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ON:

ASSESSMENT OF PHYSICOCHEMICAL PROPERTIES OF SOILS FROM
DIFFERENT LAND USE TYPES AND SOIL DEPTHS IN SENAGA
HARAWE KEBELE, DEGA DISTRICT, BUNO BEDELE ZONE, OROMIA
REGIONAL STATE SOUTHWEST ETHIOPIA

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REGIONAL STATE SOUTHWEST ETHIOPIA

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DECLARATION

I undersigned declare that, this thesis entitled “Assessment of physicochemical properties of soils in different land use types and soil depths in Senaga Harawe *Kebele*, Dega District, Buno Bedele Zone, Oromia Regional State South-West Ethiopia” is my own original work and it has not been submitted for the award of any academic degree or the like in any other institution or university, and that all the sources I have used or quoted have been indicated and acknowledged.

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LIST OF ACRONYMS AND ABBREVIATIONS

ARDO	Agricultural and Rural Development Office
Av.P	Available Phosphorus
BD	Bulk Density
CL	Cultivated Land
CEC	Cation Exchangeable Capacity
DTPA	Diethylenetriaminepentaacetic acid
EC	Electrical Conductivity
EA	Exchangeable Acidity
FAO	Food and Agriculture Organization
FL	Forest Land
GLM	General Linear Model
GPS	Global Positioning System
GL	Grazing Land
LSD	Least Significant Difference
LUT	Land Use Type
MAP	Mono Ammonium Phosphate
OC	Organic Carbon

OM	Organic Matter
PD	Particle Density
SOM	Soil Organic Matter
SAS	Statistical Analysis System
TN	Total Nitrogen
TEA	Tri Ethanol Amine
TSP	Triple Super Phosphate

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ABSTRACT

The study was conducted to determine the status of selected physicochemical properties of soils under different land use types (cultivated, grazing and forest lands) and soil depths (0-20 cm and 20-40 cm) in Senaga Harawe Kebele, located in the Dega District of Buno Bedele Zone, Oromia National Regional State Southwest Ethiopia. The soil samples were collected from the selected land uses and soil depths with its replications and finally eighteen total composite soil samples were collected from the mentioned depths. Comparisons between cultivated, grazing and forest land use types revealed a high significant difference on selected soil physicochemical properties. Soil texture (sand, silt and clay) studied was significantly affected ($P \leq 0.05$) by land use types and soil depths. Among land use types, the highest mean clay (45.04%) and bulk density 1.43 g/cm^3 values were obtained in the forest and cultivated land respectively. Considering the land use types, the highest soil pH (H_2O) (5.9) and the lowest (4.79) were recorded in the subsurface soil layer of forest and surface soil layer of cultivated land, respectively. Moreover, the range of soil pH in the surface and subsurface layers of both cultivated and grazing land use types were strongly acidic with pH (H_2O) as well as pH (KCl). On the other hand the highest average mean values of available P (9.10 mg/Kg), and SOM (5.10%) were recorded in the surface soil layer of the cultivated and forest lands. In addition, the highest mean values of EA (3.8 $\text{cmol}(+)/\text{Kg}$), CEC (30.79 $\text{cmol}(+)/\text{kg}$) and TN (0.26%) were recorded in the surface soil layer of the cultivated land ,but TN in the forest land. The mean value of exchangeable bases (Na, K, Ca and Mg) were higher (0.20, 1.60, 5.42, and 7.56 $\text{cmol}(+)/\text{kg}$) on the subsurface of the forest land. Generally, it is possible to conclude that soil physicochemical properties of the study area were significantly varied among land use types. Therefore, reducing the intensity of cultivation and grazing, application of lime and organic fertilizers could maintain the affected soil physicochemical properties of the study area.

Key words: *physicochemical properties, soil depth, land use types and soil fertility.*

1. INRODUCTION

1.1 Background of the study

Soil is one of the most important and determinant factors that strongly affects agriculture and on which most of the agricultural production and productivity is heavily dependent. This is because soil gives mechanical support to crop plants, serves as a medium for plant development and directly provides them with water and all of the nutrients that are required for their normal growth and development. Besides, it supplies animals with essential nutrients mostly indirectly through plants [1]. Soil has three important and interrelated physical, chemical and biological properties, which makes it functionally complete resources. The conversion of natural forest land to crop land resulted in change of soils physical, chemical and biological properties. Changes in land use and soil management can have a marked effect on soil physicochemical property [2]. Therefore, the assessment of soils physicochemical properties is crucial and very important to meet the many challenges that human beings face in relation to food production, natural resource management, environmental protection and above all sustainable economic development [3]. Soil as a vital natural resource which performs key environmental, economic, and social functions is non-renewable within human time scales [4].

Soil is a complex ecosystem where living organisms play a key role in the maintenance of its properties. Soil consists of a complex mixture of particulate materials derived from a biotic parent minerals, living biota and particulate organic detritus and humus substances [5]. Soil is a highly complex medium influence by environmental and physicochemical parameters, creating a varied habitat for a diverse range of soil microorganisms. Soil formation is influenced by climate (temperature and moisture), parental material, time, topography, and organisms, involve complex interactions between physical, chemical and biological processes [6, 7]. Successful agriculture requires the sustainable use of soil resource, because soils can easily lose their quality and quantity within a short period of time for many reasons. Agricultural practice therefore requires basic knowledge of sustainable use of the land in ordered to conserve soil fertility. Soil fertility is the quality of a soil to supply nutrients in proper amounts without causing toxicity, whereas soil

productivity is the capacity of a soil to produce a specific crop or sequences of crops at a specific management system [8]. It appears for certain, that the quality and quantity attributes are the driving forces towards basic processes in soils such as nutrient mineralization and release the overall effectiveness of added materials on crop yields. Therefore, the monitoring of soil process studies in relation to crop growth and yield, as well as considerations on economic benefits arising from the use of these external resources seem to have been slightly decreased [9].

Land use changes that involve conversion of natural forests to farmlands and open grazing are widely practiced in the highlands of Ethiopia. The effects of such land use changes on soil resources of the country, particularly through soil erosion, have been reported in many scientific literatures [10]. The massive soil loss in the country is caused by its' susceptibility to erosion due to the mountainous landscape coupled with mismanagement, intense rainfall and cultural practices of the farming community that leave the soil bare after harvest. The soil losses its physical and chemical properties due to erosion, vegetation removal, deforestation, leaching, and chemicals removed from industries as result of biological degradations (decline of soil humus content) [11]. Soil degradation refers to the reduction in soil fertility due to various human managements. It is this variability of human activities (biomass burning, application of fertilizer, transfer of species, after clearing plowing the land *etc.*). Studying the physicochemical properties of soil is important for sustainable management of the agricultural resources and economic growth. Physicochemical properties change is the main reasons for nutrient depletion as well as causes of fertility decline that affects crop production.

Environmental degradation caused by inappropriate land use is a worldwide problem that has attracted attention in sustainable agricultural production systems. Ethiopia is considered to be one of the developing countries where agriculture had always played a central role in the country's economy. Although agriculture has always been the mainstay of the economy, it is characterized by very low growth rate. The rapidly increasing population has led to a declining availability of cultivated land and a very high rate of soil erosion. It is apparent that soil is one of the most important and determinant factors that strongly affects crop production. Soil is the foundation resource for nearly all land uses, and the most important component of sustainable

agriculture [12]. The assessment of soil quality indicators (physical, chemical and biological soil indicators with respect to land use types and management practices is useful and primary indicator for sustainable agricultural land management. Understanding the effect of these factors on soil physicochemical properties is useful for devising land management strategies [13]. Therefore this research was initiated to investigate the influence of different land use types on selected physical and chemical properties of the soil in Senaga Harawe *Kebele*, Dega District, Oromia region, Southwest Ethiopia.

1.2 Statement of the Problem

This study concentrated on the assessment of soil physicochemical properties from different land uses based on soil depths. The types of land use that were considered under this study were: cultivated land, grazing land and the adjacent natural forest land and its implications on physicochemical properties of soil resources. Physicochemical properties of soil in this area were exposed by the land use change that can decrease soil fertility. The productivity of the soils of the study area was decreasing from year to year. Also high rain fall, erosion and intensive cultivation were observed in the study area [14]. Therefore, all those factors can increase soil acidity which is closely related to soil physicochemical properties that emphasize the health of soils [8]. But the physicochemical properties of the soils of the study area were not assessed by any researcher. Without maintaining soil physicochemical property, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. To get optimum, sustained-long lasting and self-sufficient crop production, physicochemical properties of soil has to be assessed and maintained through time. So, this research was initiated to investigate the influence of different land use types and soil depth on selected physical and chemical properties of the soil in the study area. This study may answer the following questions:

1. Which soil physicochemical properties are more affected by land use, soil depth and their interactions?
2. Which land use types need more treatment of physicochemical properties in the study area?

1.3 Objectives of the Study

1.3.1 General objective

To assess the selected physicochemical properties of soil under different land use types based on the soil depth in the study area.

1.3.2 Specific objectives

To analyze the selected physicochemical properties of soil under different land use types in the study area.

To compare the selected physicochemical properties of soil among the three lands use types and soil depths.

To identify the land use type that needs more treatment for productivity

1.4 Significance of the study

The result of this study can use to identify and treat the land use type that is more affected in physicochemical properties and to indicate the fertility variation among the three land use types. Also it may help the community who live in the study area to use necessary treatments for the affected soil physicochemical properties. Therefore, it can serve as an input for the policy makers and concerned bodies who working in natural resource conservation as well as soil physicochemical properties treatments. It can also help as a reference point to conduct further studies to enrich the area of investigation on identifying the reason for the fertility variation from the determined soil physicochemical properties of study area. Studying physiochemical properties of soil is important for sustainable management of the agricultural resources and economic growth.

2. RELATED LITERATURE REVIEW

2.1 Land Use Change

The inherent characteristics of soil which are mainly the resultant of parent material and climate undergo subtle change due to different land management practices. Soil characteristics such as soil organic matter (SOM) [15], bulk density, and water retention [16], pH and nutrient status [17], and soil biota tend to change depending on land use, climate and vegetation [18]. Land use changes are operating over an immeasurably greater proportion of the globe's land area. Different time spans have been observed for the occurrence of these changes after sedentary agriculture was started. Some changes were very short and of an exploitative nature, while others were long and stable [19]. Indeed, changes in land use cover have significant effect on the amount and diversity of biomass returned to the soil, which also disrupt the richness of nutrient restored to the soil. It is perhaps a known fact that soil erosion intensity and amount of nutrient element loss varies depending on the vegetation type at a particular place and time. This is so because, the rate of nutrient element loss in both dissolved and sediment bound forms will depend on the ability of vegetation canopy to effectively intercept the direct impact of raindrops that strike the soil surface. In developing countries, including Ethiopia, the amount, rate and intensity of land use changes are very high.

Human impacts upon the land are still very great and increasing [20]. Extensive deforestation and conversion of natural forests into agricultural fields is the most widespread change in land use system in Ethiopian ecosystems. In the past 100 years only, the total area of land covered by forest in Ethiopia has declined from about 40% to an estimated 2.4% in 1990 [21]. The rate of deforestation is estimated to be between 150,000 and 200,000 ha per annum [22] from which as a result one can see the scale of clearance has been massive. Land use changes are caused by a number of natural and human driving forces [23]. Natural effects such as climate change are felt only over a long period of time, while the effects of human activities are immediate and often radical. According to [24] changes are due to resource management strategies in terms of agriculture and livestock grazing, which significantly influence land use and in turn drives land

use changes. Hence, changes in land use are, in most cases, reflections of the dynamics of socioeconomic development [25].

2.2 Soil Physical Properties

The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with changes in land use system and its management such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses [26].

2.2.1 Soil texture

Texture refers to the relative proportions of particles of various sizes such as sand, silt and clay in the soil. The particles that make up soil are categorized into three groups by size sand, silt and clay. Sand particles are the largest and clay particles are the smallest in size. Most soils are a combination of the three particles. The relative percentages of sand, silt, and clay are what give soil its texture. A clay loam texture soil, for example, has nearly equal parts of sand, silt, and clay. These textural separates result from the weathering process. Soil texture is one of the inherent soil physical properties less affected by management. The rate of increase in stickiness or ability to mould as the moisture content increases depend on the content of silt and clay, the degree to which the clay particles are bound together into stable granules and the OM content of the soil [27]. Over a very long period of time, pedogenic processes such as erosion, deposition, eluviations and weathering can change the textures of various soil horizons [28, 29]. Soil texture determines a number of physical and chemical properties of soils. It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, and tillage and irrigation practices [30]. It is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil [31].

2.2.2 Bulk density, Particle density and Porosity

Soils are composed of solids (minerals and organic matter), and pores which hold air and water. The bulk density of a soil sample of known volume is the ratio of mass to the bulk volume. The "ideal" soil would hold sufficient air and water to meet the needs of plants with enough pore space for easy root penetration, while the mineral soil particles would provide physical support and plant essential nutrients. Soil bulk density is a basic soil property influenced by some soil physical and chemical properties. Bulk density is influenced by the amount of organic matter in soils, their texture, constituent minerals and porosity [32].

Information of soil bulk density is essential for soil management, and knowledge about it is important in soil compaction as well as in the planning of modern farming techniques. Soil bulk density measurements are often required as an input parameter for models that predict soil processes. Such models often use bulk density measurements to account for horizon mass when aggregating soil data. Methods to measure bulk density are labor intensive and time-consuming. Thus, models have been developed to predict bulk density from soil physical and chemical data [33, 34]. Bulk density typically increases with soil depth since subsurface layers are more compacted and have less organic matter, less aggregation, and less root penetration compared to surface layers, therefore contain less pore space. Bulk density normally decreases as mineral soils become finer in texture. Soils having low and high bulk density exhibit favorable and poor physical conditions, respectively. Bulk densities of soil horizons are inversely related to the amount of pore space and SOM [29, 30]. 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. Bulk density can be changed by management practices that affect soil cover, organic matter, soil structure, compaction, and porosity. Excessive tillage destroys soil organic matter and weakens the natural stability of soil aggregates making them susceptible to erosion caused by water and wind. When eroded soil particles fill pore space, porosity is reduced and bulk density increases. The study results of [15, 25] revealed that the bulk density of cultivated soils was higher than the bulk density of forest soils. Soil bulk density increased in the 0-10 and 10-20 cm layers relative to the length of time the soils were subjected to cultivation [15]. Similarly, Ahmed

reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth [35]. On the other hand, [36] reported that bulk density was higher at the surface than the subsurface horizons in the abandoned and lands left fallow for twelve years. The changes in the physical soil attributes on the farm fields can be attributed to the impacts of frequent tillage and the decline in SOM content of the soil.

Particle density is the mass or weight of a unit volume of soil solids. It affects soil porosity, aeration and rate of sedimentation of particles. The mean particle density of most mineral soils is about 2.60 to 2.75 g/cm³, but the presence of iron oxide and heavy minerals increases the average value of particle density and the presence of OM lowers it [37]. The surface soil layer had lower particle density value than the subsoil horizons and the higher particle density (2.93 g/cm³) was obtained at the subsoil horizons in different land use systems at different elevation. This is attributed to the lower OM content in the subsoil than in the surface horizons [35].

Porosity is the fraction of the total soil volume that is taken up by the pore space. Thus it is a single-value quantification of the amount of space available to fluid within a specific body of soil. Being simply a fraction of total volume can range between 0 and 1, typically falling between 0.3 and 0.7 for soils. With the assumption that soil is a continuum, adopted here as in much of soil science literature, porosity can be considered a function of position [38]. A soil's porosity and pore size distribution characterize its pore space, that portion of the soil's volume that is not occupied by or isolated by solid material. The basic character of the pore space affects and is affected by critical aspects of almost everything that occurs in the soil: the movement of water, air, and other fluids; the transport and the reaction of chemicals; and the residence of roots and other biota. Porosity is often conceptually partitioned into two components, most commonly called textural and structural porosity. The textural component is the value the porosity would have if the arrangement of the particles were random, as described above for granular material without cementing. That is, the textural porosity might be about 0.3 in a granular medium. The structural component represents nonrandom structural influences, including macro pores and is arithmetically defined as the difference between the textural porosity and the total porosity [39]. The texture of the medium relates in a general way to the pore-size distribution, as large particles give rise to large pores

between them, and therefore is a major influence on the soil water retention curve. Additionally, the structure of the medium, especially the pervasiveness of aggregation, shrinkage cracks, worm-holes, etc. substantially influences water retention [40].

2.3 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. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil.

2.3.1 Soil pH and Electrical conductivity

Soil pH is a measure of soil acidity or alkalinity. It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and soil micro-organism activity which influence key soil processes. Soil pH can be managed by measures such as applying the proper amount of nitrogen fertilizer, liming, and cropping practices that improve soil organic matter and overall soil health. Soil reaction, or pH, is one very important property that has great influence on the growth of soil microorganisms and higher plants and on the soil management required for satisfactory crop production. Soil pH is affected by land use and management. Vegetation type impacts soil pH. For example, areas of forestland tend to be more acidic than areas of grassland. Conversion of land from forestland or grassland to cropland can result in drastic pH changes after a few years. These changes are caused by a loss of organic matter, removal of soil minerals when crops are harvested, erosion of the surface layer, and effects of nitrogen and sulfur fertilizers. Addition of nitrogen and sulfur fertilizers can lower soil pH over time. Inherent factors affecting soil pH such as climate, mineral content and soil texture cannot be changed. Natural soil pH reflects the combined effects of soil-forming factors (parent material, time, relief or topography, climate, and organisms) [5].

Increasing soil acidity in crop production systems is caused by use of commercial fertilizers, especially ammonium (NH_4^+) sources that produce H^+ during nitrification; crop removal of cation in exchange for H^+ ; leaching of cation being replaced first by H^+ and subsequently by Al^{3+} ; and decomposition of organic compounds [41]. Fertilizer materials vary in their soil reaction pH. Nitrate sources carrying basic cations should be less acid forming than NH_4^+ sources. Phosphoric acid released from dissolving P fertilizers such as triple superphosphate (TSP) and mono ammonium phosphate (MAP) can temporarily acidify localized zones at the site of application. TSP will reduce soil pH to as low as 1.5, whereas MAP will decrease pH to approximately 3.5; however the quantity of H^+ produced is very small and has little long term effect of soil pH. Di-ammonium phosphate (DAP) will initially raise soil pH to about 8.0, unless the initial soil pH is greater than the pH of the fertilizer. Acidity produced by the nitrification of the NH_4^+ in DAP will offset this initial pH increase [42].

Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics. In addition to overcoming some of the ambiguities of total dissolved salts measurements, the EC measurement is quicker and sufficiently accurate for most purposes [43]. Excessive accumulation of soluble salts convert soils to salt affected soils and the process leading to accumulation of salts are common in arid and semi arid regions where rainfall amount is insufficient to leach soluble salts. The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. Sands have a low conductivity, silts have a medium conductivity, and clays have a high conductivity. Consequently, EC correlates strongly to soil particle size and texture. In addition to EC values separating variations in soil texture, EC has been shown to relate closely to other soil properties used to determine a field's productivity [44].

2.3.2 Organic matter and Total nitrogen

Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition). Most of the productive agricultural soil has between 3 and

6% organic matter. Soil organic matter contributes to soil productivity in many different ways. In this fact sheet, we describe the various components of organic matter and the different roles organic matter plays in soil productivity. Soil organic matter is heterogeneous or non-uniform in nature and does not have any defined physical or chemical structure. It can be present in soils under various stages of decomposition from mineral associated partially decomposed plant material to fully decomposed humus [45].

Soil organic matter (SOM) is the organic component of soil, consisting of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) organic matter, and stable organic matter (humus). Soil organic matter serves as a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, retains moisture, reduces compaction, reduces surface crusting, and increases water infiltration into soil [5]. Components vary in proportion and have many intermediate stages. Plant residues on the soil surface such as leaves, manure, or crop residue are not considered SOM and are usually removed from soil samples by sieving through a 2 mm wire mesh before analysis.

Soil organic matter content can be estimated in the field and tested in a lab to provide estimates for Nitrogen, Phosphorus and Sulfur mineralized available for crop production and adjust fertilizer recommendations. Soil organic matter impacts the rate of surface applied herbicides along with soil pH necessary to effectively control weeds. Soil organic matter impacts the potential for herbicide carryover for future crops, and amount of lime necessary to raise pH. The addition of organic matter to the soil usually increases the water holding capacity of the soil. This is because the addition of organic matter increases the number of microspores and macrospores in the soil by creating favorable living conditions for soil organisms. Certain types of soil organic matter can hold up to 20 times their weight in water.

Humus is the substance left after soil organisms have modified original organic materials to a rather stable group of decay products as is the colloidal remains of SOM. In most tropical environments, the conversion of forest vegetation to agricultural land results in a decline of the SOM content to a newer, lower equilibrium [25]. Organic matter affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter

include: soil structure; moisture holding capacity; diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides and herbicides. The total amount of OC in the soil can be considered as a measure of stored OM. In a sense stored OM is a mean OM store or standing stock of OM because it reflects the net product or balance between ongoing accumulation and decomposition processes and it is thus greatly influenced by crop management and productivity. Over the past few years, various attempts have been made to obtain both global and regional inventories of soil OM storage based on soil map units. Generally, sample generic soil horizons based on the effects of land use types and/or management practices provide a useful estimate of total soil carbon storage [46].

Nitrogen is the seventh most abundant element in the universe. It's the single most common element in the earth's atmosphere, comprising about 78% (4,000 trillion tons) of the gas that makes up our atmosphere. Nitrogen is found in all soils, and is required by all living creatures. In plants, nitrogen is the nutrient required in the largest amounts. It is a key constituent of critical organic molecules such as amino acids, nucleic acids, and proteins. Nitrogen is found in marine and freshwaters and is present in some minerals. In short, nitrogen is found in every ecosystem and in every part of the global environment. In the atmosphere, the predominant form of nitrogen is di nitrogen gas (N_2), which is relatively inert and must be converted into different forms to be utilized by most organisms [36].

There are several avenues for these conversion processes, collectively called nitrogen fixation, in which N_2 gas is converted to ammonium (NH_4^+). A small amount of nitrate (NO_3^-) is produced by high voltage electrical discharged in the atmosphere.[36] that there was a 30 and 76% depletion of total N from during lightning storms agricultural fields cultivated for 40 years and abandoned land respectively. Average total N increased from cultivated to grazing and forest land soils, which again declined with increasing depth from surface to subsurface soils [47]. The considerable reduction of total N in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation [46].

Moreover, the decline in soil OC and total N, although commonly expected following deforestation and conversion to farm fields, might have been exacerbated by the insufficient inputs of organic substrates from the farming system. The same author also stated that the levels of soil OC and total N in the surface soil (0-10 cm) were significantly lower, and declined increasingly with cultivation time in the farm fields, compared to the soil under the natural forest. Carbon (C) to nitrogen (N) ratio (C/N) is an indicator of net N mineralization and accumulation in soils. Organic matter rich in carbon provides a large source of energy to soil microorganisms. Consequently, it brings population expansion of microorganism and higher consumption of mineralized N. Dense populations of microorganisms inhibit the upper soil surface and have an access to the soil N sources. If the ratio of the substrate is high there will be no net mineralization and accumulation of N. They further noted that as decomposition proceeds, carbon is released as CO₂ and the C: N ratio of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients. Plant residues with C: N ratios of 20:1 or narrower have sufficient N to supply the decomposing microorganisms and also to release N for plant use. Residues with C: N ratios of 20:1 to 30:1 supply sufficient N for decomposition but not enough to result in much release of N for plant use the first few weeks after incorporation. Residues with C: N ratios wider than 30:1 decompose slowly because they lack sufficient N for the microorganisms to use for increasing their number, which causes microbes to use N already available in the soil [46].

2.3.3 Available Phosphorus

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. Phosphorus is one of the three nutrients generally added to soils in fertilizers. One of the main roles of P in living organisms is in the transfer of energy. Organic compounds that contain P are used to transfer energy from one reaction to drive another reaction within cells. Adequate P availability for plants stimulates early plant growth and hastens maturity. Although P is essential for plant growth, mismanagement of soil P can pose a threat to water quality. The concentration of P is usually sufficiently low in fresh water so that algae growth is limited. When lakes and rivers are polluted with P, excessive growth of algae often results. High levels of algae reduce water clarity and can lead to decreases in available dissolved oxygen as the algae decays, conditions that can be very detrimental to game fish populations.

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants [5]. Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forests and grasslands, 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 [30]. It is the most commonly plant growth-limiting nutrient in the tropical soils next to water and N [48]. Erosion tends to transport predominantly the clay and SOM fractions of the soil, which are relatively rich in P fractions. Thus, compared to the original soil, eroded sediments are often enriched in P by a ratio of two or more [30]. Natural soil will contain from 50 to over 1,000 mg of total P per kilogram of soil. Of this quantity, about 30 to 50% may be in inorganic form in mineral soils [5]. The main sources of plant available P are the weathering of soil minerals, the decomposition and mineralization of SOM and commercial fertilizers. [49].

2.3.4 Cation exchange capacity

Cation exchange capacity is the capacity of the soil to hold and exchange cations. The cation exchange capacity, or “CEC”, of a soil is a measurement of the magnitude of the negative charge per unit weight of soil, or the amount of cations a particular sample of soil can hold in an exchangeable form. It provides a buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes. As such it is a major controlling agent of stability of soil structure, nutrient availability for plant growth, soil pH, and the soil’s reaction to fertilizers and other ameliorants. A low CEC means the soil has a low resistance to changes in soil chemistry that are caused by land use [50]. Cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. The cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations [30]. Generally, the chemical activity of the soil depends on its CEC. The CEC of a soil is strongly affected by the amount and type of clay, and amount of SOM present in the soil [51]. Both clay and colloidal SOM are negatively charged and therefore can act as anions. As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to absorb and hold positively charged ions (cations).

Soils with large amounts of clay and SOM have higher CEC than sandy soils low in SOM. In surface horizons of mineral soils, higher SOM and clay contents significantly contribute to the CEC, while in the subsoil particularly where Bt horizon exist, more CEC is contributed by the clay fractions than by SOM due to the decline of SOM with profile depth [32]. Soil Cations are positively charged ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+), sodium (Na^+) hydrogen (H^+), aluminum (Al^{3+}), iron (Fe^{2+}), manganese (Mn^{2+}), zinc (Zn^{2+}) and copper (Cu^{2+}). The capacity of the soil to hold on to these cations called the cation exchange capacity (CEC). These cations are held by the negatively charged clay and organic matter particles in the soil through electrostatic forces (negative soil particles attract the positive cations). The cations on the CEC of the soil particles are easily exchangeable with other cations and as a result, they are plant available. Thus, the CEC of a soil represents the total amount of exchangeable cations

that the soil can absorb. This property affects the availability of potassium, calcium, and magnesium to plants. The term used to report CEC is milli equivalents/100 grams (me/100g) of soil [9].

2.3.5 Exchangeable acidity (EA)

Soil exchangeable acidity refers to the amount of acid cations, aluminum (Al) and hydrogen (H), occupied on the CEC. Soil acidity occurs when acidic H^+ ion occurs in the soil solution to a greater extent and when an acid soluble Al^{3+} reacts with water (hydrolysis) and results in the release of H^+ and hydroxyl Al ions into the soil solution [30]. As soils become strongly acidic, they may develop sufficient Al in the root zone and the amount of exchangeable basic cations decrease, solubility and availability of some toxic plant nutrient increase and the activities of many soil microorganisms are reduced, resulting in accumulation of SOM, reduced mineralization and lower availability of some macronutrients like N, S and P and limitation of growth of most crop plants [52]. Aluminum is a predominant cation in many soils and can be a critical variable in establishing effective cation exchange capacity (ECEC) values. In exchange reaction sites characterization is complicated by the coexistence of complex multiphase Al components that make its measurement specific to a particular extract and potentially difficult to interpret. When the CEC of a soil is high but has a low base saturation, the soil becomes more resistant to pH changes. As a result, it will require larger additions of lime to neutralize the acidity. The soil is then buffered against pH change and during soil acidification, protonation increases the mobilization of Al and Al forms serve as a sink for the accumulation of H^+ . The concentration the H^+ in soils to cause acidity is pronounced at pH values below 4 while excess concentration of Al^{3+} is observed at pH below 5.5 [53]. In strongly acidic conditions of humid regions where rainfall is sufficient to leach exchangeable basic cations, exchangeable Al occupies more than approximately 60% of the effective cation exchange capacity, resulting in a toxic level of aluminum in the soil solution [54]. Generally, the presence of more than 1 parts per million of Al^{3+} in the soil solution can significantly bring toxicity to plants. Hence, the management of exchangeable Al is a primary concern in acid soils.

2.3.6 Exchangeable bases (K, Na, Mg and Ca)

The four major exchangeable cation bases in soils are K, Ca, Mg, and Na. All except Na are essential plant nutrients; however Na is included here because it plays an important role in soil physical properties. Soil Na level is needed for calculations of cation exchange capacity (CEC). Ammonium acetate is used to extract exchangeable K, Ca, Mg, and Na from arid region soils, but it does not extract less plant-available forms. Some difficulty may be encountered in soils containing Ca or Mg carbonates (calcareous soils) because the ammonium acetate extraction may remove some Ca or Mg from these minerals along with the exchangeable forms. In these situations, the analytical results may indicate slightly elevated levels of these nutrients. Some laboratories adjust the pH of the ammonium acetate extract to 8.5 to minimize this error. However, this is not usually a large problem and K, Ca and Mg tests generally provide excellent estimates of plant available levels of these nutrients. Exchangeable sodium (Na) alters soil physical and chemical properties mainly by inducing swelling and dispersion of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (decrease solubility and availability of calcium (Ca) and magnesium (Mg) ions) [55]. Moreover, it also adversely affects the population, composition and activity of beneficial soil micro organisms directly through its toxicity effects and indirectly by adversely affecting soil physical and as well as chemical properties.

In general, high exchangeable Na in soils causes soil so acidity which affects soil fertility and productivity. Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, and the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution [38]. Potassium is the third most important essential element next to N and P that limit plant productivity. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike N and P, K causes no off-site environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic systems [29].

The variation in the distribution of K depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed [36]. The greater the proportion of clay mineral high in K, the greater will be the potential K availability in soils [56]. Soil K is mostly a mineral form and the daily K needs of plants are little affected by organic associated K, except for exchangeable K adsorbed on SOM. [57] described low presence of exchangeable K under acidic soils while [58] observed low K under intensive cultivation. Normally, losses of K by leaching appear to be more serious on soils with low activity clays than soils with high- activity clays, and K from fertilizer application move deeply [39].

Soils in areas of moisture scarcity (such as in arid and semi arid regions) have less potential to be affected by leaching of cations than do soils of humid and humid regions [59]. Soils under continuous cultivation, application of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH are characterized by low contents of Ca and Mg mineral nutrients resulting in Ca and Mg deficiency due to excessive leaching [60]. Exchangeable Mg commonly saturates only 5 to 20% of the effective CEC, as compared to the 60 to 90% typical for Ca in neutral to somewhat acid soils [29]. Research works conducted on Ethiopian soils indicated that exchangeable Ca and Mg cations dominate the exchange sites of most soils and contributed higher to the total percent base saturation particularly in Vertisols [48]. Different crops have different optimum ranges of nutrient requirements. The response to calcium fertilizer is expected from most crops when the exchangeable Ca is less than 0.2 cmol(+)/kg of soils, while 0.5 cmol(+)/kg soil is reported to be the deficiency threshold level for Mg in the tropics [53].

2.3.7 Micronutrients (Fe, Mn, Zn and Cu)

The term micronutrients refer to a number of elements that are required by plants in very small quantities. This term usually applies to elements that are contained in plant tissues in amounts less than 100 mg kg⁻¹. The four essential micronutrients that exist as cations in soils are zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn). Adsorption of micronutrients, either by SOM or by clay-size inorganic soil components is an important mechanism of removing micronutrients

from the soil solution. Thus, each may be added to the soil's pool of soluble micronutrients by weathering of minerals, by mineralization of SOM, or by addition as a soluble salts [38]. Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, and SOM [29, 56] stated that micronutrients have positive relation with the fine mineral fractions like clay and silt while negative relations with coarser sand particles. This is because their high retention of moisture induces the diffusion of these elements. Soil organic matter content also significantly affects the availability of micronutrients.

The presence of SOM may promote the availability of certain elements by supplying soluble complex forming agents that interfere with their fixation [61]. The main source of micronutrient elements in most soils is the parent material, from which the soil is formed [62]. Iron, Zn, Mn, and Cu are somewhat more abundant in basalt. [29] Indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn, and Zn) are more under acidic conditions (pH of 5.0 to 6.5).

3. MATERIALS AND METHOD

3.1 Apparatus and chemicals

3.1.1 Instruments

Atomic Absorption Spectrophotometer, pH meter, UV-Vis spectrophotometer, conductivity meter, Oven, Kjeldahl distillation unit and flame photometer were used in this study.

3.1.2 Chemicals:

H ₂ O ₂	(NaPO ₃) ₆ ,
H ₂ SO ₄	NaOH
NaCl	KCl
HCl	K ₂ Cr ₂ O ₇
NH ₄ F	FeSO ₄ .7H ₂ O
NaF	NH ₄ CH ₃ COO
H ₃ BO ₃	

All chemicals used are in their analytical grades and they are purchased from sigma Aldrich.

3.2 Description of the Study Area

3.2.1 Location

The study was conducted at Senaga Harawe Kebele in Dega District, Buno Bedele Zone, Oromia Regional state, South-West Ethiopia. It is about 548 km away from the capital, Addis Ababa, and located in the South-west Ethiopia, 168 km away from Jimma Town and 18 km away from the district town, Dega, to the east. Geographically it is located between $8^{\circ} 35' 16''$ to $8^{\circ} 39' 06''$ north latitude and $36^{\circ} 06' 49''$ to $36^{\circ} 10' 35''$ east longitude with an elevation ranging from 1904 – 2301 meters above sea level. This Dega District shares boundaries in the west with Chora Kumbabe District, in the north with Meko District, in the South Bedele District and east with Dabo Hana District. This District possesses a total area about 46,202 hectares [14].

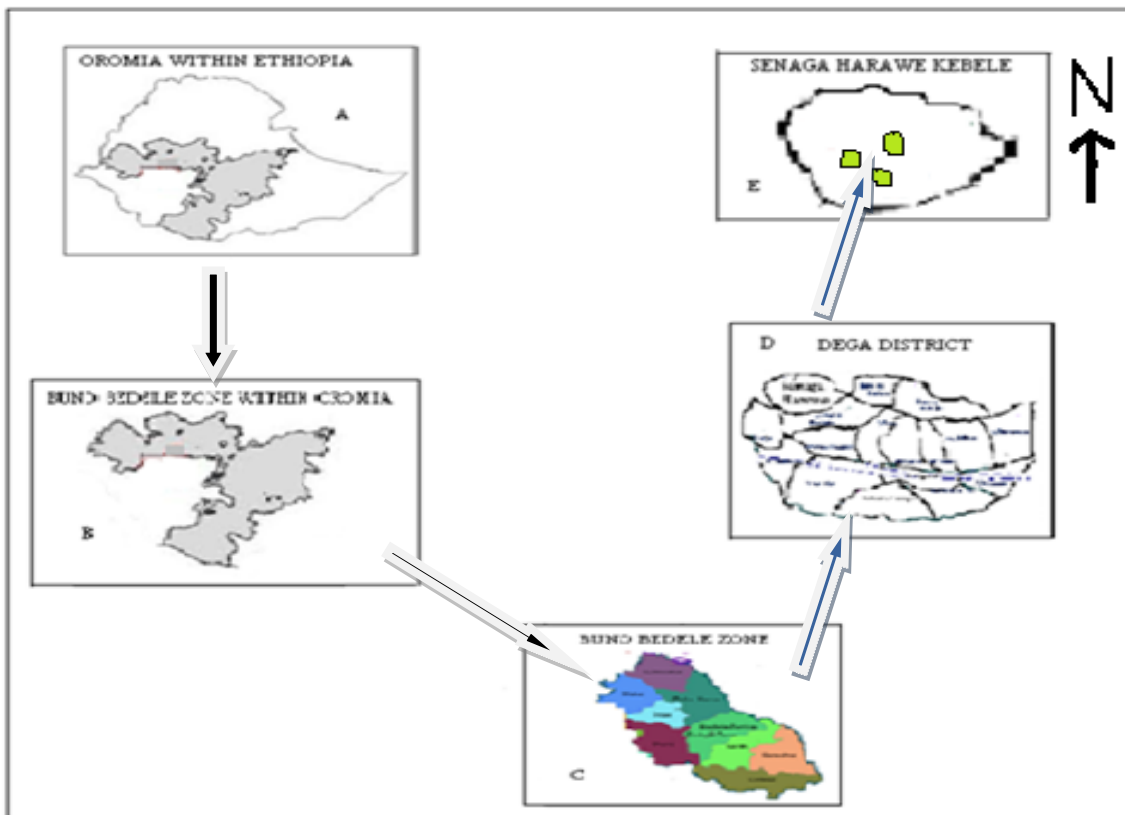


Figure 1. Location map of the study area

3.2.2 Climate

The average weather data recorded at the weather station located at Dega town near the study area indicates that the study area has a uni-modal rainfall pattern with the average annual rainfall 1200-1800 mm. The rainy season covers the period from April to October and the maximum rain is received in the months of June, July and August. The annual average minimum and maximum air temperature is 11°C and 28°C, respectively [14].

3.2.3 Soil type and vegetation

According to the district data shows, the soil of Senaga Harawe area is well drained, deep rich in humus content and characteristically suitable for coffee growth and other cereal crops and it is dominated by cultivated land. The main species of plants are broad-leaved and ever green, but the natural coverage of vegetation in the area is declining from year to year because of farm land expansion [14].

3.2.4 Farming system

Land is cultivated at the onset of the rainy season using a pair of oxen and traditional implements. The farming system is a typical mixed crop-livestock system that is carried out on a subsistence scale. The main crops grown include maize, sorghum, vegetables and fruits. Cattle, sheep, goat, poultry, horse and donkey are among the common types of livestock [14].

3.2.5 Land use types

The natural forest land covers is 4,849.75 ha and that of manmade is 357 ha. Annual cereal crop covers 23,475.17 ha, priginal 12,582.08 ha, Chat 1,817 ha and area of coffee coverage is about 3121 ha. The drainage of the district consists of 56 small rivers and two large rivers (Dabana and Canco) [14]. According to Dega District Administration office (population census 2016) the total population of the district was reported to be 53,386. Of which, 48,624 are rural residents while 4762 are urban dwellers. Among these 26,389 are males and 26,997 are females.

3.3 Site Selection, Soil Sampling and Preparation

Planning, surveying and appropriate sampling are important considerations when attempting to measure changes in surface soil chemical and physical properties to accommodate spatial variation. Primarily, a general visual field survey of the study area and Observation of Dega district agricultural and rural development office data about the study site was carried out to have a general view of the variations in the study area. Then the soil sampling fields were selected from the cultivated, grazing and forest land use types based on vegetation and cultivation history. Depending on their similarities three forest land fields, three grazing land fields and three cultivated land fields were selected, and from each fields of land use types, ten soil samples were collected from the depths of 0-20 and 20-40 cm each in a radial sampling scheme using an auger [50]. Dead plants, furrows, old manures, wet spots, areas near trees and compost pits were excluded during collection of samples. A total of one hundred eighty (180) samples (sixty (60) samples per land use type) of soil which is ninety (90) samples from 0-20 cm and ninety (90) samples from 20-40 cm of soil samples were collected. Separate soil core samples from the 0-20 and 20-40 cm depths was taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination [50]. A total of eighteen composite samples were collected and each composite sample is made from a pool of ten samples. To make one composite soil sample ten sub-samples were mixed well and about 1 kg of the mixed sub-samples was taken using quartering method and properly labeled. Finally eighteen (18 kg) total composite soil samples were prepared and packed in a plastic and transported to Jimma University College of Agricultural and Veterinary Medicine Soil Research Laboratory for further analysis. Soil samples received in the laboratory are assigned a laboratory number, placed in stainless steel pans and opened daily for air drying. The samples were grounded mechanically and passed through a 2 mm diameter sieve for all parameters except total N and OC which was passed through a 0.5 mm diameter.



Cultivated land

Grazing land

Forest land

Figure 2. Soil samples collected from the study area (Senaga Harawe kebele)

3.4 Soil Laboratory Analysis

Most of the soil physical and chemical analysis was carried out at Jimma University College Agricultural and Veterinary Medicine in Soil Research Laboratory and Addis Ababa University soil testing laboratory for further analysis. Standard laboratory procedures were used for the analysis of the selected soil physicochemical properties in the study.

3.4.1 Analysis of soil physical properties.

3.4.1.1 Soil texture

Soil texture was determined by the Bouyoucos hydrometer method after digesting organic matter (OM) by hydrogen peroxide (H_2O_2) and dispersing the soil by using sodium hexameta phosphate [29, 30]. Air dried and sieved soil of 50.0 g was transferred to 500 mL beaker. Then 20 mL of distilled water followed by 20 mL of H_2O_2 (30%) were added to the soil samples to destroy organic matter. Then 100 mL sodium hexameta phosphate (dispersing agent) solution added and the sample bottle was shook for half an hour to homogenize solution. The dispersed sample solution was transferred to 1000 mL glass measuring cylinder and filled to the mark with water. Measuring cylinder containing 1000 mL sample solution covered at the top and shook energetically for 30 seconds. Then hydrometer immersed first in blank and next in the sample

solution within 40 seconds, the hydrometer reading at 40 seconds and the temperature solution was recorded. This reading measures the percentage of silt and clay in suspension. After the first reading, the cylinder stand for two hours and the second reading was made in the same manner with the first and the percentage of clay was recorded from this second reading.

3.4.1.2 Bulky density, particle density and total porosity

Bulk density was determined from undisturbed soil samples by using procedures in core method. In this method cylindrical metal (core) of known volume was driven into the ground to the desired depth and carefully removed to preserve the known volume of as it existed in situ. The core sample containing moist soil was weighed and placed in an oven at 105 °c for about 24 hours .The dried defined volume of soil in an oven weighed [30,33]. Then bulk was calculated as the ratio of mass of oven dried soil to the volume of the sampling core.

Soil particle density was determined using pycnometer method. A clean, dry pre weighed 100 mL volumetric flask was filled with water to the marked line and weighed again. Then, weight of water was determined by subtracting the weight of the flask from the weight of the flask plus water. Then, 25 g of soil was added to the flask containing water and shook gently to remove air bubbles, the mass of soil, water and flask was recorded. The weight of water in the flask containing soil determined, by subtracting the weight of soil and flask from the sum weight of the flask, water and soil. The difference in the weight of water in the flask with and without soil was recorded. The volume of water that was displaced by the soil can represent the volume of soil solids. Therefore, the particle density of the soil was calculated using the formula $PD = \text{mass of dry soil} / \text{volume of soil solids}$. While Percentage pores space was determined from the values of bulk density (BD) and particle density (PD) [26].

3.4.2 Analysis of soil chemical properties

3.4.2.1 Soil pH and Electrical conductivity

The soil pH was measured potentiometrically with a digital pH meter in the suspension in the ratio of 1:2.5, soil to H₂O and soil to KCl mixture. In polyethylene, 10.0 g of soil sample and 25 mL of double distilled water or KCl solution mixed and shook on an automatic shaker for 30 minutes. The solution was transferred into another clean dry bottle. After calibration, glass electrode was dipped into the bottle containing the soil water suspension, pH values were recorded and the electrode removed from soil suspension and cleaned the electrode with distilled water.

Electrical conductivity (EC) was measured by digital conductivity meter from a soil water ratio of 1:2.5 soaked for one hour. The soil water suspension of 10.0 g: 25.0 mL distilled water ratio prepared for the determination of pH can also be used for conductivity measurement. After recording pH, the soil suspension in the bottle, settle for additional half hour. Calibration made and the conductivity cell was dipped in the soil water suspension of each sample turn by turn with cleaning the cell by distilled water [55, 56].

3.4.2.2 Soil organic matter and Total nitrogen

Soil organic carbon was determined by Walkley-Black wet oxidation method. In a 500 mL Erlenmeyer flask 0.5 g of air dry soil (0.5 mm) was placed. Then, 10 mL of 1 M K₂Cr₂O₇ and 20 mL H₂SO₄ were added to the flask to destroy the organic matter [45]. After digestion, titration was carried by adding 0.5 N ferrous sulphate until the color flashes to green then continue to a light green end point observed. Soil organic matter contains 58%, and then conversion of carbon to organic matter can be done with the empirical factor of 1.724, [55, 57]. % Organic matter = 1.724x % Organic carbon.

Total nitrogen was determined by micro Kjeldahl procedure (digestion, distillation and titration). 1.0 g soil sample was added to Kjeldahl tube and placed in the fume hood for digestion using with 10 mL sulphuric acid (H₂SO₄) and 5 mL hydrogen peroxide (H₂O₂) with selenium as catalyst. The digestion was carried for 3 hours until the digest was colorless. The acid digested

soil was transferred into macro kjeldah flasks for distillation. Then, 20 mL of boric acid was measured from dispenser into receiver Erlenmeyer flask corresponding to the number of samples to prevent the loss of ammonia. The distillation flasks containing the digests filled by 75 mL of 40% NaOH and mixed gently. After distillation, about 80 mL of distillate has been collected. Finally the solution was titrated with 0.1N H₂SO₄ until a pink color end point and total nitrogen was determined [47].

3.4.2.3 Available phosphorus

Available P was analyzed using the procedures in the Bray-II method because of soil acidity. 2 g of air dried soil and 20 mL of extracting solution (Bray II) were transferred to bottle flask. After a mixture solution shook and filtered 8 mL of boric acid was added. Finally available P in the sample solution was determined by UV-Vis spectrophotometer at a wave length of 882 nm [49].

3.4.2.4 Exchangeable acidity

Exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution [53]. 10 g of dry soil was transferred to a dry filter paper in funnel placed in a 100 mL volumetric flask and 10 portions of 10 mL 1M KCl solution was added with 15-minutes interval so that the percolation took about 2 1/2 hours. Then, 25 mL aliquot percolate pipette was added into a 250 mL Erlenmeyer flask with 5 drops of phenolphthalein solution and titrated by 0.02 M NaOH until the color turns just permanently pink [62]. In addition, one of the sources of acidity, exchangeable aluminum was measured, separately by titrating solution with 0.02 M HCl until the pink color disappeared. In the titration process sodium fluoride was added to the solution then the solution developed pink color and titrated with 0.02M HCl until the end point was lasting long. Exchangeable acidity is the sum of exchangeable hydrogen and exchangeable aluminum.

3.4.2.5 Cation exchange capacity (CEC) and Exchangeable basic cations

Cation exchange capacity (CEC) was determined by ammonium acetate saturation method [60]. 5.0 g soil sample and 100 mL of 1M ammonium acetate solutions at pH 7 was added to 250 mL beaker. The mixture was stirred instantly with stirring rod and allowed to stand overnight which

involved soaking method. The next day the soaked samples filtered and washed the remaining soil with 50 mL and 25 mL of 1M ammonium acetate at pH 7.0 turn by turn. The saturated soil also washed with successive 20 mL sodium chloride (NaCl 10%) solution which is followed by distillation. Sodium chloride percolate of 75 mL and 10 ml of 1 N NaOH solutions were transferred to the Kjeldah flask over the 15 mL of 0.2 N H₂SO₄ in the 250 mL Erlenmeyer flask and connected immediately to the distillation apparatus. After the distillation, the distillate solution titrated with 0.1 N NaOH using methyl red indicators until color changes from purple to yellow and CEC was calculated.

Exchangeable basic cations were extracted by 1M ammonium acetate (pH 7) method [60]. Air dried soil of 5.0 g and 100 mL of 1M ammonium acetate solutions at pH 7 were added to 250 mL beaker, and stirred instantly with stirring rod and allowed to stand overnight which involved soaking method. The next day the soaked samples were transferred onto filter funnels placed on 250 mL volumetric flasks filtered and the remaining soil washed with 50 mL and 25 mL of 1M ammonium acetate pH 7 turn by turn. Then Na and K were measured by flame photometer at wave lengths of 768 and 598 nm respectively. While Ca and Mg measured by AAS at the wave lengths 422.7 and 285.2 nm respectively.

3.4.2.6 Micronutrients (Mn, Fe, Cu, and Zn)

Micronutrients (Mn, Fe, Cu, and Zn) of the soil were extracted by diethylenetriaminepentaacetic acid (DTPA) [62]. DTPA extracting solution was prepared by dissolving 1.96g DPTA, 14.92 g tri ethanolamine (TEA) and 1.47 g calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) with distilled water in 1L of volumetric flask, then the final concentration was the mixture of 0.005M (DTPA), 0.1 M TEA and 0.01 M CaCl_2 . Then, 20.0 g air dried soil and 40 mL of extractable DTPA were added in to 100 mL poly ethylene bottle. The mixture was shook for 2hrs. Then, the sample solution was filtered and 1 mL of 0.1% La solution was added to it and homogenized. Finally, the concentrations of micro nutrients were measured by AAS at their respective wave lengths.

3.5 Statistical Analysis

The general linear model (GLM) procedure of statistical analysis system (SAS) was used for performing the significance of differences in soil parameters. A post the separation of means was done by least significant difference (LSD) test after main effects is found significant at $P < 0.05$. The analysis was performed for each land use types (cultivated, grass and forest lands) in six combined treatments. Correlation analysis was carried out to determine associations between selected soil physical and chemical parameters [63].

4. RESULTS AND DISCUSSION

4.1 Soil Physical Properties

Soil physical properties which were determined in this study include soil texture, bulk density, particle density and total porosity and their results would be discussed as follows.

4.1.1 Soil texture

The sand, silt and clay fractions were significantly ($P \leq 0.05$) different by land use, soil depth and the interaction of land use and soil depth (Table 1 and 2). The highest (50.77%) clay and (42.46%) sand contents were recorded at the subsurface layer 20-40cm and surface layer 0-20 cm of cultivated and grazing lands respectively. In contrast, the highest (23.60%) silt content was recorded at the surface layer of the forest land, whereas the lowest (27.12%) sand content was observed in the subsurface layer of the forest land (Table 1). The increase in clay contents with depth under all land use types may be due to translocation of clay from surface to subsurface layers, which ultimately increase the proportion of sand and silt contents in the surface soil layers [9]. The current results are in agreement with the findings of [9] who reported an increase in clay content with depth under cultivated lands is due to long period of cultivation.

Table 1. Interaction effects of land use and soil depth on the selected physical properties of soil in the study area.

LUT	Sand %		Silt %		Clay %	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40
CL	39.60 ^b	28.23 ^e	22.32 ^c	21.00 ^d	38.08 ^d	50.77 ^a
GL	42.46 ^a	36.94 ^c	21.40 ^d	21.20 ^d	36.14 ^e	41.86 ^c
FL	36.20 ^c	27.12 ^e	23.60 ^a	23.00 ^b	40.20 ^c	49.88 ^b
LSD(0.05)	1.29		0.46		1.67	
SEM (\pm)	0.26		0.19		0.69	

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$ LSD = Least significant difference; SEM = Standard error of the mean

Table 2. Main effects of land use and soil depth on the selected physical properties of soils in the study area.

LUT	Sand%	Silt%	clay%	STC	BD (g/cm ³)	PD(g/cm ³)	TP%
C L	33.92 ^b	21.66 ^b	44.42 ^b	C	1.43 ^a	2.54 ^c	43.49 ^c
G L	39.70 ^a	21.30 ^c	39.00 ^c	CL	1.39 ^b	2.61 ^a	47.04 ^b
F L	31.66 ^c	23.30 ^a	45.04 ^a	C	1.32 ^c	2.57 ^b	48.54 ^a
LSD	0.147	0.025	0.156		0.02	0.0129	0.815
SEM (±)	0.12	0.02	0.124		0.016	0.010	0.65
Soil depth							
0-20 cm	39.42 ^a	22.44 ^a	38.14 ^b	CL	1.37 ^b	2.58	46.97 ^a
20-40 cm	30.76 ^b	21.73 ^b	47.50 ^a	C	1.39 ^a	2.57	45.74 ^b
LSD	0.12	0.02	0.127		0.016	NS	0.67
SEM (±)	0.72	0.09	0.97		0.003	0.004	0.032

C = Clay; CL = Clay loam; STC= Soil textural classes; NS= not significant

4.1.2 Bulk density, Particle density and Total porosity

Bulk density value was significantly ($P \leq 0.05$) affected by land use, soil depth and their interaction effects (Table 3). Considering the main effect, the highest (1.43 g/cm³) mean value of bulk density was recorded on the cultivated land and the lowest (1.32 g/cm³) mean value was observed under the forest land (Table 2). From the interaction effect, Bulk density increases with soil depth because subsurface layers are more compacted and have less organic matter and less root penetration compared to surface layers, therefore contain higher bulk density and less pore space [35]. This result from intensive cultivation might have caused relatively the higher bulk density values in the surface soil layers of the cultivated land than that of the respective soil depths in the grazing and forest lands. The reason for the relatively low soil bulk density on the grazing and forest lands as well as surface soil layer could be due to the high SOM content and high clay content [64]. The highest (2.61 g/cm³) mean value of particle density was obtained under the grazing land (Table 2). Considering the surface and the subsoil depths, the highest particle density values were recorded in the grazing land among the different land use types considered in the study (Table 3). The particle density under the grazing and forest land uses increased with increasing soil depth (Table 3), which was agree with the findings reported by

[35]. But it was decreased with increasing soil depth of cultivated land. The higher particle density values on the surface soil layer of cultivated land might be due to the presence of heavy minerals of Fe and Mn in the surface soil as indicated by the higher Fe and Mn contents in the surface layer which is in agreement with past reports by [36, 37]. The particle density was not significantly ($P \geq 0.05$) different by land use, soil depth and their interaction effects. Total porosity was significantly ($P \leq 0.05$) different by land use, soil depth and the interaction of land use and soil depth (Table 3). The average (surface and subsurface) total porosity percentages of the forest, grazing and the cultivated lands were 48.54, 47.04 and 43.49%, respectively (Table 3). Generally, total porosity of surface (0-20 cm) and sub surface (20-40 cm) layers of soil were recorded (46.97%) and (45.74%) respectively (Table 2). Total porosity decreases with increasing soil depth because subsurface layers are more compacted and have less pore space compared to surface layers [35].

Table 3. Interaction effects of land use and soil depth on physical properties of soil in the study area

LUT	BD g/cm ³		PD g/cm ³		TP %	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40
CL	1.41 ^b	1.46 ^a	2.57	2.51	45.14 ^e	41.83 ^f
GL	1.38 ^c	1.39 ^c	2.61	2.62	47.13 ^c	46.95 ^d
FL	1.31 ^e	1.33 ^d	2.55	2.58	48.63 ^a	48.45 ^b
LSD(0.05)	0.012		NS		0.124	
SEM (±)	0.011		0.015		0.015	

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$ LSD = Least significant difference; SEM = Standard error of the mean; BD = Bulk density; PD = Particle density; TP = Total porosity NS = not significant; LUT = Land use type

4.2 Soil Chemical Properties

4.2.1 Soil pH and Electrical conductivity

The pH (H₂O) or KCl value of the soils content was significantly ($P \leq 0.05$) different by land use types and their interaction effects (Table 4). Soil pH values measured in a solution of soil to KCl ratio are less than a suspension of soil to water ratio. The highest pH (5.9) in the surface (20-40 cm) and the lowest (4.79) in the surface (0-20 cm) of soil pH-H₂O values were recorded under the forest and the cultivated lands, respectively. Considering the two soil depths, the mean values of pH increased from 0-20 cm to 20-40 cm soil layers (Table 5). Application of inorganic fertilizers and continuous cultivation practices and erosion could be some of factors which are responsible for the variation in pH in the soil [64]. In general, the pH (H₂O) and pH (KCl) values observed in both cultivated and grazing lands were within the ranges of strongly acidic while pH of the forest land was in the moderately acidic as indicated by [8] (appendix Table 1). Electrical conductivity (EC) of soils was not significantly ($P \geq 0.05$) difference by land use, their interaction and the soil depth (Table 4 and Table 5). Considering the main effects of land use types, the highest (0.08 dS/m) and the lowest (0.03 dS/m) EC of the soils were obtained under the forest sub layer(20-40 cm) and the grazing lands surface layer (0-20 cm), respectively (Table 4). The highest EC value under the forest land might be due to its highest exchangeable Na content, whereas the lowest EC value under the grazing land can be with the loss of base forming cations (Ca²⁺ and Mg²⁺) after deforestation and intensive cultivation [64]. As indicated in appendix table 1, EC is positively and significantly correlated with pH ($r = 0.74$), OM ($r = 0.48$), clay ($r = 0.31$). Based on the rating scale of EC range suggested by [65], the soil of the study area was ranged in low from the all land use types (appendix Table 2).

4.2.2 Soil organic matter and Total nitrogen

Soil organic matter content was significantly ($P \leq 0.05$) different by land use, soil depth and their interaction (Table 5). The highest (6.10%) and the lowest (2.72%) SOM was recorded at surface layer (0-20 cm) of the forest land and at subsurface layer (20-40 cm) of cultivated land respectively (Table 4). The reason for reduction of SOM at cultivated land may be due to intensive cultivation of the land and the total removal of crop residues for animal feed and source of energy. This result is in agreement with [43] who reported that SOM content is lower in cultivated soils than those under natural vegetations. Considering the two soil depths, the higher mean value of SOM (4.99%) and the lower (3.90%) were observed within the surface (0-20 cm) layer and the sub surface layer (20-40 cm) of soils respectively. Based on the rating scale of SOM ranges suggested by [65], the soils of the study area were ranged from low in both cultivated and grazing lands, but ranged from medium in forest land (Appendix Table 2). Total N content of soils was significantly ($P \leq 0.05$) different by land use, soil depth and the interaction of land use by soil depth (Tables 4, Table 5). Considering the effect of land use by soil depth on total N the highest (0.30%) and the lowest (0.18%) were observed at the surface (0-20 cm) layer of the forest and cultivated land respectively (Table 4). The highest total N content in soils of the forest land could be associated with the high OM contents of these soils. This is confirmed by the positive and highly significant correlation ($r = 0.9$), obtained these parameters (Appendix Table 1). The average mean values of total N was (0.24%) under surface (0-20 cm) layer and (0.19%) under the depth (20-40 cm) land use types (Table 5). The mean N content decreased considerably from in the surface (0-20cm) to in the sub surface (20-40 cm) soil layers (Table 5). The considerable reduction of total N in the continuously cultivated fields could be attributed to the mineralization of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation [46]. The mean total N content of the surface soils of the study area was within the range of high in soils of all land use types as per total N rating suggested by [65] (Appendix table 2). The carbon to nitrogen (C: N) ratio of the soils at the study area was not significantly affected ($P \geq 0.05$) by land use and the interaction of land use with soil depth. From the interaction effect of land use by soil depth the highest C: N ratio (13.70) and the

lowest 10.57 were recorded at the subsoil (20-40 cm) of the forest and grass land respectively (Table 5).

Table 4. Interaction effects land use and soil depth on some chemical properties of soil in the study area.

LUT	pH (H ₂ O)		pH (KCl)		EC (dS/m)		OM %		TN%		C:N	
	Soil depth(cm)		depth (cm)		depth (cm)		depth (cm)		depth (cm)		depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
CL	4.79 ^f	5.02 ^d	4.21 ^e	4.30 ^d	0.04 ^c	0.05 ^b	3.76 ^c	2.72 ^d	0.18 ^d	0.14 ^e	12.12 ^b	11.27 ^e
GL	4.90 ^e	5.14 ^c	4.39 ^c	4.40 ^c	0.03 ^c	0.04 ^c	5.12 ^b	4.01 ^c	0.25 ^b	0.22 ^c	11.88 ^c	10.57 ^f
FL	5.5 ^b	5.90 ^a	4.76 ^b	4.96 ^a	0.06 ^b	0.08 ^a	6.10 ^a	4.96 ^b	0.30 ^a	0.21 ^c	11.79 ^d	13.70 ^a
LSD	0.046		0.028		0.01		0.65		0.021		0.032	
SEM ±	0.027		0.016		0.005		0.44		0.018		0.015	

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$
 LSD = least significant difference; SEM = standard error of the mean; EC = Electrical conductivity; OM = organic matter;
 C: N= Carbon–nitrogen ratio.

Table 5. Main effects of land use and soil depth on selected chemical properties of soils in the study area.

LUT	pH (H ₂ O)	pH (KCl)	EC(Cmol(+)/Kg)	SOM %	TN%	C:N
CL	4.90 ^c	4.26 ^c	0.05 ^c	3.24 ^c	0.16 ^c	11.70 ^b
GL	5.22 ^b	4.40 ^b	0.04 ^b	4.57 ^b	0.24 ^b	11.23 ^c
FL	5.70 ^a	4.86 ^a	0.07 ^a	5.53 ^a	0.26 ^a	12.75 ^a
LSD (0.05)	0.238	0.0563	0.008	0.054	0.018	0.016
SEM (±)	0.19	0.045	0.01	0.043	0.014	0.024
Soil depth						
0-20 cm	5.06 ^b	4.45 ^b	0.04 ^b	4.99 ^a	0.243 ^a	11.93
20-40 cm	5.35 ^a	4.56 ^a	0.06 ^a	3.90 ^b	0.19 ^b	11.85
LSD(0.05)	0.195	0.046	0.007	0.044	0.015	NS
SEM(±)	0.32	0.03	0.05	0.051	0.014	0.005

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$
 LSD = least significant difference; SEM = standard error of the mean; EC = Electrical conductivity;
 OM = organic matter; C: N= Carbon–nitrogen ratio.

4.3.3 Available phosphorus

According to the recorded data the interaction effect of land use with soil depth, the highest (9.10 mg kg⁻¹) and the lowest (7.19 mg kg⁻¹) available P contents were recorded at the surface soil (0-20 cm) layer of the forest and subsurface soil (20-40 cm) layer of the cultivated lands, respectively (Table 6). Considering the two soil depths, the higher mean value of av.P (8.29 mg kg⁻¹) and the lower (7.76 mg kg⁻¹) were observed within the surface (0-20 cm) layer and the sub surface layer (20-40 cm) of soils respectively. The available phosphorus (P) was significantly ($P \leq 0.05$) different by land use, soil depth and their interaction (Table 6). Available P content in the forest land appeared to be higher than the other two land use types. The cultivated land soils had the lowest contents of available P due to its low pH and high exchangeable acidity [30]. The mean available P content of the soils of the study area was within the range of low in soil of all land use types as per available P rating suggested by [66] (Appendix 2)

4.3.4 Exchangeable acidity

The exchangeable acidity was significantly ($P \leq 0.05$) affected by land use, soil depth and their interaction (Table 6, and 7). The highest (3.98 cmol₍₊₎/kg) and the lowest (0.92 cmol₍₊₎/kg) exchangeable acidity were recorded under the cultivated land surface (0-20 cm) layer and the forest land sub surface (20-40 cm) layer respectively (Table 6). These results show that intensive cultivation and application of inorganic fertilizers leads to the higher exchangeable acidity content under the crop field than the other land uses. The results of this study were in agreement with those reported by [36], who reported that inorganic fertilizer application is the root cause of soil acidity. Exchangeable acidity was negatively and significantly correlated with pH (H₂O) ($r = -0.74$) and EC ($r = -0.70$), and positively correlated with CEC ($r = 0.57$) (Appendix Table 1). The concentration of the H⁺ to cause acidity is pronounced at pH value below 4 while excess concentration of Al³⁺ was observed at pH below 5.5. However, the results of this study indicated that the pH of the study area was below 5.7 and acidic cations had occupied the site. Therefore, the concentration of exchangeable Al³⁺ might be caused Al toxicity in the area [67].

4.2.5 Cation exchangeable capacity (CEC)

The CEC values of the soils in the study area were significantly ($P \leq 0.05$) different by land use and the interaction of land use by soil depth (Tables 6 and Table 7). Significant difference in CEC contents due to the interaction of land use and soil depth was observed in the study area as highest (33.98 cmol(+)/kg) in surface soil (0-20 cm) layer of the forest land and lowest (19.69 cmol(+)/kg) in surface soil (0-20 cm) layer of the grazing land. Soils containing high clay and organic matter contents have high cation exchange capacity [48]. Therefore, high clay content soils from the surface and the subsurface layer of the forest land had caused high CEC values in the study area (Table 6). It was generally low in the cultivated land than in the other land use types (Table 6 and Table 7). The depletion of exchangeable bases as the High result of intensive cultivation and application of acid forming inorganic fertilizers which reduced the CEC under the cultivated land [48]. Based on CEC ratings developed by [68], the CEC content of soils of the study area was rated a high in forest land while, medium in both cultivated and grazing lands (Appendix Table 2).

Table 6. Interaction effects of land use and soil depth on some chemical properties of soil in the study area.

LUT	EA(Cmol(+)/Kg)		Av.P(mg/Kg)		CEC(Cmol(+)/Kg)	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40
CL	3.98 ^a	3.65 ^a	7.49 ^c	7.19 ^c	20.76 ^d	20.39 ^d
GL	3.12 ^b	3.56 ^a	8.28 ^b	7.30 ^c	19.69 ^e	24.95 ^c
FL	1.26 ^c	0.92 ^c	9.10 ^a	8.80 ^a	33.98 ^a	27.59 ^b
LSD(0.05)	0.72		0.51		1.01	
SEM (±)	0.54		0.22		1.00	

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$ LSD = Least significant difference; EA =Exchangeable ; CEC = Cation exchangeable capacity; NS= not significance and Av.P = Available Phosphorus

Table 7. Main effects of land use and soil depth on selected chemical properties of soils in the study area.

Treatment	EA(Cmol(+)/Kg	Av.P (ppm)	CEC(Cmol(+)/Kg
CL	3.82 ^a	7.34 ^c	20.58 ^c
GL	3.34 ^b	7.79 ^b	22.32 ^b
FL	1.09 ^c	8.95 ^a	30.79 ^a
LSD (0.05)	0.0291	0.082	0.192
SEM (\pm)	0.023	0.065	0.153
0-20 cm	2.79 ^a	8.29 ^a	24.81 ^a
20-40 cm	2.71 ^b	7.77 ^b	24.31 ^b
LSD (0.05)	0.024	0.067	0.0157
SEM (\pm)	0.02	0.023	0.18

LSD = Least significant difference; SEM = standard error of the mean; EA = Exchangeable acidity; AvP = Available Phosphorous;; CEC= Cation exchangeable capacity

4.2.6 Exchangeable bases (Na, K, Ca and Mg)

The content of exchangeable sodium (Na) was not significantly ($P \geq 0.05$) affected by land use type and soil depth (Table 10). Considering the interaction effect, relatively the highest (0.20 cmol(+)/Kg) exchangeable Na was recorded in subsurface soil layer of the forest land whereas the lowest (0.10 cmol(+)/Kg) obtained in the surface layer of cultivated land (Table 8). According to the rating set by [76], the Na contents of soils in the study area ranged from low in all land use types (Table 8 and App. Table 3). Exchangeable K content was significantly ($P \leq 0.05$) affected by land use and the interaction of land use and soil depth. On the other hand, it was not significantly ($P \geq 0.05$) affected by soil depth (Table 10). Considering the interaction effects of land use by soil depth, the highest (1.60 cmol(+)/kg) and the lowest (0.68 cmol(+)/kg) exchangeable K contents were recorded at the subsurface layers of the forest land and the surface layers of the cultivated land, respectively (Table 8). The lower exchangeable K contents in the cultivated and the grazing lands than in the forest land might be due to its continuous losses in the harvested and grazed parts of the plants from the cultivated and grazing lands, respectively

[69]. Previous findings have also considered these factors and the application of acid forming fertilizers as major factors affecting the distribution of K^+ in soil systems mainly enhancing its depletion especially in tropical soils [36]. The K contents of soils in the study area were very high in forest land and high in both grazing and cultivated lands [68] (Appendix Table 3). The highest (5.42 cmol(+)/Kg) and the lowest (3.6 cmol (+) Kg) exchangeable Ca were obtained in sub surface layer of forest land and surface layer of cultivated land respectively (Table 8). Exchangeable Ca was significantly different ($P \leq 0.05$) from each other due to the interaction effects between land use types and soil depths. The rate of mean exchangeable Ca values observed in this study ranged from low in both cultivated and grazing lands while medium in forest land [35] (Table 8 and Appendix Table 3). The content of exchangeable Mg was significantly ($P \leq 0.05$) affected by land use and the interaction of land use by soil depth (Table 8). The effects of land use by soil depth on exchangeable Mg was significantly high (7.56 cmol(+)/kg) under subsoil layer of the forest land and low (3.02 cmol(+)/kg) under surface soil layer of the cultivated land (Table 8). The Mg contents of soils in the study area were ranged from high in all type land use types [68] (Appendix Table 3). In general, deforestation, leaching, limited recycling of crop residue in the soil, declining fallow periods or continuous cropping and soil erosion have contributed to depletion of basic cations on the cultivated land as compared to the adjust forest land [69].

Table 8. Interaction effects of land use and soil depth on exchangeable bases of soils in the study area.

LUT	Na (cmol(+)/Kg)		K (cmol(+)/Kg)		Mg (cmol(+)/Kg)		Ca (cmol(+)/Kg)	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
CL	0.10 ^c	0.14 ^b	0.68 ^d	0.99 ^c	3.02 ^c	4.73 ^b	3.60 ^e	4.35 ^d
GL	0.12 ^c	0.18 ^a	0.89 ^b	1.06 ^b	4.55 ^b	5.24 ^b	4.74 ^c	5.02 ^b
FL	0.15 ^b	0.20 ^a	1.20 ^a	1.60 ^a	5.14 ^b	7.56 ^a	5.36 ^a	5.42 ^a
LSD	0.028		0.16		0.70		0.26	
SEM(±)	0.015		0.11		0.62		0.029	

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$ LSD = Least significant difference; SEM = Standard error of the mean

4.2.7 Micro nutrients (Fe, Zn, Cu and Mn)

Considering the main effects of land use, the highest contents of Fe (24.84 mg/kg), Mn (40.88 mg/kg) Zn (2.39 mg/kg) and Cu (2.51 mg/kg) were recorded under the cultivated land, while the lowest (17.63, 30.55, and 1.14 mg/kg) contents of Fe, Mn, and Cu were observed under the grazing land, respectively (Table 10). Considering the two soil depths, the higher micronutrient contents were recorded at the surface soil layers than the subsurface soils (Table 9). The higher micronutrient contents in the surface relative to subsurface soils was likely a result of greater decomposition of soil organic matter and crop residues that contribute to micronutrient accumulation to the surface layers [70]. Secondly, root distributions and rooting depth play an important role in shaping micronutrient profiles because nutrients taken up by deep roots are transported into the above-ground parts and re-deposited on the soil surface through stem flow [71]. The contents of extractable micronutrients (Zn, Fe, Mn and Cu) were significantly ($P \leq 0.05$) affected by land use, and the interaction of land use with soil depth (Table 9 and 10).

Table 9. Interaction effects of land use and soil depth on micronutrients of soils in the study area

LUT	Fe(Cmol(+)/Kg		Cu(Cmol(+)/Kg		Zn(Cmol(+)/Kg		Mn(Cmol(+)/Kg	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
CL	25.48 ^a	24.20 ^a	2.94 ^a	2.08 ^b	2.76 ^a	2.03 ^c	44.32 ^a	37.43 ^b
GL	18.10 ^c	17.15 ^c	1.15 ^c	1.13 ^c	2.38 ^b	2.07 ^c	38.12 ^b	22.97 ^c
FL	21.14 ^b	20.65 ^b	2.30 ^b	2.03 ^b	1.88 ^c	1.13 ^d	46.62 ^a	25.42 ^c
LSD	2.39		0.75		0.24		4.79	
SEM (\pm)	1.58		0.23		0.20		2.77	

Main effect means within a column followed by the same letter are not significantly different from each other at $p \leq 0.05$ LSD = Least significant difference; SEM = Standard error of the mean; LUT= Land use type

Table 10. Main effects of land use type and soil depth on the selected chemical properties of soil in the study area.

LUT	Exchangeable bases (cmol(+)/Kg)				Micro nutrients (cmol(+)/Kg)			
	Na	K	Mg	Ca	Fe	Cu	Zn	Mn
CL	0.12 ^c	0.84 ^c	2.99 ^c	3.98 ^c	24.84 ^a	2.51 ^a	2.39 ^a	40.88 ^a
GL	0.15 ^b	0.98 ^b	3.89 ^b	4.88 ^b	17.63 ^c	1.14 ^c	2.23 ^b	30.55 ^c
FL	0.18 ^a	1.40 ^a	4.92 ^a	5.39 ^a	20.90 ^b	2.03 ^b	1.51 ^c	35.93 ^b
LSD	0.017	0.022	0.025	0.136	0.122	0.030	0.022	0.034
SEM (±)	0.013	0.017	0.02	0.11	0.21	0.024	0.018	0.027
Soil depth								
0-20 cm	0.12 ^b	0.92 ^b	4.24 ^b	4.57 ^b	21.59 ^a	2.05 ^a	2.34 ^a	43.35 ^a
20-40 cm	0.17 ^a	1.22 ^a	5.84 ^a	5.93 ^a	20.13 ^b	1.74 ^b	1.62 ^b	28.61 ^b
LSD	0.014	0.018	0.021	0.11	0.099	0.025	0.018	0.028
SEM (±)	0.032	0.12	0.24	0.30	0.63	0.36	0.31	1.09

LSD = least significant difference; SEM = Standard error of the mean; LUT= Land Use Type
 CL = Cultivated Land FL = Forest Land GL = Grazing Land

Appendix Table 1. Pearson's correlation matrix for various soil physicochemical parameters

	pH (H ₂ O)	pH (KCl)	EC	OM	AV.P	EA	CEC	TN	CN	Sand	Silt	Clay	BD
pH(H ₂ O)	1												
pH (KCl)	0.80	1											
EC	0.74	0.86	1										
OM	0.43	0.67	0.48	1									
AV.P	-0.85	-0.79	-0.33	-0.42	1								
EA	-0.74	-0.97	-0.70	-0.85	0.40	1							
CEC	-0.68	-0.77	0.03	-0.82	0.37	0.57	1						
TN	0.34	0.47	0.47	0.9	-0.42	-0.84	-0.81	1					
CN	-0.59	-0.83	-0.40	-0.46	0.29	0.45	0.30	-0.44	1				
Sand	-0.51	-0.28	-0.05	0.74	0.51	-0.56	0.55	0.69	-0.45	1			
Silt	-0.28	-0.42	-0.14	0.63	0.47	0.22	0.61	0.72	-0.38	0.61	1		
Clay	0.55	0.39	0.31	0.89	-0.65	-0.34	-0.81	-0.91	0.65	-0.74	-0.82	1	
BD	-0.39	-0.44	-0.19	-0.53	-0.22	0.37	0.43	-0.48	0.57	-0.39	-0.4	0.59	1
PD	0.25	0.20	-0.34	-0.27	-0.56	-0.45	-0.33	-0.42	0.45	-0.51	0.49	0.72	-0.38
TP	-0.31	-0.20	0.32	-0.42	-0.35	-0.17	0.25	0.58	0.16	0.68	0.34	-0.68	-0.55
Na	0.96	0.70	0.12	0.22	0.03	-0.42	0.24	0.21	-0.19	0.70	0.29	-0.21	-0.39
K	0.89	0.93	0.07	-0.66	-0.04	-0.05	-0.76	-0.66	0.30	-0.69	-0.70	0.77	0.54
Ca	0.82	0.92	0.21	0.10	0.22	-0.32	0.57	0.09	-0.13	0.01	0.24	-0.12	-0.18
Mg	0.79	0.70	0.23	0.42	0.44	-0.41	0.63	0.42	-0.30	0.45	0.49	-0.51	-0.69
Fe	-0.53	-0.42	-0.42	-0.18	-0.07	-0.63	-0.50	-0.16	0.52	-0.11	0.09	0.14	0.09
Zn	-0.74	-0.75	0.08	0.36	0.25	0.35	0.27	0.38	-0.37	0.41	0.30	-0.41	0.19
Cu	-0.24	-0.09	-0.32	-0.21	-0.72	0.60	-0.43	-0.23	0.35	-0.15	0.10	0.09	0.50
Mn	-0.55	-0.26	-0.40	0.24	0.59	0.58	-0.30	0.24	0.45	0.23	0.39	-0.3	0.33

SOM = soil organic matter; Total N = total nitrogen; C/N = carbon to nitrogen ratio; Av.P = available Phosphorous; EA = exchangeable acidity; CEC = cation exchange capacity.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It was apparent that shift in land use systems from natural forest to other land use system had determinant effect on soil physicochemical properties. The result shown that soils in both cultivated and grazing land use types were strongly acidic ($\text{pH} < 5.5$), While pH of the forest land was moderately acidic. Cultivated land was highly affected by soil acidity ($\text{PH} < 4.9$). Electrical conductivity of soil obtained in all land use types were low (0.02-0.07 dS/m). SOM in cultivated land was less than in both forest and grazing lands. The level of accessible phosphorus on the soils of all land use types can be illustrated as a low in the study area (appendix table 2). The high values of exchangeable acidity was observed in the cultivated (3.82 $\text{cmol}(+)/\text{Kg}$). The highest CEC (30.75 $\text{cmol}(+)/\text{Kg}$) was obtained in the forest land could be because of the amount and nature of the clay particles content in the forest land. Sodium content of soil in the study area ranged from low while potassium and magnesium contents high in all land use types. Calcium contents of soil in the study area ranged in low in both cultivated and grazing lands, but medium in forest land. The values of available Fe, Mn, Zn, and Cu observed were significantly affected by land use and interaction of land use and soil depth. Most of the soil parameters measured in this study indicates that there were some variations in soil physicochemical properties which might lead to a decrease in soil productivity. Therefore, to maintain a decrease in soil nutrients and to increase sustainable agricultural outputs, reducing the intensity of cultivation and application of lime and organic fertilizers could maintain the existing soil condition and replenish the affected soil properties of the study area.

5.2 Recommendations

Based on the result of the study, variations in soil physicochemical properties were observed under soils of selected land use types in the study area. This variation in soil physicochemical properties could be related to intensive cultivation, 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 productivity. The attributes of the soils under the cultivated lands showed overall change towards the direction of loss of their fertility compared to the soils attributes of the adjacent forest and grazing land soils. Major declines were observed for soil organic matter. Furthermore, the result revealed that soil in cultivated land and grazing land use types of the study area were strongly acidic.

Therefore, these problems would be prevented by: addition of lime, reducing the intensive cultivation, using integrated fertilizers and increasing soil conservation practices. Generally the government and non government rural development strategies should emphasize: to conserve the soil physicochemical properties of study area and to make up farmers capacity how to apply integrated soil fertility management techniques.

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7. APPENDICES

Appendix Table 1. Ratings of soil pH for 1:2.5 soils to water ratio suspension [8].

No	pH	Rating
1	< 4.5	Very strongly acidic
2	4.6 – 5.2	Strongly acidic
3	5.3 – 5.9	Moderately acidic
4	6.0 – 6.6	Slightly acidic
5	6.7 – 7.3	Neutral
6	7.4 – 8.0	Moderately alkaline
7	>8	Strongly alkaline

Appendix Table 2. Ratings of organic matter and total nitrogen [65], CEC [68], ava.P [66]

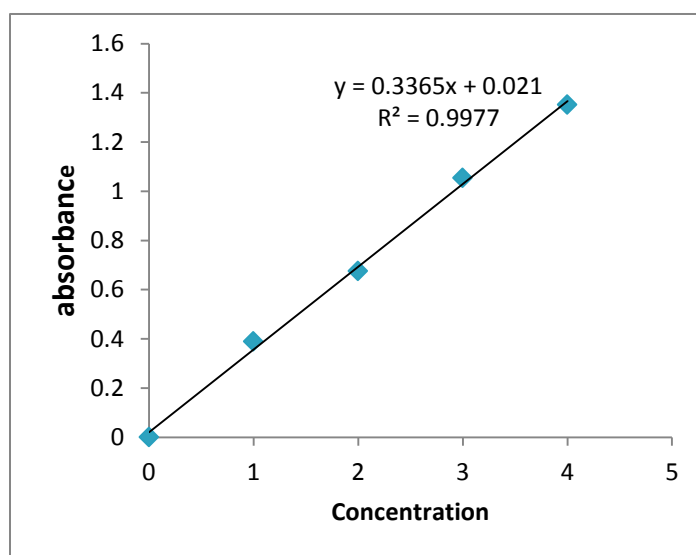
SOM%	TN %	CEC cmol(+)/Kg	Ava.P (cmol(+)/Kg	EC (cmol(+)/Kg	Rating
> 20	> 0.3	>40	>20	> 15	Very high
10-20	0.225 -0.3	26-40	15-20	8-15	High
4 -10	0.125 -0.225	13-25	10-15	4-8	Medium
2-4	0.05-0.125	6-12	5-10	2-4	Low
< 2	< 0.05	< 6	<5	< 2	Very low

Appendix Table 3. Rating of exchangeable bases [38, 68]

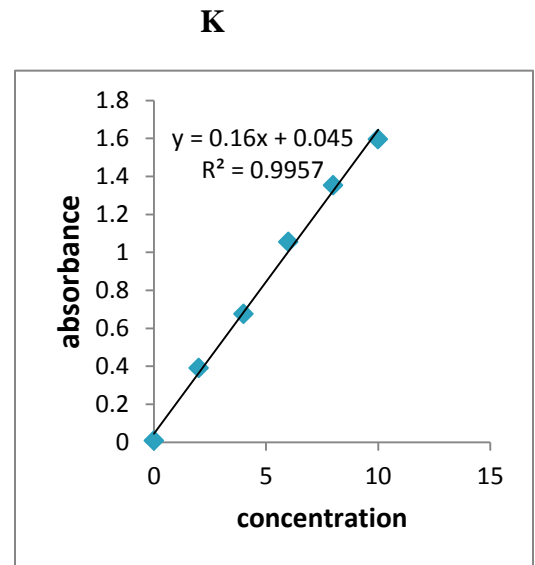
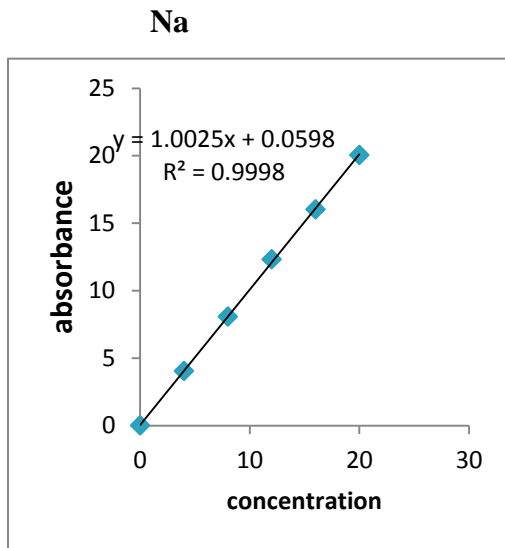
Exchangeable bases (cmol(+)/Kg)				Rating
Ca	Mg	K	Na	
>20	>8	> 1.2	> 2	Very high
10-20	3-8	0.6-1.2	0.7-2	High
5-10	1-3	0.3-0.6	0.3-0.7	Medium
2-5	0.3-1	0.2-0.3	0.1-0.3	Low
<2	< 0.3	< 0.2	< 0.2	Very low

Appendix Table 4. Rating of micronutrients [38, 68]

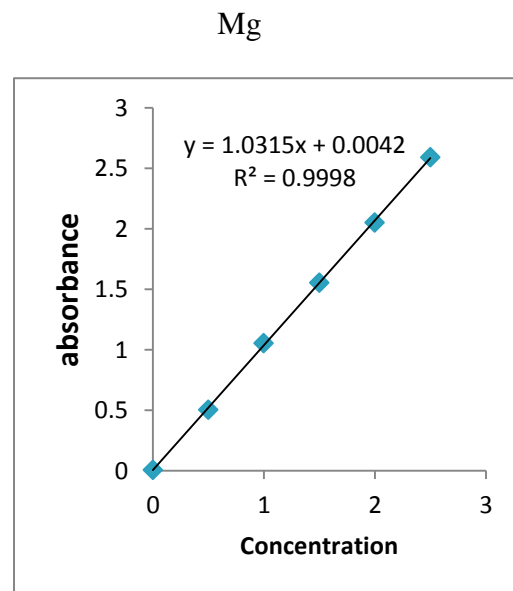
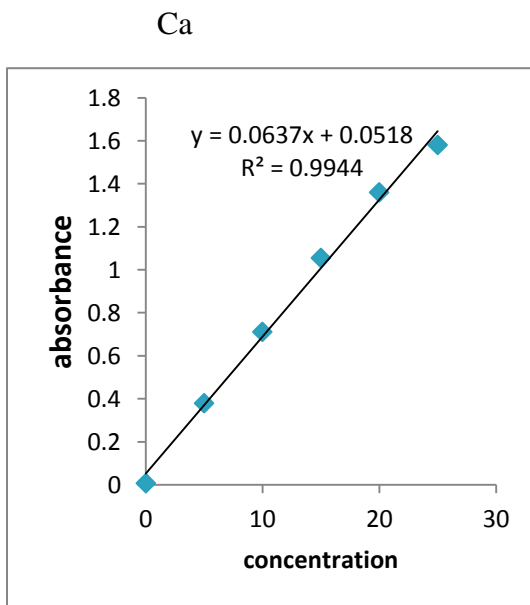
Micronutrients (cmol(+)/Kg)				Rating
Fe	Zn	Cu	Mn	
30.0	3.0	0.6	30.0	Very high
20.0	2.0	0.4	20.0	High
7.0	1.0	0.3	3.0	Medium
5.0	0.8	0.2	1.0	Low
3.0	<0.4	<0.1	<0.6	Very low



Appendix Figure 1. Calibration curve for determination of available P

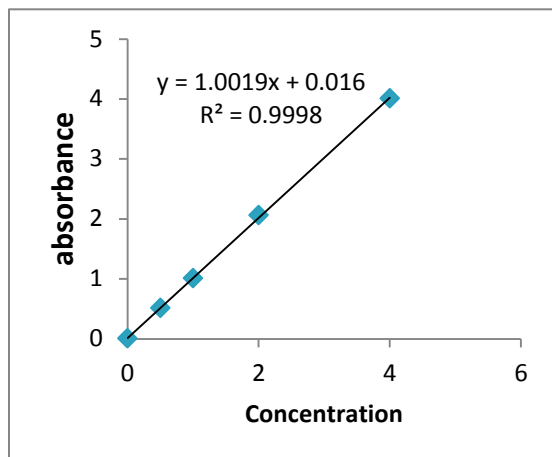


Appendix Figure 2 Calibration curve for determination of Na and K

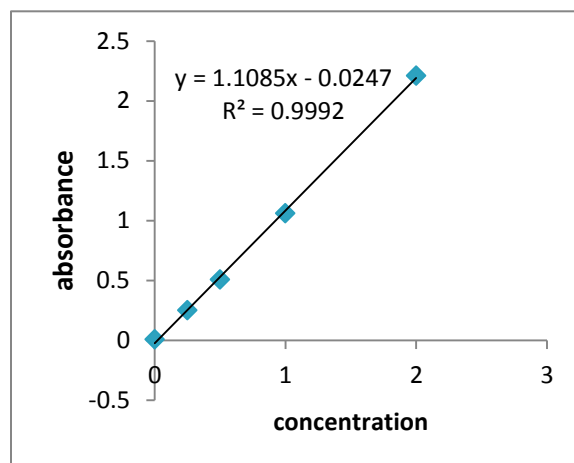


Appendix Figure 3 Calibration curve for determination of Ca and Mg

Fe

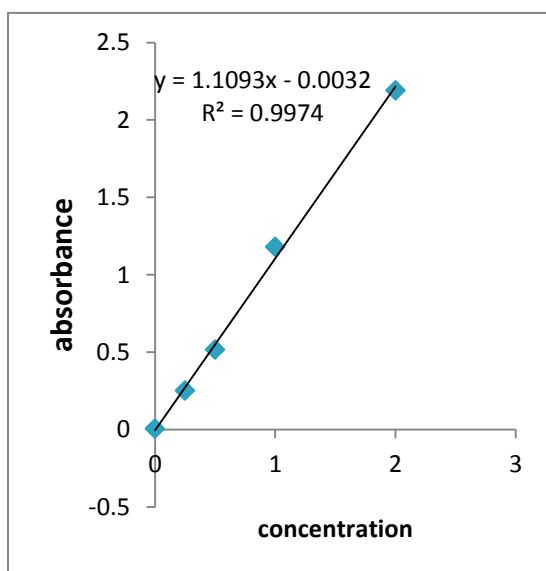


Zn

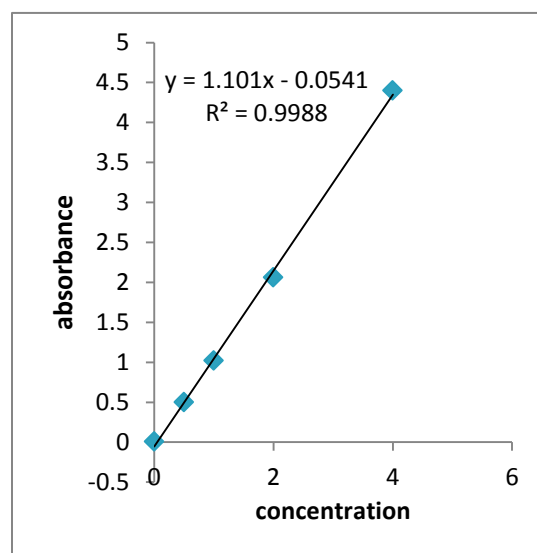


Appendix Figure 4. Calibration curve for determination of Fe and Zn

Cu



Mn



Appendix Figure 5. Calibration curve for determination of Cu and Mn