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Effects of land use changes on the dynamics of selected soil properties in the Northeast Wollega, 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 land uses, namely forestland, grazing land and cultivated land at 0–15 cm depth, and tested in National Soil Testing Center, Ministry of Agriculture of Ethiopia. Percentage changes of soil properties on cultivated and grazing land was computed and compared to forestland, and Analysis of variance (ANOVA) was used to test the significance of the changes. The results indicate that sand, silt, SOM, N, pH, CEC and Ca were the highest in forestlands. Mg was the highest in grazing land while clay, P and K were the highest in cultivated land. The percentage changes in sand, clay, SOM, pH, CEC, Ca and Mg were higher in cultivated land than the change in grazing land compared to forestland, except P. In terms of relationship between soil properties; SOM, N, CEC and Ca were strongly positively correlated with most of soil properties while P and silt have no significant relationship with any of other considered soil properties. Clay has negative correlation with all of soil properties. Generally, cultivated land has the least concentration of soil physical and chemical properties except clay and AP which suggest increasing degradation rate in soils of cultivated land. So as to increase SOM and other nutrients in the soil of cultivated land, integrated implementation of land management through compost, cover crops, manures, minimum tillage and crop rotation; and liming to increase soil pH are suggested.

1 Introduction

Land use changes have remarkable effects on the dynamics of soil properties (Ozgoz et al., 2013). For example, land use changes from forest cover to cultivated land may hinder addition of litter that enhances nutrient content of soils (Ozgoz et al., 2013), increase rates of erosion (Biro et al., 2013), loss of soil organic matter and nutrient

(Saha and Kukal, 2015), and accelerate rate of soil degradation (Barua and Haque, 2013). This process, in turn, leads to a decline in soil fertility and loss of biological activity and diversity (Yao et al., 2010). Vegetation cover is, therefore, a key indicator of soil degradation as plants play a role in the control of soil erosion (Bochet, 2015; Tejada and Benitez, 2014; Kropfl et al., 2013; Keesstra et al., 2009; Cedar, 1998). Zhang et al. (2015) has shown that forest destruction accelerated soil salinization in the Middle Reaches of the Tarim River, Xinjiang, China. Biro et al. (2013) in their study conducted in Gadarif region (Sudan), have found that management variables like grazing intensity and frequency, and over cultivation can substantially affect soil nutrient level by reducing composition of plant species, net primary productivity, above and belowground allocation in plants, and nutrient cycling pathways. Soil organic matter is lesser in extremely degraded areas where overgrazing manifested. Wang et al. (2011) found out that SOM, total N, available P, pH, exchangeable cations contents and CEC of the soil decreased significantly with conversion of secondary forest to Chinese Fir plantations in subtropical China. Saha and Kukal (2015) found higher bulk density and lower macro-porosity and water retention in cultivated soils than soils of grassland and forests. These indicated a degradation of soil properties due to the conversion of natural ecosystem to agricultural system.

In Ethiopia, rapid population growth and environmental factors lead to the conversion of natural forest and grassland into cultivated farmland (Gebreyesus, 2013). Such human-induced land use changes have contributed to soil degradation and soil loss by deteriorating the soil physical and chemical properties and make the ecosystem more delicate and susceptible to land degradation (Karltun et al., 2013). The country's inherently fragile soils, undulating terrain, highly erosive rainfall and the environmentally destructive farming methods that many farmers practice make soil highly vulnerable to soil erosion. Soil erosion is highest in cropland (42 $\mathrm{Mt\,ha^{-1}}$ average annual rate) compared with 5 $\mathrm{Mt\,ha^{-1}}$ from grassland. The problems of soil degradation caused both on-site and off-site changes; the country lost an estimated USD 1 billion per year. This has been confirmed by empirical studies carried out in different parts of Ethiopia (for example, Angassa, 2014; de Mulenaere et al., 2014; Tesfaye et al., 2014; Gebreyesus, 2013; Asmamaw and Mohamed, 2013; Fantaw and Abdu, 2011; Eyayu et al., 2009). And this is why is necessary to apply restoration strategies (Mekonnen et al., 2015, 2014; Bizoza, 2014; Zhao et al., 2013; Morera et al., 2010). The protection of soil is fundamental to keep having services from the soils 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) recounted an increase in bulk density and decrease in SOM, total N, exchangeable cations and CEC contents following the conversion of native woodlands into farmland and grazing land. In 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 declining pH value and the content of SOM in leached and degraded cultivated land than forestland in the Tara Gedam catchment and the adjacent agro-ecosystems of north western Ethiopia. Nega and Heluf (2013) on their part indicated deforestation has resulted in deterioration of soil organic matter and nutrient level in the soil. Similarly, Gebreyesus (2013) showed that soil quality indicators varied across the land use and soil management systems, among which natural forestland and afforestation protected areas are the most important systems in maintaining soil quality, where as cultivated and marginal lands seriously deteriorated the physical soil system. The same author revealed that soil organic carbon, pH, TN, available phosphorous and clay are significantly higher in natural forest and afforestation protected areas. On the other hand, Yeshanew et al. (2005) found SOC, total N and S concentration at 0–20 cm depth remained the same after natural forest conversion into eucalyptus plantation in Munesa, Ethiopia. Fantaw et al. (2007) in their study in Bale Mountains of Ethiopia have found no appreciable variation in soil organic carbon content after conversion of the natural forest to grazing land. These conflicting findings suggest that the hypothesis that conversion of forestland into cultivated or grazing land leads to changes of soil physical and chemical properties and degradation of the land is not at all times and in all places applicable.

This further suggests the need for empirical inquiry into effects of land use changes on the dynamics of selected soil properties and subsequent degradation of farm household land at different geographical area. To this end, little work was established on the effects of land use on soil properties which have implications for land degradation and land management strategies in the study area. Natural forest, the only preserved public forestland in the study area, was selected as the control field against which the selected soil parameters of cultivated and grazing lands were compared to assess the level of land degradation in the Northeast Wollega, Ethiopia. The interpretation of our results is limited to the current status of soil parameters considered in this study due to the fact that there was no documented data on the former land uses.

2 Materials and methods

2.1 Study area

The study area, covering 14 979 ha, is located between 9°45′ and 10°00′ N and 37°00′ and 37°15′ E (Fig. 1). Administratively, Northeast Wollega belongs Jarte Woreda, Horo-Guduru Wolega zone of Oromia Regional State, Ethiopia. Geologically, 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. As a result of degradation, the soils on steep slopes appear to have been downgraded to Regosols and Cambisols. Its altitude ranges between 1800 and 2657 m. Mean annual temperatures range between 22 and 28 °C. Annual rainfall, which is heavy during the summer months (June–August) ranges between 1750 and

2000 mm (EMS, 2013). For 2013, the population of the study area was projected to 58 339 of which only 10.09 % was urban population (CSA, 2013). The same document reported that the population of the district has increased by 39 % from 1980 to 2013. Except for a small percentage of the population living in the urban area, the inhabitants are farmers engaged in mixed crop-livestock farming system.

2.2 Current land use types

We identified and classified the present land use types through surveys in 2012 and 2013 supported by the elderly households who are assumed smart by the local community and aged 60 and above. 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 were under the same land cover i.e. forestland 40 years back. Since then, some portions were converted into cultivated and grazing lands while some area remained as forestland.

2.3 Soil sampling

Three adjacent sites were used in this study from study area, each located within the three different land use types, representing forestland, cultivated land and grazing land. All the three fields were almost similar in their slope, altitude and aspects. Each land use has been divided into five tiles (100 × 100 m in size); and within each tile four subplots were established, each with an area of 100 m^2, one in the center and three on a radial arm with 120° angles between them (Vågen and Winowiecki, 2013; Vågen et al., 2013). This form of sampling allows the assessment of variability of soil properties at different spatial scales (Vågen et al., 2013) (in our case among land uses at site level). Soil sampling was carried out in February 2014 from each of the three land use types. For each tile, soil samples were collected from each sub-plot and composite samples were prepared by hand mixing for 0–15 cm soil depth. Totally, we had 15 composite soil samples (five each from forestland, cultivated and grazing lands) at a depth of 0–15 cm, because the 0–15 cm represents the average plough layer in the area.

2.4 Soil analysis

Soil sample were analyzed following standard procedures as applied to tropical soils at the National Soil Laboratory Centre of the Ministry of Agriculture (MoA), Addis Ababa, Ethiopia. Disturbed soil sample were air-dried and grounded to pass through a 2 mm sieve prior to any laboratory analysis. Black et al. (1965) procedures have been used for particle size analysis (Bouyoucos Hydrometer Method); soil pH (potentiometric method in a 1 : 2.5 soil-water ratio); total nitrogen (following Kjeldhal procedure); and CEC and exchangeable Ca, Mg, K and Na (by the ammonium acetate at pH 7). Percentage organic carbon was estimated based on the Walkey-Black Method (Walkey and Black, 1934) and equivalent % content of SOM was determined by multiplying the % OC by the Van Bermmelen factor of 1.724 (Thompson and Troeh, 1978). Phosphorous was determined by means of Olsen method (Olsen et al., 1954).

2.5 Statistical analysis

The data was organized and entered into Statistical Package for Social Sciences (SPSS) software version 20 for windows. One-way ANOVA was under taken to test the significance of the effects of land use changes on the variation of soil textural class, soil pH, available P, soil organic matter content (%), total Nitrogen (%), CEC Cmol kg^{-1}, and Exchangeable bases (K^+, Ca^{2+}, and Mg^{2+}) Cmol kg^{-1} at the 0.05 level. After computing the ANOVA, all soil properties that showed significant differences among the land uses were subsequently analyzed for the significance of mean differences between land-use types employing the LSD Post Hoc multiple comparisons test at the 0.05 level.

Percentage changes in the soil properties of cultivated land or grazing land compared to forestland $\left(\mathrm{Ch}_{\mathrm{Cl,Gl}}\right)$ were computed by:

$$\mathrm{Ch}_{\mathrm{Cl,Gr}} = \frac{Lu_{\mathrm{Cl,orGl}} - Lu_{\mathrm{Fl}}}{Lu_{\mathrm{F1}}} \times 100 \tag{1}$$

Where, $\mathrm{Ch}_{\mathrm{Cl,Gl}}$:Percentage changes in soil property of cultivated or grazing lands compared to forestland; Lu_{Cl}, Lu_{Gl} and Lu_{Fl}: Mean value of 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

Soils physical properties such as depth, particle size distribution (texture), bulk density, structure and porosity are often among the most important parameters for evaluating the limitation and suitability of a unit of land (Gebreyesus, 2013). In this study only soil texture has been studied and the changes in this property have been related to the changes in these properties and soil chemistry.

Textural classes of topsoil of forestland, cultivated land and grazing land are sandy loam, clay and clay loam respectively (Table 3). Sand content of soils of forestland (73.6 %) is the highest and is the lowest on soils of cultivated land (29.6 %) while clay content of soils is the highest on cultivated land (42.9 %) and the lowest on soils of forestland (15.6 %). These differences are statistically significant ($P < 0.05$, Table 4). On the other hand, though the differences are not statistically significant, silt fraction is the highest in the forestland (32.8 %) and the lowest in grazing land (26.8 %). The percentage changes in sand particle size distribution is higher in cultivated land (−43 %) than the change in grazing land (−26 %) compared to forestland (Table 2). On the other hand, clay fraction on cultivated land and grazing land increased by 169 % and 123 %, respectively, compared to forestland. Lower content of sand and higher content of clay fractions in the cultivated land may be attributed to the process of plowing, clearing, disposing and leveling of farming fields (Table 1). These processes in turn enhance the weathering process that transforms sand and silt fractions into clay fractions. On the other hand, higher content of sand and lower content of clay fraction of forestland may be attributed to low rate of weathering processes and continual leaching of clay fraction from the upper mineral horizons of the forestland since leaching is most active in forestlands (Ozgoz, 2013).

Soils with high clay content have sufficient particle-to-particle contact points to form strong bonds when the soil dries which can lead to the formation of a strong crust (FAO, 2006). Soils of forestland with sandy loam texture are highly desirable for plant growth, because texturally this soil is permeable to air, water and plant roots and optimum store houses for plant nutrients (Eyayu et al., 2009). On the contrary, soils of cultivated land with highest clay fraction are the most compact soils. These soils though assumed to hold much more water and plant nutrients (Kartul et al., 2013) than forest and grazing lands respectively with sandy loam and clay loam texture, is manifested with problems of inadequate aeration, water lagging, increased runoff and erosion, and problem of workability during very dry and very wet periods (field observation).

3.2 Soil organic matter (SOM), total nitrogen (TN) and available phosphorous (AP)

The content of SOM was the highest in forest lands (9.04 %) and the lowest in cultivated land (4.59 %) while in grazing land (7.31 %) is in between (Table 3), and the differences are statistically significant ($P < 0.05$, Table 3). The percentage changes in SOM is higher in cultivated land (−49 %) than the change in grazing land (−19 %) compared to forestland (Table 2). Higher content of OM in the forest land attributed to the role played by plants; soil macrofauna (worms, large insects, etc.); soil microflora (bacteria, fungi, protozoa, algae, etc.); and microbial biomass (Table 1). Leaves from plants fall to the soil surface and dead macrofauna, microflora, and microbial biomass in the soil decompose and form organic matter of soils of forest land. Living soil organisms also decompose leaves and mix them with the upper part of the soil. On grazing lands, grass roots were fibrous near the soil surface and easily decompose, and adding organic matter. On the other hand, lower content of SOM on cultivated land may be attributed to accelerated rates of erosion and decomposition, because these processes were most active on cultivated lands than forest and grazing lands.

Since soil organic matter is composed chiefly of carbon, hydrogen, oxygen, nitrogen and smaller quantities of sulfur and other elements (USDA, 2014; Gebreyesus, 2013), it is an important indicator of soil and land health as it integrates several inherent soil properties and responds strongly to land-use change and land degradation processes (Vågen and Winowiecki, 2013; Aguilera et al., 2013). Thus, the highest organic fraction of forestland is potentially with the highest reservoir for plant essential nutrients of nitrogen, phosphorus, and sulfur (Zhang et al., 2015) compared to grazing and cultivated lands. It also increases soil water holding and cation exchange capacities, and enhances soil aggregation and structure of soils of forestland.

TN was lowest on cultivated land (0.25 %) followed by on grazing land (0.37 %). Expectedly, the mean value of TN was highest on soils of forestland (0.44 %) (Table 3). The differences between forest and cultivated lands and cultivated and grazing lands are statistically significant ($P < 0.05$), while the difference between forest and grazing lands is not significant (Table 4). The C : N ratio (12.1) was the highest on soils of forestland while it is the lowest on grazing land (10.8) (Table 3). The wider C : N ratio on soils of forestland indicates the prevalence of more biological (microbial) activities that might have been resulted by highest consumption rate of nitrogen by microbial in forest land than in grazing and cultivated lands. The content of AP was the highest in cultivated lands (3.7 ppm) and lowest in grazing land (2.1 ppm) while it is in between in forest land (3.6 ppm) (Table 3). The mean differences between soil-AP of forest and grazing lands, and cultivated and grazing lands are statistically significant ($P < 0.05$, Table 4), while the mean difference between forest and cultivated lands is not statistically significant (Table 4). Compared to the AP contents of forestland, AP of cultivated and grazing lands are higher by 2.8 % and lower by 4.2 % respectively (Table 2).

Weathered soil minerals, organic fertilizer and inorganic fertilizer are important pools of soil P (Assefa and van Keulen, 2009). Thus, the fact that soils in the forest land has higher AP than the grazing land may be attributed to two reasons. Firstly, even though, in forestland, a pool of available P could be removed by trees, there is a probability of P return through litter fall to soil surface (Asmamaw and Mohammed, 2013; Wang et al., 2011). Secondly, microbes which are abundant in the litter layers of the forest may quickly add high proportion of P pool under forest cover. On the other hand, a higher AP in cultivated land than grazing land may be attributed to three reasons. Firstly, applied cattle dung on cultivated field may increase level of P concentration in this land use, while cattle dung has been collected from grazing land (Table 1). Secondly, frequent application of inorganic P-fertilizer on the cultivated fields (Table 1) may provide a considerable amount of inorganic P pool to the soil of cultivated filed. Thirdly, a higher P release as a result of higher weathering process on cultivated land than on grazing land may provide higher amount of P to the soil of cultivated land. The finding in this study appeared in agreement with the observation made in Ethiopia by Fantaw and Abdu (2007).

3.3 pH, cation exchange capacity (CEC) and Exchangeable basic cations (Ca^{2+}, K^+ and Mg^{2+})

Dynamics in soil pH, CEC and exchangeable cations are important indicators of soil qualities of different land uses (Saha and Kukal, 2015). Soil pH affects the process of other nutrient transformations, solubility, or plant availability of many plant essential nutrients (McKie, 2014). It also affects the quantity, activity, and types of microorganisms in soils which in turn influence decomposition of organic materials (Barua and Haque, 2013). Therefore, soil pH is one of the several soil quality indicators that give useful information on soil dynamics and nutrient availability and how the soil resource is functioning (McKie, 2014). The soils in the study land uses have a mean pH of 5.4, 5.7 and

6.1 respectively on cultivated, grazing, and forest lands (Table 3). The mean differences between forestland and cultivated land, and forest land and grazing land are statistically significant ($P < 0.05$, Table 5), but the mean difference between cultivated and grazing lands is not significant (Table 5). Compared to the pH of soils of forestland, pH of soils of cultivated and grazing lands were lower by 11.5 and 6.6 %, respectively (Table 2). Different nutrients are available at different pH levels (McKie, 2014; de Mulenaere et al., 2014; Nega and Heluf, 2013). Low pH favors free metal cations and protonated anions, while higher pH favors carbonate or hydroxyl complexes (Tejada and Bentez, 2014; Yao et al., 2010).

Soil pH of the study area lies in the range between moderate to slight acidity denominations (Tejada and Bentez, 2014). Thus, soils in the cultivated land appeared more acidic than those of the forest and grazing lands. Recent studies have shown the pH decline occurring more rapidly in continuously cropped land (Gelaw et al., 2013). This variation may be happened because of intensive farming over a number of years with nitrogen fertilizers on cultivated land than forest and grazing lands. In general, it is said that a soil with an optimum pH today may be too acid or alkaline a decade from now, depending on land management (Gelaw et al., 2013). In the study area, on soil of cultivated land, aluminum and manganese may be toxic (Parra-Alcantra et al., 2013) to crops growth since its pH is less than 5.5 (Table 3). Lifting the soil pH of cultivated land > 5.5 effectively can eliminate this toxicity and there should also be an adequate supply of molybdenum available for legumes to flourish which in turn could fix good quantities of nitrogen in the soil (McKie, 2014).

PH also influences plants' and crops' N uptake. Plants and crops can take up N in the form of ammonium (NH_4^+) and nitrate (NO_3^-) respectively (Zeng et al., 2009). At pH's between 6 and 7, the microbial conversion of NH_4^+ to nitrate (nitrification) will be rapid, and crops generally take up nitrate, while in acid soils ($pH < 6$), nitrification will be slow, and plants with the ability to take up NH_4^+ may have an advantage (Parra-Alcantra et al., 2013). Thus, in the study area, in soils of cultivated land at pH's less than 6, nitrification will be slow, and crops with the ability to take up nitrate (NO_3^-) may have disadvantage. Problem of soil acidity of cultivated land can be managed by soil liming program (Gelaw et al., 2013). Soil liming can increase soil pH, supply essential plant nutrients (Ca and Mg), make other essential nutrients more available and prevent Mn and Al from being toxic to plant growth (Yao et al., 2010).

CEC, which is a good measure of the ability of a soil to retain and supply nutrient to a crop is naturally reliant on soil organic matter, pH, amount and type of clay mineralogy, land management (Tahir et al., 2009; Gol et al., 2010). The mean CEC was highest on forestland (32.85 $\mathrm{C\,mol\,kg^{-1}}$) and followed by grazing land (25.85 $\mathrm{C\,mol\,kg^{-1}}$), whereas it is the lowest on cultivated land (20.19 $\mathrm{C\,mol\,kg^{-1}}$) (Table 3); and the differences among the land uses are statistically significant ($P < 0.05$, Table 5). Compared to the CEC of soils of forestland, CEC of soils of cultivated and grazing lands were lower by 38.5 and 22.0 % respectively (Table 2). The mean $\mathrm{Ca^{2+}}$ was highest on forest land (12.81 $\mathrm{C\,mol\,kg^{-1}}$) and followed by grazing land (5.98 $\mathrm{C\,mol\,kg^{-1}}$), whereas it is the lowest on cultivated land (4.08 $\mathrm{C\,mol\,kg^{-1}}$). The mean differences between forest and cultivated lands, and forest and grazing lands are statistically significant ($P < 0.05$, Table 5).

The mean $\mathrm{Mg^{2+}}$ was highest (4.80 $\mathrm{C\,mol\,kg^{-1}}$) on grazing land and followed by forestland (3.96 $\mathrm{C\,mol\,kg^{-1}}$) whereas it is the lowest on cultivated land (1.71 $\mathrm{C\,mol\,kg^{-1}}$). The mean differences between forest and cultivated lands and cultivated and grazing lands are statistically significant ($P < 0.05$, Table 5). On the other hand, $\mathrm{K^{+}}$ was highest on cultivated land (0.14 $\mathrm{C\,mol\,g^{-1}}$) and followed by forestland (0.13 $\mathrm{C\,mol\,kg^{-1}}$), whereas it is the lowest on grazing land (0.12 $\mathrm{C\,mol\,kg^{-1}}$) (Table 3), however these differences are not statistically significant. Compared to $\mathrm{Ca^{2+}}$ and $\mathrm{Mg^{2+}}$ of soils of forestland, $\mathrm{Ca^{2+}}$ and $\mathrm{Mg^{2+}}$ of soils of cultivated land were lower by 68.0 and 56.8 % respectively, whereas on soils of grazing lands; $\mathrm{Ca^{2+}}$ was lower by 54.0 % while $\mathrm{Mg^{2+}}$ was higher by 21.2 % (Table 2). Compared to soils of forest land, the overall pattern of CEC, $\mathrm{Ca^{2+}}$ and $\mathrm{Mg^{2+}}$ concentration on cultivated land showed declining trends, however with varying rates; i.e., the highest rate of $\mathrm{Ca^{2+}}$, followed by $\mathrm{Mg^{2+}}$ and CEC (Table 2).

3.4 Relationships between selected soil properties

Bivariate relations between the different soil properties are presented in a correlation matrix, Table 6. Each of OM, TN, CEC, Ca, Mg, and pH are positively and significantly ($P < 0.05$) associated with each of soil properties except with AP, silt and clay (Table 6). In contrast, clay fraction is negatively and significantly ($P < 0.05$) associated with OM, TN, CEC, Ca, pH, and silt. Silt and AP have no any significant association ($P > 0.05$) with each of the soil properties.

SOM significantly and strongly associated with PH ($r = +0.83$, $P < 0.001$), TN (($r = +0.80$, $P < 0.001$), and CEC ($r = +0.80$, P<0.001). This finding was in agreement with other studies made in different places of the country (e.g. Tadele et al., 2013; Asmamaw and Mohammed, 2013; Lelisa et al., 2010). Thus, conversion of forestland into cultivated lands implies degradation of SOM that influences most of soil properties, since SOM is the major natural sources of N in the soil, provides P, increases CEC and provides other micronutrients through an effective soil food web (Braimoh and Vlak, 2014). However, SOM in soils of cultivated land possibly could be increased through compost, cover crops, manures, minimum tillage and crop rotation and consequently enhancing the concentration of other nutrients in the soil (Munoz-Rojas et al., 2015). Nevertheless, there is no significant correlation between AP and any of the other chemical properties most probably due to the generally low available potassium content in the soil sampled. This finding contradicts the fact that phosphorus availability is related to soil pH. CEC significantly and strongly associated with Ca ($r = +0.89$, $P < 0.001$), pH ($r = +0.89$, $P < 0.001$) and clay ($r = -0.77$, $P < 0.001$). Ca significantly and strongly associated with pH ($r = 0.88$, $P < 0.001$) and clay ($r = -0.74$, $P < 0.001$). Similarly, Mg significantly and strongly associated with pH ($r = 0.71$, $P < 0.01$). On the other hand, clay is negatively correlated with all soil properties. The correlation was strong and statistically significant except for Mg and AP. Thus, clay in the soil has negative influence on most of soil properties (Nega and Heluf, 2013). The strong and negative correlation between clay and CEC/OM can be attributed to the kaolinite clay mineral and crystal structure and pH level of the study area. The same relationship was also observed by some researchers in other regions of the country (e.g. Fantaw and Abdu, 2011; Lelissa et al., 2010).

4 Conclusion

The purpose of our study was to explore the effects of land use changes on the dynamics of soil properties and its implications for land degradation. The result indicate that cultivated land has the lowest OM, TN, CEC, pH, Ca and Mg contents compared to forestland and grazing land. Soil organic matter is lowest as caused by land use changes, cropping pattern and frequency, removal of crop residues, faster decomposition and oxidation process 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, is impairing the capacity of land to contribute to food security. So as to increase SOM and consequently enhancing the concentration of other nutrients in the soil of cultivated land, we suggest integrated implementation of land management through compost, cover crops, manures, minimum tillage and crop rotation. Soils in the cultivated land appeared more acidic ($\text{pH} < 5.5$) than those of the forest and grazing lands. This may lead to aluminum and manganese toxicity, microbial conversion of NH_4^+ to nitrate (nitrification) will be slow and crops with the ability to take up nitrate (NO_3^-) will be negatively affected. Thus, we suggest liming of cultivated land so as to increase soil pH, supply essential plant nutrients (Ca and Mg), make other essential nutrients more available and prevent Mn and Al from being toxic to crop growth (McKie, 2014).

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Table 1. A brief descriptions of the three land use types in the Jarte Area.

Land use type	Description
Forest land	Areas covered with long and dense trees forming closed canopy or nearly closed canopy (70–100 %), and without apparent and reported human impacts. This unit also includes undercanopy trees mixed with short bushes and open areas. Dominant tree species in this group include *Celtisaafricana*, *Calpurinasubdecandra* and *Croton mycrostachyus*. In addition, leaves from plants 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 was under forest cover. Since 40 years back, this land use evolved with permanent grass cover, with continuous grazing systems (information from local elders). Cattle dung is continuously collected as a source of household energy from this land use. Short grass species dominate this land unit. In some places rill erosions are observed.
Cultivated land	Formerly this land use was under forest cover and this land use evolved since 40 years back with continuous plowing, clearing and removal of above ground biomass (yield and crop residue), disposing and leveling of farming fields (information from local elders). 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 unit includes areas used for rain-fed agriculture. Major crops grown include cereals (maize, *teff*, and barley), legumes (beans, pea) and oil crops (*neug*).

Table 2. Changes in selected soil properties on cultivated and grazing land uses compared to forestland in Northeast Wollega, 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: − indicates loss and + indicates gains

Table 3. Selected soil properties at 0–15 cm depth at different land use types in Northeast Wollega.

Land use type	Depth (cm)	Soil fraction (%)			Textural class	pH (1 : 2.5 H_2O)	Available P (ppm)	Organic Matter (%)	Total Nitrogen (%)	C : N ratio	CEC C mol (+) kg^{-1}	Exchangeable bases C mol (+) kg^{-1}		
		Sand	Silt	Clay								K^+	Ca^{2+}	Mg^{2+}
FL	0–15	51.6	32.8	15.6	Sandy loam	6.1	3.6	9.04	0.44	12.1	32.85	0.13	12.81	3.96
GL	0–15	38.4	26.8	34.8	Clay loam	5.7	2.09	7.31	0.37	11.9	25.65	0.12	5.98	4.80
CL	0–15	29.6	28.4	42.0	Clay	5.4	3.7	4.59	0.25	10.8	20.19	0.14	4.08	1.71

Notes: FL = Forestland, CL = Cultivated land, GL = Grazing land, P = Phosphorous, C : N = Carbon : Nitrogen ratio, CEC = Cation exchange capacity, K^+ = Potassium, Ca^{2+} = Calcium, Mg^{2+} = Magnesium

Table 4. Variation of soil fractions (sand, silt and clay), available P and organic matter at 0–15 cm depth at three land use types in Northeast Wollega.

Land use	Land use	Sand %				Clay %				Available P (ppm)				Organic Matter (%)			
(I)	(J)	Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA	
		(I – J)		F	Sig.	(I – J)		F	Sig.	(I – J)		F	Sig.	(I – J)		F	Sig.
FL	CL	22[a]	2.4	41.4	0.000	−26.4[a]	4.6	17.03	0.000	−0.1[NS]	0.7	3.6	0.059	2.6[a]	0.4	17.2	0.000
	GL	13[a]	2.4			−19.2[a]	4.6			1.5[b]	0.7			1.0[b]	0.4		
CL	GL	−8.8[a]	2.4			7.2[NS]	4.6			1.6[b]	0.7			−1.6[a]	0.4		

Notes: FL = Forestland, CL = Cultivated land, GL = Grazing land, S.E = Standard Error of the mean, [a] significant at 0.01 level; [b] significant at 0.05 level; NS = Not Significant

Table 5. Variation of total nitrogen, pH (1 : 2.5 H_2O), CEC and exchangeable bases (Ca^{2+} and Mg^{2+}) at 0–15 cm depth at three land use types in Northeast Wollega.

Land use	Land use	Total Nitrogen (%)				pH (1 : 2.5 H_2O)				CECC mol(+) kg^{-1}				Exchangeable bases C mol (+) kg^{-1}							
(I)	(J)													Ca^{2+}				Mg^{2+}			
		Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA		Mean difference	S.E	One-way ANOVA	
		(I – J)		F	Sig.	(I – J)		F	Sig.	(I – J)		F	Sig.	(I – J)		F	Sig.	(I – J)		F	Sig.
FL	CL	0.19^{a}	0.03	11.8	0.001	0.73^{a}	0.16	10.03	0.003	12.7^{a}	2.3	14.85	0.001	8.7^{a}	1.7	14.96	0.001	2.3^{a}	0.6	13.92	0.001
	GL	0.07^{NS}	0.03			0.38^{b}	0.16			7.2^{a}	2.3			6.8^{a}	1.7			-0.8^{NS}	0.6		
CL	GL	-0.11^{b}	0.03			-0.34^{NS}	0.16			-5.5^{b}	2.3			-1.9^{NS}	1.7			-3.1^{a}	0.6		

Notes: FL = Forestland, CL = Cultivated land, GL = Grazing land, CEC = Cation exchange capacity, Ca^{2+} = Calcium, Mg^{2+} = Magnesium, S.E= Standard Error of the mean; ** Significant at 0.01 level; * Significant at 0.05 level; NS = Not Significant

Table 6. The correlation matrix for selected soil properties at 0–15 cm depth in Northeast Wollega.

	OM	TN	AP	CEC	Ca	Mg	pH	Silt	Clay
OM	1								
TN	0.80[a]	1							
AP	0.13	0.15	1						
CEC	0.80[a]	0.81[a]	0.24	1					
Ca	0.82[a]	0.76[a]	0.38	0.89[a]	1				
Mg	0.71[a]	0.67[a]	−0.20	0.65[a]	0.52[b]	1			
pH	0.83[a]	0.76[a]	0.23	0.89[a]	0.88[a]	0.71[a]	1		
Silt	0.25	0.06	0.22	0.37	0.32	−0.17	0.31	1	
Clay	−0.74[a]	−0.54[b]	−0.13	−0.77[a]	−0.74[a]	−0.32	−0.71[a]	−0.69[a]	1

[a], [b] Correlations are significant at the 0.01 level and at the 0.05 level respectively, (2-tailed).

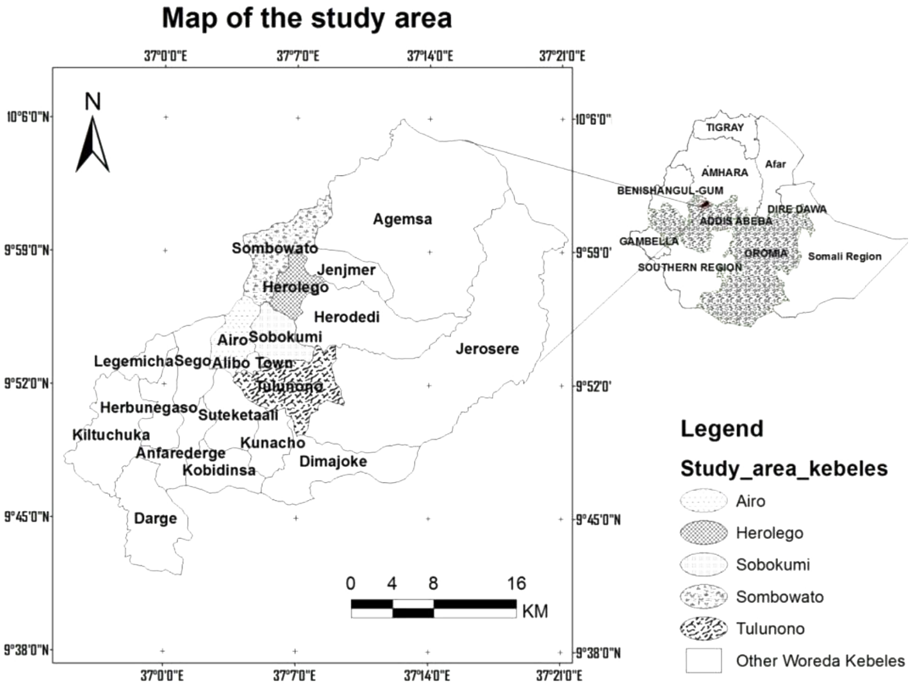

Figure 1. Location of Northeast Wollega, Jarte Area in Horo-Guduru Wollega Zone of Ethiopia.