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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DEDICATION

This Thesis is dedicated to my beloved mother Mrs. Dinkitu Deme and my wife Miss. Tigist Gelan who through the last several years celebrated the best of days with me and ceaselessly encouraged and strengthened me at times of stress.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
Av.P	Available Phosphorus
AWHC	Available Water Holding Capacity
BD	Bulk Density
C: N	Carbon to Nitrogen Ratio
CEC	Cation Exchange Capacity
CL	Cultivated Land
EA	Exchangeable Acidity
EB	Exchangeable Bases
EC	Electrical Conductivity
ECEC	Effective Cation Exchange Capacity
FC	Field Capacity
FL	Forest Land
GL	Grazing Land
HL	Homestead Land
ISSS	Indian Society of Soil Science
KWARDO	Kuyu Woreda Agricultural and Rural Development Office
LSD	Least Significant Difference
MoE	Ministry of Education
OM	Organic Matter
PBS	Percent Base Saturation
PD	Particle Density
PWP	Permanent Wilting Point
SOC	Soil Organic Carbon
SLM	Sustainable Land Management
SSSA	Soil Science Society of America
TEB	Total Exchangeable Bases
TN	Total Nitrogen
TP	Total Porosity
USDA	United States Department of Agriculture

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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 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 was 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 forest to low (1.12) in cultivated and high (0.31) in forest to low (0.12) in cultivated and homestead lands, respectively. The C: N was high (18.91) in 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 account the site-soil-crop interaction since soil is a dynamic and complex system.

Key words: 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 unwise use of land resources and land use changes. Land use/land cover changes that involve 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 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 generation 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 soil physicochemical depletion under different land uses and management practices in the country (Elias, 2002). Among these, the study conducted by Habtamu *et al.* (2014) and Birhanu (2016) indicated that conversion of 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 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 soil nutrients significantly decreased due to soil erosion from 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 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 causes 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 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

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2. LITERATURE REVIEW

2.1. Land, Land Use and Land Use Types

Land is a delineable area of the earth's terrestrial surface embracing all attributes of the biosphere immediately above or below this surface, including those near surface climate, the soil and terrain forms, the plant, animal populations, the human settlement pattern of past and present activity (IDWG/LUP, 1994). Land is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth (Richards, 1990). As a result, control over land and its use are often subjected to intense human interaction. Human activities that make use of, and hence change or maintain, attributes of land cover are considered the proximate source of change.

According to FAO (1997) land use is characterized by the arrangement, activities and inputs, people undertaken in certain land to produce, change or maintain it. This includes rural land use and also urban and industrial land use (FAO, 1993). Land use is obviously constrained by environmental factors such as soil characteristics, climate, topography and vegetation. It also reflects, the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation and water catchment and storage (Turner *et al*., 1993). Land use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing transformations in the rooting zone. It can either help or hinder soil erosion, and thus land use is the main factor that impact physical, chemical and biological processes of the soil.

The possible major land use type is agriculture, grazing, forestry and settlement and industry, each of them has subdivisions (FAO, 1976). A crop or cultivated land use type refers to a land used for the production of adapted crops. These include arable lands under protective cover and land under permanent in open air both naturally grown and cultivated (FAO, 1995). Grassland is a land use type with plant communities in which naturally grown grasses are dominant, shrubs are rare and trees absent (Skerman and Riveros, 1990). Natural forest land is a land use type with forest which has spontaneously generated itself on the location and which consists of naturally immigrant tree species and strains. In Ethiopia, massive deforestation of natural forests and extensive use of agricultural lands have resulted in soil degradation and loss of environmental quality. The major causes for the disappearance of forests are rapid population growth leading to the extensive forest clearing for cultivation and grazing, exploitation of forests for fuel wood and construction material (EFAP, 1994). The destruction of forest has widespread implications for all mankind and has wider implication of global importance.

2.2. Overview of Soil Fertility Status in Ethiopia

Ethiopia faces a wide set of issues in soil fertility that require approaches that include, but go beyond, the application of chemical fertilizers – the only practice applied at scale, to date. Core constraints include: top soil erosion (some sources list Ethiopia among the most severe erosion-affected countries in the world, along with Lesotho and Haiti (FAO, 1998); rates estimated at 10-13 mm per annum on average); acidity-affected soils covering over 40 percent of the country; significantly depleted organic matter due to widespread use of biomass and dung as fuel; depleted macro and micro-nutrients, and depletion of soil physical properties and salinity. Improving Ethiopia's soil fertility will lead to increased crop productivity. The application of soil fertility management practices and the knowledge to adapt these to local conditions, maximizing fertilizer and organic resource use efficiency and crop productivity (IFPRI, 2010).

2.3. Impacts of Land Use Change on Soil Physical Properties

Soil physical properties strongly influence the fertility status and productivity of soils through their parameters such as structure, texture, bulk density, moisture holding characteristics and soil aeration. These soil physical properties vary from place to place and even within a micro level as a result of natural and anthropogenic activities. Land use systems and management influence several physical properties of soils. For instance, many soil physical properties change with cultivation, intensity of cultivation, the instruments used and the nature of the land under cultivation (Sanchez, 1976; Achalu *et al*., 2012).

The adverse effect of soil compaction on soil-plant system can be associated with harmful effects on plants, and on physical, hydraulic and mechanical soil properties (Bennie and Kryhauw, 1985). Compaction of soil surface produces crust, which severely hampers seedling emergence (Kamara and Haque, 1988). Increasing bulk density due to compaction results in decreasing total porosity, macrospores and increase in micro or capillary pores. This leads to reduction in soil water conductivity in drier soils (Ahmed *et al*., 1987). Physical changes in surface soil, compaction resulting from grazing occurs more slowly than in vegetation (Van Havers, 1983). The presence of compacted subsoil layer may under prolonged water infiltration; causes anaerobic condition in the compacted layer and overlying topsoil (Bennie and Krynauw, 1985).

2.3.1. Soil texture

Soil texture is the relative percentage of sand, silt and clay in a soil. It refers to the relative proportion of particles of various sizes in a given soil (i.e., it refers to the percentage by weight of each of the three mineral fractions: sand, silt and clay in the fine earth fractions i.e., particles <2mm in diameter). The soil solid phase as a whole can be characterized in terms of the relative proportions of its particle size groups called soil separates. The relative size range of the soil particles is expressed by the term texture, which, qualitatively, refers to the fineness or coarseness of the soil. Quantitatively, it refers to the relative proportions of the different particle size fractions, specifically referred to as sand, silt and clay (with organic and cementing materials removed) (ISSS, 2002).

Studies showed that, sand, silt and clay fractions differed significantly along cultivating, grazing and woodlot land use types and the decreasing clay content can be used as an indicator for reducing the degree of weathering (Siraj *et al*., 2015). Another author also reported that relatively the highest clay content (68.56%) was recorded under cultivated land use type at upper position of the south facing slope, whereas the lower clay percentage (43.59%) was recorded under natural forest land use. This may be because, in cultivated land use there is the continuous cultivation of the soil this which leads to movement of particles from one place to another place (from higher to lower position) and results deposition of one particle to a particular place by erosion especially at lower part (Wakene, 2001; Tewabe, 2013; Abera and Kefyalew, 2017).

Gebeyaw (2007, 2015) reported that the highest average surface sand content (66%) was observed under the grazing land and the lowest (60%) was recorded in the forest land, whereas, the average clay fraction of the forest, grazing and crop lands were 23, 9 and 14%, respectively. The textural class of the surface (0-20 cm) soil was sandy loam. The same author also reported that the higher mean sand fraction (64.66%) was observed within the surface soils. Unlike the other land use types, the clay fraction in both layers of the cultivated land was the same (14%). This may be due to the intensive and continuous cultivation, which might cause compaction on the surface that reduces translocation of clay particles within the different layers and due to mixing up by tillage activities. In addition, the author reported that on the interaction effects of land use with soil depth, the highest values of both sand (68%) and silt (26%) contents were recorded at the surface (0-20 cm) layer of the grazing land while clay content was highest (24%) at the subsoil (20-40 cm) layer of the forest land. On the other hand, the lowest interaction mean values of sand, silt and clay were observed in both the surface and subsoil layers of the forest land, the subsurface layer of the forest land and the surface layer of the grazing land, respectively (Gebeyaw, 2007). Higher clay fraction recorded in the cultivated land was attributed to the impacts of deforestation and farming practices (Achalu *et al*., 2012).

2.3.2. Bulk density and total porosity

Soil bulk density (BD) is the mass of a unit volume of oven-dry soil. Soil BD varies among soils of different textures, structures, and organic matter content, but within a given soil type, it can be used for the determination of degree of soil compaction and lessivage, as a measure of soil structure, for calculating soil pore space and as an indicator of aeration status and water content. Changes in soil bulk density affect most of the other properties and processes that influence water and oxygen supply (Schoenholtz *et al*., 2000). Soil bulk density is highly affected by soil management practices such as land use type and soil management practices. Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity.

A study revealed that the highest mean (1.41 g/cm^3) value of bulk density was recorded on the grazing land and the lowest mean (1.35 g/cm^3) value under the forest land (Gebeyaw, 2015). Compaction resulting from intensively grazing animals might have caused the relatively higher bulk density values in both soil depths in the grazing land than that of the respective soil depths in the forest land. The reason for the low soil bulk density on the forest land as well as in the subsurface soil depth could be due to the hight clay content and less disturbance of the land under forest unlike other land uses and the surface layer (Hillel, 1980; Gebeyaw, 2007, 2015). The same author also reported that the bulk density increased from 0-20 to 20-40 cm layer under the grazing land and decreased under the forest and the cultivated lands.

Another study in Girar Jarso indicated that considering the interaction effects, the highest mean value of soil bulk density (1.41 g cm^{-3}) was recorded in the subsurface layer of the cultivated land, whereas, the lowest (1.03 g cm^{-3}) was observed in the surface layer of the grazing land. The low organic carbon content observed in the cultivated soils might have contributed to its highest bulk density value. In this case, high bulk density coupled with low organic carbon in soils of cultivated land may restrict root penetration and air supply to plant roots due to compacting effect (Berhanu, 2016).

As many research results indicated, the change of bulk density in the cultivated land might be attributed to the commonly intense tillage activities practiced by the farmers. Intense tillage practices often temporarily loosen the tilled soil layer while compacting of the layer beneath, which then increases bulk density. Furthermore, the continuous exposure of the soil surface to the direct impact of rain drops under fields with long period of continuous cultivation might have also contributed to the increment of bulk density as a rain drop impacts cause soil compaction through disintegration of the soil structure (Landon, 1991; Brady and Weil, 2002; Berhanu, 2016).

Total porosity (TP) is the ratio of total volume of pore spaces to the total volume of soil, and is an index of the relative pore space in the soil. Its value generally ranges from 30 (in compacted subsoil) to more than 60% in well-aggregated high-OM surface soils (Brady and Weil, 2002). Coarse textured soils tend to be less porous than fine-textured soils, although the mean size of individual pores is greater in coarse-textured soils. Furthermore, in clayey soils, the porosity is highly variable as the soil alternately swells, shrinks, aggregates, disperses, compacts and cracks (ISSS, 2002).

The total porosity of soils usually lies between 30% and 70%. In soils with the same particle density, the lower the bulk density, the higher is the percent total porosity. As soil particles vary in size and shape, pore spaces also vary in size, shape and direction (Foth, 1990). Total porosity (TP) of the soil can be used as an indication of the degree of compaction in soil in the same way as bulk density is used. It is very important characteristics of soil. It is pore space which transfer air and water in the soil and related with surface area. A study revealed that since total porosity values were derived solely from manipulating values of BD, with a generally assumed particle density value of (2.65 g/cm^3), those factors that affect BD has also a direct effect on porosity. Therefore, similar to BD the sources of variation in total porosity are variation in OM contents and intensity of cultivation (Kedir, 2015).

A study by Siraj *et al*. (2015) showed that the highest mean soil porosity in woodlot might come from high organic matter and finer soil particle. On the other hand, the soil porosity varied from 54 to 45% in the surface soil. An ideal total pore space value, which are acceptable for crop production, is around 50%. Tadele and Alemu (2016) reported an acceptable range of total porosity values for crop production.

A study by Dagne (2016) showed that the total porosity was recorded ranged from 47.17 to 52.83%. The lowest (47.17%) and highest (52.83%) total porosity were observed in the Bt4 horizon at Ongobo and surface horizon at Kejo, respectively. Another author reported in Koka Nagawo Area of Lumme that, the relatively higher total porosity under land units of irrigated floodplain corresponds to the relatively higher OM that improves aggregation, clay content, and the lower BD, whereas the lower total porosity under the land units of rain-fed agriculture corresponds to the higher BD value, the relatively lower organic matter and clay content of the land units (Haile and Muktar, 2014).

2.3.3. Soil water content and retention capacity

Soil water content is the basic parameter required to answer the wetness, quantity of water held in the soil, the amount of water absorbed before surface runoff started, and the amount of water a particular soil supply to maintain optimum plant growth. A quantitative measure of soil's moisture content is important to the understanding soil behavior, plant growth, and soil's numerous other physical processes. Information on soil's moisture content is useful for assessing plant water uptake and consumptive use, depth of water infiltration into soil, water storage capacity of soil, rate and quantity of water movement, deep drainage and leaching of chemicals, soil-strength and soil compact ability (Foth, 1990). Woodlot had a high leaf cover while grazing and cultivating land uses had a little leaf cover. This can result in the larger differences in infiltration rate, drainage and evapotranspiration between different land uses (Siraj *et al*., 2015). Soil moisture content can be high or low depending on the presence or absence of rainfall.

The variation in percent moisture content of the soils may be due to differences in their sand, silt and clay fractions (Achalu *et al*., 2012; Achalu, 2014). On the other hand, research revealed that, the soil-water content at FC and AWHC decreased with depth within the profiles from the surface to the bottom horizons under grazing and cultivated land uses. This could be due to decreasing trend of silt and OM, and subsequent increase in bulk density with depth, which is indicated that, available water in many soils is closely correlated with the content of silt (Foth, 1990; Tadele and Alemu, 2016; Abera and Kefyale, 2017).

Considering the main effects of land use in a study by Gebeyaw (2015), the highest (27.35%) and lowest (24.40%) water contents at FC were found in the forest and cultivated lands, respectively. Similarly, the highest (19.40%) and lowest (16.44%) water contents at PWP were recorded in the forest and grazing lands, respectively. On the contrary, the highest AWHC of 9.32% among the land use types was obtained in the grazing land and the lowest (7.81%) in the cultivated land. On the other hand, the water content at PWP was highest (19.71%) under the forest land and lowest (16.17%) in the grazing land and the cultivated land had 16.56%. The observed results generally showed that, the soils under different land uses differed in their water content both at FC and PWP because they vary in sand, silt and clay contents as reported by Wakene (2001) and Gebeyaw (2015).

2.4. Impacts of Land Use Changes on Soil Chemical Properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. A chemically fertile soil contains adequate amounts of the various substances required for plant nutrition, in available forms, which is not excessively acidic or alkaline and is free from toxic agents (Hillel, 1980; Foth and Ellis, 1997). Chemical properties of soils change with change in management and land use. Variations in land use alter the condition of soil organic matter, nitrogen and other essential nutrients (Bohn *et al*., 2001).

2.4.1. Soil reaction and electrical conductivity

Soil reaction (pH) is a measure of the concentration of hydrogen ions (H^+) in the soil solution. In other words, it is a measure of acidity or alkalinity of a soil that gives an indication of the activity of the hydrogen ion (H^+) and hydroxyl ion (OH^-) in a water solution. Soil pH is also an indicator of the chemical processes that occur in the soil, and is a guide to likely nutrient deficiencies and/or toxicities (Hazelton and Murphy, 2007). Soil acidity (low pH) is common in all regions where precipitation is high enough leaching appreciable quantities of cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) from the surface layers of soils (Brady and Weil, 2002).

Higher (6.01) soil pH-H_2O value was recorded in soils of the agricultural fields of Gida Ayana Districts while lower value (4.63) was recorded in soils of Way Tuka districts as reported by Achalu (2014). Another study also revealed that the relatively lower pH values in the soil of the crop fields and grazing land, as compared to those under woodlot, might be due to depletion of basic cations by the harvested crop biomass, over grazing and leaching (Gebeyaw, 2007; Siraj *et al*., 2015). On the other hand, the same study showed that lower pH value in cultivated land was attributed to a high rate of organic matter oxidation. This is important to produce organic acids and provide H^+ to the soil solution, and thereby reduces soil pH values. Considering the 0-20 cm depth; the higher mean values of pH-H_2O (6.50) was observed within the surface soils (Gebeyaw, 2015).

A study in South Western Ethiopia showed that the highest value of pH-H_2O was observed at coffee agro-ecosystem, while the lowest values were observed at cultivated land (Abebe and Endalkachew, 2012). The highest value of soil pH in the coffee agro-ecosystem was probably due to the high organic matter content observed under coffee agro-ecosystem helped a lot as humified organic matter can bind tightly with aluminum and iron ions and reduce their activity in the soil solution and thereby increase pH and reduce acidity. The increasing trend of soil acidity under cultivated land could be due to the effect of continues application of ammonium based fertilizers, such as; diammonium phosphate, $(NH4)_2HPO4$, in such cereal based cultivated fields, which upon its oxidation by soil microbes produces strong inorganic acids (Wakene and Heluf, 2003; Abebe and Endalkachew, 2012).

Electrical conductivity (EC) is a measure of salinity of soil solution. In addition to overcoming some of the ambiguities of total dissolved salts measurements, the EC measurement is quicker and sufficiently accurate for most purposes (Bohn *et al.,* 2001). Land uses change electrical conductivity (EC). Electrical conductivity (EC) was higher in the woodlot with a mean of 0.355 $dS^{-1}m$, whereas the lowest 0.014 $dS^{-1}m$ in the crop land according to a study by Siraj *et al*. (2015). Small electrical conductivity values of about 0.023 mS/cm at Diga district and a maximum of 1.226 mS/cm was recorded for the soils collected from Guto Gida district as reported by Achalu (2014).

A study indicated that with high amount of rainfall (>1000 mm), the values of electrical conductivity (EC) were very low across all land use systems. The highest values of electrical conductivity were recorded at coffee agro-ecosystem and at the surface of the soil whereas the lowest values were observed at grazing land. The lowest figures in electrical conductivity were observed in grazing and cultivated lands can be associated to the profound loss of soluble salts after continuous grazing and cultivation. Moreover, accumulation of exchangeable bases from decomposition of organic matter results high EC at coffee agro-ecosystem (Abebe and Endalkachew, 2012).

2.4.2. Soil organic carbon, total nitrogen, carbon to nitrogen ratio and available phosphorus

Soil organic carbon (OC) is the measure soil organic matter (OM). Soil OM is defined as any living or dead plant and animal materials in the soil and it comprises a wide range of organic species such as humic substances, carbohydrates, proteins, and plant residues (Foth and Ellis, 1997). Land use changes, changes soil organic carbon. A study showed that the lower organic matter observed in crop and grazing land comparing to woodlot which be explained by the seasonal cover in the former following over cultivation, free grazing and absence of soil nutrient balance. Removal of the surface soil rich in organic matter by soil erosion which undoubtedly could have accelerated with the removal of the plant cover is also expected to contribute to the lower organic matter contents observed in the crop and grazing land. The maintenance high levels of organic matter under woodlot are apparently attributed to the presence of vegetation and the associated high biomass and litter fall in the soils (Pan and Bhardwaj, 2013; Siraj *et al*., 2015).

Total soil nitrogen (TN) includes all forms of inorganic and organic soil N. Inorganic N includes soluble forms, such as; NO_2^- and NO_3^-, exchangeable $NH4^+$, and clay-fixed non exchangeable $NH4^+$and can be determined by the difference between total soil N and inorganic soil N content. Organic N content includes numerous identifiable and non identifiable forms (Stevenson, 1986; as cited by (Achalu, 2014). Change in land use type also results in significant effect on the content of total N. Generally many researchers indicated that total N under forest land was higher than those under cultivated land soils (Achalu *et al*., 2012; Teshome *et al.,* 2013). The total N content of soil is directly associated with its OC content and its amount on cultivated soils is between 0.03% and 0.04% by weight (Mengel and Kirkby, 1987; Tisdale *et al*., 2002).

The study in Nadda Assendabo watershed showed that the highest (0.65%) mean soil total nitrogen was observed in the woodlot followed by the grazing land (0.5%); whereas the lowest (0.13%) value of total nitrogen was recorded in the crop lands. Reduced input of plant residues into the soils also has contributed to the depletion of organic matter thereby enhanced rate of nitrogen in crop land. I areas that receive high mean annual rain fall, leaching could be another reason for the decline in TN in cropped fields. Nitrate ions which are not adsorbed by the negatively charged colloids dominate in most soils and thus move downward with drainage water and are readily leached from the soil (Siraj *et al*., 2015).

The relatively low total nitrogen content recorded in the soils of the cultivated land could be attributed to the usually anticipated rapid mineralization of soil organic matter following frequent tillage operations, which increase aeration and microbial accessibility to organic matter. Furthermore, reduced input of plant residues in such cereal-based farming systems in to the soils is also expected to have contributed to the depletion of OM, there by total N in these cultivated soils. On the other hand, nitrate ions which are not absorbed by the negatively charged colloids that dominate most soils, may move below the considered depth (0–40 cm) with drainage water and leached from the soil (Berhanu, 2016).

Carbon (C) to nitrogen (N) ratio (C: N) is an indicator of net N mineralization and accumulation in soils. If the ratio of the substrate is high there will be no net mineralization and accumulation of N (Attiwill and Leeper, 1987). The C: N ratio of soil can be affected by land use change, soil management and environmental factors, particularly, temperature and precipitation. A study revealed a narrow C/N ratio at the surface soil and said that may be due to higher microbial activity and more CO_2 evolution and its loss to the atmosphere in the surface (0-20 cm) soil layer (Achalu, 2014). The C: N ratios of soils were within the range of 8:1–15:1, which is commonly cited as the general C: N ratio of mineral soils reported by Berhanu (2016).

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. In most natural ecosystems, such as; forests and grass lands P uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002). The available P content in the top soils of the agricultural lands varied from 7.34-11.30 ppm when measured using Bray-II method reported by Achalu (2014). The results of analysis of variance in a study by Berhanu (2016) indicated that available phosphorus (P) content was significantly ($P \leq 0.01$) affected by land uses. The highest available P content recorded in the surface (0–20 cm) soils of the cultivated land could be ascribed to carryover effects from the continuous application of P fertilizers.

2.4.3. Exchangeable bases and total exchangeable bases

Exchangeable basic cation (EB) includes Ca, Mg, K and Na. The distribution of exchangeable basic cations in most agricultural soil is generally Ca > Mg > K > Na with a pH of 5.5 or more (Bohn *et al*., 2001; Teshome *et al*., 2013). Exchangeable basic cations, Ca, Mg, Na and K were significantly ($P \leq 0.05$) different in woodlot (subsurface) due to land use (Siraj *et al*., 2015).

Considering the main effects, the highest mean value of exchangeable K was observed in the soils of the grazing and forest lands and the lowest (0.32 coml (+) kg^{-1}) was recorded in the soils of the cultivated land (Berhanu, 2016). The highest exchangeable K content in the soils of the grazing land and forest land than that of the cultivated land could be attributed to the high organic matter content. High intensity of weathering, intensive cultivation and use of acid forming inorganic fertilizers has been reported to affect 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 cultivated land (Saikh *et al*., 1998; Berhanu, 2016). Berhanu (2016) reported that high amount of annual rainfall leaches Na easily.

The findings by Berhanu (2016) showed that, exchangeable calcium (Ca) and magnesium (Mg) contents of soils of Girar Jarso showed differences in response to variations in land uses. The highest exchangeable Ca was observed in the surface soils of the grazing land and it could be due to the relatively higher OM content of this soil. On the other hand, the lowest exchangeable Ca recorded in the soils of the cultivated land could be due to its continuous removal in crop harvest with no or little organic matter input in to the soil. On the other hand, based on the main effects, the highest mean exchangeable Mg (8.88 coml (+) kg^{-1}) was observed in soils of the grazing land and the lowest exchangeable Mg (4.78 coml (+) kg^{-1}) was observed in soils of the cultivated land. Furthermore, the exchangeable Mg decreased from the surface to subsurface soil depths, which could be attributed to the higher OM observed in the surface depth (Berhanu, 2016). The relatively low exchangeable Mg observed in the soils of the cultivated land could be due to its continuous removal in crop harvest. Continuous cultivation enhances the depletion of Ca^{2+} and Mg^{2+}, especially in acidic tropical soils (Gebrekidan and Negassa, 2006; Berhanu, 2016).

2.4.4. Cation exchange capacity and percent base saturation

Cation exchange capacity is defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). Cation exchange capacity was greater in woodlot land use type as reported by Siraj *et al*. (2015). Deforestation and continuous cropping mainly contributed to depletion of CEC as reported by Achalu (2014). On the other hand the study in Girar Jarso showed that, the highest mean CEC value (53.77 coml (+) kg^{-1}) was observed in the soils of the grazing land and the lowest (43.06 coml (+) kg^{-1}) was obtained in the soils of the cultivated land (Berhanu (2016). In all the three land uses, CEC decreased from the grazing land followed by the forest land to the cultivated land accordance with the OC contents. As it is also evident from the fact that, the higher CEC was obtained in the surface layer which also contained the highest organic carbon content. The depletion of OM because of continuous cultivation might reduce the CEC of the soils in the cultivated land. Basically, CEC of a soil is determined by the relative amount and/or of two main colloidal substances; humus and clay. Particularly, organic matter plays an important role in exchange process, because it provides more negatively charged surfaces than clay particles do. In general, higher CEC values might imply that the soils have high buffering capacity against induced change as reported by Gao and Change (1996) and Berhanu (2016).

Percent base saturation is define as the sum of the major exchangeable cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} [ΣExch. (Ca + Mg + Na + K)/CEC] multiplied by 100% was referred to historically as total exchangeable bases (TEB). A study by (Achalu, 2014) revealed that the lowest value of CEC (4.18%) was obtained in soils of Sasiga district and the highest value (37.86%) in soils of Gidda Ayana district. Another study indicated that, percent base saturation of soils of in Girar Jarso area was significantly affected by the land uses ($P \leq 0.01$). The lowest PBS recorded in the surface layer of the cultivated land could be attributed to the low sum of bases in this layer. This indicated that the virgin/grazing lands retain more basic cations than the cultivated land of Vertisols at the central highlands of Ethiopia. On the other hand, unlike the cultivated and forestlands, the mean values of PBS was significantly reduced from 50.42% in the surface (0–20 cm) soil to 42.60% in the subsurface (20–40 cm) soil of the grazing land (Berhanu, 2016). This could be attributed to the high organic matter (organic carbon) and high sum of bases in the surface layer of the grazing land (Murphy, 1959; Abebe, 1998; Berhanu, 2016).

4.4.5. Cation exchange capacity of the clay fraction

Clay minerals have the property of absorbing certain ions and retaining them in an exchangeable state. In clay minerals, the most common exchangeable cations, in order of usual relative abundance, are Ca^{+2}, Mg^{+2}, H^{+}, K^{+}, $NH4^{+}$ and Na^{+}. Abera and Kefyalew (2017) reported that considering the surface layers, the CEC of clay was higher (8.25 cmol (+) kg^{-1} clay) in the grazing land and lower (5.25 cmol (+) kg^{-1} in the cultivated land. On the other way, Tadele and Alemu (2016) reported that, the CEC/clay values were also found to be high for the surface soil. The CEC clay for clay minerals was not the highest (96.85 cmolc kg^{-1} clay) for the virgin land. Rather, the highest (108.23 cmol c kg^{-1}) and the lowest (46.67 cmol c kg^{-1} clay) mean values were recorded for the cultivated land units 6 and 11, respectively as reported by Teferi (2008). The CEC of clay minerals followed a similar trend with the CEC also reported by Wakene (2001) and Teferi (2008).

2.4.6. Exchangeable acidity

Exchangeable acidity (EA) is expressed as the sum of hydrogen and aluminum ions in soil solutions. The study showed that, EA varied significantly across the land uses ($P \leq 0.01$. The highest exchangeable acidity value (2.76 coml (+) kg^{-1}) was recorded in the surface layer of the cultivated land and the lowest (1.10 coml (+) kg^{-1}) exchangeable acidity was recorded in the subsurface layer of forest land. The relatively high exchangeable acidity observed in the surface soils of the cultivated land could be related to the low content of base-forming cations recorded in this layer due to the cultivation and continuous use of inorganic fertilizers. Intensive cultivation and continuous use of inorganic fertilizers could intensify soil acidity (Berhanu, 2016).

The amount of exchangeable acidity is largely a function of soil pH and the exchange capacity. In most soils, the exchangeable acidity will be composed of exchangeable H^+, exchangeable Al as either Al_3^+ or partially neutralized Al-OH compounds, such as; $AlOH_2$ or $Al(OH^{+2})$ and weak organic acids (Brady and Weil, 2002). Highest (3.96 coml (+) kg^{-1}) exchangeable acidity in soils of Jimma Arjo and lowest (1.94 coml (+) kg^{-1}) in the soils collected from agricultural land of Kiremu district were recorded by Achalu (2014). A study showed that deforestation, intensive cultivation and application of inorganic fertilizers leads to higher exchangeable acidity content under the crop field of almost all the studied districts of the East Wollega Zone (Achalu, 2014).

2.4.7. Effective cation exchange capacity

Effective cation exchange capacity (ECEC) is the summation of exchangeable bases and exchangeable acidity. It is also affected by land uses. Effective cation exchange capacity (ECEC) followed similar trend as that of the CEC of the soils in a study by Berhanu (2016). Analysis of variance for the ECEC of the soil in the study in Girar Jarso revealed significant differences across the land use ($P \leq 0.01$). In this study, the highest ECEC value (26.29 coml (+) kg^{-1}) was observed in the grazing land and the lowest ECEC (14.07 cmol (+) kg^{-1}) was obtained in the soils of the cultivated land. Along the soil depths, the mean ECEC (19.90 cmol (+) kg^{-1}) of the surface layer was significantly higher than that of the subsurface layer (18.49 cmol(+) kg^{-1}). In general, the ECEC value of soils in Gira Jarso indicated association with CEC value (Berhanu, 2016). Effective cation exchange capacity is highly related to CEC and OM (Moody *et al*., 1997; Berhanu, 2016).

2.4.8. Micronutrients

Micronutrients are essential nutrients that are required by the plant in very smaller amount as compared to macronutrients. This term usually applies to elements that are contained in plant tissues in amounts less than 100 mg/kg (Foth and Ellis, 1997). According to the same authors, the four essential micronutrients that exist as cations in soils unlike boron and molybdenum are zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn). A research in Girar Jarso, North Shoa (Berhanu, 2016) showed that the concentrations of the micronutrients (Fe, Mn, Zn and Cu) of the soil was affected by different land uses, except Cu and Zn; and the other micronutrients (Fe and Mn) were significantly affected by land uses ($P \leq 0.01$). The highest mean iron content (16.25 mg kg^{-1}) in this study was recorded in the surface layer of the forest land as compared to the other land uses, while the lowest mean iron content was observed in the subsurface layers of the cultivated and grazing lands. On the other hand, the highest mean Mn content (15.04 mg kg^{-1}) was found in the surface layer of the cultivated land and the lowest (5.91 mg kg^{-1}) was recorded in the subsurface layer of the grazing land. The same author also reported that, the highest available Cu was obtained in the soils of the forest and grazing lands, while the lowest (1.18 mg kg^{-1}) available Cu was recorded in the soils of the cultivated land (Berhanu, 2016).

Moreover, the available Cu concentration of the study area significantly decreased from 2.15 to 1.45 mg kg^{-1} along the soil depths (0–20 to 20–40 cm) and it seems to be related with OM contents both across the land uses and down the soil depths. Considering the main effects of land uses and soil depths; the finding indicated that, the highest available Zn (0.66 mg kg^{-1}) was observed in the soils of the grazing land and the lowest 0.57 mg kg^{-1}) value was recorded in the soils of the cultivated land. It also decreased from 0.71 to 0.50 mg kg^{-1} along the soil depths. Similar to the available Cu, 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 top soil Zn removal by erosion which is also aggravated by tillage activities that is coupled with continuous removal in crop harvest and micronutrients are influenced by different land uses differently (Gebrekidan and Negassa, 2006; Berhanu, 2016).

Another study indicated that, the highest Cu (14.2, 24.1 and 2.9 ppm) were observed on the surface layer of forest land which might be due to high OM concentrations that acted as a chelating effect and source of such micronutrients. Significant ($P \leq 0.01$) difference was also observed in Cu content by which the highest (2.7 ppm) was recorded on the surface layer of forest land that might be also due to its high OM contents (Wakene, 2001; Habtamu *et al*., 2014). Another study by Lindsay and Norvell (1978) indicated that the critical levels of available Fe and Mn for crop production are > 40 and 48 ppm, respectively.

2.5. Soil Testing

The evolving knowledge of the nature and properties of soil has served in better articulation of the potentials and limitations of soils to compatible land use over the years and sustainable agricultural productivity. As a result, testing soil for the better understanding of its property is very crucial (Tekwa *et al*., 2011). Soil testing can be defined as a method used to estimate the nutrient supply power of a soil (physical, chemical and biological measurement made on a soil). In restricted sense, soil testing means rapid chemical analysis of soil to assess the plant available nutrient status, salinity, acidity and elemental toxicity of soil, while in the broader sense; it represents a program that includes interpretations, evaluation, fertilizer and amendment recommendations based on result of soil chemical analysis and other considerations (Peck and Soltanpour, 1990).

With the recent increase in fertilizer costs and deterioration of soil fertility over time; the needs for sound soil testing along with appropriate interpretation of the results have increased in importance to decision makers. Information obtained from soil testing enables to predict the amounts of nutrients needed to supplement the supply in the soil. Moreover, the information could be used to build and/or maintain fertility status of a given field, predict the probability of obtaining a profitable response to fertilization and liming, provide a basis for recommendations on the amount of fertilizers and lime to apply and evaluate the fertility status of soils on a watershed, district, zone, region or national basis by the use of test summaries. The problem of obtaining representative samples, accurate analysis, correct interpretation and environmental factors that influence crop responses strongly influence nutrient recommendations and crop recovery of applied nutrients. However, soil test helps to reduce the guesswork in fertilization. The test may be used to periodically monitor to determine general soil fertility levels, and adequate quantities of fertilizers are applied to supply the current crops (Havlin *et al*., 2003). In general, soil testing is an accurate and indispensable tool essential for the assessment of the fertility status of soil.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

The study was conducted at Wuye Gose sub-watershed, located in 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 at 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).

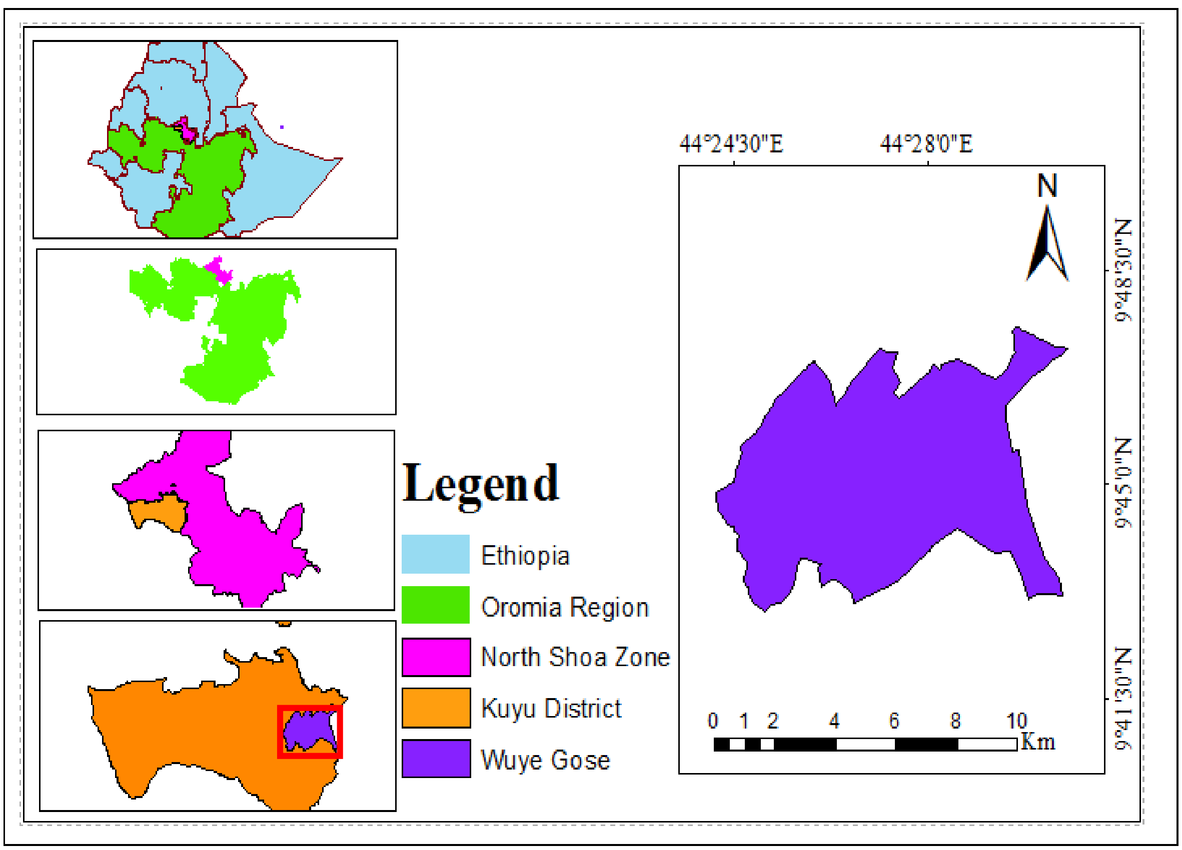

Figure 1. Loction map of the study area

3.1.2. 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 (Appendix Table 5 and 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)*.

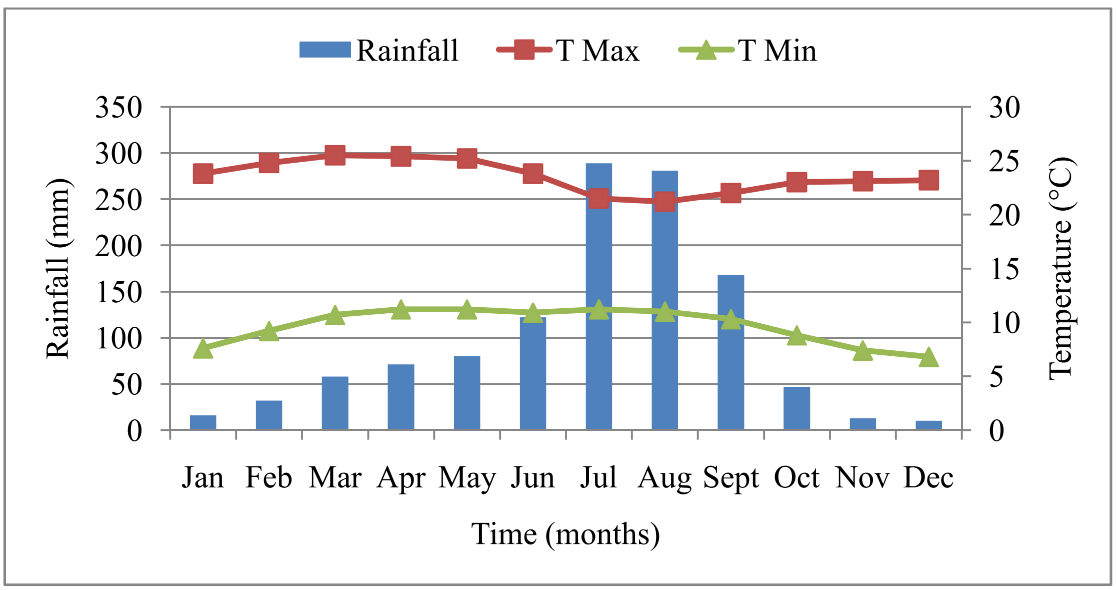

Figure 2. Average monthly rainfall, maximum (max) and minimum (min) temperature of Gerbe Guracha

According to the data from 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 semi-structured questionnaire (Appendix I), the soil of 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, fertility of the soils is medium and they attributed medium productivity of the soils to weakness of the land (soil fertility declining).

3.1.3. 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 on 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 semi-structured questionnaire (Appendix I) currently, 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 is 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 shortage of land and high population pressure.

3.2. 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 long-term experiment are very rare, the spatial sampling approaches is valuable alternatives to study ecosystem dynamics in 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 valuable complement. Therefore, a series of group discussions was 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 (Appendix I).

3.2.1. 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 indigenous natural forest (reserved area), tree and shrub species.
Homestead land	This category of land consisted at residence areas.

3.2.2. 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 introduction of the new land management. A plot with 25 x 25 m^2 area was marked as 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 open interview with local farmers and government agencies (Appendix I).

Based on the information obtained from semi-structured questionnaires (Appendix I), 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 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 is a very few natural forest and no fallow practices because of agricultural land expansion.

3.2.3. Soil sampling, techniques and sample preparations

Three main factors, such as depth, sampling intensity per unit area of 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 samples from each land uses with each replications. Additionally, from each land use types 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 collection of soil samples; dead plants, furrow, old manures, wet spots, and areas near trees were excluded. One kg of the composite samples was 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).

3.2.4. 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 the 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

3.2.5. Analysis of soil chemical properties

The pH (pH-H_2O) of the soil was measured potentiometrically using 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 atomic absorption spectrophotometer (AAS), while exchangeable K and Na were determined from the same extract with 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: Cation exchange of soil divided by percentage of clay multiplied by 100.

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

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 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.

3. 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 plant nutrients was employed as a soil fertility evaluation procedure.

3.4. Statistical Analysis

The data obtained from the laboratory analysis were subjected to 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 statistical difference in soil characteristics among land use types. Moreover, least significant difference fisher's (LSD) test ($P \leq 0.05$) was used to compare and separate for significant means. Simple linear correlation coefficient analysis was also carried out for selected soil parameters to examine the associations among selected soil physicochemical parameters.

4. RESULTS AND DISCUSSION

4.1. Soil Physical Properties under Different Land Use Types

4.1.1. Texture

The mean values of the particle size distribution (texture) of each land uses 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) is 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 difference in parent material, land use changes over 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 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 the 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 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 (Appendix Table 6). The reason for 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 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 highest silt in CL. However, Achalu *et al.* (2012) reported highest silt fraction for soils of FL in 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 (Appendix Table 6).

4.1.2. Bulk density and total porosity

The results of 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 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. In addition to this, Wakene and Heluf (2003) in line with current findings reported the highest BD in the abandoned land which was due to the soil compaction and organic matter (OM) degradation. Contrary to the case of GL, the lowest BD recorded in HL was due to highest clay and TP content (Table 2). This was showed by correlation analysis result that clay fraction was negatively ($r = -0.60^{*}$) and significantly ($p \leq 0.05$) correlated to BD (Appendix Table 6).

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 study area were high in GL and CL uses which are high to limit root penetration and restrict 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 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 good structure.

Total porosity (TP) of the soil can be used as an indication of the degree of compaction in a 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 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 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 was 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 has also 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

Land uses	Particle size distribution (%) Sand	Silt	Clay	Textural class	BD ($g\ cm^{-3}$)	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 column followed by the same letter are not significantly different from each other at $P \leq 0.05$ according to Fisher's LSD

4.1.3. 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 were highly significantly ($P \leq 0.01$) affected by different land use types (Appendix Table 1). The highest (45.18%v) numerical values of FC was recorded from soils under HL of 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 was the highest and its BD was lowest, which contributes to higher water content at FC, while GL had 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 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 uses differ in their water content at PWP and AWHC. The highest water content (16.99%v) at PWP was recorded under soil of HL and FL uses, while the smallest (8.49%v) was recorded under 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 land uses contain 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 adsorption of clay rather than capillary effects according to Teferi (2008). Adsorption is dependent on the specific surface available for 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 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 sand, silt and clay contents, BD, TP and land uses. On the other hand, Gebeyaw (2007) demonstrated and generalized that soils under different land uses in Maybar areas of South Wello Zone, North Ethiopia differed in their water content at FC and PWP because they vary in sand, silt and clay contents. Changes in 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 (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.

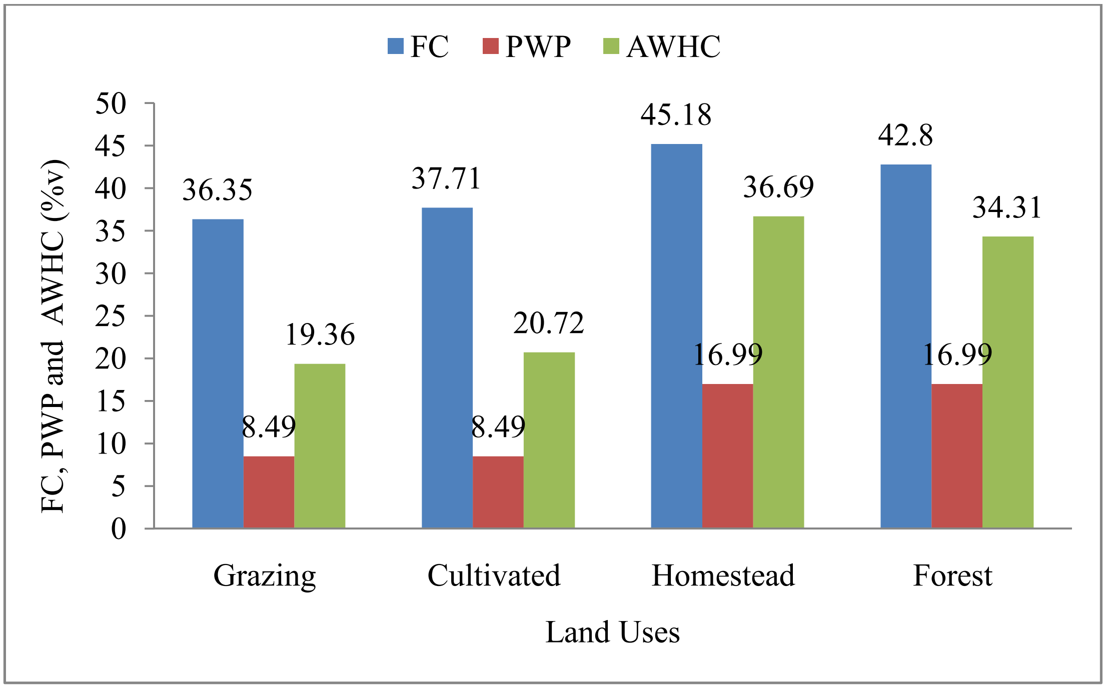

Figure 3. Soil water retention capacity at FC, PWP and AWHC for different land uses at study area

4.2. 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.

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

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 may 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 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 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 to 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 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

4.2.2. 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 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. In contrary, the lower SOC content of CL might result from 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 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 was depleted by 54.62% and conversion of FL to CL has been associated with 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 medium for the soils of the FL and GL, while low for soils of HL and CL uses types (Appendix Table 2).

4.2.3. 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 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 leached 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 SOC of this study are in accordance with the findings of Wakene and Heluf (2003) and Tuma (2007) who reported that the intensive and continuous cultivation forced oxidation of SOC and thus resulted in 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 low for rest lands (Appendix Table 2).

Statistically, distribution of C: N followed similar patterns with SOC distribution except 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 low level of C: N ratio in CL. The narrow C: N ratio in 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 soil of FL and GL were greater than the range suggested by Prasad and Power (1997) which indicates low rate of mineralization of SOC in those land uses.

4.2.4. Available phosphorus

The results of 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 (Appendix Table 3).

The reason for relatively high Av.P content of HL might be 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 (Appendix Table 6). A 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 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 soils of FL and GL. Thus, intensive and continuous cultivation can negatively affect Av.P and nutrient levels in soil. Mishra *et al*. (2004) reported lower Av.P in GL and CL and attributed to lower soil organic matter content of 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.

4.2.5. 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 could be due to lower pH and SOC (Table 3). Low exchangeable Ca could 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) and Wakene and Heluf (2003) who indicated that cultivation enhances 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 (Appendix Table 3).

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 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 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 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 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 (Appendix Table 3).

As per exchangeable Na ratings by FAO (2006a), the mean exchangeable Na values were medium in the soils of all land uses types (Appendix Table 3). Generally, study by Gebrekidan and Negassa (2006) revealed that variations in the distribution of exchangeable bases depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, 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 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.

4.2.6. 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 a 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 study area increased with clay content and vice versa and positively ($r = 0.82^{**}$) and highly significantly ($p \leq 0.01$) correlated with clay. This finding revealed that high amount of clay (colloidal particle) content of the HL is responsible for high CEC. Clay contains 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 (Appendix Table 6).

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 relatively high buffering capacity, while GL had low buffering capacity. As 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 (Appendix Table 3).

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 soil of rest lands, while medium in GL uses (Appendix Table 3).

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 column followed by the same letter are not significantly different from each other at $P \leq 0.05$ Fisher's LSD

4.2.7. 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). Thehighest (239.85 cmol (+) kg^{-1}clay) CEC-clay for clay minerals fraction was recorded for soil of HL followed by FL and the lowest (137.13 cmol (+) kg^{-1}clay) was recorded for 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). Similar observation was also reported by Wakene (2001) and Teferi (2008).

4.2.8. Exchangeable acidity and effective cation exchange capacity

Exchangeable acidity (EA) can be expressed as the sum of 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 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 similar way, Abera and Kefyalew (2017) reported low ECEC in 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 column followed by the same letter are not significantly different from each other at $P \leq 0.05$ Fisher's LSD

4.2.9. 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) and depicted in Appendix Table 4, all four soils of land uses 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 (Appendix Table 6). 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 (Appendix Table 6).

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 ($\pm$)	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 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 correlation analysis result depicted in Appendix Table 6 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 may also be responsible for 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) and shown in Appendix Table 4 extractable Cu was medium in rest land uses, while low in CL use. On the other hand, extractable Zn was very low in GL and CL uses, while medium in HL and FL uses.

The higher extractable Cu content of HL seems to be related with 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 (Appendix Table 6). 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 is 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 (Appendix Table 6). 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 is 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 is 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 were found to be Fe > Mn > Cu> Zn in almost all surface soils. Unlike this, in 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), availability of micronutrients is particularly sensitive to changes in soil environment. The factors that affect the contents of such micronutrients are organic matter, soil pH, and sand and clay contents. Besides of these, 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 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.

5. 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 Wuye Gose sub-watershed to assess 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 types with three replications. A total of 12 distributed and 24 undisturbed composite soil samples were collected for soil physicochemical analysis. Moreover, least significant difference fisher's (LSD) test ($P \leq 0.05$) was used to compare and separate the means. Finally, 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 movement of water and air and BD values of HL and FL were in the range that could not limit root penetration and restrict movement of water and air. Soils under different land uses 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) condition. A significant ($P \leq 0.01$) difference was recorded among SOC values of land uses. Soil's OC was categorized as 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 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. Increase in CEC with clay content was observed. Soils of 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, 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 fall 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 ($p \leq 0.01$) difference 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 soil of rest lands, while medium in GL use 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 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 medium in HL and FL uses. The concentration of EDTA extractable micronutrients in the study area were in 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 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 uses 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 long period cannot go further than the identification of soil nutrient status for some years after the assessment due to 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 works to come up with site-soil-crop specific fertility condition and fertilizer recommendation with appropriate rate. For future research direction, soil physicochemical assessment should be done frequently by taking account the site-soil-crop interaction since soil is a dynamic and complex system.

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7. APPENDICES

Appendix I. Semi-structured Questions

1. Location

Region_______Zone ___District_______

2. Climate and topography of the study area

A. Mean annual rainfall

B. Mean annual temperature

C. Slope

D. Elevation (upland, lowland)

3. Nature resource

A. What are the dominant tree species in the study area?

B. Conservation and management practices of natural resources

C. What is the progress of terracing practices?

D. Soil type (heavy, water logged, salt affected

E. Soil drainage condition

F. Soil local name

G. Local soil fertility indicators (poor, medium, good)

4. Agronomy and livestock

A. What is the dominant farming system of the study area?

B. What is the intensity of grazing and cultivation? Why?

C. Crop growth (good, poor, medium

D. What are the major livestock produced in the study area?

E. Irrigation practices and sources of irrigation

5. What is the dominant soil type in the study area?

6. What are the types of crops grown in the study area?

7. Type and amount of fertilizers used in the study area:

A. commercial fertilizers

B. organic fertilizers

C. commercial and/or organic fertilizers

8. What are the limitations of using organic and/ or commercial fertilizers in the study area?

9. What are the cropping sequences in the study area?

A. crop rotation

Appendix I. Semi-structured Questions (*Continued…*)

B. previous crop

C. present crop

D. fallow

10. What do you think are the major production constraints of the study area

A. soil fertility

B. economic background

C. climate

D. social conditions

E. other

11. How do you compare the back history or the former land use systems with the present ones?

12. What are the reasons for the poor productivity of soils (declining soil fertility) in the study area?

Appendix Table 1. One way analysis of variance (ANOVA) results of mean square estimates, standard error mean, F and Pr- value of soil physical and chemical parameters from under the four lands uses (grazing, cultivated, homestead and forest land) at Wuye Gose sub-watershed

Parameters considered	Meansquares for source of variation			F	Pr
	Land uses(3)[a]	Error(8)[b]	SEM(±)[c]	Value	Value
Sand	85.623*	13.25	2.10	6.46	0.0157
Clay	27.01**	2.67	0.94	10.11	0.0043
Silt	19.78**	0.11	0.19	187.02	<.0001
Bulk density	0.09*	0.02	0.09	3.93	0.0540
Total porosity	123.23*	31.33	3.23	3.93	0.0539
Field capacity	52.24**	0.10	0.18	525.45	<.0001
Permanent wilting point	72.13**	0.16	0.23	455.00	<.0001
Available water	242.65**	0.07	0.15	3426.48	<.0001
Soil Reaction pH	0.36[NS]	0.24	0.28	1.54	0.2765
Electrical Conductivity	0.09**	0.001	0.02	97.29	<.0001
Soil OC	0.54**	0.01	0.06	56.29	<.0001
Total N	0.03*	0.003	0.03	8.04	0.0085
C:N	43.07**	0.08	0.16	537.06	<.0001
Available P	1.71*	0.17	0.24	10.01	0.0044
Exchangeable Ca	1.24*	0.21	0.27	5.85	0.0204
Exchangeable Mg	10.42**	0.28	0.30	37.51	<.0001
Exchangeable K	2.11**	0.09	0.17	24.81	0.0002
Exchangeable Na	0.010[NS]	0.003	0.03	3.61	0.0650
TEB	29.30**	0.22	0.27	132.69	<.0001
CEC	254.75**	0.65	0.47	392.13	<.0001
CE Clay	5752.81*	665.04	14.89	8.65	0.0134
Percent Base Saturation	432.05**	5.66	1.37	76.31	<.0001
Exchangeable Acidity	0.02**	0.002	0.02	9.87	0.0046
ECEC	30.20**	0.17	0.24	177.68	<.0001
Extractable Fe	82.76**	0.32	0.33	254.82	<.0001
Extractable Mn	17.13**	1.25	0.65	13.71	0.0016
Extractable Cu	1.50*	0.25	0.29	6.02	0.0189
Extractable Zn	7.71**	0.17	0.24	45.92	<.0001

[a,b]Figures in parentheses are values of degrees of freedom for respective source of variation; [c]SEM = Standard error of means; NS = non significant; *, ** = Significant at $P \leq 0.05$ and at $P \leq 0.01$, respectively

Appendix Table 2. Ratings of pH (H_2O), organic carbon (OC) and total nitrogen (TN) in the soil

pH[a] (1:2.5 H_2O)		OC[a] (%)		Total N[b] (%)	
pH	Rating		Rating		Rating
< 4.5	Very SAc	< 0.50	Very L.	< 0.1	Very low
4.5-5.2	Sac	0.5-1.5	Low	0.1-0.3	Low
5.3-5.9	MAc	1.5-3.0	Medium	0.3-0.5	Medium
6.0-6.6	Slightly acid	>3.0	High	0.5-1	High
				>1	Very high
6.7-7.3	Neutral				
7.4-8.0	MAk				
>8.0	SAk				

SAc= strongly acid, MAc= moderately acid, MAk= moderately alkaline, SAk= strongly alkaline, L=low

Sources: [a]Tekalign (1991), [b]Landon (1991)

Appendix Table 3. Ratings of available phosphorus (Av.P), exchangeable (Ca, Mg, K, Na), CEC and PBS in the soil

	Av.P	Exchangeable Ca, Mg, K, Na and CEC (in cmol(+) kg^{-1})					
Rating	(mg/kg)[a]	Ca[b]	Mg[b]	K[b]	Na[b]	CEC[c]	PBS[c] (%)
Very low	< 5	< 2	< 0.3	< 0.2	< 0.1	< 6	0 - 20
Low	5 – 9	2 -5	0.3 - 1	0.2 - 0.3	0.1 - 0.3	6 - 12	20 - 40
Medium	10 – 17	5 - 10	1 - 3	0.3 - 0.6	0.3 - 0.7	12 - 25	40 - 60
High	18 – 25	10 - 20	3 - 8	0.6 - 1.2	0.7 - 2	25- 40	60 - 80
Very High	> 25	> 20	> 8	> 1.2	> 2	> 40	> 80

Sources: [a]Cottenie (1980), [b]FAO (2006a), [c]Hazelton and Murphy (2007)

Appendix Table 4. Ratings of EDTA extractable iron (Fe), manganese (Mn), copper (Cu) and Zinc (Zn) in the soil

Micronutrient (mg/l)	Very Low	Low	Medium	High	Very High
Extractable Fe	< 30	30-75	75-200	200-500	> 500
Extractable Mn	< 23	23-90	90-360	360-1,400	> 1,400
Extractable Cu	< 0.7	0.7-2.0	2.0-6.0	6.0-18.0	> 18.0
Extractable Zn	< 0.5	0.5-1.5	1.5-5.0	5.0-15.0	> 15.0

Sources: FAO (1982)

Appendix Table 5. Average monthly rainfall, maximum (max) and minimum (min) temperature of Gebre Guracha

Month	Rainfall (mm)	Maximum Temperature (ºC)	Minimum Temperature (ºC)
January	16	23.8	7.6
February	32	24.8	9.2
March	58	25.5	10.7
April	71	25.4	11.2
May	80	25.2	11.2
June	122	23.8	10.9
July	289	21.5	11.2
August	281	21.2	11
September	168	22	10.3
October	47	23	8.8
November	13	23.1	7.4
December	10	23.2	6.8

Source: (https://www.weather2visit.com/africa/ethiopia/gebre-guracha.htm)

Appendix Table 6. 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