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Effects of land use changes on the dynamics of selected soil properties in northeast Wellega, Ethiopia

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Abstract. Land use change can have negative or positive effects on soil quality. Our objective was to assess the effects of land uses changes on the dynamics of selected soil physical and chemical properties. Soil samples were collected from three adjacent soil plots under different land uses, namely forestland, grazing land, and cultivated land at 0–15 cm depth. Changes in soil properties on cultivated and grazing land were computed and compared to forestland, and ANOVA (analysis of variance) was used to test the significance of the changes. Sand and silt proportions, soil organic content, total nitrogen content, acidity, cation exchange capacity, and exchangeable Ca^{2+} content were higher in forestlands. Exchangeable Mg^{2+} was highest in grazing land, while clay, available phosphorous, and exchangeable K^{+} were highest in cultivated land. The percentage changes in sand, clay, soil organic matter, cation exchange capacity, and exchangeable Ca^{2+} and Mg^{2+} were higher in cultivated land than in grazing land and forestland. In terms of the relation between soil properties, soil organic matter, total nitrogen, cation exchange capacity, and exchangeable Ca^{2+} were strongly positively correlated with most of soil properties, while available phosphorous and silt have no significant relationship with any of the other considered soil properties. Clay has a negative correlation with all soil properties. Generally, cultivated land has the least concentration of soil physical and chemical properties except clay and available phosphorous, which suggests an increasing degradation rate in soils of cultivated land. So as to increase soil organic matter and other nutrients in the soil of cultivated land, the integrated implementation of land management through compost, cover crops, manures, minimum tillage, crop rotation, and liming to decrease soil acidity are suggested.

1 Introduction

Land use changes have remarkable effects on the dynamics of soil properties (Biro et al., 2013). Land use changes from forest cover to cultivated land may reduce the input or organic residues that lead to a decline in soil fertility (Muñoz-Rojas et al., 2015), increased rates of erosion (Biro et al., 2013), the loss of soil organic matter and nutrients (Saha and Kukal, 2015), and an accelerated rate of soil degradation (Barua and Haque, 2013). Vegetation cover is, therefore, a key indicator of soil degradation as plants play a role in controlling soil erosion (Kröpfl et al., 2013; Keesstra et al., 2009; Cerdà, 1998). Biro et al. (2013) observed that the expansion of cultivated areas can substantially affect soil nutrient content by reducing the composition of plant species, net primary productivity, above- and belowground allocation in plants, and nutrient cycling. Soil organic matter is less in extremely degraded areas where overgrazing is manifest. Saha and Kukal (2015) found a higher bulk density and lower macroporosity and water retention in cultivated soils than in soils of grassland and forests. This indicated a degradation of soil properties due to the conversion of natural ecosystems to agricultural systems.

In Ethiopia, rapid population growth and environmental factors lead to the conversion of natural forestland and grassland into cultivated farmland (Tesfahunegn, 2016). Such land use changes have contributed to soil degradation and soil loss by deteriorating the soil physical and chemical properties (Karltun et al., 2013). Soil compaction, the loss of soil structure, soil organic matter (SOM) degradation, undulating terrain, highly erosive rainfall, and inappropriate farming practices make soil highly vulnerable to erosion. Soil erosion is highest in cropland (42 $Mt\,ha^{-1}$ average annual rate) compared with 5 $Mt\,ha^{-1}$ from grassland. Soil degradation causes the loss of fertile topsoil and reduces the productive capacity of the land. The country lost an estimated USD 1 billion per year from both on-site and off-site changes (Bewket and Teferi, 2009). This has been confirmed by empirical studies carried out in different parts of Ethiopia (for example, Angassa, 2014; De Mûlenaere et al., 2014; Tesfaye et al., 2014; Tesfahunegn, 2016; Asmamaw and Mohamed, 2013; Fantaw and Abdu, 2011; Eyayu et al., 2009). Soil degradation in the area makes it necessary to apply restoration strategies (Mekonnen et al., 2015; Bizoza, 2014; Zhang et al., 2009). Soil protection is fundamental so as to maintain soil services and avoid land degradation (Berendse et al., 2015; Keesstra et al., 2012).

In a study conducted in the Rift Valley area of Ethiopia, Fantaw and Abdu (2011) observed an increase in bulk density and decrease in SOM, total nitrogen (TN), exchangeable cations, and cation exchange capacity (CEC) contents following the conversion of native woodlands into farmland and grazing land. In the Gerado catchment, northeastern Ethiopia, Asmamaw and Mohammed (2013) observed changes in the amount of clay, SOM, and total N following changes in land use and land cover. Eyayu et al. (2009) reported a declining pH value and SOM conted in leached and degraded cultivated land when compared to forestland in the Tara Gedam catchment and the adjacent agro-ecosystems of northwestern Ethiopia. Emiru and Gebrekidan (2013) indicated that deforestation has resulted in deterioration of SOM in the soil. Similarly, Tesfahunegn (2016) showed that soil quality indicators varied across the land use and soil management systems, among which natural forestland and protected afforestation areas are the most important systems in maintaining soil quality, whereas cultivated and marginal lands seriously deteriorated the physical soil system. The same author showed that soil organic carbon (SOC), pH, total N, available phosphorous (AP), and clay are significantly higher in natural forest and protected afforestation areas. On the other hand, Yeshanew et al. (2005) found that SOC and total N at 0–20 cm depth remained the same after natural forest conversion into eucalyptus plantations in Munesa, Ethiopia. Fantaw et al. (2007) in their study in the Bale Mountains of Ethiopia found no variation in soil organic carbon content after natural forest was converted into grazing land. These conflicting findings suggest that the conversion of forestland into cultivated or grazing land leads to changes in soil physical and chemical properties and that the degradation of the land is not applicable at all times and in all places applicable. This further suggests the need for empirical inquiry into the effects of land use changes on the dynamics of selected soil properties and subsequent degradation of farm household land. Little work which has implications for land degradation and land management strategies in eastern Africa has been done on the effects of land use on soil properties. Natural forest, comprising tree species such as *Podocarpus falcatus* (Zigba), *Olea europaea* (Woyera), and *Rosa abyssinica* (Kega), was selected as the control field against which different soil properties of cultivated and grazing lands were compared to assess the level of land degradation in northeast Wellega, Ethiopia. The interpretation of our results is limited to the current status of some soil parameters such as soil texture, soil pH, TN, CEC, exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}), AP, and SOC, due to the fact that there were no documented data on the former land uses.

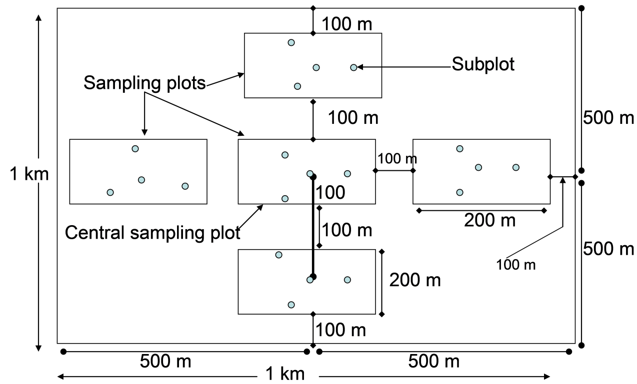

Figure 1. Adapted sampling design of soil samples in northeast Wellega, Ethiopia (after Vågen and Winowiecki, 2013, Vågen et al., 2013, and Abegaz et al., 2016).

2 Materials and methods

2.1 Study area

The study area is located in northeast Wellega (Horo-Guduru Wellega Zone, Oromia Region, Ethiopia; approximate coordinates 9°45′–10°00′ N, 37°00′–37°15′ E). The area belongs to the Trap Series of tertiary volcanic eruptions (ORLEPB, 2013). Its topography is typical of volcanic landscapes, which were later deeply incised by streams, resulting in the current diversity of landforms. The soils have developed from volcanic ashes and reworked materials resulting from tertiary volcanic eruptions and sedimentation processes (ORLEPB, 2013). Nitosols are the dominant soil type, mainly on undulating to steep slopes. Relatively flat areas and especially those closer to river valleys are largely covered by well-developed Vertisols. Dominant soils on steep slopes are Leptosols, Regosols, and Cambisols. The study area has an elevation of between 1800 and 2657 m. The mean annual temperature of the area is 25 °C. Annual rainfall, which is heavy during the summer months (June–August), ranges between 1750 and 2000 mm (EMA, 2013). For 2013, the population of the study area was projected to be 58 339,

Table 1. A brief description of the three land use types in northeastern Wellega, Ethiopia.

Land use	Description
Forestland	Areas covered with tall and dense trees forming a closed or nearly closed canopy (70–100 %) and without apparent or reported human impacts. This unit also includes undercanopy trees mixed with low bushes and open areas. Dominant tree species in this group include *Celtis africana*, *Calpurina subdecandra*, and *Croton mycrostachyus*. In addition, leaf fall, macrofauna (worms, large insects, etc.), soil microflora (bacteria, fungi, algae, etc.), and microbial activities are common in this land use. No sign of rill or sheet erosion.
Grazing land	Formerly this land use took place under forest cover. Forty years ago, land use evolved with permanent grass cover, with continuous grazing systems (information from local elders). Cattle dung is regularly collected as a source of household energy from this land use. Short grass species dominate this land unit. In some places rill erosion is observed.
Cultivated land	Formerly this land use took place under forest cover. For the last 40 years, continuous plowing, clearing and the removal of aboveground biomass (yield and crop residue), and the leveling of farming fields (information from local elders) has led to changes. Weathered fragmented rock materials are common in the plowing soil layer. Structural soil conservation (rock and earth terracing) practices are common. For the last 30 years Urea, and DAP (up to 100 kg ha^{-1} each) and cattle manure have been applied. This land includes areas used for rain-fed agriculture. Major crops grown include cereals (maize, *teff*, and barley), legumes (beans, peas), and oil crops (neug).

of which only 10 % was urban population (CSA, 2008). CSA (2008) reported that the population of the district increased by 39 % from 1980 to 2013. Except for a small percentage of the population living in urban areas, the inhabitants are farmers engaged in mixed crop–livestock farming.

2.2 Current land use types

We identified and classified the present land use types through surveys in 2012 and 2013. The information was obtained from elderly members of the community (aged 60 and above), whom we assumed to be knowledgable about the land use types in the local community. Accordingly, three major land use categories, namely forestland, grazing land, and cultivated land, were identified for the purpose of this study (Table 1). Based on the information obtained from the elders, these sites had the same land cover before 1970. Since then, some portions have been converted into cultivated and grazing lands, while some portions remained as forestland.

2.3 Soil sampling

The cluster sampling design by Thompson (1991), which was later applied by Vågen et al. (2013), Vågen and Winowiecki (2013), and Abegaz et al. (2016) was modified and used for this study. The study by Vågen et al. (2013) was on the mapping of land degradation prevalence and soil functional properties in Ethiopia; the study of Vågen and Winowiecki (2013) was on mapping of soil organic carbon stocks for spatially explicit assessments of climate change mitigation potential along the Ethiopian and Kenyan highlands; and Abegaz et al. (2016) was on spatial and temporal dynamics of soil organic carbon in landscapes of the upper Blue Nile Basin of the Ethiopian Highlands. In each of these studies, three different areas each 10 km × 10 km and with 16 clusters or tiles have been used. Since our study is on a small catchment so as to assess the impact of land use differences on selected soil properties, we modified and applied this sampling design to suit our study area.

Accordingly, three adjacent sites under different land use types (forestland, cultivated land, and grazing land) were selected for this study, with similar slope, elevation, and aspect in each land use. We established a 1 km × 1 km cluster (sampling area) and five cluster centroids (sampling plots) were stratified into 200 m × 200 m tiles and their locations within the sampling area were chosen systematically (Fig. 1). The first tile (sampling plot) was first established by fixing its central point at the center of a 1 km × 1 km area. Then, the area of this sampling plot was established using a 100 m radius from the cluster center (sampling area) point. The centers of the other four sampling plots were established at a 300 m distance from the center of this sampling plot (the central plot) to the north, east, south, and west. The area of each of these sampling plots was established using a 100 m radius

Table 2. Mean variation and standard deviation (SD) of soil fraction, organic matter, total nitrogen, C : N ratio, and available phosphorous at 0–15 cm depth in different land use types in northeastern Wellega, Ethiopia.

Land use type	Soil fraction (%)						Organic		Total				Available	
	Sand		Silt		Clay		matter (%)		nitrogen (%)		C : N ratio		phosphorus (PPM)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Forestland	51.6^{a}	3.6	32.8^{c}	1.1	15.6^{a}	2.6	$9.0^{a,c}$	1.3	$0.4^{a,c}$	0.1	12.1^{c}	0.4	$3.6^{b,c}$	1.0
Grazing land	38.4^{a}	1.7	26.8^{c}	10.8	34.8^{c}	10.6	$7.3^{a,b,c}$	1.5	$0.4^{a,b,c}$	0.1	11.9^{c}	3.8	2.1^{b}	0.4
Cultivated land	29.6^{a}	5.4	28.4^{c}	4.56	$42.0^{a,c}$	6.6	$4.6^{a,b}$	0.7	$0.3^{a,b}$	0.1	10.8^{c}	1.9	$3.7^{b,c}$	1.5

Note: ^{a,b} the mean differences of soil properties in each column are significant at $P < 0.01$ and 0.05, respectively; ^{c} the mean difference is not significant.

from their center point. Thus, a 100 m buffered area exists between the boarder of the sampling area and the neighboring sampling plots. Within each tile four subplots were randomly established, each with an area of 100 m^2: one in the center and three on radial arms with 120° angles between them (Vågen and Winowiecki, 2013; Vågen et al., 2013; Abegaz et al., 2016). This form of sampling allows the assessment of variability in soil properties on different spatial scales (Vågen et al., 2013) (in our case among land uses at site level). For each tile, soil samples (0–15 cm depth, the average plough layer in the area) were collected from the center of each subplot and composite samples were prepared by hand mixing. In total, we prepared 15 composite soils.

2.4 Soil analysis

Composite soil samples were air-dried, ground, and passed through a 2 mm sieve prior to laboratory analysis. Soil analysis included soil texture (determined by Bouyoucos Hydrometer Method; Black et al., 1965), soil pH (determined in a 1 : 2.5 soil : water ratio), total N content, cation exchange capacity (CEC), exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) by atomic absorption spectrophotometery (AP; Olsen et al., 1954), and organic carbon (OC) content (Walkley and Black, 1934). Soil organic matter (SOM) content (%) was determined by multiplying the OC percentage by 2.

2.5 Statistical analysis

One-way ANOVA (analysis of variance) was used to analyze the differences in soil texture, pH, available P, SOM, N (Kjeldahl), CEC, and exchangeable cations of the three land use types from 15 composite soil samples (5 from each land use type) at the 0.05 level.

Percentage changes in the soil properties of cultivated land or grazing land compared to forestland (Ch_{Cl}, Ch_{Gl}) were computed by

$$Ch_{Cl,Gr} = \frac{Lu_{CI,or\,Gl} - Lu_{FI}}{Lu_{FI}} \times 100, \quad (1)$$

where Ch_{Cl}, Ch_{Gl} is the percentage changes in soil property of cultivated or grazing lands compared to forestland and Lu_{CI}, Lu_{GI}, and Lu_{FI} are the mean values of the soil property under consideration of cultivated, grazing, and forestland, respectively. Bivariate correlation analysis was conducted to assess the relationships between the studied soil properties.

3 Results and discussion

3.1 Particle size distribution

The sand content of soils of forestland is the highest and the lowest on soils of cultivated land (Table 2). These differences are statistically significant ($P < 0.05$; Table 4). The percentage change in sand particle size distribution is higher in cultivated land than in grazing land and forestland (Table 4). The clay content of soils is the highest in cultivated land and the lowest in soils of forestland (Table 2). The clay fraction on cultivated land and grazing land increased compared to forestland, but the change is greater in cultivated land than grazing land (Table 4). The lower content of sand and higher content of clay fractions in the cultivated land may be attributed to the process of plowing, clearing, and the leveling of farming fields. Because the clay particles are very small in size, silt, and sand fractions could be removed by runoff from the cultivated land. These are deposited in the topsoil of forestland and grazing land (Biro et al., 2013). Differences in the clay content of soil influence the levels of microbial biomass. Clay soils are assumed to hold much more water and plant nutrients than forestland and grazing lands (Karltun et al., 2013). Soils with a high clay content have sufficient particle-to-particle contact points to form strong bonds when the soil dries (Eyayu et al., 2009). Cultivated land with the highest clay fraction has the most compact soils.

3.2 Soil organic matter, total nitrogen, and available phosphorous

The content of SOM was the highest in forestlands and the lowest in cultivated land (Table 2), and the differences are statistically significant (Table 4). SOM decreases as forestland land changes into cultivated and grazing land (Table 4). The percentage change is higher in cultivated land than in grazing land (Table 4). The more rapid decrease in SOM contents in cultivated land may be attributed to accelerated rates of erosion and decomposition because these processes were

Table 3. Mean variation and standard deviation (SD) of soil acidity (pH), cation exchange capacity (CEC), and exchangeable bases (K^+, Ca^{2+}, and Mg^{2+}) at 0–15 cm depth in different land use types in northeastern Wellega, Ethiopia.

Land use type	pH (1 : 2.5 H_2O)		CEC Cmol(+) kg^{-1}		Exchangeable bases Cmol(+) kg^{-1}					
					K^+		Ca^{2+}		Mg^{2+}	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Forestland	$6.1^{a,b}$	0.36	32.85^{a}	4.04	0.13^{c}	0.04	12.81^{a}	4.01	$3.96^{a,c}$	1.21
Grazing land	$5.7^{c,b}$	0.22	$25.65^{a,b}$	3.32	0.12^{c}	0.07	$5.98^{a,c}$	1.34	$4.80^{a,c}$	1.10
Cultivated land	$5.4^{a,c}$	0.13	$20.19^{a,b}$	3.66	0.14^{c}	0.08	4.08^{c}	1.79	1.71^{a}	0.27

Note: [a,b] the mean differences of soil properties in each column are significant at $P < 0.01$ and 0.05, respectively; [c] the mean difference is not significant.

more active in cultivated lands than forestland and grazing lands (Abegaz et al., 2016). On the other hand, the reduction is less in grazing land because grass roots are fibrous near the soil surface and easily decompose, increasing organic matter. Land management such as poorly designed terracing and cutoff drainage, which was implemented on cultivated land, facilitated the drainage of water and soil from this land and deposited water and soil on forestland. The farming system in the area, which is heavily dependent on traditional practices, also facilitates the removal of topsoil on the cultivated land. This suggests that SOM shows a strong response to land use, land use change, and land degradation (Vågen and Winowiecki, 2013). Thus, the high SOM in forestland is potentially the highest reservoir for the plant essential nutrients nitrogen, phosphorus, and sulfur (Zeng et al., 2009). SOM also increases soil water-holding capacity and CEC and enhances soil aggregation and the structure of soils of forestland.

As expected, the mean value of total N was highest in soils of forestland and lowest in cultivated land (Table 2). The change in total N is higher in cultivated land than in grazing land and forestland (Table 4). The C : N ratio is the highest in soils of forestland, while it is the lowest in grazing land (Table 2). Due to the close relationship between SOM and total N, the soil C : N ratio indicates the status of soil fertility. The C : N ratio is often influenced by climate, soil condition, vegetation type, and agricultural management practices (Oedraogo et al., 2006; Zhang et al., 2009). The content of available P was the highest in cultivated land and the lowest in grazing land (Table 2). The mean differences between soil-available P of forestland and grazing lands, on the one hand, and cultivated and grazing lands, on the other hand, are statistically significant ($P < 0.05$, Table 4), while the mean difference between forestland and cultivated lands is not statistically significant. Compared to the available P contents of forestland, the available P of cultivated and grazing lands is increased (Table 4).

Secondary minerals, organic, and inorganic fertilizer are important pools of soil phosphorous (P) (Assefa and van Keulen, 2009). Thus, the fact that soils in the forestland have higher available P than in the grazing land may have to two reasons. Firstly, even though a pool of available P could be removed by trees in forestland, there is a probability of P return through litter fall to the soil surface (Asmamaw and Mohammed, 2013). Secondly, microbes, which are abundant in the litter layers of the forest, may quickly add a high proportion of P under forest cover.

On the other hand, a higher AP in cultivated land than in grazing land may have three reasons. Firstly, cattle dung applied to cultivated fields may increase the level of P concentration in this land use; on the other hand, while cattle dung is collected, and thus removed, from grazing land (Table 1). Secondly, the frequent application of inorganic P fertilizer to the cultivated fields (Table 1) may provide a considerable amount of inorganic P to the soil of cultivated fields. Thirdly, a higher P release as a result of greater weathering processes on cultivated land than on grazing land may provide a higher amount of available P to the soil of cultivated land. This is because of repeated plowing to prepare the plot for cereal crop production. The finding in this study is in agreement with the observation made by Fantaw and Abdu (2011), also in Ethiopia.

3.3 pH, cation exchange capacity, and exchangeable basic cations

The soils in the study land uses have a mean pH between 5.4 and 6.1 (Table 3). Mean pH from forest soils was statistically different from the cultivated and grazing land ($P < 0.05$; Table 5). Compared to the pH of soils of forestland, the pH of soils of cultivated and grazing lands was lower (Table 4). Thus, soils in the cultivated land were more acidic than those of the forestland and grazing lands. This is expected as 13.2 % of Ethiopian soils are strongly to moderately acidic (pH < 5.5) (Ermias et al., 2013). This is because of intensive farming over a number of years with nitrogen fertilizers on cultivated land. Soil acidity is also a consequence of the leaching of basic cations in soils due to high rainfall, which results in rapid erosion. Cultivated land is characterized by the acidifying effects of acid-forming nitrogen fertilizer, poor nutrient cycling, and the mining of basic cations through harvested crops, soil erosion, and acid rain.

Table 4. Percentage changes in selected soil properties in cultivated and grazing land uses compared to forestland in northeastern Wellega, Ethiopia.

LU type	Sand	Silt	Clay	pH	AP	OM	TN	CEC	EK^+	ECa^{2+}	EMg^{2+}
Cropland	−43	−13	+169	−11.5	+2.8	−49	−43	−38.5	+7.7	−68	−56.8
Grassland	−26	−18	+123	−6.6	−42	−19	−16	−22	−7.7	−54	+21.2

Notes: LU – land use; EK^+ – exchangeable K^+; Eca^{2+} – exchangeable Ca^{2+}; EMg^{2+} – exchangeable Mg^{2+}; − indicates loss and + indicates gains.

Table 5. The correlation matrix for selected soil properties at 0–15 cm depth in northeastern Wellega, Ethiopia.

	OM	TN	CEC	Ca^{2+}	Mg^{2+}	pH	Silt
TN	0.80**						
CEC	0.80**	0.81**					
Ca	0.82**	0.76**	0.89**				
Mg	0.71**	0.67**	0.65**	0.52*			
pH	0.83**	0.76**	0.89**	0.88**	0.71**		
Clay	−0.74**	−0.54*	−0.77**	−0.74**	−0.32	−0.71**	−0.69**

**, * Correlations are significant at the 0.01 level and at the 0.05 level, respectively (two-tailed).

Soil acidity affects the process of other nutrient transformations, solubility, or plant availability of many plant essential nutrients (Barua and Haque, 2013). In acid soils (pH <6), nitrification will be slow and plants with the ability to take up NH^{+4} may have an advantage (Parras-Alcántra et al., 2013). Thus, in the study area, nitrification will be slow in cultivated land due to the acidity of soil. Acid soils affect the quantity, activity, and types of microorganisms in soils, which in turn influence the decomposition of organic materials (De Mûlenaere et al., 2014; Emiru and Gebrekidan, 2013). Acid soil prone areas are characterized by aluminum and manganese toxic to crop growth, constrained productivity through stunted growth, a poor response to applied fertilizer, and vulnerability to drought. In Ethiopia, soil management strategies such as the application of mineral fertilizers, lime, compost, and manure are used to ameliorate soil acidity. Soil liming can increase soil pH, supply essential plant nutrients (exchangeable Ca^{2+} and Mg^{2+}), make other essential nutrients more available, and prevent Mn and Al from being toxic to plant growth (Yao et al., 2010).

The mean CEC was highest in forestland and lowest in cultivated land (Table 3), and the differences between land uses are statistically significant ($P<0.05$; Table 5). Compared to the CEC of the soils of forestland, the CEC of the soils of cultivated and grazing lands were decreased (Table 4). Mean exchangeable Ca^{2+} content was highest in forestland and lowest in cultivated land (Table 3). The mean differences between forestland and cultivated lands and forestland and grazing lands are statistically significant ($P<0.05$, Table 5). The mean exchangeable Mg^{2+} was highest in grazing land and lowest in cultivated land (Table 3). Exchangeable Ca^{2+} was highest in forestland and lowest in cultivated land (Table 3). Compared to the soils of forestland, the overall pattern of CEC and exchangeable Ca^{2+}, and Mg^{2+} concentrations in cultivated land showed declining trends, but with varying rates (Table 4). Exchangeable Ca^{2+} showed the highest decline, followed by exchangeable Mg^{2+} and CEC (Table 4).

3.4 Relationships between selected soil properties

SOM, TN, CEC, exchangeable Ca^{2+} and Mg^{2+}, and pH are positively and significantly ($P<0.05$; Table 4) associated with each soil property except with available P, silt, and clay. In contrast, clay fraction is negatively and significantly ($P<0.05$) associated with organic matter (OM), total N, CEC, exchangeable Ca^{2+}, pH, and silt. SOM is significantly and strongly associated with pH. This finding was in agreement with other studies carried out in different parts of the country (e.g., Amare et al., 2013; Asmamaw and Mohammed, 2013; Lelisa et al., 2010). Thus, the conversion of forestland into cultivated lands likely leads to the degradation of SOM. Since SOM is the major influence for N in the soil, soil-available P, and CEC, it provides micronutrients through an effective soil food web. However, SOM in the soils of cultivated land can be increased through compost, cover crops, manures, minimum tillage, and crop rotation (Mikha et al., 2015; Martins et al., 2009). These can improve the concentration of physical, chemical, and biological soil parameters in the cultivated land.

There is no significant correlation between available P and any of the other chemical properties, most probably due to the generally low availability of potassium and the limited range of pH in the soil sampled. This finding does not agree with the fact that phosphorus availability is related to soil pH. CEC is significantly and strongly associated with exchangeable Ca^{2+}, pH, and clay; exchangeable Ca^{2+} is significantly and strongly associated with pH and clay. This shows the ability of CEC to retain cations and the dependency of CEC upon the pH of the soil, soil nutrient retention capacity, and the capacity to protect groundwater from cation contamination. Exchangeable Mg^{2+} is significantly and strongly associated with pH. On the other hand, clay is negatively correlated with all soil properties. The correlation was strong and statistically significant except for exchangeable Mg^{2+} and AP. Thus, clay in the soil has a negative influence on most soil properties. This suggests that both chemical and physical properties of soils are regulated by the clay properties of soil. Fantaw and Abdu (2011) and Lelissa et al. (2010) observed similar relationships.

4 Conclusions

The purpose of our study was to explore the effects of land use changes on the dynamics of soil properties and their implications for land degradation. The results indicate that cultivated land has the lowest organic matter, total nitrogen, cation exchange capacity, pH, and exchangeable Ca^{2+} and Mg^{2+} contents compared to forestland and grazing land. Soil organic matter is lowest, and it is caused by land use changes, cropping pattern and frequency, the removal of crop residues, and faster decomposition and oxidation processes as well as soil erosion on cultivated lands. The losses of these essential elements may contribute to increasing degradation prevalence on cultivated land. Land degradation, in turn, impairs the capacity of land to contribute to food security. So as to increase soil organic matter and consequently enhance the concentration of other nutrients in the soil of cultivated land, we suggest an integrated implementation of land management through compost, cover crops, manures, minimum tillage, and crop rotation. Soils in the cultivated land are more acidic ($pH < 5.5$) than those of the forestland and grazing lands. This may lead to aluminum and manganese toxicity, microbial conversion of NH_4^+ to nitrate will be slow, and crops with the ability to take up nitrate (NO_3^-) will be negatively affected. Thus, we suggest the liming of cultivated land so as to increase soil pH, supply essential plant nutrients (Ca^{2+} and Mg^{2+}), make other essential nutrients more available, and prevent Mn and Al^{-3} from being toxic to crop growth.

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