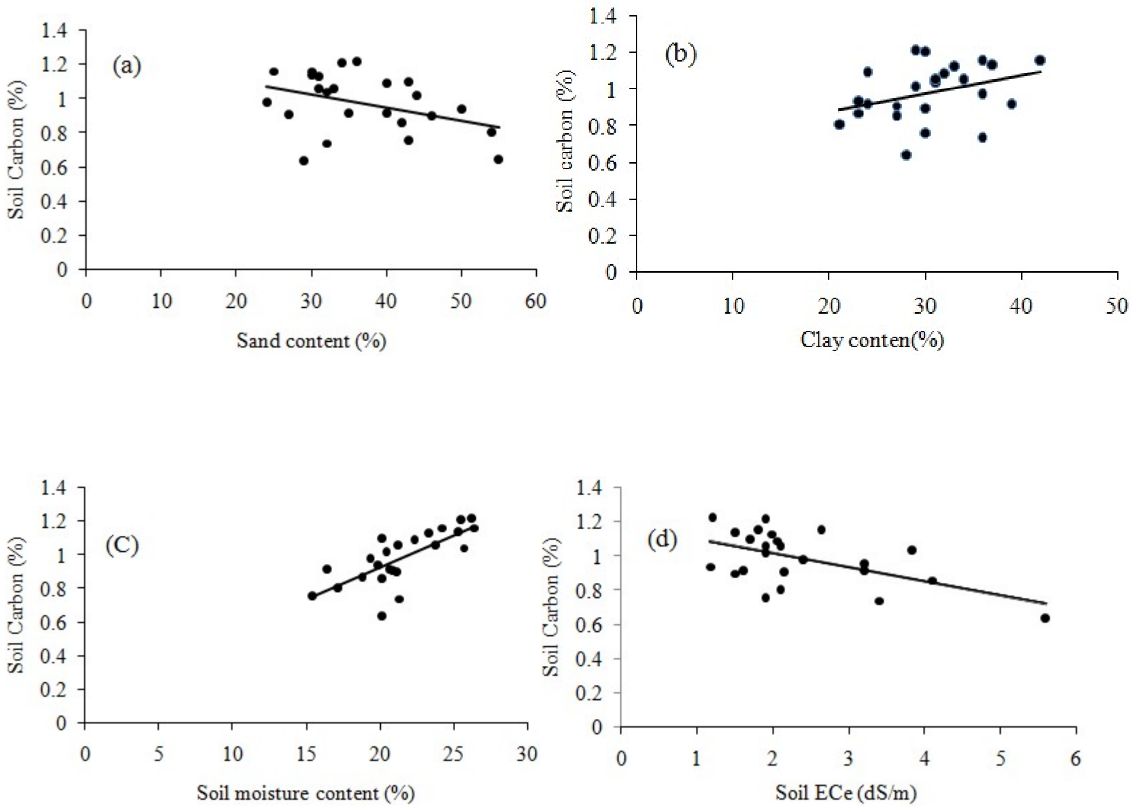
The result also indicates that the amount of both the soil carbon and nitrogen contents were significantly higher in the CP compared to MF site (Table 2). This is probably justified due to differences in soil management practiced between the two farming systems. Conversion of previously uncultivated land to agricultural cultivation generally reduces soil carbon and nutrient levels though its magnitude among other things depends on human management practices (Solomon *et al.,* 2014). In the study site, the practice of sugarcane growing has been primarily depend on uses of N fertilizer and irrigation water compared to the traditional dry farming without fertilizer application and irrigation as well. This confirms the fact that improved management practices enable to increase and/or maintain the soil quantity through increasing productivity and soil organic matter. Towards this, Lemenih et al. *(*2005) reported significantly higher level of both soil carbon and total nitrogen under mechanized farming than traditional farming due to the differences in soil management practices in south Central parts of the Ethiopian Rift Valley.

Soil C/N ratio reveals a slight though statistically consistent pattern of variations among the land use types ($P<0.05$, $F= 3.41$). Although the average C/N ratio for all land use types was about 12, it was generally higher in the CP site compared to FG, MF and RP sites (Table 2). This suggests higher rates of N losses in the CP site. The MF site (farming practice without fertilizer application) had slightly lower C/ N ratio than the CP site (farming practice with fertilizer application), and this suggests the MF site is less 'labile' to soil organic matter. This result is comparable to that of Walker and Desanker (2004) who found the C/ N ratio (averaging 12 at the surface soil) in older agricultural sites that converted from woodland-savanna in Malawi.

Phosphorus is one of the most limited nutrients in the tropics due to its adsorption on oxides, and clay minerals making unavailable to plants (Oberson *et al.,* 2001). However, the finding of this study did not indicate a significant difference in soil level of available phosphorous among the land use types ($P> 0.05$, $F=1.49$). This suggests difference in land use types was not a significant factor for soil available P in the study area. The availability of P is more problem in alkaline and calcareous soils due to formation of poorly soluble calcium phosphate raw materials, and fixation of applied P (Mohammod *et al.,* 2013). The mean value of available phosphorus (6.2 ppm) calculated from all sample sites in this study was generally very low according Landon's (1991) classification. Despite this fact, a higher level of available P in the CP than the MF site within agricultural land use system is likely due to the ongoing soil management efforts. The soil phosphorus may also available from off-site effect due to the soil erosion process and surface runoff (Messiga *et al.,* 2013) despite our data did not verify this fact. The observed P levels were rather very low in both the FG and RP sites in the present study suggesting plant productivity in the area would be primarily limited by P supply.

4.3. Factors influencing the Soil Carbon and Nitrogen Levels

The result also reveals the effect of soil physico-chemical properties on soil carbon and nitrogen through independent plotting of the soil physical properties (clay, silt and moisture contents) against soil organic carbon and nitrogen for the entire data set. The soil carbon content had significant correlation with covariate of soil properties including sand and clay fraction contents (Fig. 2a & b), moisture content (Fig.2c) and soil EC_e (Fig. 2d). Regardless of the land use types, soil physical properties such as soil textural class and moisture content are an important control on soil carbon and nitrogen storages. In general, soil carbon storage increases as clay content increases since higher fraction of clay particles can protect and stabilize the soil organic carbon from microbial disturbance (Walker and Desanker, 2004). While the content of total nitrogen was correlated with silt content (Fig. 2e) and soil EC_e (Fig. 2f), soil pH is the only variable that had significant correlation with available P.



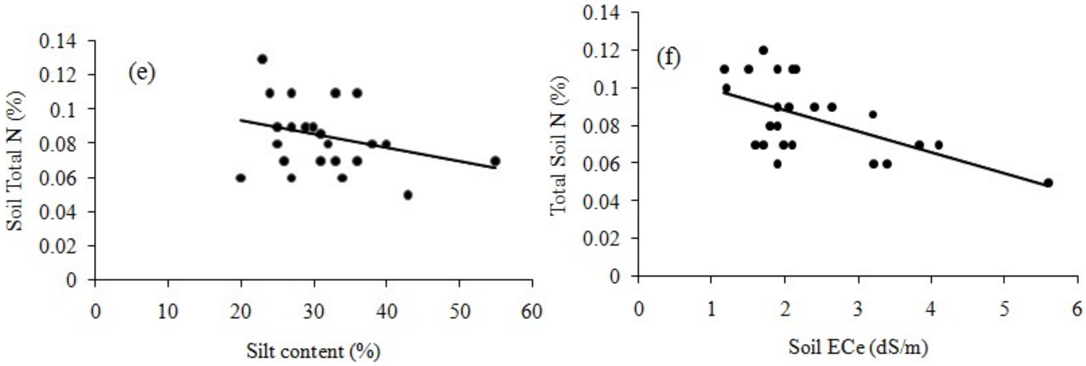


Figure 2 The relationship of soil organic C with sand (a), clay (b) fraction contents, soil moisture (c), soil ECe d); and soil total N with silt fraction content (e), soil ECe (f) determined at P< 0.05.

The stepwise multiple regression constructed using the soil property covariates was able to explain the variation in soil organic carbon (R^2 = 0.54; P<0.001) and total nitrogen (R^2 = 0.39; P<0.05) levels. On the other hand, the land use type explained the variations in soil carbon (R^2 =0.77,P<0.001, df = 23), and total nitrogen (R^2 =0.39, P<0.05).All soil properties combined with the site in regression model were able to explain the variations in soil carbon (R^2 = 0.82; P<0.001) and total nitrogen (R^2=42, P<0.01). This indicates insignificant effects on soil carbon and nitrogen variations when combining the soil properties covariate with land use factor in statistical model than the variation explained by land use type. This suggests that land type was the primary factor controlling the distributions of soil organic carbon and nitrogen levels.

Soil EC_e was a substantial contributor to explain the variations both in soil carbon and total nitrogen in this study. Salinity is a common problem in agriculture, which usually induced under irrigational farming. High salts content not only affect physical and chemical properties but also affect microbiological properties of the soil. In the present study, the soil salinity (EC_e) was found to correlate negatively both with soil carbon and total nitrogen levels though the effect was stronger on the soil total nitrogen than soil carbon. Increases in salinity have been shown to decrease soil respiration rates and the soil microbial biomass (Jackson and Vallaire, 2009).

4.4. Soil Carbon and Total Nitrogen Stocks (Mg Ha^{-1}) Under Different Land Use Types

The mean values of both the soil carbon and total nitrogen stocks were higher under the RP followed by the CP, FG and MF (Figure 3a & b). The average differences of the restored pasture to that of the CP, FG and MF sites varied from 2.55 (± 1.85) to 16.93 (± 2.04) Mg ha^{-1} for soil carbon stocks, and 0.404 (± 0. 06) to 1.68 (± 0.34) Mg ha^{-1} for total nitrogen stocks.

These indicate about 6 - 44% and 11- 53% increases of the soil carbon and total nitrogen stocks, respectively.

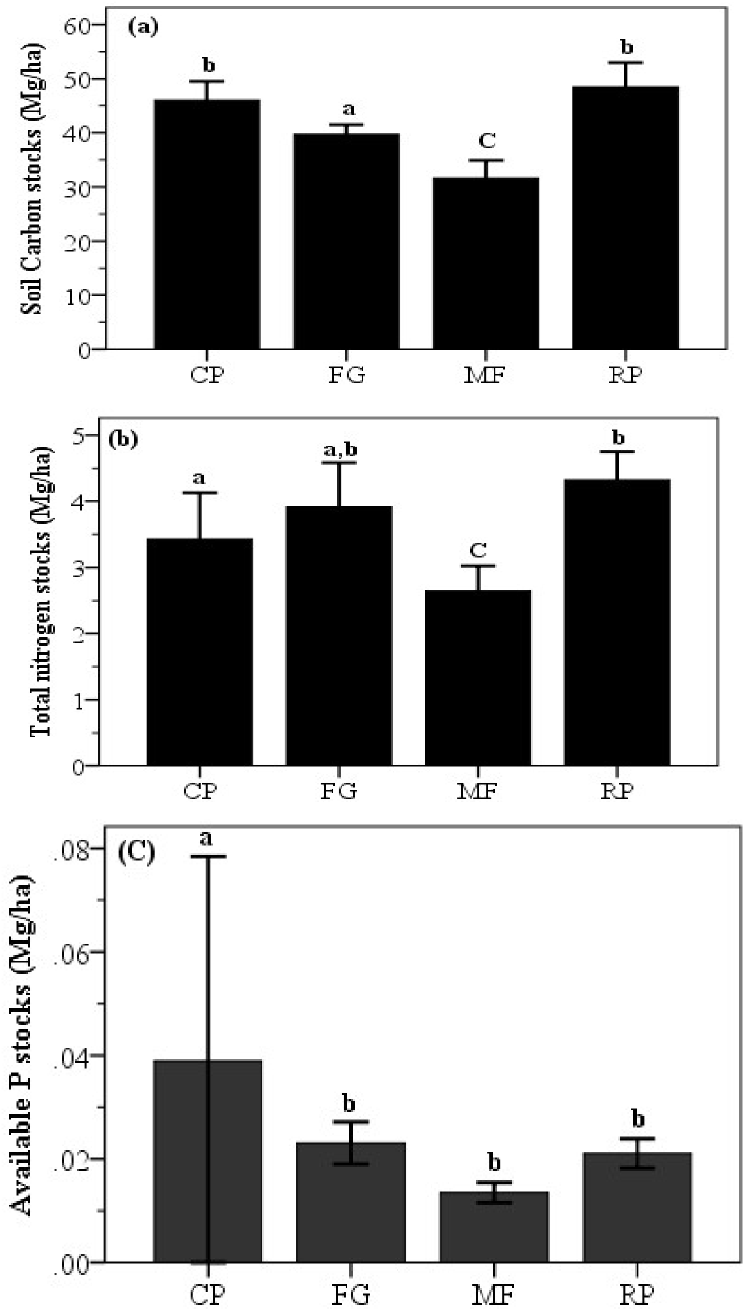


Figure 3 The soil carbon(a), total nitrogen(b) and Ava. P stocks (c) under different land use types: CP- cane plantation; FG- free grazing land; MF- subsistence maize farming, and RP,- restored pasture. The error bars represent the standard deviation of the mean

In comparison to the soil C content of the FG site (39.7± 1.5 Mg/ha), the soil C contents in the RP site (48.5 ±2.04Mg/ha) was approximately 10 Mg/ha higher (Fig.3a) in the present study. The observed soil C gain of 23% (i.e., 10 of 39.7 Mg/ha); however, is very lower compared to the soil C gains that reported in previous studies for similar environmental setting. This might be due the differences in management practices and socio-economic setting surrounding protected area. Area exclosure is a land management option whereby livestock and humans are excluded from openly accessing of the area. However, most of the existing protected areas in Ethiopia including the Awash National Park (ANP) have been loosely regulated, being increasingly faced human pressures attributed to land use and socioeconomic dynamics surrounding them (Asebe, 2012; Anteneh *et al.,* 2014; Solomon *et al.,* 2014). Area exclosure under the restricted human and animal access supplemented with plantings of native and/or exotic species can improve the soil quality (Birhane*et al.,* 2006) than observed in the present study.

5. Conclusion

The study attempted to compare the measurement of soil properties, and carbon and nutrient storages among four land use types which had different management history. The findings revealed the effects of grazing land retirement on soil properties improvements, particularly on soil carbon and total nitrogen contents. However, the estimated soil organic carbon and nitrogen contents under the current restoration measures are lower than exclosure under strict regulation measures. Area exclosure under restricted human and animal access together with appropriate management interventions is a key to accelerate self-regenerating potential of an ecosystem and improve the soil quality better than observed in the present study.

Agricultural use disturbs the flow of soil carbon and nutrients in the ecosystems. However, the effect is not the same since the capacity of soils to store soil carbon and nutrient levels depends on human cultural factors, which in turn vary in space and time. As a result, soil carbon and nutrients under human managed ecosystems have been rarely maintained to pre-disturbance levels even in agricultural systems that use relatively improved management practice over traditional farming. This study may justify the notion that how human land use and management practices have caused the variations in soil properties, and carbon and nutrient storages. From management point of view, these further demonstrate how land use change have increasingly affected semi-arid ecosystems and highlight the need to improve our knowledge of human land use and land management decision impacts in the semi- arid areas of the Ethiopian Rift Valley.

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