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Assessment of Physicochemical Properties of Soil under Different Land Use Types at Wuye Gose Sub-Watershed, North Shoa Zone of Oromia Region, Ethiopia

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Abstract:

Assessing soil physicochemical properties and subsequent implication on soil fertility is essential for understanding the influence of agro-ecosystem transformation on agricultural soil quality and productivity. A study was conducted at Wuye Gose sub-watershed, North Shoa Zone of Oromia Region, Ethiopia, to assess the physicochemical properties of soil under different land use types. A total of 12 disturbed soil samples were taken for soil physicochemical properties determination and 24 undisturbed soil samples were taken for FC and BD determination from 0-30 cm depth. Grazing, cultivated, homestead and forest lands were identified. The soil samples were analyzed with standard laboratory procedures. All of the analyzed soil physicochemical properties were varied significantly ($P \leq 0.05$) among land uses, except pH and exchangeable Na. Textural classes of grazing land and cultivated land were loamy sand while it was sandy loam in homestead land and forest land. The BD ranged from 1.51 (GL) to 1.13 g/cm^3 (HL) and TP varied 57.25 (HL) to 43.04% (GL). Soil water content at FC was ranged from (45.18) in homestead to (36.35%v) in grazing land. Permanent wilting point, in %v, was high (16.99) in homestead and forest to low (8.49) in grazing and cultivated lands. Available water holding capacity was high (36.69) in homestead to low (19.36%v) in grazing lands. The EC in d S m$^{-,1}$ was high (0.420) in homestead to low (0.055) in cultivated land uses. The SOC and TN, in %, were high (2.13) in the forest to low (1.12) in cultivated and high (0.31) in the forest to low (0.12) in cultivated and homestead lands, respectively. The C: N was high (18.91) in the forest to low (10.07) in cultivated lands. The Av. P was high (2.52) in homestead to low (0.86 mg/kg) in cultivated lands. The CEC, exchangeable Ca, Mg, K and TEB, in cmol (+) kg $^{-1}$, were high (27.87) in homestead to low (9.28) in grazing, high (2.83) in homestead to low (1.27) in cultivated, high (5.45) in forest to low (1.81) in cultivated, high (2.00) in homestead to low (0.17) in cultivated and high (10.59) in homestead to low (3.63) in cultivated lands, respectively. The ranges of EDTA extractable Fe, Mn, Cu and Zn, in mg/kg, were 18.10 to 6.42, 12.20 to 6.87, 3.59 to 1.89, and 3.74 to 0.32, respectively. Most of the soil physicochemical properties of the study area varied from land use to land uses. In conclusion, fertility status varies as homestead land > forest land > grazing land > cultivated lands in the study area. Therefore, soil physicochemical management in CL and GL should be highly needed for the study area. For future research direction, soil physicochemical assessment should be done frequently by taking into account the site-soil-crop interaction since the soil is a dynamic and complex system.

Keywords: *Cultivated land; Forest land; Grazing land; Homestead land; Physicochemical*

1. **Introduction**

Soil productivity in Africa is declining as a result of inappropriate land use that lead to soil erosion and fertility depletion (Abreha, 2013). In Sub-Saharan Africa (SSA), soil fertility depletion is the fundamental cause for declining per capital food production as a result of a negative nutrient balance, with annual average losses ranging from 1.5 - 7.1 tons ha^{-1} year^{-1} of nitrogen (N), phosphorus (P) and potassium (K) mainly due to crop harvest, soil erosion, leaching and low inputs applied to the soil (Adesodu *et al.*, 2007).

In most developing countries like Ethiopia, the economy is primarily based on agricultural production (IFPRI, 2010). However, Ethiopian agriculture is under risk due to the unwise use of land resources and land use changes. Land use/land cover changes that involve the conversion of natural forest to farmland, open grazing and homestead land are widely practiced in Ethiopia. Such changes in land use are common, particularly in the highlands where there is high population density that directly depend on the natural resources (Tekle and Hedlund, 2000). These practices have caused agricultural soil quality degradation and land productivity decline contributing to low agricultural productivity and food insecurity in the country. Agricultural soil quality degradation, in this case, refers to the reduction in soil fertility due to various human activities. It is these human practices (application of fertilizer, removal of crop residues and plowing the land, etc.,) that are significant sources of the changes in soil physicochemical properties in Ethiopia (Kippe, 2002). In addition, intensive and continuous cultivation of land without proper management resulted in a decline in soil physical, chemical and biological properties which aggravate crop yield reduction and food insecurity (Habtamu *et al*., 2014).

The quality of soils determines the human's existing standard of living. The implication is that the survival and well-being of the present and future generations in countries with subsistence agriculture and old farming practices depends on the extent of maintaining soil qualities that are the basis of agricultural resources (Brady and Weil, 2002). The success in soil management to maintain the soil quality depends on an understanding of how the soil responds to agricultural practices over time (Negassa and Gebrekidan, 2004).

Despite the general understanding that land degradation is a threat to agricultural productivity, very few studies have been done to quantify the extent, rate (status) and processes of physicochemical soil depletion under different land uses and management practices in the country (Elias, 2002). Among these, the study conducted by Habtamu *et al.* (2014*)* and Berhanu (2016) indicated that conversion of the natural ecosystem into crop/cultivated land ecosystem has resulted in deterioration of the soil resource base and most of the physicochemical properties of soils were considerably influenced by the different land uses.

On the other hand, land use change, particularly from natural ecosystem to agricultural lands in general and to crop cultivation under poor management practices, in particular, is among the major causes of the decline in soil fertility followed by land degradation and low agricultural productivity as reported by Achalu *et al.* (2012). Another study also showed that the lower organic matter content in the cultivated land units might be due to higher rates of OM decomposition aggravated by intensive cultivation, and also perhaps because of low rates of return of organic materials as crop residues due to a number of competing ends, such as; animal feed, fuel, construction, etc. (Kedir *et al*., 2016). However, Kibebew and Mishra (2017) also reviewed the works on the relevance of organic farming in Ethiopian agriculture and concluded that tremendous organic resources are available in Ethiopia, particularly in the highlands, rather need to be exploited for their scientific utilization in maintaining as well as promoting the soil health and fertility status.

According to Addis *et al*. (2016), deforestation of native forests for crop production in the Gumara-Maksegnit watershed, in the Lake Tana basin, Ethiopia, dramatically increased the vulnerability of the soil for rainfall driven erosion. Most of the soil nutrients significantly decreased due to soil erosion from the landscape with increasing slope steepness and unwise utilization of land (Siraj *et al*., 2015). Similarly, Teshome *et al*. (2013) reported low clay in surface layers of cultivated lands in the Ababo Gambella region which might be due to selective removal of clay from the surface by erosion. The authors indicated that difference in land use systems (forest, cultivated, homestead and grazing) has a significant influence on soil physicochemical properties. The influence on most parameters was negative on soils of the cultivated land. For instance, soil OM, available P, CEC and available Cu contents of cultivated land was significantly lower than the adjacent forest land by 33, 20.3, 16 and 53.9%, respectively. Results of the study by Mulugeta and Kibebew (2016) also revealed that the exchangeable cations (Mg, K and Na), percent base saturation (PBS) and available micronutrient (Fe, Mn, Zn and Cu) contents of the grazing land were significantly lower than the adjacent forest land. In addition, research reports indicate that slope gradient and/or management practices are probably the reasons for the variation in physical and chemical fertility parameters from place to place (Mulugeta and Kibebew, 2016).

The study by Muche *et al*. (2015) indicated that variations in soil physicochemical properties were observed under the soils of selected land use types in the Northwestern Ethiopia. They further explained that variation in soil physicochemical properties could be related to frequent tillage practice, crop residue harvest, application of acid forming fertilizers and conversion of forest land to the other land use types that cause poor nutrient availability in the soil and hence limits crop production. According to Desta (1983), considerable differences were also observed in the micronutrient contents of cultivated lands in Ethiopia. While iron and manganese levels were reported adequate, zinc varied from low to high, and copper seemed to be the most deficient.

Even though the consequences of converting forest land to farmland, homestead land and grazing are well known, studies on the effects of land use types on physicochemical properties of soils and evaluation of soil fertility status in northern high lands of Ethiopia is not adequate. With regard to this, there is no information available on soil physicochemical properties under different land uses at Wuye Gose sub-watershed. Thus, assessing the impacts of land use induced changes on soil physicochemical properties and subsequent implication on soil fertility is essential for understanding the influence of agro-ecosystem transformation on agricultural soil quality and productivity and to indicate appropriate and sustainable agricultural soil and land management options. Therefore, this study was conducted at Wuye Gose sub-watershed with the following objectives:-

- To assess the physicochemical properties of soil under different land use types in the study area
- To determine the impact of different land use types on the physicochemical properties of soil under four different land uses in the study area

2. Materials and methods

2.1. Description of the Study Area

2.1.1. Location

The study was conducted at the Wuye Gose sub-watershed, located in the Kuyu District of North Shoa Zone in the Oromia National Regional State (Figure 1). The watershed is situated at about 25 km south of Gerbe Guracha town and Gerbe Guracha is located 156 km northwest of Addis Ababa (capital of Ethiopia). Geographically, the sub-watershed lies between $9^0$8'00" to $9^0$48'34"N and $38^0$4'00" to $38^0$24'13"E with altitudinal range of 2290 to 2346 m.a.s.l. The study site covers a total area of 200 hectares. The study site is surrounded by mountains with thick trap series of volcanic rocks, cretaceous sandstone and shaly sandstone (https://www.revolvy.com/main/index.php?s=Semien+Shewa).

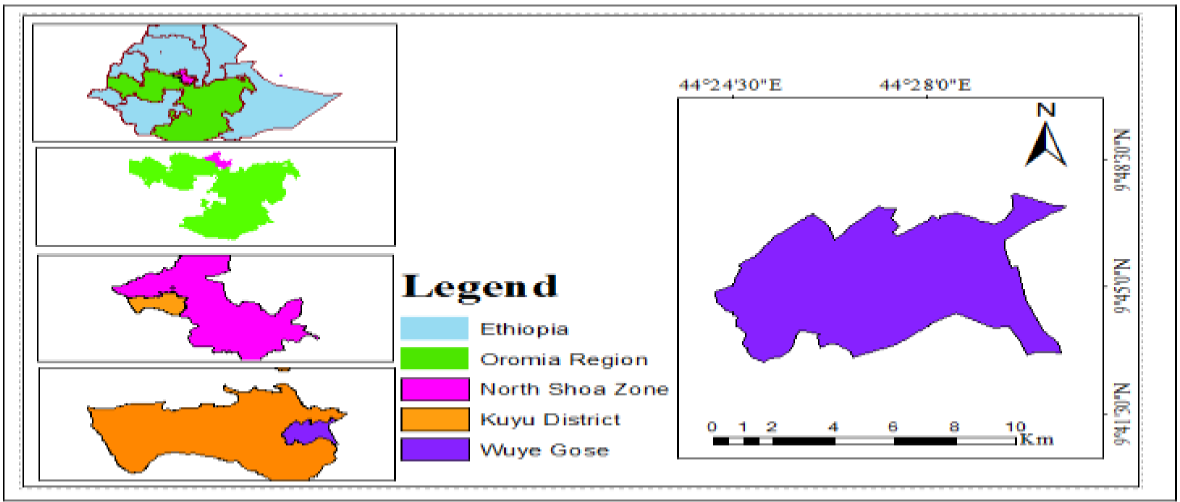

Figure 1. Loction map of the study area

2.1.2. Climate and soils of the study area

Based on the average monthly rainfall and temperature data available on the website (https://www.weather2visit.com/africa/ethiopia/gebre-guracha.htm) the study area is characterized by unimodal rainfall pattern with a total annual average rainfall of 1187 mm. The highest and the lowest rainfall are received in July and December, respectively. The maximum and minimum monthly average temperatures are 25.5 and 6.8 ºC, respectively. The mean monthly temperature is 16.15 ºC (Figure 2). The hottest and coldest months are April and December, respectively. The highest (71%) and lowest (45%) average relative humidity is in August and February, respectively. In some parts of the study area, there is some frost hazard during November and December. However, it does not happen regularly. According to the Ethiopian agro-climatic zonation (MOA, 1998), the study area falls in the highland (*Baddaa)* and mid altitude *(Badda darree)*.

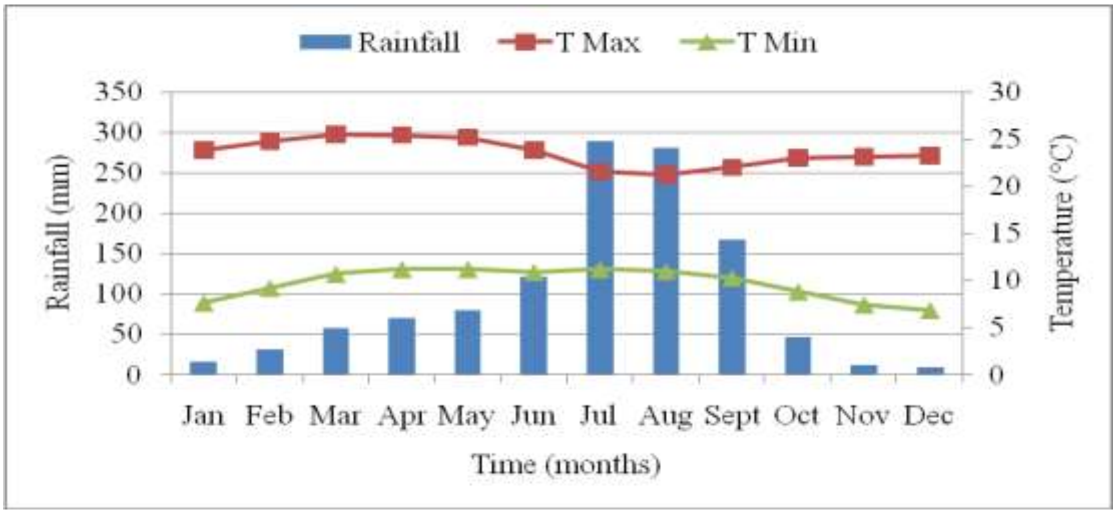

Figure 2. Average monthly rainfall, maximum (max) and minimum (min) temperature of Gerbe Guracha

According to the data from the Kuyu Woreda Agricultural and Rural Development Office (KWARDO), the dominant soil type of the district is Vertisols and soil depth of cultivable land ranges between 25 to 125 cm. Based on the information obtained from the semi-structured questionnaire, the soil of the study area is heavy clay and locally farmers call the soils of the study area white mixed with black "*Biyyee cabaree*", black "Biyye *kotichaa*" and red "*Biyyee dimilee*." According to local farmers` soil fertility evaluation, the fertility of the soils is medium and they attributed medium productivity of the soils to the weakness of the land (soil fertility declining).

2.1.3. Land use types, vegetation and management practices

Crop production (cultivation) and animal husbandry are the two main farming systems in the study area. Crop production is widely practiced through traditional subsistence farming on individual land holding under rainfed agriculture. The second land use type is the grazing land which is individually held by the farmers. Natural forest land that is found in the limited areas of the study area is the third land use type. Homestead land is the fourth land use type which is the residence area of the people in the study area. In the Wuye Gose sub-watershed, the cultivated land accounts for about 45.94%, while the grazing, homestead and natural forest lands together with lands under area closure are about 18.81, 7.50 and 2.48%, respectively.

The annual crops under rainfed production in the study area are *teff (Eragrostis tef (Zucc.) Trotter)* followed by niger seed *(Guizotia abyssinica)*, sorghum *(Sorghum bicolor L.)*, maize *(Zea mays L.) and* wheat (*Triticum aestivum* and *Triticum durum*), faba bean (*Vicia faba), and* pea *(Pisum sativum)*. In some pockets, barely (*Hordeum vulgare*), linseed (*Linum usitatissimum*), chickpea (*Cicer arietinum*), cowpea *(Vigna ungulculata)* and lentil (*Lens culinaris*) are produced. In addition, some horticultural crops like tomato

(*Lycopersicum esculentu***)**, potato (*Solanum tubersoum*), hot pepper (*Capsicum frutescence*), garlic (*Allium Sativum*) and onion (*Allium cepa L.*) are produced under irrigation and rainfed. Agriculture is entirely dependent upon rainfall and land is cultivated and/or plowed using draft animals.

The natural vegetation of Wuye Gose sub-watershed is very scattered except some trees and grasses on reserved areas. Almost all flat-topped plateaus have some form of natural vegetation whereas the gorges, valleys and sloppy sections are covered with scattered bushes and shrubs. Particularly, river valleys are covered with short and dense natural vegetation. Thorny bushes are the typical vegetation of the valleys. *Zigba* (*Podocarpus talacta*), *wanza* (*Cordiala africana*), *weira* (*Olean africana*), *sombo* (*Ekebcrgia capensis*) and acacia's species are also found in the lowland parts of the study area. On the area plateaus locally called "*Kawa Jirubusa*" now around the churches, many species of dense evergreen trees are found. Based on the information obtained from the semi-structured questionnaire currently, the re-plantation strategy is being implemented mainly dominated by *Eucalyptus* trees in the study area. In addition to re-plantation, under sustainable land management project II (SLMPII) currently funded by the World Bank and multiple stakeholders, several activities are being undertaken to manage soil erosion by terracing and planting grasses which are called "*Lagadasho*." The land management systems for the cultivation of such crops in the sub-watershed include terracing, repeated contour plowing, application of chemical fertilizers and herbicide, composting and hand weeding and so on for better yield. However, there is no practice of fallowing due to a shortage of land and high population pressure.

2.2. The Study Approach

In this study, a spatial analogue (alternative) approach was employed (Bhojvaid and Timmer, 1998). The spatial analogue method involves spatial sampling on sites that are subject to different land uses, but operating within a similar environment and on similar soil types. This approach has been widely used in several contexts such as to (1) evaluate effects of deforestation and subsequent cultivation (McDonagh *et al*., 2001), (2) assess soil carbon dynamics due to long-term land uses (Balesdent *et al*., 1988; Dominy *et al*., 2002), and (3) study nutrient dynamics and carbon storage changes.

In situations like Ethiopia in particular, where data on the long-term experiment are very rare, the spatial sampling approaches are valuable alternatives to study ecosystem dynamics from a temporal perspective. According to Young (1991), the analysis of soil fertility gradients using spatial sampling under different land use/management regimes could yield important information on where and to what extent, a soil fertility decline is taking place and a position could be reached from which to take action to arrest or reverse the problem. By using multiple samples for each field replicate, similar within-site variability is found in each of the ecosystems (Ruark and Zarnoch, 1992). Similarities between sites in soil properties that are known to be little influenced by land use and time can be used to justify comparability for soil studies in a chrono-sequence or spatial analogue system. Availability and/or cost may limit the use of remote sensing. To compensate for the gaps in information from remote sensing data, interviews with local people are a valuable complement. Therefore, a series of group discussions were made with the local community, government officials and development agens (DAs) members at Wuye Gose sub-watershed, Kuyu Woreda Agricultural and Rural Development Office (KWARDO) to get the primary data using a semi-structured questionnaire.

2.2.1. Selection of the study sites

In order to have general information about the land forms, land uses, topography and vegetation cover, a preliminary survey and field observation using the topographic map (1:50,000) of the study area was carried out during the year 2017. Field observation was made to determine the representative land uses and soils of the study area. Thus, cultivated land, grazing land, homestead land (residence areas) and forest land use types were identified for the study. From the cultivated lands, cereal crop land, especially *teff (Eragrostis tef (Zucc.) Trotter)*, under rainfed agriculture, was used while from the grazing lands, homestead and forest lands, for domestic animal grazing land, at residence area and indigenous natural forest land (reserved area), tree and shrub species, respectively, were selected (Table 1).

Table 1. Description of land use/cover classes identified in Wuye Gose sub-watershed area

Land use/cover	Description
Cultivated land	Land allocated for annual crop production especially *teff (Eragrostis tef (Zucc.) Trotter).*
Grazing land	Land allocated for domestic animal grazing, which is dominated by tall and short grasses.
Forest land	A land consisted of indigenous natural forest (reserved area), tree and shrub species.
Homestead land	This category of land consisted of residence areas.

2.2.2. Site selection

Four representative land use types, namely cultivated land (CL), grazing land (GL), homestead land (HL) and natural forest land (FL) were considered. The soils that are found at present under different land use types were presumed to have similar morphological, physical and chemical properties prior to their disturbance by different land use types. The observed differences in present soil conditions were assumed as being caused by the present land use practices or the introduction of the new land management. A plot with a 25 x 25 m^2 area was marked as a sample plot following a method applied by Chapman *et al.* (2009) for each land use type with three replications. Regarding the history of each sampling site from 50 years ago to present, including fertilization, management practices, drainage, surface soil color, and others were recorded using an open interview with local farmers and government agencies.

Based on the information obtained from semi-structured questionnaires, commercial fertilizers diammonium phosphate (DAP) and urea and organic fertilizers were used in the study area. The management practices of soil were terracing, draining by ridge and reforestation was undertaken to rehabilitate degraded soil and to restore its fertility for a long period of time. Before 50–60 years, many areas of the district were covered with forest. Since then, the natural woodland vegetation of the study area gradually decreased due to agricultural land expansion that brought the land under cultivation, grazing and homestead lands, as well as increased demand for fuel-wood. Currently, in the study area, there are very few natural forests and no fallow practices because of agricultural land expansion.

2.2.3. Soil sampling, techniques and sample preparations

Three main factors, such as depth, sampling intensity per unit area of the site, and the sampling design, were usually considered when developing soil-sampling protocols to monitor change in major soil fertility parameters. For the determination of soil physical and chemical properties, representative soil samples were collected from 25 m*25 m plot area from each land use with three replications based on slope similarity. Representative samples were collected from ten points per plot for each land use using sampling auger in an ‘X’ pattern and replicated three times. The samples were composited replication wise for each land use to make a total of 12 composite samples for all the four land use types considered. The samples were collected from the top 0-30 cm depth of the soil. Ten sub-samples were taken to prepare one composite soil sample from each land uses with each replication. Additionally, from each land use type three replicate of undisturbed soil samples (i.e., a total of 4*3*2= 24 undisturbed) of known volume were taken by using a sharp-edged steel cylinder core-sampler forced manually into the soil for bulk density (Wilding, 1985) and field capacity measurement.

During the collection of soil samples, dead plants, furrow, old manures, wet spots, and areas near trees were excluded. One kg of the composite samples were then properly labeled, bagged and transported to Haramaya University soil laboratory and air dried, ground and passed through 0.5 mm for total N and OC and through 2 mm sieve for the analysis of texture, BD, FC, PWP, pH, EC, SOC, TN, Av.P, CEC, exchangeable basic cations (Ca, Mg, K and Na), EA and extractable micronutrients (Fe, Mn, Zn and Cu).

2.2.4. Analysis of soil physical properties

Soil texture (%) was analyzed by the hydrometer method (Buoyoucos, 1951) after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$). Bulk density of the soil was determined for the undisturbed soil samples following the procedure, as indicated in Sahlemedhin and Taye (2000). The soils from core samples were oven dried at 105 °C for 24 hours (Blake, 1965) and the bulk density was calculated by dividing the masses of the oven dry soils (g) by the respective volumes (cm^3).

$$\text{Bulk density}\,(BD) = \frac{M\,(g)}{V\,(cm^3)}$$

where, M = Mass of oven- dry soil
V = Volume of the soil

Total porosity (%) was estimated from the values of bulk density (BD) and particle density (PD), with the latter assumed to have the generally used average value of 2.65 g cm^{-3} because, it is the average value of most particle density of agricultural soils (Brady and Weil, 2002) as:

$$\text{Total porosity}(\%) = \left[1 - \frac{BD}{2.65\ (\text{gcm}^{-3})}\right]*100$$

where BD = Bulk density

The soil-water retention capacity (%v) of the soil at -0.33 bar (FC) and -15 bars (PWP) were measured in the laboratory with the pressure plate apparatus while available water holding capacity was obtained by subtracting PWP from FC (Klute, 1965)

$$\text{AWHC (\%v)} = \text{FC} - \text{PWP}$$

where, AWHC = Available water holding capacity
FC = Field capacity
PWP = Permanent wilting point

2.2.5. Analysis of soil chemical properties

The pH (pH-H_2O) of the soil was measured potentiometrically using a glass electrode and pH meter in the supernatant suspension of 1:2.5 soil to water ratio (Jackson, 1973). Electrical conductivity (d S/m) was determined from the suspension prepared for pH analysis by (Jackson, 1973). Soil organic carbon (SOC) was determined by the wet oxidation method, as described by Walkley and Black (1934).

Total nitrogen (TN) (%) was measured titrimetrically following the Kjeldhal method, as described by Jackson (1973). Carbon to nitrogen ratio (C: N) was calculated from the ratio of soil organic carbon to total nitrogen. Available phosphorus (Av.P) was determined calorimetrically using spectrophotometer after the extraction of the soil samples with 0.5 M sodium bicarbonate ($NaHCO_3$) at pH 8.5 following the Olsen extraction method (Olsen *et al.*, 1954). Cation exchange capacity (CEC) (cmol (+) /kg of the soil) was determined from ammonium acetate saturated sample that is subsequently replaced by sodium from a percolated sodium chloride solution after removal of excess ammonium by repeated washing with alcohol (Chapman, 1965).

The exchangeable basic cations (Ca, Mg, K and Na) (cmol (+)/kg) were extracted with 1N ammonium acetate at pH 7 (Chapman, 1965). Exchangeable Ca and Mg were determined from this extract with an atomic absorption spectrophotometer (AAS), while exchangeable K and Na were determined from the same extract with a flame photometer (FP) (Chapman, 1965). Percent base saturation (PBS %) was computed as the ratio of the sum of exchangeable bases to the CEC multiplied by 100%.

$$\text{Percent base saturation (PBS\%)} = \frac{\sum EBC(cmol(+)kg^{-1})}{CEC(cmol(+)kg^{-1})} * 100$$

where, EBC = Exchangeable basic cation

CEC= Cation exchange capacity

The CEC of clay fraction was calculated from the soil CEC as the Cation exchange of soil divided by the percentage of clay multiplied by 100.

$$\text{CEC (cmol(+) kg}^{-1}\text{ clay)} = \frac{\text{CEC(cmol(+) kg}^{-1}\text{ soil)}}{\text{\% clay}} * 100$$

Exchangeable acidity (H^+ and AL^{+3}) (cmol (+) kg^{-1} of soil) was determined by saturating the soil sample with 1M KCl solution and titrating with 0.02M NaOH as described by Rowell (1994). Effective cation exchange capacity (ECEC) (cmol (+)/kg of soil) was determined by the summation of exchangeable bases and exchangeable acidity (Sahlemedhin and Taye, 2000).

$$\text{Effective cation exchange capacity (ECEC)} = \text{EB} + \text{EA}$$

where EB= Exchangeable bases

EA= Exchangeable acidity

Extractable micronutrients (Fe, Mn, Zn and Cu) were extracted with ethylene-diamaine-tetra acetic acid (EDTA) method as described by Okalebo *et al.* (2002). The amount of the micronutrients in the extract was determined by the atomic absorption spectrophotometer in comparison with the standards at 248.3, 279.5, 324.7 and 213.9 nm wavelengths for Fe, Mn, Cu and Zn, respectively.

2. 3. Soil Fertility Evaluation

Nutrient management practices formulated to achieve economically optimum plant performance as well as minimal leakage of plant nutrients from the soil-plant system can only be optimized after soil fertility evaluation. Thus, soil fertility evaluation is a central feature of modern soil fertility management. The fundamental purpose of soil fertility evaluation is to quantify the ability of soils to supply nutrients for plant growth. Soil fertility evaluation can be carried out using a range of field and laboratory diagnostic techniques and a series of increasingly sophisticated empirical and/or theoretical models that quantitatively relate indicators of soil fertility to plant response (Bijay *et al.*, 2015). In this research description based on ratings of plants, nutrients were employed as a soil fertility evaluation procedure.

3.4. Statistical Analysis

The data obtained from the laboratory analysis were subjected to a one-way analysis of variance (ANOVA) using the general linear model (GLM) procedure of the statistical analysis system (SAS) software version 9.1.3 (SAS, 2002) to determine the statistical difference in soil characteristics among land use types. Moreover, the least significant difference fisher's (LSD) test ($P \leq 0.05$) was used to compare and separate for significant means. A simple linear correlation coefficient analysis was also carried out for selected soil parameters to examine the associations among selected soil physicochemical parameters.

3. Results and discussion

3.1. Soil Physical Properties under Different Land Use Types

3.1.1. Texture

The mean values of the particle size distribution (texture) of each land use are presented in (Table 2). The results of the study revealed that the textural classes of soils under the grazing land (GL) and cultivated land (CL) are loamy sand while sandy loam in homestead land (HL) and forest land (FL) uses (Table 2). The differences in textural class among land use might be due to the difference in parent material, land use changes over a long period and pedogenic processes in the study area. This is in agreement with the study by

Brady and Weil (2002) who reported that land uses might have contributed indirectly for the changes in soil particle size distribution, particularly in the surface layers as a result of removal of particles through pedogenic processes over a long period, such as; translocation, transformation, deposition and weathering, which are regulated by management practices and which can alter the texture of soils. Generally, sand size fraction is dominant in the upper 0 - 30 cm layer of the soil from which samples were collected.

A sand fraction was significantly ($p \leq 0.05$) different among the four land uses, while the silt and clay fractions were highly significantly ($p \leq 0.01$) different between land uses (Table 2). Considering the four land uses, the highest (88.00%) mean sand fraction was recorded in the soils of the GL and the lowest (76.90%) was recorded in the soils of the FL followed by the HL (Table 2). This may be due to selective removal of clay and silt fraction downward through percolation from GL because it is vulnerable to the percolation of fine particles while animals remove protective grasses. Similarly, Teshome *et al.* (2013) reported the highest sand fraction in GL than other adjacent CL and natural FL uses.

However, mean clay content in the surface layer (0-30 cm) was lowest (5.00%) in GL and lower (8.43%) in CL as compared to the HL which recorded the highest (11.62%) mean value (Table 2). A negative (r = -0.89***) and significant ($p \leq 0.001$) correlation was obtained between clay and sand fractions (Table 7). The reason for the lowest clay in surface layers of GL and lower in CL's might be due to selective removal of clay from the surface by erosion, tillage activities in CL and transformation of clay minerals to other minerals by weathering and other pedogenetic processes. This is in agreement with the previous finding of Teshome *et al*. (2013) at the Abobo area, western Ethiopia.

On the other hand, the highest (11.70%) mean silt fraction was recorded for soils of the FL which is statistically equal to the silt in the HL (10.61%) in the 0-30 cm surface layer, whereas, it was lowest (7.00%) in the soils of the CL followed by GL (7.30%) (Table 2). This result disagrees with the result of Teshome *et al*. (2013) who reported the highest silt in CL. However, Achalu *et al.* (2012) reported the highest silt fraction for soils of FL in the Bedele area in Ilubabor Zone, South western Ethiopia. A negative (r = -0.78**) and significant ($p \leq 0.01$) correlation was observed between silt and sand, while positive (r = 0.74**) and significant ($p \leq 0.01$) correlation was recorded between silt and clay fractions (Table 7).

3.1.2. Bulk density and total porosity

The results of the analysis of variance indicated that land use types significantly ($P \leq 0.05$) affected soil bulk density (BD) (Table 2). Based on the different land uses effects on soil BD, the highest (1.51 g cm^{-3}) mean soil BD value was recorded for the surface layer (0-30 cm) of the GL which is similar to that of CL (1.44 g cm^{-3}), whereas, the lowest (1.13 g cm^{-3}) was recorded for the surface layer of the HL which is statistically not different from that of the FL (1.27 g cm^{-3}) (Table 2). The possible reason for the highest BD value recorded for GL was due to the trampling effect of livestock during free grazing. Muche *et al.* (2015) reported higher BD value for soils of GL and attributed to the trampling effect of livestock during free grazing activities. Contrary to the case of GL, the lowest BD recorded in HL was due to the highest clay and TP content (Table 2). This was shown by correlation analysis result that clay fraction was negatively (r = -0.60*) and significantly ($p \leq 0.05$) correlated to BD (Table 7).

According to Bohn *et al.* (2001), the acceptable range of BD is 1.3 to 1.4 gm cm^{-3} for inorganic agricultural soils. Based on this, two of the BD values of the studied soils of the study area were high in GL and CL uses which are high to limit root penetration and restrict the movement of water and air. On the other hand, the soil BD values of HL and FL were in the range that could not limit root penetration and restrict the movement of water and air. This indicates the existence of loose soil conditions in HL and FL; therefore, the soils of the study area under FL and HL uses have a good structure.

Total porosity (TP) of the soil can be used as an indication of the degree of compaction in the soil in the same way as BD is used. Statistically, the TP was significantly ($P \leq 0.05$) different among the land uses (Table 2). Accordingly, the highest (57.25%) mean TP was observed in the soils of the HL, while the lowest

(43.04%) was recorded in the soils of the GL (Table 2). This was due to the highest clay fraction and lowest BD content of HL. On the other hand, the low clay content and high BD of soils under GL might be the reason for the lower TP. This is in agreement with the result reported by Habtamu *et al.* (2014) implyied that compaction by grazing increased BD and intern lowered TP of soil.

The TP decreased from the HL, followed by the FL to the CL and GL (Table 2). This trend followed clay fraction (Table 2) and the fact that as BD decreased TP of the soil increased and vice versa. This was due to the fact that as BD increases the pore space of the soil might decrease and the soil particle compact together hindering the air and water circulation between soil pore spaces which intern decrease TP of the soil. According to the rating of FAO (2006b), the percent TP of all land uses was very high (> 40%). Higher TP observed in the study area implies that the soil has a better aggregation and indicates better conditions for crop production and to provide good aeration for microorganisms. Since, TP values were derived solely from manipulating values of BD, with a generally assumed of particle density to be 2.65 g cm^{-3}, therefore, factors that affect BD also has a direct effect on TP.

Table 2. Soil particle size distribution**,** textural class, bulk density and total porosity under different land uses at Wuye Gose sub-watershed

	Particle size distribution (%)			Textural class	BD	
Land uses	Sand	Silt	Clay		(g cm^{-3})	TP (%)
GL	88.00^{a}	7.30^{b}	5.00^{c}	Loamy Sand	1.51^{a}	43.04^{b}
CL	84.27^{ab}	7.00^{b}	8.43^{b}	Loamy sand	1.44^{a}	45.52^{b}
HL	77.77^{cb}	10.61^{a}	11.62^{a}	Sandy Loam	1.13^{b}	57.25^{a}
FL	76.90^{c}	11.70^{a}	11.40^{ab}	Sandy Loam	1.27^{ab}	51.90^{ab}
LSD (0.05)	6.85	0.61	3.08		0.28	10.54
SEM (±)	2.10	0.19	0.94		0.09	3.23
F-test	*	**	**		*	*
CV (%)	4.45	3.59	17.82		11.08	11.32

GL= grazing land; CL= cultivated land; HL= homestead land; FL= forest land; BD= bulk density; TP=total porosity; LSD = least significant difference; SEM = Standard error of mean; F= Fisher's, CV = Coefficient of variation. Means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$ according to Fisher's LSD

3.1.3. Soil water content and retention capacity

The mean values of soil-water content at field capacity (FC), permanent wilting point (PWP) and available water holding capacity (AWHC) content under different land uses are presented in (Figure 3). Soil-water retention at FC, PWP and AWHC was highly significantly ($P \leq 0.01$) affected by different land use types (Appendix Table 1). The highest (45.18%v) numerical values of FC were recorded from soils under HL of the surface layer (0-30 cm), while the smallest (36.35%v) was recorded for GL soils (Figure 3). This indicates the fact that the water holding capacity of the soil depends on the soil particle size distribution, such as; sand, silt, clay, land uses, soil BD and TP. The clay fraction and TP of HL were the highest and its BD was lowest, which contributes to higher water content at FC, while GL had the lowest value of clay fraction and TP and highest BD which led to lower water content at FC. Achalu et *al.* (2012) reported similar results for the soil of Western Oromia, Ethiopia and attributed variation in water content at FC and PWP to differences in their sand, silt and clay fractions.

Results of the present study demonstrated that soils under different land use differ in their water content at PWP and AWHC. The highest water content (16.99%v) at PWP was recorded under the soil of HL and FL uses, while the smallest (8.49%v) was recorded under the soil of GL and CL uses (Figure 3). The reason for the highest mean value of water at PWP recorded for HL and FL might be that soil under both lands uses contain a high amount of clay which absorb hydroscopic water in clay colloidal particle. This result is in consent with the finding of Abera and Kefyalew (2017) who reported increased water content at PWP with increased clay content.

Water retention at this matric suction (PWP) is mainly due to the adsorption of clay rather than capillary effects according to Teferi (2008). Adsorption is dependent on the specific surface available for the attraction of water molecules around the charged colloidal surfaces. The present study revealed that the highest (36.69%v) AWHC was recorded from HL, while the lowest (19.36%v) was recorded from GL (Figure 3). This is due to high and low clay (colloidal particles) content of HL and GL's, respectively. This is in agreement with the finding of Emerson (1995), who concluded that higher clay content caused an increase in water content at FC and PWP.

The observed results of this study revealed that soils under different land uses differed in their water content at FC and PWP because they vary in the sand, silt and clay contents, BD, TP and land use. On the other hand, Gebeyaw (2007) demonstrated and generalized that soils under different land use in Maybar areas of South Wello Zone, North Ethiopia differed in their water content at FC and PWP because they vary in the sand, silt and clay contents. Changes in the soil-water level and its possible effect on AWHC indicate that the soil water retention of the study area has been disturbed by changes in land use types. In favor of this, Ebtisam and Dardiry (2007) reported that variations in soil organic matter and clay contents of land uses cause variation in soil water retention capacity.

Water holding capacity is one of the physical properties of soils in terms of which soil physical fertility (the physical property of soil responsibly for soil fertility) status is evaluated. According to Beernaert (1990), available water content values of < 8, 8-12, 12-19, 19-21 and > 21% (by volume) are rated as very low, low, medium, high and as very high, respectively. In line with this, the status of AWHC (in %v) of the soils in the study area was high for land uses of GL and CL and very high for the HL and FL uses.

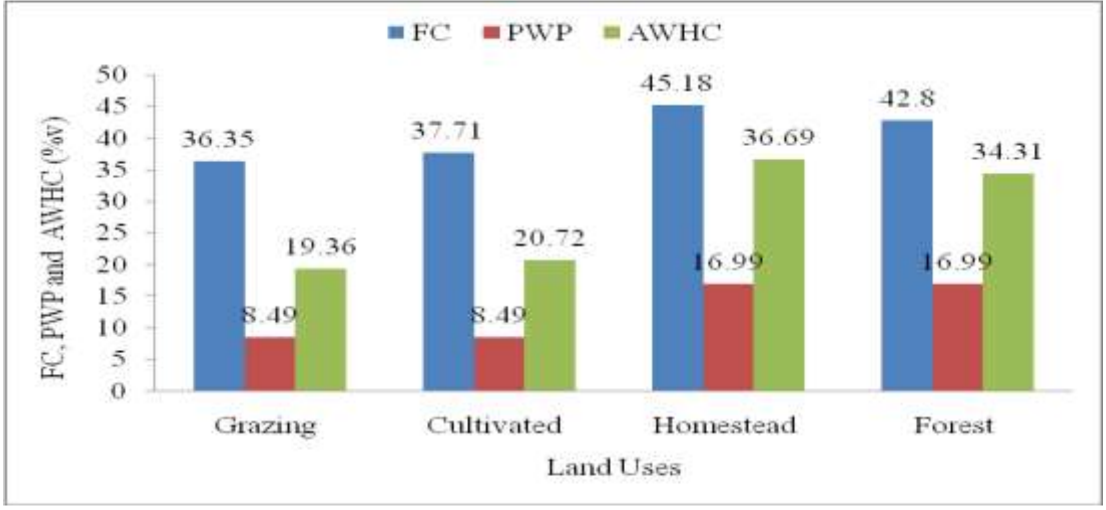

Figure 3. Soil water retention capacity at FC, PWP and AWHC for different land uses at the study area

3.2. Soil Chemical Properties Under different Land Uses

Soil chemical properties are the most important factors that affect soil fertility and determine the nutrient supplying power of soil to the plants and microbes. In this study, the most important soil chemical properties were analyzed and are presented in Tables 3-6.

3.2.1. Soil reaction pH (1:2.5 H_2O) and electrical conductivity

The difference in soil pH (1:2.5 H_2O) was found to be non significant ($P > 0.05$) among the land use types (Table 3). However, there were slight numerical variations among the soil pH values of the land uses. On the contrary, Gebeyaw (2015) found a significant difference in pH value among land uses and indicated that the lower value of pH under the CL might be due to two major reasons. The first is depletion of basic cations in crop harvest and drainage to streams in runoff generated from accelerated erosions. Secondly, it might be due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution and thereby lowers soil pH. Generally, the pH values recorded for the soil of the study area are within the ranges slightly acid for GL and FL, while moderately acid for CL and neutral for HL according to Tekalign (1991), soil pH (1:2.5 H_2O) rating.

Electrical conductivity (EC) of soils was highly significantly ($P \leq 0.01$) different due to the land uses (Table 3). Considering the effects of land uses on EC, the lowest (0.055 d S m^{-1}) mean value was recorded for the surface layer (0-30 cm) of the CL and the highest (0.420 d S m^{-1}) mean value of EC was recorded for the HL. The EC values are invariably insignificant to cause any soil salinity problem.

The reason for the highest EC recorded in HL might be that it contains the highest amount of basic cations (Table 4). In contrast to this, the CL contains the lowest amount of basic cations which might be removed by intensive cultivation and washing away of basic cation by erosion and leaching. This result is in agreement with the results reported by Berhanu (2016) who stated that the lowest EC of CL could be associated with the profound loss of exchangeable bases. As per the rating established by US Salinity Laboratory Staff (1954), the soils of the study area fall under non saline (low EC, <2 d S/m) condition. This might be due to relatively higher rainfall and the undulating nature of the watershed with free drainage conditions, which favored the removal of soluble salts with the percolating and drainage water. This was also similar to the research finding, reported by Swarnam *et al.* (2004) and Kedir (2015).

Table 3. Soil pH, electrical conductivity, organic carbon, total nitrogen, C: N ratio and available phosphorus (Av.P) at the study area

Land uses	pH-H_2O (1:2.5)	EC (dS/m)	OC	TN	C:N	Av.P (mg/Kg soil)
GL	6.00	0.070^c	1.56^b	0.13^b	16.80^b	1.69^b
CL	5.99	0.055^c	1.12^c	0.12^b	10.07^d	0.86^c
HL	6.70	0.420^a	1.44^b	0.12^b	14.58^c	2.52^a
FL	6.02	0.155^b	2.13^a	0.31^a	18.91^a	2.36^{ab}
LSD(0.05)	NS	0.05	0.18	0.11	0.53	0.77
SEM ($\pm$)	0.28	0.02	0.06	0.03	0.16	0.24
F-test	NS	**	**	*	**	*
CV (%)	7.85	16.98	6.25	34.41	1.88	22.16

GL= grazing land; CL= cultivated land; HL= homestead land; FL= forest land; NS = non significant; LSD = least significant difference; SEM = Standard error of mean; F= Fisher's; CV = Coefficient of variation. Means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$ Fisher's LSD

3.2.2. Soil organic carbon

Analysis of variance indicated that soil organic carbon (SOC) content was highly significantly ($P \leq 0.01$) influenced by land use types (Table 3). The highest (2.13%) mean SOC content was recorded for the FL soil, while the lowest (1.12%) was recorded for the soil under CL. The SOC mean value has increased from CL to HL, GL and FL, respectively (Table 3). This is due to the fact that in FL, falling of plant materials could increase SOC. On the contrary, the lower SOC content of CL might result from the removal of SOC through oxidation as a result of intensive cultivation and erosion which deplete SOC.

In consent to this, the study by Abebe and Endalkachew (2012), Abebe *et al*. (2013) and Tuma (2007) on SOC in Ethiopia implied that over-cultivation depletes SOC. In addition to this, the depletion of SOC was higher in CL than other land uses. This is attributed to the fact that cultivation increases soil aeration which enhances decompositions of SOC by soil microorganisms and most of the percent SOC produced in soils of CL is removed with harvested plant biomass, causing a reduction in SOC contents. On the other hand, less soil disturbance in the FL and GL might have apparently led to the observed increase in SOC content as compared to the soils under HL and CL. This result is in agreement with the result reported by Berhanu (2016) which stated that under the CL use type losses of SOC were not fully compensated by organic matter inputs from the crop residues. These effects in such tropical soils could also be due to the effects of frequent tillage practices coupled with reduced SOC inputs and almost complete removal of crop residues from the cultivated fields for various uses.

This result is also in agreement with the result reported by Achalu *et al.* (2012) in western Oromia stating higher SOC content was observed in natural FL while the lower in CL due to plant litter fall which intern enhanced the fraction of soil organic matter in soils of FL. The authors also described that relative to the FL, percent SOC contents in soils of CL were depleted by 54.62% and conversion of FL to CL has been associated with a reduction in percent soil organic matter content of the top soil. As per the rating of SOC content suggested by Tekalign (1991), the SOC content of the study area is categorized as a medium for the soils of the FL and GL, while the low for soils of HL and CL uses types (Appendix Table 2).

3.2.3. Total nitrogen and carbon to nitrogen ratio

Analysis of variance showed that the total nitrogen (TN) was significantly ($P \leq 0.05$) and carbon to nitrogen ratio (C: N) was highly significantly ($P \leq 0.01$) influenced by different land use types (Table 3). Based on the effect of land uses on soil TN under different land uses, the highest (0.31%) mean value of the TN was recorded in the surface layers (0-30 cm) of the FL, while the lowest (0.12%) was obtained from the other land use types (Table 3). This trend indicates soil TN comes from the SOC of FL which had relatively high SOC, while CL and HL had a low amount of SOC content (Table 3).

The low TN content recorded in the soils of the CL and HL might be due to the rapid mineralization of SOC. Reduced input of plant residues in such cereal-based farming systems into the soils is expected to contribute to the depletion of SOC, thereby TN in these CL of soils. On the other hand, nitrate ions which are not absorbed by the negatively charged colloids that dominate most soils, may move with drainage water and leach from the soil in CL and HL. This finding is in agreement with the findings of Berhanu (2016) who reported variation of TN paralleled with that of the change in SOC content in soils of Girar Jarso of North Shoa Zone, Oromia, Ethiopia.

Furthermore, Tisdale *et al*. (2002) and Gebreselassie (2002) reported low input of plant residues resulted in low TN. Similarly, the results of the SOC of this study are in accordance with the findings of Tuma (2007) who reported that the intensive and continuous cultivation forced oxidation of SOC and thus resulted in a reduction of TN. Tewabe (2013) stated that OM is the main supplier of soil N, S and P in low input farming systems and continuous decline in the SOC content of soils of CL use types is likely to affect the soil productivity. Thus, as per the ratings of TN by Landon (1991), the TN content of soils of the study area was medium for FL, while the low for rest lands.

Statistically, the distribution of C: N followed similar patterns with SOC distribution except for little variation within the land uses. The highest (18.91) C: N mean value was recorded for FL while the lowest (10.07) C: N for the soil of CL, followed by GL to HL uses. Aeration during tillage that enhanced mineralization rates of organic nitrogen and low input of SOC, crop residues removal from CL could probably be the causes for the low level of C: N ratio in CL. The narrow C: N ratio in the soil of CL concurs with the study of Abbasi *et al*. (2007) who concluded that higher microbial activity and more CO_2 evolution and its loss to the atmosphere in the top (0-20 cm) soil layer resulted to the narrow C: N ratio. The C: N ratios of soils in the study area were within the range of 8:1–15:1 (Prasad and Power, 1997), in CL and HL, which is commonly cited as the general C: N ratio of mineral soils. In contrary to this, C: N ratios of the soil of FL and GL were greater than the range suggested by Prasad and Power (1997) which indicates a low rate of mineralization of SOC in those land uses.

3.2.4. Available phosphorus

The results of the analysis of variance indicated that available phosphorus (Av.P) content was significantly ($P \leq 0.05$) affected by land uses (Table 3). Accordingly, the highest (2.52 mg kg^{-1}) mean Av.P was recorded in the surface layer (0-30 cm) of the HL, followed by FL, while the lowest (0.86 mg kg^{-1}) was for the surface layers (0-30 cm) of CL (Table 3). As per the ratings of Cottenie (1980), the Av.P was very low Av.P in all land use types.

The reason for the relatively high Av.P content of HL might be the addition of manures and ashes. Furthermore, higher Av.P could be attributed to higher CEC content soil of the HL. These relations were revealed by significant ($P \leq 0.01$) and positive ($r = 0.74^{**}$) correlation between soil CEC and Av.P (Table 7). The lower content of Av.P in CL might be due to intensive cultivation and removal of phosphate anion by erosion. These results are in consent with the finding of Abera and Kefyalew (2017) who reported for Bedele area in Ilubabor zone, southwestern Ethiopia that continuous P removal by crop harvest in the cultivated and in grazing field soils are apparently the causes for relatively low Av.P in the surface horizon soils under the respective land uses.

Similarly, Achalu *et al*. (2012) reported low Av.P in CL compared to the soils of FL and GL. Thus, intensive and continuous cultivation can negatively affect Av.P and nutrient levels in the soil. Mishra *et al*. (2004) reported lower Av.P in GL and CL and attributed to lower soil organic matter content of the soil. Paulos (1996) also reported variations in Av.P content of soils and related this variation with the intensity of soil disturbance, the degree of P- fixation by Fe and Ca ions. Similarly, Tekalign and Haque (1987) and Dawit *et al*. (2002b) reported soil organic matter as the main source of Av.P and the availability of P in most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion. Generally, the low Av.P of the soils is the major soil fertility limiting factors in the study area.

3.2.5. Exchangeable bases

Exchangeable calcium (Ca) and magnesium (Mg) contents of soils of the study area showed differences in response to variations in land uses. Accordingly, exchangeable Ca was significantly ($P \leq 0.05$) different among the land use types and exchangeable Mg showed highly significant ($P \leq 0.01$) (Table 4). On the basis of the effects of different land uses on exchangeable (Ca), the highest exchangeable Ca (2.83 cmol (+) kg^{-1}) was recorded for the surface layer (0-30 cm) of the HL, whereas the lowest (1.27 cmol (+) kg^{-1}) exchangeable Ca was recorded for the surface soil of the CL (Table 4). The highest exchangeable Ca observed in the surface soils of the HL could be due to the relatively higher clay and CEC content of the soil (Table 2, 4). The lowest exchangeable Ca in the soils of the CL be due to lower pH and SOC (Table 3). Low exchangeable Ca be due to its continuous removal with crop harvest with no or little organic matter input into the soil. This result is in agreement with the findings of Wakene (2001), who indicated that cultivation enhances the leaching of Ca^{2+} especially in acidic tropical soils. In the same way, Abera and Kefyalew (2017) reported lower exchangeable Ca in the surface horizon of the cultivated field and attributed to the removal of Ca with crop harvest, high leaching as a result of continuous cultivation and OM decomposition.

The highest (5.45 cmol (+) kg^{-1}) mean exchangeable Mg was recorded for soils of the FL followed by HL while the lowest (1.81 cmol (+) kg^{-1}) was for the CL (Table 4). The exchangeable Mg decreased from the FL to CL could be attributed to the higher SOC observed in the FL surface (0-30 cm) (Table 3). This is in agreement with the finding of Nega (2006), who reported that forest and shrub land soils are somewhat richer in Mg contents than other land uses.

In addition, the relatively low exchangeable Mg observed in the soils of the CL could be due to its low SOC and continuous cultivation, which is the cause for leaching and removal in crop harvest. This is in agreement with the investigation of Gebrekidan and Negassa (2006) who reported that continuous cultivation enhances the depletion of Ca^{2+} and Mg^{2+}, especially in acidic tropical soils. According to the ratings of exchangeable Ca and Mg by FAO (2006a), the observed mean exchangeable Ca was low in the soils of rest land uses, while very low in the soils of CL. On the other hand, the mean exchangeable Mg recorded was medium in CL and GL, while high in HL and FL uses.

Exchangeable potassium (K) contents varied in response to variation in land uses. Accordingly, exchangeable K was highly significantly ($P \leq 0.01$) different among land uses, while exchangeable Na did not show significant ($P > 0.05$) differences among land uses. Indicating the effects different land uses on exchangeable K, the highest (2.00 cmol (+) kg^{-1}) mean value of exchangeable K was observed in the soils of the HL followed by FL and the lowest (0.17cmol (+) kg^{-1}) was recorded in the soils of the CL (Table 4). But except for the HL, the rest land uses are statistically similar in terms of exchangeable K.

The highest exchangeable K content in the soils of the HL could be attributed to the high clay content of the soil of the study area (Table 2). As reported by Saikh *et al*. (1998) high intensity of weathering, intensive cultivation and use of acid forming inorganic fertilizers (diammonium phosphate and urea) has an impact on the distribution of K in soils and enhance its depletion. This might be the possible reason for the relatively low exchangeable K in soils of the CL. However, according to the exchangeable K rating by FAO (2006a), the observed mean values of the exchangeable K of the soil of the study area fall in the range of very low in CL, medium in GL and FL while very high in HL uses.

As per exchangeable Na ratings by FAO (2006a), the mean exchangeable Na values were medium in the soils of all land uses types. Generally, a study by Gebrekidan and Negassa (2006) revealed that variations in the distribution of exchangeable bases depend on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed.

The order/distribution of exchangeable basic cations in most agricultural soil is generally Ca > Mg > K > Na with a pH of 5.5 or more. Dissimilar to this, the result of this study showed that the relative abundance of exchangeable basic cations in the exchange complex of the studied soils was in the order of Mg > Ca > K > Na. The disorder of exchangeable basic cations in the study area might be due to laboratory contamination while analysis or/and unbalanced quantities of exchangeable basic cations present in the soil.

3.2.6. Cation exchange capacity and percent base saturation

One of the most important components of soil fertility evaluation is a measurement of the cation exchange capacity (CEC) of a soil which is commonly undertaken as part of the overall assessment of potential fertility of the soil and possible response to fertilizer application (Landon, 1991). Analysis of variance for the CEC of the soil under the study showed highly significant ($P \leq 0.01$) differences across the land uses (Table 4). Accordingly, the highest (27.87 cmol (+) kg^{-1}) mean CEC value was recorded for soils of the HL followed by FL (24.34 cmol (+) kg^{-1}), while the lowest (9.28 cmol (+) kg^{-1}) was recorded for soils of the GL followed by CL (11.56 cmol (+) kg^{-1}) (Table 4).

In all the four land uses, CEC decreased from the HL followed by the FL and the CL to GL in surface layers (0-30 cm) in accordance with the clay contents (Tables 2, 4). The CEC of soils of the study area increased with clay content and vice versa and positively ($r = 0.82^{**}$) and highly significantly ($p \leq 0.01$) correlated with clay (Table 7). This finding revealed that a high amount of clay (colloidal particle) content of the HL is responsible for high CEC. Clay contains a high amount of colloidal particles and negatively charged on their surface, which is responsible for high CEC of HL soil, while GL contains low clay and high sand content which is significantly ($p \leq 0.01$) and negatively ($r = -0.80^{**}$) correlated to CEC (Table 7).

Fassil and Charles (2009) reported that the amount and type of clay mineral are responsible for high CEC since both clay and organic colloidals are negatively charged and therefore, can act as anions. Thus, clay and OM can absorb and hold positively charged ions (cations). Berhanu (2016) generalized that higher CEC values might imply that the soils have high buffering capacity against induced change. In line with this, HL soil had a relatively high buffering capacity, while GL had low buffering capacity. A study by Teferi (2008) revealed that CEC is a reflection of basic cations existing in a given soil and the natural and/or anthropogenic activities acting upon these cations thereby influencing the CEC of the soil. In agreement with this finding, the HL soil had high TEB and therefore high CEC. As per the ratings of the CEC of soil by Hazelton and Murphy (2007), CEC of the soil of the study area was classified as low in GL and CL, while the medium in FL and high in HL.

Percent base saturation (PBS) was showed highly significant ($p \leq 0.01$) different among land use types (Table 4). The highest mean value of PBS (57.87%) was calculated from the surface layer (0-30 cm) of the GL, while the lowest (31.23%) was in the surface layer of the CL (Table 4). The reason for the high PBS content of the GL may be due to the high SOC content of this soil. The lowest PBS recorded in the surface layer of the CL could be attributed to the low sum of bases (TEB), pH and low SOC content in this layer (Table 4). Apparently, Kedir (2015) suggested that variation in PBS could also be because of variation in pH, SOC content, soil texture, parent materials, and intensity of cultivation, leaching, slope and soil management practices. Another finding by Abebe (1998) indicated that Vertisols of virgin/grazing lands retain more basic cations than the cultivated land in the central highlands of Ethiopia. According to Hazelton and Murphy (2007) rating, PBS was low in the soil of rest lands, while the medium in GL uses.

Table 4. Soil exchangeable bases (Ca, Mg, K and Na), total exchangeable bases, cation exchange capacity and percent base saturation (PBS) in the study area

	(cmol(+)/kg soil)						
Land uses	Ca	Mg	K	Na	TEB	CEC	PBS (%)
GL	2.08^{ab}	2.52^{b}	0.38^{b}	0.39	5.37^{c}	9.28^{d}	57.87^{a}
CL	1.27^{b}	1.81^{b}	0.17^{b}	0.36	3.61^{d}	11.56^{c}	31.23^{c}
HL	2.83^{a}	5.25^{a}	2.00^{a}	0.49	10.57^{a}	27.87^{a}	37.93^{b}
FL	2.24^{a}	5.45^{a}	0.45^{b}	0.40	8.54^{b}	24.34^{b}	35.09^{bc}
LSD(0.05)	0.86	0.99	0.54	NS	0.88	1.51	4.75
SEM (±)	0.27	0.30	0.17	0.03	0.27	0.47	1.37
F-test	*	**	**	NS	**	**	**
CV (%)	21.80	14.00	38.62	12.35	6.66	4.41	5.86

GL= grazing land; CL= cultivated land; HL= homestead land; FL= forest land; TEB= total exchangeable bases; CEC= cation exchange capacity; PBS= percent base saturation; LSD= least significant different; SEM=standard error mean; F= fisher's; CV= coefficient of variation. Means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$ Fisher's LSD

3.2.7. Cation exchange capacity of the clay fraction

The statistical analysis revealed that the cation exchange capacity of clay (CEC clay) fraction was significantly ($p \leq 0.05$) different among different land uses (Table 5). The highest (239.85 cmol (+) kg^{-1}clay) CEC-clay for clay minerals fraction was recorded for the soil of HL, followed by FL and the lowest (137.13 cmol (+) kg^{-1}clay) was recorded for the soil of CL followed by GL (Table 5). From this study, the observed CEC of clay minerals followed a similar trend with the ECEC of soil under respective land uses (Tables 5). A similar observation was also reported by Wakene (2001) and Teferi (2008).

3.2.8. Exchangeable acidity and effective cation exchange capacity

Exchangeable acidity (EA) can be expressed as the sum of the concentration of exchangeable hydrogen and aluminum ions in soil solutions. Analysis of variance depicted that the EA and ECEC varied highly significantly ($P \leq 0.01$) across the land uses (Table 5). The highest (0.30 cmol (+) kg^{-1}) EA was recorded for the surface layer (0-30 cm) of the CL while the lowest (0.14 cmol (+) kg^{-1}) was recorded for the surface layer (0-30 cm) of HL (Table 5).

The relatively high EA observed in the surface soils of the CL could be related to the low content of base-forming cations recorded in this layer due to the cultivation, low pH and removal of basic cation by erosion and continuous use of inorganic fertilizers like diammonium phosphate and urea. This result is in harmony with many research findings (Baligar *et al.*, 1997; Blamey *et al.*, 1997; Tewabe, 2013; Berhanu, 2016) who reported that relatively high EA in the surface soil of CL due to the low content of base-forming cations, continuous cultivation and use of inorganic fertilizers like diammonium phosphate and urea. The lower EA of HL was due to higher basic cations and pH values of this soil (Table 3, 4).

Effective cation exchange capacity (ECEC) followed a similar trend as that of the TEB, Av.P, pH and EC of the soils (Table 3, 4). The study revealed that ECEC of the soil under the study area was highest (10.89 cmol

(+) kg^{-1}) in the HL and the lowest (3.79 cmol (+) kg^{-1}) ECEC value was obtained in the soils of the CL (Table 5). In general, the ECEC values of soils of the study area indicated an association with TEB value. This result disagrees with the report of Moody *et al*. (1997) who stated that ECEC is highly related to CEC and OM. In a similar way, Abera and Kefyalew (2017) reported low ECEC in the surface layer of CL.

Table 5. Soil cation exchange capacity of the clay fraction, exchangeable acidity and effective cation exchange capacity in the study area

	(cmol(+)/kg soil)		
Land uses	CEC clay	EA	ECEC
GL	185.6^{bc}	0.17^{b}	5.56^{c}
CL	137.13^{c}	0.30^{a}	3.79^{d}
HL	239.85^{a}	0.14^{b}	10.89^{a}
FL	213.51^{ab}	0.16^{b}	8.71^{b}
LSD (0.05)	51.52	0.08	0.77
SEM (+)	14.89	0.02	0.24
F-test	*	**	**
CV (%)	13.28	20.72	5.69

GL= grazing land; CL= cultivated land; HL= homestead land; FL= forest land; CEC= cation exchange capacity; EA= exchangeable acidity; ECEC= effective cation exchange capacity; LSD=least significant difference; SEM= standard error mean; F= fisher's; CV= coefficient of variation. Means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$ Fisher's LSD

3.2.9. Extractable micronutrients (Fe, Mn, Cu and Zn)

The statistical analysis indicated that the extractable micronutrients (Fe, Mn and Zn) were highly significantly ($P \leq 0.01$) affected by land use types and extractable Cu was significantly ($P \leq 0.05$) under different land uses (Table 6). The highest (18.10 mg kg^{-1} soil) and the lowest (6.42 mg kg^{-1} soil) mean extractable Fe was recorded in HL and CL, respectively. On the other hand, the highest (12.20 mg kg^{-1}) and lowest (6.87 mg kg^{-1}) mean values of extractable Mn was observed in GL and CL, respectively (Table 6). According to the fertility classes suggested for EDTA extractable micronutrients by FAO (1982), all soils of land use were very low in Fe and Mn contents.

As described by Kang and Osinama (1985), the available Fe and Mn elements have similar chemical properties in tropical soils. However, unlike Fe, the highest mean extractable Mn content of the study area was obtained in the surface layer of the GL than the other of land uses. Linear correlation analysis revealed that the soil CEC was positively (r = 0.88***) and significantly ($P \leq 0.001$) correlated with mean extractable Fe and insignificantly ($P > 0.05$) correlated with extractable Mn (Table 7). In addition, the correlation analysis showed that soil sand fraction was negatively (r = -0.59*) and significantly ($p \leq 0.05$) correlated to extractable Fe and insignificantly ($P > 0.05$) correlated with extractable Mn. Moreover, Av.P was positively (r = 0.73**and r = 0.66*) and significantly ($p \leq 0.01$ and $p \leq 0.05$) correlated with extractable Fe and Mn, respectively (Table 7).

Table 6. Selected EDTA extractable micronutrients in the soils of the study area as affected by different land uses

	Extractable micronutrients (mgkg^{-1}soil)			
Land uses	Fe	Mn	Cu	Zn
GL	7.61^{c}	12.20^{a}	2.60^{b}	0.44^{c}
CL	6.42^{d}	6.87^{b}	1.89^{b}	0.32^{c}
HL	18.10^{a}	10.32^{a}	3.59^{a}	3.74^{a}
FL	10.92^{b}	11.64^{a}	2.45^{b}	2.01^{b}
LSD (0.05)	1.07	2.10	0.93	0.77
SEM (+)	0.33	0.65	0.29	0.24
F-test	**	**	*	**
CV (%)	5.29	10.89	18.92	25.07

GL= grazing land; CL= cultivated land; HL= homestead land; FL= forest land; EDTA = ethylene-diamaine-tetra-acetic acid; LSD = least significant difference; SEM = Standard error of mean; F= fisher's; CV = Coefficient of variation. Means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$ Fisher's LSD

Higher extractable Fe content of HL might be due to higher clay content. This is in line with the correlation analysis result depicted in Table 7 that clay fraction is positively ($r = 0.62^*$) and significantly ($p \leq 0.05$) correlated to extractable Fe. However, the lower extractable Fe content recorded in CL might be due to leaching and low SOC content. The lower extractable Mn content of CL might be due to low SOC content and leaching of extractable Mn by erosion. This result is in consent with the finding of Kedir (2015) who reported that variation in intensity of leaching, probably higher erosion, higher rainfall in that particular microclimate might also be responsible for the low level of micronutrients.

Statistically, the highest (3.59 mg kg^{-1} soil) extractable Cu and (3.74 mg kg^{-1} soil) extractable Zn were recorded in HL uses while the lowest (1.89 mg kg^{-1} soil) extractable Cu and (0.32 mg kg^{-1} soil) extractable Zn were recorded in CL uses (Table 6). As rating micronutrient to the fertility classes implied for EDTA extractable micronutrients by FAO (1982), extractable Cu was medium in rest land use, while low in CL use. On the other hand, extractable Zn was very low in GL and CL uses, while the medium in HL and FL uses.

The higher extractable Cu content of HL seems to be related to Av.P, CEC and extractable Fe. This result was proved by positive ($r = 0.65^*$, $r=0.57^*$ and $r = 0.78^{**}$) and significant ($p \leq 0.05$) for Av.P and CEC and $p \leq 0.01$) extractable Cu with Av.P, CEC, and Fe, respectively (Table 7). However, the lower extractable Cu content of CL might be due to crop harvest removal, low SOC content and leaching of extractable Cu contenting parent minerals by erosion. This result is in line with the research of Berhanu (2016) who demonstrated that the lowest available Cu in the soils of the cultivated field as compared to the other land uses could be due to the lower organic matter content and topsoil Cu removal by erosion which is also aggravated by tillage activities that are coupled with continuous removal in crop harvest.

Similar to the extractable Cu, the higher and lower extractable Zn was recorded in the soils of HL and CL uses, respectively as compared to the other land uses. This could be due to the higher clay, Av.P, CEC, Fe and Cu content of HL uses. This was revealed by correlation analysis that, the clay fraction, Av.P, CEC, extractable Fe and Cu were positively ($r = 0.70^{**}$, $r=0.73^{**}$, $r = 0.91^{***}$, $r= 0.96^{***}$ and $r= 0.65^*$) and significantly ($p \leq 0.01$, $p \leq 0.01$, $p \leq 0.001$, $p \leq 0.001$ and $p \leq 0.05$) correlated to extractable Zn respectively (Table 7). On the other hand, lower extractable Zn in CL use might be due to low Av.P, extractable Fe and Cu content, low SOC content and topsoil Zn removal by erosion, which is also aggravated by tillage activities that are coupled with continuous removal in crop harvest. This is the same with the result of Berhanu (2016) who stated that the lowest available Zn in the soils of the cultivated field as compared to the other land uses could be due to the lower organic matter content and topsoil Zn removal by erosion which is also aggravated by tillage activities that are coupled with continuous removal in crop harvest.

Moreover, these variations of extractable micronutrients content of the study area were in agreement with the findings of Gebrekidan and Negassa (2006) who reported that micronutrients are influenced by different land uses differently. Tuma *et al*. (2013) and Kedir (2015) reported that the concentration of available micronutrients was found to be Fe > Mn > Cu> Zn in almost all surface soils. Unlike this, in the current study area, the concentration of EDTA extractable micronutrients was in the order of Fe>Mn>Zn>Cu were recorded in such a way that; Fe in HL, Mn in GL, Zn and Cu in HL uses, respectively. The main sources of micronutrients are parent material (phosphate rocks, bedrocks, and sediment rocks etc.,), farmyard manure and other SOC sources. Variation in these sources and soil environments results in different content of micronutrients.

According to Wajahat *et al.* (2006), the availability of micronutrients is particularly sensitive to changes in the soil environment. The factors that affect the contents of such micronutrients are organic matter, soil pH, and sand and clay contents. Besides these, the intensity of cultivation, soil drainage properties, soil type, leaching and erosion can also be responsible for the variation in soil micronutrient content. Accordingly, the variation in each extractable micronutrient contents among land uses in the current study area might not be out of the above mentioned factors. As the study by Kedir *et al*. (2016) reported, especially, variation in soil textural classes may probably be the main factor for the different values of micronutrients. This current study was also similarly investigated that variations in contents of extractable micronutrient across the land uses might be due to the influences of various factors, such as; environmental and anthropogenic factors, parent material, pH, soil texture, CEC, SOC, and Av.P level in soil affects the availability of micronutrients under different land uses in the study area

Table 7. Pearson's correlation matrix for selected soil physicochemical parameters of Wuye Gose sub-watershed area

	Sand	Clay	Silt	BD	pH	TN	Av.P	CEC	Fe	Mn	Cu	Zn
Sand	1.00											
Clay	-0.89***	1.00										
Silt	-0.78**	0.74**	1.00									
BD	0.40	-0.60*	0.68*	1.00								
P^H	0.37	-0.34	0.35	0.40	1.00							
OM	-0.15	0.06	0.53	-0.19	-0.07							
TN	-0.41	0.29	0.55	0.03	-0.19	1.00						
Av.P	-0.48	0.39	0.84***	-0.50	-0.18	0.41	1.00					
CEC	-0.80**	0.82**	0.95***	-0.77**	-0.38	0.34	0.74**	1.00				
Fe	-0.59*	0.62*	0.80***	-0.70**	-0.20	0.02	0.73**	0.88***	1.00			
Mn	-0.11	-0.12	0.39	0.05	0.28	0.34	0.66*	0.21	0.24	1.00		
Cu	-0.37	0.28	0.52	-0.33	-0.14	-0.09	0.65*	0.57*	0.78**	0.47	1.00	
Zn	-0.70**	0.70**	0.86***	0.86***	-0.21	0.17	0.73**	0.91***	0.96***	0.21	0.65*	1.00

*Significant at $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.001$; BD=Bulk density, OM=Organic matter's; TN=Total nitrogen; Av.P=Available phosphorus; CEC=Cation exchange capacity

4. Summary and conclusions

Assessing land use induced changes on soil physicochemical properties and subsequent implication on soil fertility is essential for understanding the influence of agro-ecosystem transformation on agricultural soil quality and productivity and to indicate appropriate and sustainable agricultural soil and land management options. Therefore, this study was conducted at the Wuye Gose sub-watershed to assess the physicochemical properties of soil under different land use types. Cultivated land, grazing land, homestead land and forest land use types were identified for the study. A plot with (25 x 25) m^2 area was marked as a sample plot for each land use type with three replications. A total of 12 distributed and 24 undisturbed composite soil samples were collected for soil physicochemical analysis. Moreover, the least significant difference between fisher's (LSD) test ($P \leq 0.05$) was used to compare and separate the means. Finally, a simple linear correlation coefficient analysis was carried out for selected soil parameters to examine the associations between soil physicochemical parameters.

Textural classes of grazing land and cultivated land is loamy sand while sandy loam in homestead land and forest land. The BD ranged from 1.51 (GL) to 1.13 g/cm^3 (HL) and TP varied 57.25 (HL) to 43.04% (GL).

The BD was high in GL and CL use types which are high to limit root penetration and restrict the movement of water and air and BD values of HL and FL were in the range that could not limit root penetration and restrict the movement of water and air. Soils under different land use differ in their water content at FC, AWHC and PWP because they vary in silt, sand and clay, land uses, TP and BD contents.

Soil chemical characteristics, such as; EC, SOC, TN, C: N, Av.P, CEC, exchangeable basic cations (Ca, Mg, K and Na), TEB, PBS, CEC-clay, EA, ECEC and extractable micronutrients (Fe, Mn, Cu and Zn) showed variability among land uses. None significant ($P > 0.05$) differences were obtained among soil pH values of the land uses. The pH value was within the ranges slightly acid in GL and FL while moderately acid in CL and neutral in HL uses. Electrical conductivity (EC) of soils was significantly ($P \leq 0.01$) different due to land uses. The soils of the study area fall under low EC (non saline) conditions. A significant ($P \leq 0.01$) difference was recorded among SOC values of land uses. Soil's OC was categorized as a medium in the soils of FL and GL while low in soils of HL and CL uses in the study area. Total nitrogen content in the study area ranged from 0.31% (FL) to 0.12% (CL and HL) uses. The amount of TN in the study area showed variation in relation to levels of SOC. The TN was found to be high in the FL, while the rest are moderate in the study area. The average C: N of the soils of the study area ranged from 18.91 to 10.07. Available P (in mg/kg) ranged from 2.52 (HL) to 0.86 (CL), and very low Av. P contents were recorded in all land use types.

The CEC in the study area varied significantly ($P \leq 0.01$) among the land uses. The highest (27.87) and lowest (9.28 cmol (+) kg^{-1}) mean CEC values were recorded in the soils of HL and GL, respectively. An increase in CEC with clay content was observed. Soils of the study area are classified as low in GL and CL uses while the medium in FL and high in HL uses in their CEC value. Some of the exchangeable basic cations varied significantly at ($P \leq 0.01$) for Mg and K; and ($P < 0.05$) for Ca) among land uses types and exchangeable Na did not show significant ($P > 0.05$) variation between land uses. Exchangeable Ca, Mg, K and Na, in cmol(+)/kg, the soil of the study area ranged from 2.83 to 1.27, 5.45 to 1.81, 2.00 to 0.17 and 0.49 to 0.36, respectively. Exchangeable Ca was low in soils of rest land uses while very low under the soils of CL use and exchangeable Mg was medium under the soils of CL and GL while high in soils of HL and FL uses. Exchangeable K falls in the range of medium in soils of GL and FL while very low in CL and very high in HL uses; and exchangeable Na was medium in the soils of all land uses in the study area. There is no sodicity problem in the study area. Total exchangeable bases and percent base saturation showed significant ($p \leq 0.01$) differences among different land uses. Total exchangeable bases, in cmol (+) kg^{-1} and PBS, in %, in the soils of the study area were 10.59 (HL) to 3.63 (CL); and 58.15 (GL) to 31.29 (CL), respectively. Soils of study site are low in the soil of rest lands, while the medium in GL uses in PBS status.

Analysis of variance depicted that CEC- clay fraction, EA and ECEC varied significantly among land uses. The ranges of CEC- clay fraction, EA and ECEC, in cmol(+)/kg in the soils of the study area was 239.86 to 137.49, 0.30 to 0.14 and 10.89 to 3.79, respectively. The CEC of clay minerals followed a similar trend with the ECEC. Effective cation exchange capacity (ECEC) followed a similar trend as TEB, Av.P, pH and EC in soils of the study area. In general, the ECEC value of the study area indicated an association with TEB value. Analysis of variance also showed that the extractable micronutrients (Fe Mn and Zn) were significantly ($P \leq 0.01$); and ($P \leq 0.05$) (for Cu) varied among land uses. The ranges of extractable Fe, Mn, Cu and Zn, in mg/kg, the soil of the study area were from 18.10 to 6.42, 12.20 to 6.87, 3.59 to 1.89, and 3.74 to 0.32, respectively. The fertility classes suggested for EDTA extractable micronutrients that all land uses were very low in Fe and Mn contents. Extractable Cu was medium in rest lands uses while low in CL uses and extractable Zn was very low in GL and CL uses while the medium in HL and FL uses. The concentration of EDTA extractable micronutrients in the study area was in the order of Fe > Mn > Zn > Cu.

Most of the physicochemical properties of soils of the study area vary from land uses to land uses probably due to variation in land-use types, parent material, elevation, agricultural practices (anthropogenic) and environmental factors, translocation and transformation of nutrients, lateral movement of nutrients along with sub-watershed and soil management practices. Generally, soils of the study area had high BD and TP content; high to very high AWHC content; low to medium SOC, extractable Cu and PBS contents; Very low Av. P, extractable Fe and Mn contents; low to high CEC content; very low to low exchangeable Ca content; medium to high exchangeable Mg and TN contents; very low to very high exchangeable K content; medium exchangeable Na content; very low to medium extractable Zn contents.

In conclusion, based on assessed soil physicochemical properties under four different land use at study area fertility status varies as HL > FL > GL > CL uses. Therefore, soil physicochemical management in CL and GL should be highly needed for the study area. Nevertheless, soil analysis once over a long period cannot go further than the identification of soil nutrient status for some years after the assessment due to the dynamic and intricate (complicated) nature of soils. In line with this, the nutrient supplying power of the soils and demanding levels of the plants needs frequent analysis, correlation and calibration work to come up with site-soil-crop specific fertility condition and fertilizer recommendation with the appropriate rate. For future research direction, soil physicochemical assessment should be done frequently by taking into account the site-soil-crop interaction since the soil is a dynamic and complex system.

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