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Impact of land use types and soil depths on selected soil physicochemical properties in Fasha District, Konso Zone, Southern Ethiopia

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Agricultural activities such as deforestation, continuous cultivation and intensive grazing cause deterioration of soil properties. This study was conducted with the objective to investigate the influence of land use types (cultivated, grazing and forest lands) and soil depths (0-15 and 15-30 cm) on soil properties. Eighteen composite soil samples were collected and analyzed using standard procedures and the data was subjected to statistical analysis software (SAS). The result showed the highest mean values of pH, OC, TN, C:N, AP, CEC and exchangeable bases (Ca, Mg, K and Na) under forest and grassland soils while the lowest values of these parameters were observed in cultivated soil. Clay content and bulk density of cultivated soil were significantly ($P < 0.05$) higher than uncultivated lands. The result also showed the significant ($P < 0.05$) decline of sand fractions, OC, TN, C:N and AP with soil depth while clay content, bulk density, and exchange bases (Ca, Mg, K and Na) significantly ($P < 0.05$) increased with soil depth. In general, the soil properties under the cultivated land are deteriorating compared to the soils under forest and grass lands. Therefore, to improve soil properties of cultivated soil, integrated implementation of conservative tillage, crop rotation, application of manures and residue addition to the land was suggested for the study area.

Key words: Cultivated land, forestland**,** grassland, land use types, soil properties.

INTRODUCTION

Land use practices such as deforestations, overgrazing and cultivation are known to have noticeable effects on soil properties (Biro et al., 2013). The impact of these changes varies depending on the use and management practices employed on the lands (Javad et al., 2014). Several studies reported that deforestation and cultivation of forestlands leads to depletion of soil organic matter, plant nutrients such as N, Ca, Mg, K, etc. and increase soil bulk density (Girma et al., 2012; Ovie et al., 2013; Teshome et al., 2013). These impacts, in turn, reduce the fertility of the soils. In Ethiopia, land use changes such as conversion of natural vegetation to cultivated land results in rapid nutrient depletion from the soils (Alemayehu, 2016). Intensive and continuous cultivation without proper land management has resulted in deterioration of soil physical, chemical and biological properties (Ragassa and Bekele, 2016). Getahun and Bobe (2015) reported that the amount of OM, TN and CEC in cultivated land have declined by about 76, 61 and 39%, respectively. Tesfahunegn (2016) found the highest soil organic

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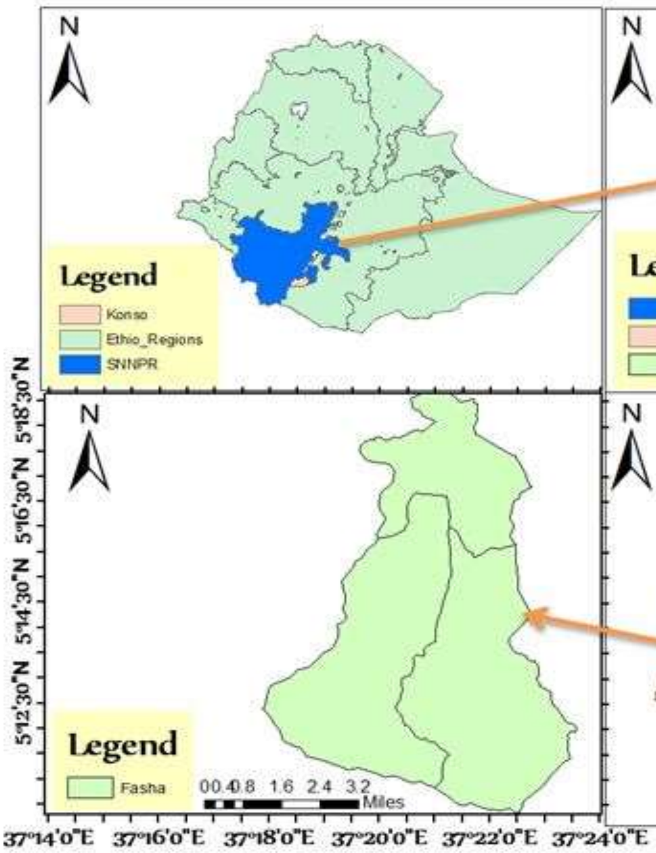

Figure 1. Map of the study area.

matter, pH, total nitrogen, available phosphorus and clay under forest land as compared to cultivated land. Alemayehu and Assefa (2016) also obtained the lowest soil OM content, total nitrogen, CEC, pH and exchangeable Ca and Mg in cultivated land as compared to forest and grass lands.

In the present study area, Konso, shortage of land for cultivation and livestock grazing, low fertility of the soil and increasing population pressure are major agricultural constraints. As a result, natural vegetation was converted to cultivated and grazing lands. Cultivation is also carried out on steep slopes which accelerate soil erosion and soil fertility decline. This in turn, has exacerbated soil degradation and led to deterioration of soil properties. Therefore, this study was initiated with the objective to investigate the influence of different land use types and soil depths on soil properties.

MATERIAL AND METHODS

Description of the study area

The study was conducted at Fasha watershed located in the Konso District, Southern Ethiopia (Figure 1). Geographically it is located between latitudes 5° 15′ 0″ to 5° 56′0″ N and longitudes 37° 01′ 0″ to 37° 69′0″ E. The altitude of the area varies from 500 m to 2,000 m a.s.l. Rainfall of the district has a bi-modal pattern. The average annual rainfall is 750 mm. Temperature of the area ranges from 16.5 to 31.3°C (Figure 2). The soil of the area is developed from volcanic-sedimentary rocks characterized by rockiness nature with little soil alone (Hailu and Yohannes, 2011). The soil of the area varies from place to place and comprises six major soil groups namely Eutric Regosols, Lithosols, Chromic Vertisols, Eutric Nitosols, Chromic Luvisols and Eutric Fluvisols (Tesfaye, 2003). Topographically, the area comprises of a rugged landscape which is predominantly composed of many hills and steep slopes.

Soil sampling and laboratory analysis

Three major land use types (cultivated, grazing, and forest lands) were selected from the watershed as major land use types of the study area. Eighteen composite soil samples (3 land use types x 2 soil depths x 3 replication) were collected from 0-15 and 15-30 cm soil depths using an auger. Disturbed soil samples were used for analysis of particle size distribution, soil pH, OC, total N, available P, exchangeable bases (Na, K, Mg and Ca) and CEC whereas undisturbed soil samples collected by sharp-edged steel cylinders forced manually into soil for the determination of soil bulk density.

Soil particle size distribution was determined by the Boycouos hydrometer method (Bouyoucos, 1962; Van Reeuwijk, 1992). Soil bulk density was determined by the undisturbed core sample method (Black, 1965). The pH of the soils was determined in 1:2.5

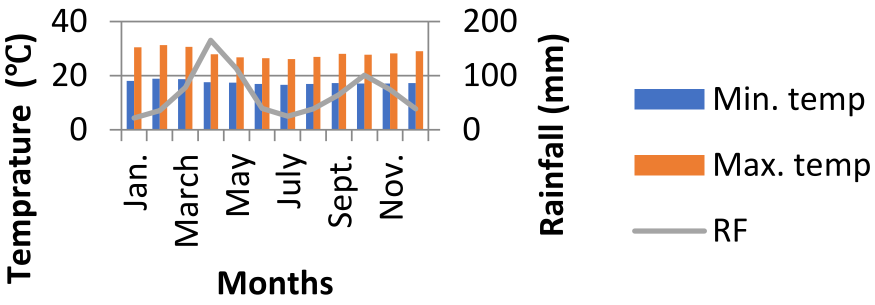

Figure 2. Mean monthly temperature (℃) and rainfall (mm) of the study area for the years from 1988 to 2017.

Table 1. Main effects of land use types and soil depths on soil texture, BD, pH, OC, TN, C:N and AP of the soil.

Land use types	Soil texture (%)			BD (g/cm)	pH	OC (%)	TN (%)	C:N	AP (mg/kg)
	Sand	Silt	Clay						
Land use types									
CL	29.27^{b}	10.22^{b}	59.85^{a}	1.33^{a}	6.23^{b}	1.97^{c}	0.13^{b}	14.81^{a}	2.87^{c}
GL	31.51^{a}	13.04^{a}	55.45^{c}	1.20^{c}	6.92^{a}	3.38^{a}	0.24^{a}	13.15^{b}	4.73^{a}
FL	30.27^{ab}	12.60^{a}	57.13^{b}	1.23^{b}	6.88^{a}	2.71^{c}	0.25^{a}	10.62^{c}	4.04^{b}
LSD(0.05)	1.74	1.28	1.51	0.02	0.08	0.21	0.01	1.50	0.51
Soil depth (cm)									
0-15	32.00^{a}	12.30^{a}	55.35^{b}	1.24^{b}	6.64^{a}	3.70^{a}	0.25a	15.46^{a}	4.22^{a}
15-30	28.69^{b}	11.60^{a}	59.60^{a}	1.27^{a}	6.69^{a}	1.68^{b}	0.17b	10.26^{b}	3.55^{b}
LSD(0.05)	1.42	1.04	1.23	0.02	0.06	0.17	0.01	1.22	0.42
CV (%)	4.46	8.31	2.04	1.59	0.93	6.11	4.70	9.05	10.25

Means with the same letters are not significantly different at $P \leq 0.05$ LSD test; LSD=Least Significance Difference; CV=Coefficient of variation; CL=Cultivated Land; GL=Grass Land; FL=Forest Land; BD=Bulk Density; OC=Organic Carbon; TN=Total Nitrogen; C:N=Carbon to Nitrogen Ratio and AP=Available Phosphorus.

soil-to-water suspensions (Van Reeuwijk, 1992). The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon. Total nitrogen was determined using the Kjeldahl digestion, distillation and titration method as described by Black (1965). Available soil phosphorus was analyzed according to the standard procedure of Olsen et al. (1954) extraction method. Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after leaching the soil samples with ammonium acetate (1N NH_4OAc) buffered at pH 7.0.

Statistical analysis

The data was subjected to mean comparison and correlation analysis using statistical analysis system (SAS, 2004). The least significance difference (LSD) test was used at $P < 0.05$.

RESULTS AND DISCUSSION

Soil physical and chemical properties

The result showed that sand and silt contents of cultivated land were significantly ($P < 0.05$) lower than that of forest and grassland soils. The clay content was significantly ($P < 0.05$) different across all land use types. The highest (59.85%) and lowest (55.45%) clay contents were recorded in cultivated land and grassland, respectively (Table 1). This might be due to breakdown of soil particles during intensive cultivation. In agreement with this finding Alemayehu and Assefa (2016) reported the highest and lowest clay content in cultivated and forest lands, respectively. The result also showed the declines of sand and silt contents from 0-15 to 15-30 cm while clay content significantly ($P < 0.05$) increased with depth. The highest clay content in sub-surface soil may be due to leaching of clay particles down the soil profile with percolating water and parent materials of the study area.

The bulk density was significantly ($P < 0.05$) affected by land use types and soil depths interaction (Table 2). The highest (1.33 g/cm^3) and the lowest (1.20 g/cm^3) bulk density was recorded in the cultivated land and grassland, respectively (Table 1). The higher bulk density

Table 2. Interaction effects of land use types and soil depths on soil texture, BD, pH, OC, TN, C:N and AP of the soil.

Land use type	Depth (cm)	Soil texture (%)			BD (g/cm)	pH	OC (%)	TN (%)	C:N	AP (mg/kg)
		Sand	Silt	Clay						
Cultivated land	0-15	31.93^{a}	10.97^{bc}	56.10^{cd}	1.31^{a}	6.20^{b}	2.58^{c}	0.14^{c}	17.92^{a}	3.12^{c}
	15-30	26.00^{b}	9.47^{c}	63.60^{a}	1.34^{a}	6.27^{b}	1.36^{e}	0.12^{d}	11.70^{bc}	2.63^{c}
Grass land	0-15	32.02^{a}	13.75^{a}	55.73^{cd}	1.21^{c}	6.83^{a}	3.66^{b}	0.30^{a}	12.10^{b}	4.06^{b}
	15-30	31.00^{a}	12.33^{ab}	58.53^{b}	1.26^{b}	6.87^{a}	1.76^{d}	0.19^{b}	9.14^{d}	4.02^{b}
Forest land	0-15	32.07^{a}	12.20^{ab}	54.23^{d}	1.19^{c}	6.90^{a}	4.86^{a}	0.29^{a}	16.35^{a}	5.47^{a}
	15-30	28.47^{b}	13.00^{a}	56.67^{cb}	1.22^{c}	6.93^{a}	1.91^{d}	0.19^{b}	9.96^{cd}	4.00^{b}
LSD(0.05)		2.46	1.81	2.13	0.04	0.11	0.30	0.02	2.12	0.72
CV (%)		4.46	8.31	2.04	1.59	0.93	6.11	4.70	9.05	10.25

Means with the same letters are not significantly different at $P \leq 0.05$ LSD test; LSD=Least Significance Difference; CV=Coefficient of Variation; BD=Bulk Density; OC=Organic Carbon; TN=Total Nitrogen; C:N=Carbon to Nitrogen Ratio and AP=Available Phosphorus.

of cultivated soil was due to compaction resulting from intensive cultivation, low organic matter content and more disturbances of soils under cultivated land than uncultivated land. Soils in the current study area are tilled several times a year (at least six times per year) as farmers of the area work hard and this may indirectly have contributed to increase in bulk density in cultivated soil. Similarly, Mostafa et al. (2008) reported that soil under cultivation had higher bulk density than soils under forest and pasture. The result also showed significant ($P < 0.05$) and negative correlation (r= -0.65) of bulk density with OC Table 5. Similarly, Achalu et al. (2012) reported the highest value of bulk density in cultivated land and the lowest in forest land. The result also showed a significant ($P < 0.05$) increase in bulk density from surface soil (1.24 g/cm) to sub-soils (1.27 g/cm) (Table 1). Similarly, Awdenegest et al. (2013) reported the increase of bulk density with increasing soil layer due to the decrease in OM content with soil depth.

The pH of the soils varies from 6.23 to 6.9 as indicated in Table 1. The highest (6.9) was observed in forest followed by grass land (6.85) while the lowest (6.23) was recorded in cultivated land as shown in Table 1. According to the rating of soil pH by Foth and Ellis (1997) the pH of the soils of the study was rated as slightly acidic for cultivated lands and neutral for grass and forest lands. The lowest pH in cultivated land was due to continuous removal of basic cations (Ca, Mg and K) by harvested crops, which provide hydrogen ion to the soil. It is also due to erosion and leaching of cations in cultivated soil as this process is aggravated by intensive tillage, which correspondingly decreases the pH of the soil. The result of these finding is in line with several finding such as Yimer et al. (2007), Tegenu et al. (2008) and Wasihun et al. (2015), who reported lower soil pH values under cultivated lands as compared to uncultivated lands. The result also revealed the increase in pH from 0-15 to 15-30 cm but, the result was not statistically significant.

Soil organic carbon was significantly ($P \leq 0.01$) affected by land use types and soil depth interaction (Table 2). The highest (4.86%) was founded in surface layer of forest land while the lowest (1.36%) was recorded in sub-surface layer of cultivated soil. According to the rating of OM by Berhnu (1980), the OC contents of the study area were rated as medium for grass and forest lands and low for cultivated land. In forest and grassland, high vegetation covers or above ground biomass, high root biomass and plant litter fall returned to the soil surface increases the fraction of OC in the soil of forest land. In cultivated land, cultivation enhances soil aeration which promotes rapid decomposition and oxidation of soil OM. Similarly, Alemayehu and Sheleme (2013) reported that continuous cultivation accelerates OM oxidation which leads to decline of OM on cultivated soils. The current result was in agreement with several findings such as Achalu et al. (2012), Habtamu et al. (2014), Arasa et al. (2015), Alemayehu and Assefa (2016) and Mengistu et al. (2017) who reported the high organic carbon in grassland and forest land than cultivated lands. Generally organic carbon significantly ($P < 0.05$) declines with increasing soil depth.

The TN of cultivated land was significantly ($P < 0.05$) lower than TN of forest and grassland. The highest (0.25%) TN was observed in forest land followed by grass land (0.24%) and cultivated land (0.13%) (Table 1). According to the rating by Berhnu (1980), the TN of the both land use types was rated as medium. The low TN of the cultivated soil was due to rapid decomposition and oxidation process encouraged by intensive cultivation than uncultivated soils which in turn to reduce the TN content. The high TN of the uncultivated land (forest and grassland) was due to high organic matter content which is the main source for soil total nitrogen. The current finding is in line with several findings such as Yifru and Taye (2011), Teshome et al. (2013) and Ufot et al. (2016) who reported that soil under cultivation have low TN as

Table 3. Main effects of land use types and soil depths on exchangeable bases (Ca, Mg, K and Na) and CEC.

Land use types	CEC	Ca (Cmol(+)kg^{-1})	Mg	K	Na
Land use types					
Cultivated land	22.11^{b}	$3.7c^{b}$	2.15^{b}	1.31c	1.37^{b}
Grass land	28.71^{a}	5.41^{a}	3.10^{a}	2.70^{a}	2.26^{a}
Forest land	24.56^{ab}	$4.5b^{a}$	3.10^{a}	1.90^{b}	2.26^{a}
LSD(0.05)	6.06	0.16	0.27	0.41	0.32
Soil depth (cm)					
0-15	23.74^{a}	4.33^{a}	2.51^{b}	1.69^{b}	1.74^{b}
15-30	26.51^{a}	4.77^{b}	3.05^{a}	2.25^{a}	2.18^{a}
LSD(0.05)	4.95	0.13	0.22	0.34	0.26
CV (%)	18.76	2.80	7.46	16.34	12.64

Means with the same letters are not significantly different at $P \le 0.05$ LSD test, LSD = Least Significance Difference; SEM = Standard Error of Mean; CV = Coefficient of Variation; CEC = Cation Exchange Capacity.

compared to uncultivated soils. Considering soil depth, the soil total nitrogen significantly ($P < 0.05$) decreased with increasing soil depth. This might be attributed to decrease in soil OM content with soil depth as shown in Table 1. The result also indicated highly significant ($P \le 0.001$) and strong positive associations (r=0.84) of TN with OC (Table 5). The current finding was in agreement with finding of Nega and Heluf (2013) who reported that the TN declines from surface to subsurface soils.

C:N ratio was significantly ($P \le 0.05$) affected by land use types and soil depths. The highest (14.81) was recorded in cultivated land followed by grass land (13.15) and forest land (10.62) (Table 1). Regassa and Bekele (2016) reported that when the C:N > 30:1, nitrogen is immobilized by soil microbes while if C:N < 20:1; there is a release of mineral nitrogen into the soil environment. Accordingly, the C:N of the soil of the study were below 20:1 range. This indicates the release of mineral nutrient to plant and soil environment. The result also indicted the significant ($P \le 0.05$) decline of C:N ratio with increasing soil depth. This attributed to the decline of OM and TN with soil depth as value of C:N ratio was calculated from the value of OC and TN. The result also showed significant ($P \le 0.05$) and positive correlation (r=0.57) of C:N ratio with OC (Table 5).

The result showed that AP was significantly ($P \le 0.05$) increases from cultivated land (2.87 mgkg^{-1}) to forest (4.04 mgkg^{-1}) and grass land (4.04 mgkg^{-1}). According to the rating by Landon (1991) AP of the study was less than 5 mgkg^{-1}, qualifying for the low range. This indicates the deficiency of P nutrient in the current study area. This might be due to low inherent P content of the parent material, and might also be due to high clay content which increases the retention capacity. Similarly, Brady and Weil (2002) reported that P in soil was constrained by the low total quantity and very low solubility. Contrarily, Mengistu et al. (2017) reported that AP was higher in cultivated land than other land uses due to continuous application of P. In the present study area there was no history of inorganic P fertilizer application. Considering soil depth, AP significantly ($P \le 0.05$) declines with increasing soil depth. This was probably due to type of parent material which may increase the fixation of the P beside the very small amount of the nutrient of the soil. The result revealed that CEC of cultivated land was significantly ($P \le 0.05$) different from the CEC of grass land soil and forest soil. The low CEC in cultivated land was attributed to low OM, high leaching of basic cations and clay and uptake of basic cations like Ca and Mg by crops in cultivated land than uncultivated lands. According to the rating by Landon (1991) the CEC across land use types and soil depths were rated as medium. Nega and Heluf (2013) reported that soil CEC values in cultivated land uses decreased mainly due to the reduction in organic matter content. Similar finding was also reported by Woldeamlak and Stroosnijder (2003), Habtamu et al. (2014) who reported the highest mean value of CEC in forest land and lowest in cultivated land. The finding also indicated positive and highly significant ($P \le 0.01$) correlation (r=0.65 and r=0.61) of CEC with exchangeable Ca and K, and significant ($P \le 0.05$) correlation (r=0.51 and r=0.55) with exchangeable Mg and Na.

The result showed that exchangeable bases (Ca, Mg, K and Na) of cultivated soils was significantly ($P \le 0.05$) lower than those of the forest and grassland soils (Table 4). This is mainly due to uptake of basic cations by crops, leaching and low organic matter in cultivated soils than uncultivated lands. Similar finding have been reported by Getahun and Bobe (2015).

The result also showed the significant ($P \le 0.05$) increase of exchangeable bases (Ca, Mg, K and Na) bases from surface (0-15 cm) to sub- surface (15-30cm) soil depths as indicated in Table 3. This might be due to translocation of basic cations to lower layers. High clay content in the lower layer h increased the retention of

Table 4. Interaction effects of land use types and soil depths on exchangeable bases (Ca, Mg, K and Na) and CEC.

LUT	**Depth**	**CEC**	**Ca**	**Mg**	**K**	**Na**
	(cm)			**(Cmol(+)kg^{-1})**		
CL	0-15	18.83^{b}	3.46^{f}	1.84^{d}	0.93^{d}	1.22^{c}
	15-30	25.39^{ab}	4.01^{e}	2.45^{c}	1.68^{c}	1.52^{c}
GL	0-15	28.14^{ab}	5.28^{d}	2.83^{b}	2.39^{c}	2.01^{b}
	15-30	29.27^{ab}	5.54^{c}	3.36^{b}	3.01^{c}	2.49^{b}
FL	0-15	24.26^{a}	4.25^{b}	2.85^{a}	1.75^{b}	1.99^{a}
	15-30	24.86^{a}	4.77^{e}	3.33^{a}	2.05^{a}	2.53^{a}
LSD(0.05)		8.57	0.23	0.58	0.37	0.45
CV (%)		18.76	2.80	16.34	7.46	12.65

Means with the same letters are not significantly different at $P \leq 0.05$ LSD test; LUT=Land Use Types; CL=Cultivated Land; GL=Grass Land FL=Forest Land; CEC=Cation Exchange Capacity and LSD=Least Significance Difference and CV=Coefficient of Variation.

Table 5. Pearson's correlation matrix for selected soil physicochemical properties under different land use types and soil depths.

	BD	**pH**	**OC**	**TN**	**C:N**	**AP**	**CEC**	**Ca**	**Mg**	**K**	**Na**
BD	1.00										
PH	-0.88**	1.00									
OC	-0.65*	0.37^{ns}	1.00								
TN	-0.85**	0.72**	0.84***	1.00							
C:N	0.10^{NS}	-0.43^{ns}	0.57*	0.06^{ns}	1.00						
AP	-0.83***	0.75**	0.71**	0.78**	0.07^{ns}	1.00					
CEC	-0.29^{Ns}	0.42^{ns}	0.06^{ns}	0.22^{ns}	-0.30^{ns}	0.26^{ns}	1.00				
Ca	-0.69**	0.84***	0.22^{ns}	0.44^{ns}	-0.38^{ns}	0.63*	0.65**	1.00			
Mg	-0.53*	0.83***	-0.06^{ns}	0.37^{ns}	-0.73**	0.41^{ns}	0.51*	0.81***	1.00		
K	-0.59**	0.73**	0.06^{ns}	0.34^{ns}	-0.50*	0.54*	0.61**	0.88***	0.71**	1.00	
Na	-0.55*	0.80***	-0.05^{ns}	0.37^{ns}	-0.68*	0.47*	0.55*	0.76**	0.82***	0.78**	1.00

***= very highly significant; ** highly Significant at 1%; * Significant at 5%. Means with the same letters are not significantly different at $P \leq 0.05$ LSD test; LUT=Land Use Types; CL=Cultivated Land; GL=Grass Land FL=Forest Land; CEC=Cation Exchange Capacity and LSD=Least Significance Difference and CV=Coefficient of Variation.

cations. In line with this finding, Mengistu et al. (2017) reported the increase in basic cation concentration with soil depth.

Conclusions

The result of this finding indicates that soil properties such as bulk density, soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K and Na) and CEC are better under uncultivated (forestland and grassland) soils than cultivated soils in terms of soil fertility indictors. This indicates that conversion of natural forest and grasslands to cultivated soils diminishes soil quality. This indicates cultivated soils are poor in maintaining and keeping the fertility status of the soil due to continuous tillage as compared to grassland and forest soils. The overall soil condition under the cultivated land is deteriorating and getting poor compared to the soils under the forest and grass lands. The changes in soil properties were not limited to surface soils but also the subsurface soils across the land uses. Integrated implementations of soil fertility improvement practices such as application of organic inputs, leaving crop residues after harvest and crop rotation of cereals with leguminous crops are also suggested to restore already degraded soil under cultivated lands. Finally, further researches addressing sustainable land management issues for the study area are needed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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