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AGRICULTURAL SOIL SCIENCE AND AGROECOLOGY

Changes in Soil Properties Attributable to Land-Use Variation in Southwestern Ethiopia

Tesfaye Lishan[a],* and Abu Regasa[b]

[a] *Department of Plant Science, College of Agriculture and Natural Resources, Mizan-Tepi University, Mizan-Tepi, Ethiopia*

[b] *Department of Natural Resource College of Agriculture and Veterinary Medicine, Dambi Dolo University, Dambi Dolo, Ethiopia*

** e-mail: tesfishmtu@gmail.com*

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Abstract—Evidence on the land-use system for soil properties is essential for sustainable soil management. Hence, this research was investigated to exploit the status of soil properties in Sayo District, southwestern Ethiopia. For this investigation, soil was sampled at two depths from shrub, crop (cultivated), pasture (grazing) and forest lands. The investigation revealed that land-use had significant effect on soil properties. The maximum values of sand particle in cultivated, silt in forest and clay in shrub land were observed. Bulk density of the soils under the different land-use was ranged from 1.10–1.37 g cm^{-3}. The higher (5.00) and lower (4.68) soil pH were observed in cultivated and shrub land, respectively. The higher values of electrical conductivity (0.28 dS/m) in the forest and lower (0.01 dS/m) in shrub land were measured, whereas soil organic matter was ranged between 3.15% in grazing land to 5.02% in forest land. The higher value of C:N (11.50) were observed in forest and lower (10.00) in cultivated land. Available P was ranged from 1.26 to 5.37 ppm which implies that high deficiency of phosphorus. The entire exchangeable base except Na and CEC values were found high to very high in studied lands. Generally, the adverse influence of land variation on soil properties was remarkable. The mean values of most of the soil properties were lower in cultivated and grazing lands compared to the rest land use. Therefore, the proper soil management practices are important for the investigated district to enhance crop productivity and sustainable utilization of soil resources.

Keywords: land use types, physicochemical properties, soil depth, soil fertility

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INTRODUCTION

Land-use is a combination of biological and technical anthropological actions, involved in economic and social purposes (FAO, 1976). Land-dwelling use signifies the arrangements, activities and involvements people commence in a specific land to produce, modification or sustain it (Heluf and Wakene, 2006; Ufot et al., 2016). Productive farming needs the viable use of soil management and supply, targeted at soil can simply miss its quality and quantity within a short period of time (Alemayehu and Sheleme, 2013). Agricultural practice, therefore, requires basic knowledge of viable use of the land (Lechisa et al., 2014). Soil supply has also a great part in the feeding local, regional, and worldwide environmental quality (Getahun and Bobe, 2015).

High population density and heavy dependence on agricultural activities in Ethiopia are the awful threats in which soil properties are severely impaired in that way leads to land degradation and hampered the sustainability of soil resources (Heluf and Wakene, 2006; Fantaw and Abdu, 2011). The main reasons of land worsening and environmental deterioration in Ethiopia are: agricultural practices on steep soil with inadequate management in soil conservation, erratic and torrential rainfall patterns, the inadequate recycling died part of plant and animal manures in the soil, deforestation and overgrazing (Kizilkaya and Dengiz, 2010; Mulugeta and Kibebew, 2016). Furthermore, the landscape has similar effect on the soil quality and soil depth because of the interaction effect of cultivation practices and inclines. Thus, possible effort should be focused on the maintenance of the physical, biological and socio-economic environment for production of food crops, livestock, wood and other goods through maintaining of natural resources (Adeyemo and Agele, 2010).

The anthropogenic changes in land-use have changed the features of the earth's surface. Prominent changes in soil physicochemical properties include soil fertility, soil erosion sensitivity and content of soil moisture (Tsehaye and Mohammed, 2013). Evaluating soil properties, setting soil management option and employing stakeholder to realize and restore soil properties and productivity are some of the imperative attentions in extensive range design for effective and sustainable use of soil resources. Conversion of land use types such as forest land, cultivated land, grassland and grazing land are known to result the changes of soil physical, chemical and biological properties (Kizilkaya and Dengiz, 2010; Ayoubi et al., 2011). In order to take measures for sustainable utilizations of soil resources and, the information about the effect of land-use types on soil physicochemical properties are essential. Therefore, the preset study was initiated with the objective to investigate the influence of land utilization types on soil physicochemical properties in the study area.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Ano Mikael, Sayo district, Kellem Wollega Zone of southwestern Ethiopia. The district is located 652km away from Addis Ababa, capital city. Geographically, it is located in ranges between 8°33′30″–8°35′30″ N latitude and 34°48′00″–34°52′00″ E longitude with altitude ranges between 1100 to 2750 m.a.s.l. The annual average temperature ranges between 10 to 28°C. The area receives annual rainfall ranging from 600–1500 mm. For this study, Ano Mikael was purposively selected from Sayo district because higher land degradation and soil erosion problems are commonly observed in this area, which has a deleterious impact on soil physicochemical properties under different land-use types.

Soil Sampling and Laboratory Analysis

Composite sampled was taken from the four land-use types, i.e. shrub, crop, pasture and forest lands at two soil depths (0–20 cm and 20–40 cm) with three replications by using randomized completely block design method. Both undisturbed and composite soil samples were taken based on the heterogeneity of land unit in a zigzag method. Standard laboratory procedures were followed for the analysis of soil parameters, i.e. soil texture (Bouyoucous, 1962), bulk density (BD) (Black, 1965), pH of the soils, electrical conductivity (EC) (Van Reeuwijk, 1992), organic carbon (OC) (Walkley and Black, 1934), total nitrogen (TN) (Black, 1965), available P (Olsen et al., 1954), exchangeable Na and K (flame photometer), Ca^{2+} and Mg (Rowell, 1994) and cation exchange capacity (CEC) (Chapman, 1965).

Statistical Analysis

The two way analysis of variance (ANOVA) was used to test differences in soil physical and chemical properties across land use types and soil depths. Probability was measured at 5% ($p < 0.05$); means were separated by the Duncan's Multiple Range Test (DMRT) using SAS software version 9.4 (SAS, 2013).

RESULTS AND DISCUSSION

Effects of Land-Use Variation on Soil Particles and Bulk Density

According to the result of analysis of variance (ANOVA), there was no significant ($p > 0.05$) effects on the sand particle under land-use types and soil depths and their interactions. But, silt and clay particles were significantly ($p < 0.05$) affected by land-use types. The highest (51.0%) and lowest (36.7%) values of clay content were recorded in the subsurface (20–40 cm) soil layer of the cultivated and forest lands, respectively (Table 1). Generally, the clay content was higher in the subsurface layer of cultivated land. The reason might be due to the preferential removal of clay particles by erosion agents from the surface layer of cultivated land. Heluf and Wakene (2006) and Mengistu et al. (2017) stated that the clay content of cultivated land was increased from the surface to subsurface soil layer due to the long period of cultivation. Additionally, Tsehaye and Mohammed (2013) also reported that lower clay and higher sand content was found in the surface layer and higher clay contents was recorded in the lower surface of cultivated land than the others adjacent land use types.

The soil bulk density was highly significantly ($p < 0.001$) influenced by land-use and soil depth, and their interaction, whereas it was significantly ($p < 0.01$) affected by only soil depths (Table 2). Seeing the interaction effects, the highest (1.37 g cm^{-3}) BD was recorded on the cultivated land and the lowest (1.10 g cm^{-3}) was found under the shrub land. The higher BD of soil in cultivated land is attributed to the practice of ploughing in cultivated soil (effects from farm mechanization) and low availability of the organic matter in the cultivated and grazing land, and lower bulk density was observed in forest land since there was no soil compactness due to animal trampling and accumulation of soil organic matter in the forest soil. This result is in line with the findings of Teshome et al. (2013) who observed that the highest BD from cultivated land when compared with grazing and forest lands at a soil depth of 0–20 cm. Furthermore, Gebeyaw (2007), Abad et al. (2014) and Lechisa et al. (2014) suggested that the BD of soil was highest under cultivated land compared with the adjacent forest and grazing lands. Paradoxically, Abiyot and Alemayehu (2016) described sophisticated BD in the shrub land related to neighboring plain and conserved land at a soil depth of 0–10 cm, 20–30 cm and 30–40 cm.

Effects of Land-Use on Soil pH and Electrical Conductivity

The ANOVA showed that the soil pH was not significantly ($p > 0.05$) influenced by land variation, soil deepness and their interactions. The electrical conductivity (EC) of soil was significantly ($p < 0.01$) influenced by land-use but not affected by the soil depths

Table 1. Main effects of land-use types and soil depth on soil texture and bulk density

	Sand, %		Silt, %		Clay, %		BD, g cm^{-3}	
	Soil depth, cm							
Land-use types	0–20	20–40	0–20	20–40	0–20	20–40	0–20	20–40
Shrub land	25.0	24.7	26.0	25.0^{b}	49.0	50.3^{a}	1.09^{c}	1.10^{d}
Cultivated	34.3	26.3	26.7	22.7^{b}	39.1	51.0^{a}	1.38^{a}	1.36^{a}
Forest	21.3	25.3	32.7	38.0^{a}	46.0	36.7^{b}	1.15^{b}	1.16^{c}
Grazing	27.7	25.0	28.7	30.7^{ab}	43.7	44.3^{ab}	1.39^{a}	1.34^{b}
CV, %	19.62	18.24	20.55	16.05	17.05	12.51	0.64	0.67
P-values	ns	ns	ns	*	ns	*	***	***

Main effect means within a column followed by the different letter(s) are significantly different from each other at $p > 0.05$; ns—not significant; * significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$.

and their interaction. The maximum (0.28 dS/m) and the minimum (0.01 dS/m) EC of the soils were obtained in the forest and the shrub lands, respectively (Table 3). This might attribute to the rapid decomposition of litter fall and grass in the shrub-land contributes for minimum values under shrub-lands. The highest EC value under the forest land might be due to the higher exchangeable bases since there was no or little disturbance of erosion, which remove basic cation from upper surface layer of soil that triggered by torrential rainfall. The lowest EC value under the grassland could be associated with the loss of base forming cations through high water percolation since grassland had a low bulk density and higher total porosity.

This finding is in line with the study by Sintayehu et al. (2006) and Liu et al. (2010) who found the lower EC under shrub land compared to the adjacent crop lands, bush lands and bushed-grasslands at 0–20 cm of soil depth. The EC of soil has increased with depth, i.e. it increased from the surface (0–20 cm) soil layer to subsurface (20–40 cm) soil layer except in forest and shrub land in which it was decreased from surface to subsurface soil layer. According to the standard classification of EC values by Landon (1991), the EC values measured under all land-use types in the study area indicated that the concentration of soluble salts is below the levels at which growth and productivity of most crops are affected.

Effects of Land-Use on Soil Organic Matter, Total Nitrogen and C:N Ratio

The ANOVA analysis revealed that the soil organic matter (SOM) content was significantly ($p < 0.001$) affected by land-use types and soil depth ($p < 0.01$) (Table 4). The highest (5.6%) value of SOM content was recorded on the surface (0–20 cm) soil layer of forest land and the lowest (2.73%) value of SOM was found in the subsurface (20–40 cm) soil layer of grazing land. The decline of SOM content in the grazing land might be due to the overgrazing and the heavy compactness of the soil by livestock trampling. Higher values of SOM of forest and shrub lands might be due to rooting systems; these lands have dense roots which can play a great contribution in the enhancement of soil microorganism (Tsehaye and Mohammed, 2013). This finding is in agreement with the findings of Tilahun and Asefa (2009) who proposed that the SOM decrease with increasing soil depth with more accumulation on the upper surface soil layer.

The total nitrogen (TN) of soil was significantly ($p < 0.001$) affected by land-use types and depth of soil ($p < 0.01$) (Table 4). In addition, the interaction of both was also significant ($p < 0.01$). The maximum TN (0.26%) was recorded on the forest terrestrial and minimum (0.18%) on the grazing land. The variations

Table 2. Interaction effects of land-use types and soil depth on soil texture and bulk density

Treatments	Sand, %	Silt, %	Clay, %	BD, g cm^{-3}
Land-use types				
shrub land	23.3	25.33^{b}	51.33^{a}	1.10^{d}
Cultivated	30.3	24.70^{b}	45.00^{ab}	1.37^{a}
Forest	23.3	35.33^{a}	41.33^{b}	1.16^{c}
Grazing	26.3	29.70^{ab}	44.00^{ab}	1.36^{b}
Soil depth, cm				
0–20	27.6	28.5	43.92	1.25^{a}
20–40	24.1	29.0	46.90	1.24^{b}
Land-use	ns	*	*	***
Depth	ns	ns	ns	**
Land use*depth	ns	ns	ns	***
CV, %	22.4	22.54	14.32	0.62

Interaction effect means within a column followed by the different letter(s) are significantly different from each other at $p > 0.05$; ns—not significant; * significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$.

Table 3. Main effects of land use types and soil depth on soil pH and EC

Soil parameters				
	pH		EC, dS/m	
	Soil depth, cm			
Land use types	0–20	20–40	0–20	20–40
Shrub land	5.1	4.9	0.03[b]	0.01[b]
Cultivated	4.6	4.7	0.02[b]	0.10[ab]
Forest	4.8	4.9	0.28[a]	0.25[a]
Grazing	4.7	4.7	0.01[b]	0.12[ab]
CV, %	4.24	4.82	20.53	25.24
P-values	ns	ns	**	*

Means within a column followed by the different letter(s) are significantly different from each other at $p < 0.05$; * significant at $p = 0.05$; ** significant at $p = 0.01$; ns—not significant.

Table 4. Main effects of land-use and soil depth on SOM, total N and C:N

Land use types	SOM, %		Total N, %		C:N	
	Soil depth, cm					
	0–20	20–40	0–20	20–40	0–20	20–40
Shrub land	4.6[ab]	3.60[b]	0.26[ab]	0.21[ab]	10.5[b]	10.0
Cultivated	3.7[b]	3.30[b]	0.21[b]	0.20[ab]	10.2[b]	10.0
Forest	5.6[a]	4.30[a]	0.28[a]	0.22[a]	11.6[a]	11.3
Grazing	3.5[b]	2.73[b]	0.20[b]	0.16[b]	10.1[b]	9.9
CV, %	13.31	7.83	5.90	16.47	8.77	8.81
P-values	***	*	***	**	*	ns

Means within a column followed by the different letter(s) are significantly different from each other at $p < 0.05$; * significant at $p = 0.05$; ** significant at $p = 0.01$; *** significant at $p = 0.001$, ns—not significant.

of TN value amongst diverse land-use types were parallel with that of SOM content which decreased while soil depth was increased. This study is in line with the findings of Heluf and Wakene (2006), Getahun et al. (2014) and Ufot et al. (2016) who concluded that the TN remained higher in the forest covered land when associated to the crop land at a soil depth of 0–15 cm and 15–30 cm. Similarly, the lowest TN was observed under crop land-use type which might be attributed to the fast decomposition of residues (OM) and greater erosion than compared land-use types (Gebretsadik et al., 2020).

The ANOVA showed the C:N ratio of the soils in the investigated area was significantly ($p < 0.05$) varied by land-use but it was not significant ($p > 0.05$) for soil depth and their interactions (Table 5). Regarding the soil depth, the maximum value of C:N (10.5) was found on the surface (0–20 cm) layer. The highest C:N (11.6) value was found at the surface soil layer of forest while, the lowest C:N (9.9) was observed at the subsurface soil layers of grazing lands. The maximum C:N in forest soil showed the occurrence of ideal biotic activities whereas, the lower C:N value in the subsurface soil layer of feeding land attributed to the removal of cow dung by erosion and collected for fuel purposes. The present investigation was coherent with the findings of Tsehaye and Mohammed (2013) who found the maximum C:N in forest land up to soil depth of 0–20 cm. Moreover, Yihenew and Getachew (2013) determined the maximum C:N in the natural forest cover than in the feeding and croplands for the soil depth at 0–15 cm and 15–30 cm.

Effects of Land-Use on Available Phosphorus, Exchangeable Base and Cation Exchange Capacity

The ANOVA results indicated that the available phosphorus (Av.P) of the study area was highly significant ($p < 0.001$) and significant ($p < 0.05$) for land-use and soil deepness, respectively. The available P was higher in the shallow depth 0–20 cm soil layer than in the subsurface 20–40 cm soil layer (Tables 6). As per the main effects of land-use types, the highest (7.70 ppm) and the lowest (0.88 ppm) were obtained from the forest land at the depth of 0–20 cm and shrub land at subsurface of 20–40 cm, respectively. For the interaction, the highest (5.37 ppm) available P was recorded on the forest land and the lowest (1.26 ppm) on the grazing land. The presence of maximum content of P in the forest land might be attributed to the high value of soil organic matter resulting in the release of organic phosphorus thereby enhancing available P under forest land. The available P of the soil under this study was rated as very low in the shrub crop and grazing lands whereas, it was rated as low in forest land. This implies that the study area has a high deficiency of available *p* thereby the external input of P fertilizers through both organic and inorganic sources are strongly recommended. Our results are in agreement with the statements of Yang et al. (2006) and Solomon et al. (2006) who stated that the available phosphorus dynamics are affected by land-use changes.

Analysis of variance showed that exchangeable Na was not significantly ($p > 0.05$) affected by land-use types, soil depth and their interactions (Tables 6, 7). The exchangeable potassium (K) was highly significantly ($p < 0.001$) affected by land-use but it was not significantly ($p > 0.05$) affected by soil depths and their interaction. Exchangeable potassium among the grass, cultivated, forest and grazing lands, the higher K (1.50 cmol c/kg) was found on the surface layer at soil depth (0–20 cm) of the study area (Tables 6, 7). The higher exchangeable K on the surface layer of forest land could be due to the availability of leaf biomass through litter falling and little or no surface soil disturbance by rain drops, surface runoff and other severe

Table 5. Interaction effects of land use and soil depth on SOM, total N and C:N

Treatments	OM, %	Total N, %	C:N
Land use types			
Shrub land	4.12[b]	0.24[b]	10.30[b]
Cultivated	3.51[b]	0.21[b]	10.10[b]
Forest	5.02[a]	0.26[a]	11.50[a]
Grazing	3.15[b]	0.18[b]	10.00[b]
Soil depth, cm			
0–20	0.24[a]	4.4[a]	10.5
20–40	0.20[b]	3.5[b]	10.3
Land-use	***	***	*
Depth	**	**	ns
Land-use*depth	*	**	ns
CV, %	9.47	10.03	8.73

Means within a column followed by the different letter(s) are significantly different from each other at $p < 0.05$; * significant at $p = 0.05$; ** significant at $p = 0.01$; *** significant at $p = 0.001$, ns—not significant.

erosion agents. The derivative of this phenomenon is the reasonable for lower exchangeable K in case of surface layer of grazing land; in which higher disturbance was severe and exacerbated soil erosion. This result is in agreement with the work of Teshome et al. (2013) and Lalisa et al. (2014) whose findings suggested that the exchangeable K of soil is higher in the forest land than cultivated and grazing lands. According to the rate of exchangeable K cited by FAO (2006), the exchangeable K contents of grass and cultivated lands of the study area were rated as high, whereas that of grazing and forest lands were in the range of medium and very high rate, respectively. Similarly, Teshome et al. (2013) reported that the exchangeable K of soil is higher in the forest land than crop and grazing ands. However, Yihenew and Getachew (2013) and Mulugeta and Kibebew (2016) reported that exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ are also affected by land-use types.

Furthermore, the analysis of variance result of exchangeable magnesium (Mg^{2+}) indicated that it was significantly ($p < 0.05$) affected by land-use types (Table 6), while it was highly significantly ($p < 0.01$) influenced by the interaction effects; but not significantly ($p > 0.05$) affected by the interaction between soil depth and land-use types (Table 7). The main effects of land-use variation in the exchangeable Mg^{2+} under shrub, crop, forest, and grazing lands were 5.4, 5.8, 8.7, and 5.3 cmol c/kg, respectively. The maximum exchangeable Mg^{2+} (6.40 cmol c/kg) was recorded at 0–20 cm soil layer. Main effects of land-use types with soil depth resulted in the maximum (9.1 cmol c/kg) value of Mg^{2+} was found on the surface (0–20 cm) soil layer of forest land, while the minimum (5.2 cmol c/kg) was obtained under the second soil layer (20–40 cm) soil layer of grazing. As per the ratings of FAO (2006) the exchangeable Mg^{2+} contents of the area under a shrub, crop and grazing land-use were in the range of maximum rate and very high under forest land. The holistic implication of this finding is indicated like that of calcium the magnesium content of the study area was high. Additionally, the ratios of exchangeable calcium to magnesium were within the critical values (3:1 to 5:1) which may not cause the nutrient imbalance in the study area nearby considered land-use types. According to the finding by Yihenew and Getachew (2013) and Mulugeta and Kibebew (2016), exchangeable Mg^{2+} affected by land-use types based on the interaction between land-use types and soil depth the highest value (0.47 cmol c/kg) of exchangeable sodium was obtained under the subsurface soil layer 0–20 cm of cultivated land whereas, the lowest value (0.42 cmol c/kg) was obtained from similar soil depth 0–20cm on grazing lands.

The ANOVA results indicated that the exchangeable base, i.e. calcium (Ca^{2+}) was significantly influ-

Table 6. Main effects of land-use types and soil depth on Av.P, exchangeable bases and CEC

Land-use types	Av.P (ppm)		Exchangeable bases, $cmol_c/kg$								CEC, $cmol_c/kg$	
			Na		K		Mg		Ca			
Soil depth, cm	0–20	20–40	0–20	20–40	0–20	20–40	0–20	20–40	0–20	20–40	0–20	20–40
Shrubland	2.22[bc]	0.88[b]	0.43	0.45	0.62[b]	0.65	5.4[b]	5.50[b]	23.2[b]	24.0[a]	36.60[b]	38.60[a]
Cultivated	3.03[b]	1.75[ab]	0.42	0.47	0.64[b]	0.78	5.8[b]	5.68[ab]	16.8[c]	19.2[c]	33.05[c]	33.42[b]
Forest	7.70[a]	3.05[a]	0.44	0.43	1.50[a]	1.00	9.1[a]	8.30[a]	25.4[a]	21.2[b]	43.40[a]	39.40[a]
Grazing	1.40[c]	1.13[b]	0.42	0.43	0.35[b]	0.36	5.4[b]	5.20[b]	15.2[c]	15.4[d]	27.13[d]	28.90[b]
CV, %	21.86	10.33	17.61	15.37	23.37	14.40	18.8	21.81	3.62	5.45	3.89	6.98
P-values	***	*	ns	ns	**	ns	*	*	***	***	***	**

Means within a column followed by the different letter(s) are significantly different from each other at $p < 0.05$; * significant at $p = 0.05$; ** significant at $p = 0.01$; *** significant at $p = 0.001$, ns—not significant.

Table 7. Interaction effects of land-use and soil depth on Av.P, exchangeable bases and CEC

Treatments	Av.P, ppm	Na	K	Mg	Ca	CEC
		cmol$_c$/kg				
Land-use types						
Shrub land	1.55[bc]	0.45	0.63[bc]	5.4[b]	23.6[b]	38.5[a]
Cultivated	2.40[b]	0.44	0.72[b]	5.8[b]	17.7[c]	33.2[ab]
Forest	5.37[a]	0.46	1.30[a]	8.7[a]	24.1[a]	41.7[a]
Grazing	1.26[c]	0.42	0.36[c]	5.3[b]	16.2[d]	30.1[b]
Soil depth, cm						
0–20	3.58[a]	0.43	0.75	6.40	20.8[a]	35.3
20–40	1.71[b]	0.41	0.71	6.09	19.9[b]	35.7
Land-use	***	ns	**	**	***	*
Depth	***	ns	ns	ns	**	ns
Land use*depth	***	ns	ns	ns	***	ns
CV, %	28.10	16.04	21.19	20.50	5.06	6.16

Means within a column followed by the different letter(s) are significantly different from each other at $p < 0.05$; * significant at $p = 0.05$; ** significant at $p = 0.01$; *** significant at $p = 0.001$, ns—not significant.

enced by land-use ($p < 0.001$) and soil depths ($p < 0.01$) and their interactions ($p < 0.001$) (Tables 6, 7). Regarding exchangeable Ca^{2+} at both depths of the soil, Ca^{2+} was more available at the surface 0–20 cm (20.8 cmol c/kg) than at the lower 20–40 cm depth (19.9 cmol c/kg). The maximum (25.4 cmol c/kg) and the minimum (15.2 cmol c/kg) exchangeable calcium was observed at 0–20 cm soil layer under forest and grazing lands, respectively. This could be the possibility of the high Ca^{2+} is available on the surface layer with an abundance of cow dung, and remains of plant, grass, etc. than the inner layer of soil. This finding is parallel to the work of Fantaw et al. (2008) and Alemayehu and Sheleme (2013) in which it was revealed that Ca^{2+} contents of soil was higher on the shallow soil surface than the inner one owing to the association of organic matter accumulation with biological activity and accumulation from plant residues. As per the ratings of FAO (2006), the Ca^{2+} contents of the soil of the study area were categorized as a high rate under crop and feeding lands were characterized as a very high rate under grass and forest lands. Yihenew and Getachew (2013) and Mulugeta and Kibebew (2016) reported that exchangeable Ca^{2+} is also affected by land-use types and interaction between land-use types and soil depth.

The ANOVA revealed that the cation exchange capacity (CEC) of soil was significantly ($p < 0.05$) influenced by the land-use and soil depth, while it was not significantly ($p > 0.05$) affected by soil depth and its interaction with land-use (Tables 6, 7). The CEC values under the shrub, cultivated, forest and grazing plots were 38.5, 33.2, 41.7, 30.1 cmol c/kg, respectively. The higher and lower CEC in forest and grazing land might be due to high soil organic matter and higher soil surface coverage reduce erosion and deep percolation of basic cations which contribute to the accumulation of CEC in the forest. This research outcome is in line with the findings of Heluf and Wakene (2006) and Teshome et al. (2013) who confirmed that the CEC of soil was higher in forest land compared to the grazing and crop land. Likewise, Gebeyaw (2007) also reported that the CEC of soil was more in the subsurface of soil layer under the forest, crop and feeding lands at the soil depth of 0–20 cm and 20–40 cm.

CONCLUSIONS

Soil physicochemical properties were affected by management activities and land-use conversion to other land-use types. According to our findings, the conversion of different land-use types resulted in the variation of soil physicochemical properties and it confirmed that the soil physicochemical properties of the cultivated and grazing land in study area were rated as lower to medium which need management interventions. Hence, it can be concluded that regarding all the soil parameters discussed earlier, forest and shrub lands have performed much better than the cultivated and grazing land. Therefore, reduction of intensive cultivation, minimize conversion of land-use, avoiding the removal of crop residues and animal manures from farm land, and controlling overgrazing should be practiced in the study area as well as in other agro-ecological zones with similar lands.

COMPLIANCE WITH ETHICAL STANDARDS

This article does not contain any studies involving animals or human participants performed by any of the authors.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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