EFFECTS OF LAND USE TYPES ON SELECTED SOIL PHYSICO-CHEMICAL PROPERTIES: THE CASE OF KUYU DISTRICT, CENTRAL HIGHLAND OF ETHIOPIA

MSc. Thesis

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Debre Berhan, Ethiopia

EFFECTS OF LAND USE TYPES ON SELECTED SOIL PHYSICO-CHEMICAL PROPERTIES: THE CASE OF KUYU DISTRICT, CENTRAL HIGHLAND OF ETHIOPIA

A Thesis Submitted to the Department of Plant Science
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In Partial Fulfillment of the Requirements for the Degree of Master of Science in Soil Science

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Major Advisor: Asmare Melese (PhD)

Co-Advisor: Wondwosen Tena (PhD)

April 2018

Debre Berhan, Ethiopia

SCHOOL OF GRADUATE STUDIES

COLLEGE OF AGRICULTURE AND NATURAL RESOURCE SCIENCES

DEBRE BERHAN UNIVERSITY

APPROVAL SHEET – I

This is to certify that the thesis entitled: **Effects of Land Use Types on Selected Soil Physico-Chemical Properties: The Case of Kuyu District, Central Highland of Ethiopia** submitted in partial fulfillment of the requirements for the degree of Masters of Science with specialization in **Soil Science** of the Graduate Program of the **Plant Science**, College of Agriculture and Natural Resource Sciences, Debre Berhan University and is a record of original research carried out by **Mulugeta Tufa, PGR/135/09**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it to be accepted as fulfilling the thesis requirements.

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Name of Major Advisor	Signature	Date
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APPROVAL SHEET – II

We, the undersigned members of the boarded of the examiners of the final open defense by **Mulugeta Tufa** have read and evaluated his thesis entitled **Effects of Land Use Types on Selected Soil Physico-Chemical Properties: The Case of Kuyu District, Central Highland of Ethiopia**, and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of **Master of Science in Soil Science.**

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the Council of Graduate Studies (CGS) through the department graduate committee (DGC) of the candidate's major department.

DEDICATION

This thesis is dedicated to his beloved and esteemed families.

STATEMENT OF THE AUTHOR

I Mulugeta Tufa hereby declare that, this thesis is my genuine work, and that all sources of materials used for this thesis have been profoundly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Master of Science (MSc) at Debre Berhan University and it is deposited at the University library to be made available for users under the rule of the library. I intensely declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Name: **Mulugeta Tufa Ejersa** **Signature**: ---------------------

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Date of Submission: -------------------------------------

BIOGRAPHICAL SKETCH

The author, Mr. Mulugeta Tufa Ejersa, was born on June 17, 1994 in Jila Kerensa kebele, Kuyu district, North Shewa Zone of Oromia National Regional State, Ethiopia. He attended his primary education at Chare Michael School. The author attended his secondary and preparatory education at Gerba Guracha Secondary High School and Preparatory School, respectively. After he successfully passed the Ethiopian Higher Education Entrance Qualification Exam, he joined Ambo University in 2014 and graduated with a BSc degree in Natural Resource Management in June 2016. Following his graduation, in the same year he was assigned by the Ethiopian Ministry of Education and joined the School of Graduate Studies of Debre Berhan University in October 2017 to pursue his MSc degree in Soil Science.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOV	Analysis of Variance
AAS	Atomic Absorption Spectrophotometry
BD	Bulk Density
C:N	Carbon to Nitrogen Ratio
CEC	Cation Exchange Capacity
$cmol_c/kg$	Centimol Charge per Kilogram
CGS	Council of Graduate Studies
dS/m	Deci Siemens per Meter
DMRT	Duncan’s Multiple Range Test
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
GPS	Global Positioning System
ha	Hectare
KWAO	Kuyu Woreda Agricultural Office
masl	Meters above Sea Level
OM	Organic Matter
PD	Particle Density
PBS	Percent Base Saturation
SGC	School of Graduate Committee
SAS	Statistical Analysis System
SSA	Sub-Sahara Africa
USDA	United States Department of Agriculture

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Effects of Land Use Types on Selected Soil Physico-Chemical Properties: The Case of Kuyu District, Central Highland of Ethiopia

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ABSTRACT

Information about the effect of land use types on selected soil physical-chemical properties is essential in sustainable utilization of soil resources. Therefore, this study was conducted to evaluate the effect of land use types on selected soil physico-chemical properties on Jila Kerensa kebele, Kuyu district, Central Highland of Ethiopia. Totally, 24 composite soil samples were collected from grass, cultivated, forest and grazing lands by two depths (0-20 cm and 20-40 cm) and with three replications. The two way analysis of variance was used to test the mean differences of the soil physico-chemical properties by SAS software. The highest mean values of sand, silt and clay were recorded in cultivated, forest and grasslands, respectively. This implies that, the high removal of clay particles from cultivated lands and leaves the sand particles on the surface soil layer. The bulk density and total porosity were significantly ($P \leq 0.001$) affected by land use types. The mean bulk density of the soils under the different land use types ranged from 1.10 and 1.37 g cm^{-3} and the mean total porosity was ranged from 48.2 to 58.7%, which indicated that the less soil compaction in the study area. The higher (8.00) and the lower (7.68) mean values of soil pH were observed in cultivated and grasslands, respectively, which indicated that there was no soil acidity problem. The higher (0.53 dS/m) and lower (0.26 dS/m) mean values of EC were found in the forest and grasslands, respectively. The mean values of soil OM were ranged between 3.15% in grazing to 5.02% in forest land. However, the mean values of total N ranged from 0.18 to 0.26%. The higher (11.50) and the lower (10.00) mean value of C:N observed in forest and cultivated lands, respectively. The mean value of Av.P ranged from 1.26 to 5.37 ppm, which implies that high deficiency of available P in the study area. All the exchangeable basic cations values were within high to very high ranges in all land use types. The values of CEC were also ranged from high to very high rate in all land use types, which showed the high soil capability of nutrient reservoir and low leaching. Generally, the adverse effect of land use types on soil properties was the remarkable problems. The mean values of most of soil properties were low in cultivated and in grazing lands compared to the rest land use types. Therefore, the proper soil and water conservation practice are important in the study area to enhance crop productivity and sustainable utilization of soil resources.

Key words: Cultivated, Forest, Grazing, Soil depth, Soil fertility.

1. INTRODUCTION

Land use is defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Ufot *et al*., 2016). Successful agriculture requires the sustainable use of soil resource, because soil can easily lose its quality and quantity within a short period of time for different reasons such as intensive cultivation, leaching and soil erosion (Alemayehu and Sheleme, 2013). It was possible to improve the soil resources through the enhancement of sustainable development of the agricultural sector. Agricultural practice, therefore, requires basic knowledge of sustainable use of the land (Lechisa *et al*., 2014). A success in soil management to maintain the soil quality depends on the understanding of how the soil responds to agricultural practices over time (Lalisa *et al*., 2010). However, the basis of this sustainable agricultural development is good quality of the soil, since maintenance of soil quality is an integral part of sustainable agriculture and the convenient witness to enhance the crop productivities (Liu *et al*., 2010). Soil resource has also provided a great contribution in the production of food and fiber, in the maintenance of local, regional, and worldwide environmental quality (Getahun and Bobe, 2015).

On the other hand, the ever-increasing human population is most challenging in areas like central Ethiopia, where there is a very high population density and heavy dependence on land resources. This is the atrocious threat in which soil properties are adversely damaged thereby leads to land degradation and hampered the sustainability of soil resources (Fantaw and Abdu, 2011). The major causes of land degradation, natural resources depletion and environmental deterioration in Ethiopia are: cultivation on steep soil with inadequate management in soil conservation or vegetation cover, erratic and torrential rainfall patterns, the declining use of fallow, limited recycling of plants and animal residues in the soil, limited application of external sources of plant nutrients, deforestation and overgrazing (Mulugeta and Kibebew, 2016). In addition, the topography of the land has also a great impact on the soil quality and soil depth due to the interaction impact of cultivation practices and slope (Pavlu *et al*., 2007).

Therefore, reducing resource degradation, increasing agricultural productivity, reducing poverty, and achieving food security are major challenges of the countries in tropical Africa (Qadir *et al*., 2014). Thus, possible effort should be focused on the maintenance the physical, biological and socio- economic environment for production of food crops, livestock, wood and other products through sustainable use of natural resources (Adeyemo and Agele, 2010).

According to Boyles *et al*. (2012), climate and geological history are the decisive factors affecting soil properties at regional and continental scales. However, conversion of land use types may be the dominant factors affecting soil properties under small catchment scale. Land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, mineralization, and leaching (Abad *et al*., 2014). Recently, to fit the demand of local community and food security, forest lands are degraded and converted to agricultural lands in which the soil physico-chemical are adversely affected (Tayel *et al*., 2010). The anthropogenic changes in land use have altered the characteristics of the Earth's surface, leading to changes in soil physico-chemical properties, soil fertility, soil erosion sensitivity and content of soil moisture (Tsehaye and Mohammed, 2013). Conversion of land use types such as forest land, cultivated land, grassland and grazing land are known to result the changes of soil physical, chemical and biological properties (Ayoubi *et al*., 2011).

Conversion of land use types and agricultural practices, especially the cultivation of deforested land may not only rapidly diminish soil properties, but also hamper the soil productivity (Osakwe, 2014). With the increment of human and livestock population, temporary intensively expansion of farmland and grazing areas has begun to influence the soil properties. This resulted, as the expansion of land use conversion is based on the conversion of the existing forest lands into cultivated lands and grazing lands (Mengistu *et al*., 2017). However, when the intensification limit is reached, for example, in countries like Ethiopia, where the forest land area dropped from 40% to below 3% of the land cover and the human population is rapidly growing (MOFED, 2007) (almost doubling every 26 years), intensification i.e. the frequent and continuous utilization of the available land has continued. However, the current studies indicated that the forest coverage area is becoming 15% by afforestation and plantation systems.

Various studies have been conducted to assess the effect of land use types on soil physical and chemical properties in Ethiopia (Mulugeta *et al*., 2005; Lemma *et al*., 2006; Fantaw *et al*., 2008). Lemma *et al.* (2006) showed that afforestation of farmland with various trees specious increased total nitrogen (N), exchangeable potassium (K), and exchangeable calcium (Ca) on the surface soil layer than subsurface soil layer. Fantaw *et al*. (2008) also compared crop lands, forest lands and grazing lands and found that soil organic carbon (OC) and total N decreased in crop lands as compared to forest lands. He also suggested that the OC was abundant of surface soil layer compared to the lower soil horizon. Yang *et al*. (2011) indicated that long practices of deforestation and replacement of natural forests by agro ecosystem and uncontrolled overgrazing have been the major causes of soil erosion, which in turn affecting soil properties and its productivity.

Severe deterioration in soil quality may lead to a permanent degradation of land productivity and soil properties under different land use types (Kizilkaya and Dengiz, 2010). Currently, the forest land was drastically degraded in the study area because of the timber production, firewood, expansion of cultivated and grazing lands, which may reults in the decline of soil fertility and limit crop productivity, which in turns affect the livelihood of local communities. Additionally, the grassland has been converted into grazing lands in the sudy area. This is because of the increament of livestock and its overgrazing, which leads to soil compaction and remove the palatable shrubs and bush trees, which in turns expose the surface soil for the erosion problems. In order to put the proper recommendations for sustainable utilizations of soil resources and improve crop productivity, the information about the effect of land use types on soil physico-chemical properties are essential. Therefore, the objective of this study was to evaluate the effects of land use types on selected soil physico-chemical properties on Jila Kerensa kebele, Kuyu district.

2. LITERATURE REVIEW

2.1. Concept of Land Use Types

The term land cover and land use are very common and can be confused. Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and artificial structures (Ellis and Robert, 2007). Land cover is usually examined by means of field mapping or remote sensing; the expression is traditionally used in the natural sciences-landscape ecology or physical geography. The approach towards land cover research much depends on the purpose of study, which influences classification, legend, scale and minimal size of the grid (Lorencova *et al*., 2013). Land use is a more complicated term and has different definition from a different view. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity. Social scientists and land managers define land use more broadly to include the social and economic purposes and contexts for and within which lands are managed or unmanaged, such as subsistence versus commercial agriculture, rented vs owned, or private vs communal land (Aspinall and Hill, 2008).

Lambin *et al*. (2011) defines land use type as "the purpose for which humans exploit land cover". Land use type includes both the manner in which biophysical attributes of the land are manipulated and the intent underlying that manipulation, i.e., the purpose for which the land is used (Abad *et al*., 2014). Land use types are also regarded as important components in the agricultural activity that is the decisive factors in the economy of the country (Zeng *et al*., 2009). The effect of land use types cannot limit on the specific area of the country, it is a primary cause of global environmental changes (Neris *et al*., 2012). These changes have received the major focus of global change research as its impacts on global biogeochemical cycles, climatic and hydrologic processes. The change of environmental condition at local or global level can drive by the interaction in space and time between biophysical and intervention of human activities that in turns adversely affect soil properties (Haberl *et al*., 2013). In most of developing countries, its research has evolved to identify, predict and manage ecologically damaging land use types such as forest land, cultivated land, grassland and grazing land as its implications for human livelihood systems are immense (Zeleke *et al*., 2004). Soil fertility can vary spatially and temporarily from land use type to others land use types at a local and global level and from field to larger regional scale, in which it can influence by both land use and soil management practices. Revealing spatial variability of soil fertility and its influencing factors are important to improve sustainable land use strategies (Osakwe, 2014).

2.2. General Overview of Soil Fertility Status in Ethiopia

Soil fertility is a function of soil physico-chemical and biological properties on which it can have qualitative and quantitative information to formulate the appropriate fertility management and agrarian practices (Mulugeta and Kibebew, 2016). Although it omits the importance of soil physical and biological conditions for crop productivity, it is a useful simplification and it is a major concern of the world, including Ethiopia, which is the second most populous African country (Wang *et al*., 2009). High quality soils not only produce better food and fiber, but also help to establish natural ecosystems and enhance air and water quality. Soil fertility changes and the nutrient balances are taken as key indicators of soil quality (Griffiths *et al*., 2010)

According to Mesfin (2007), extensive research is required on the physical, chemical and biological properties of Ethiopian soils. According to the same author reported that the top soils of the agricultural lands of Ethiopia loss through soil erosion with a rate of 137 t/ha year^{-1} or 10 mm/ha year^{-1}, when it estimated in terms of the soil depth. The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil properties also largely determine the soil's water and air supplying capacity to plants (Uzoho *et al*., 2007). Many soil properties change with changes in land use types and its management, such as intensity of cultivation, the instrument used and the nature of the land under cultivation (Getachew and Heluf, 2007). For example annual deforestation was estimated at about 160,000 to 200,000 ha and the annual fertile top soil lost at about 42 t/ha has on crop land in Toke Kutaye district of western Ethiopia (Demoze, 2014). The different improper management practices carried out in different land use types can render the soil with less permeable, more susceptible to runoff, soil erosion and ultimately cause the decline of soil fertility (Abbasi *et al*., 2007).

A decline in soil fertility implies a decline in the quality of the soil, and soil fertility decline is defined as the decline in soil physical and chemical soil fertility, or a decrease in the levels of soil OM, nitogen (N), pH, cation exchange capacity, exchangeable basic cations, phosphorous (P) and adverse alteration of others physico- chemical and biological properties of soil with the soil depth. Due to the continuous cultivation, removal of crop residues and erosion problems the Ethiopian agricultural lands was losses averagically 41 kg/ha of nitrogen (N), 6 kg/ha of phosphorous (P), and 26 kg/ha of potassium (K) (Nega and Heluf, 2013). The adversely alteration of soil properyties and soil fertility decline are ultimately leads to affect the activities of soil microorganisms and availability of plant nutrients which inturns affect the crop productivity (Mengistu *et al*., 2017). Decline in soil fertility has been also described generally as the most constraint to food security in Sub-Saharan Africa (SSA) and as a worldwide level (Iqbal *et al*., 2012).

Soil fertility is not just a problem of nutrient deficiency in addition to a problem of soil physico-chemical and biological degradation, but it also causes the deterioration of natural resources and environmental problems (Sintayehu *et al*., 2006). The problem relates to the linkage between poverty and land degradation, often perverse national and global policies with respect to incentives and institutional failures (Habtamu *et al*., 2009). The secret of ensuring food security for the ever-increasing world population is strongly linked to the productivity of soils since the loss of soil fertility affect the soil productivity. According to Aklilu (2006) from the total gross domestic product (GDP) of the Ethiopian land production 17% is lost due to the soil fertility decline. Thus, soil is one of the most precious resources of land plays critical and irreplaceable role in determining man’s standard of living. This implies that the overall productivity and sustainability of a given agricultural sector is heavily dependent on the fertility and productivity of soil resources (Teshome *et al*., 2013).

In Ethiopia, the present declining of soil fertility is a major challenge to carry out the proper agricultural practices on different land use types and to bring sustainable productivity in order to feed the ever-increasing population of the country (Yihenew and Getachew, 2013). As a result, millions are suffering from poverty and malnutrition. Ahukaemere *et al*. (2012) indicated that under increasing demographic pressure, cultivation becomes permanent. According to the same author stated that the traditional farming systems in SSA lead to the mining of the natural soil fertility when cultivation becomes more permanent due to increasing population pressure. In many cases, removals of vegetation cover, depletion of soil nutrients and OM, and accelerated soil erosion have all leads to change of physico-chemical properties of soil under different land use types and drastic decline in soil productivity (Ufot *et al*., 2016).

2.3. Soil Physical Properties

The physical properties of soils determine the different function of soil and vary activities upon the soil resources. It determines their adaptability to cultivation and the level of biological activity that can be supported by the soil (Iqbal *et al*., 2012). Soil physical properties also largely determine the soil's water holding capacity and air supplying capacity to plants (Abiyot and Alemayehu, 2016). Even though different soil physical properties are either dynamic or inherit soil fertility, many soil physical properties change with changes in land use types and its management practices. These have included the intensity of cultivation, presence or absence of crop residues and animal manures on cultivated land, the instrument used for cultivation and application of organic and inorganic fertilizers (White, 2006).

2.3.1. Soil texture

Soil texture can be defined in technical and non-technical ways, non-technical definition is how the soil feels to the touch and technical definition is the proportions of sand, silt and clay in the soil. Therefore, in technical definition soil texture is the proportion of sand, silt and clay particles with varying range of their size in diameter. Sand particles range in size from 0.05 to 2.00 mm, silt ranges from 0.002 to 0.050 mm, and the clay fraction is made up of particles smaller than

0.002 mm in diameter. Particles larger than 2.0 mm are referred to as rock fragments and are not considered in determining soil texture, although they can influence both soil structure and soil water relationships (Brady and Weil, 2008). Once the sand, silt, and clay fractions are known, the textural class can be determined using a soil textural triangle (USDA, 2008). Soil texture is an important soil physical characteristic because it in part, determines water intake rate (infiltration), water storage in the soil, the ease of tilling and/or workability of the soil, the amount of aeration (vital to root growth), susceptibility to erosion, cation exchange capacity, pH buffering capacity and also influence soil fertility (Gupta, 2004).

It is also one of the inherent soil physical properties less affected by management and which determines nutrient status, organic matter content and decomposition. Whereas, this property is subject to change under conditions of land use change which leads to varied soil management practices that may contribute indirectly, for changes in particle size distribution (Ahukaemere *et al*., 2012). Fine particles are preferentially moved, resulting in a greater concentration of clay and silt in the sediments than in the original soil. This ultimately caused to change the particle size fraction composition of the original soil in which sand particles are high on the surface soil layer while clay particles are more abundant in subsurface soil layer of cultivated lands than forest lands at a soil depths of 0-10, 0-20, and 20-30 cm (Lechisa *et al*., 2010). 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 (Sintayehu *et al*., 2006).

Although the soil texture is the inherit soil fertility, the texture soil properties may be modified by soil structure, the nature of the clay minerals, OM content, lime content and cultivation activities. In general, sandy soils have low water and nutrient holding capacity, low OM content, little or no swelling, and shrinkage and high leaching of nutrients and pollutants (Getahun and Bobe, 2015). On the other hand, clayey soils have high nutrient and water holding capacity, poorly aerated, very slow drainage unless cracked, high to medium organic matter and relatively high swelling ad shrinkage property compared to the sandy soils (Nega, 2006).

2.3.2. Soil bulk and particle densities

Soil bulk density expresses the ratio of the mass of dry soil to the total volume occupied in the soil. The total volume includes both the solids (mineral and organic) and the pore spaces. Soil bulk density is an important soil physical property because it is an indicator of the soil's porosity and soil compaction (Lechisa *et al*., 2014). Bulk density is generally measured in a soil sample obtained with a core, which is used to extract undisturbed samples from various depths in the soil profile. Soil bulk density is among the hydro-physical properties affected by soil management practices, mainly cultivation and thus, the value(s) of bulk density of the soil are different under different land use types (Easton *et al*., 2015). Bulk densities are found to be high in cultivated tropical soils due to two major reasons: first rapid loss of organic matter due to its turnover and rapid rate of oxidation and the second is soil compaction due to heavy machinery (Tilahun and Asefa, 2009). This demonstrates cultivation of deforested land may rapidly diminish soil quality, as ecologically sensitive components of the previous ecosystem are not able to buffer the effects of agricultural practices. Therefore, these changes are the functions of the length of time where the soil resource is subject to cultivation (Mulugeta and Kibebew, 2016).

Bulk densities of soil also vary within a soil textural composition. Based on USDA (2008) classification, the optimum soil bulk densities for sand, silt and clay soils are about 1.6, 1.4, and 1.1 g cm^{-3}, respectively. Soils are said to be compacted if the bulk density value of the layer is above the respective optimum value, resulting in restricted water and air movements in the root zone which can in turns generate high surface runoff. Additionally, Gupta (2004) stated that values of bulk density range from less than 1 g cm^{-3} for soils high in OM, 1.0 to 1.4 g cm^{-3} for well aggregated loamy soils and 1.2 to 1.8 g cm^{-3} for sands and compacted horizons in clay soils. Bulk density normally decreases as mineral soils become finer in texture. Soils having a low bulk density exhibit favorable physical conditions and vice versa.

Further study by Boyles *et al.* (2012) revealed that bulk density exhibited significant differences among the different land use types; the results which validated again cultivation could lower soil quality levels. However, it was found lowest in areas under forest, and highest in areas of

Eucalyptus plantations. Soils under Eucalyptus plantation had a higher bulk density than other land use types and those all differences are attributable to, among others, the differences in soil OM content which is highly influenced by land use or management practices (Adeyemo and Agele, 2010). Besides Mulugeta *et al.* (2005) investigated the variation in bulk density due to soil depth which as a result has increased in the 0-10 cm and 10-20 cm layers relative to the length of time the soils were subjected to cultivation after deforestation.

According to Heluf and Wakene (2006) revealed that bulk density was affected by soil depth at Bako which as a result was higher at the surface than the underlying horizons observed in abandoned fields and fallow lands left for twelve years. This finding is not in agreement with the general established fact that bulk density is low at the surface due to the higher available soil OM content of the surface soil layer. Besides, varying in long-term cropping systems caused no effect on soil bulk density in Mexico (Getahun *et al*., 2014). Bulk density also provides information about the potential for leaching of agrochemicals, erosion, and crop productivity (Ufot *et al*., 2016). Surface runoff and soil erosion both of which can remove available nutrients are severely occurring on soils with a high bulk density because water is restricted from moving through the soil and thus ends up as surface runoff and carry away soil and soil-bound nutrients (Mengistu *et al*., 2017). Soils with high bulk density, such as sands, can promote vertical leaching of nutrients and reduce their availability to crops. As soil structure and OM, soil bulk density is the dynamic soil fertility that can be affected or modified by physical management practices, such as tillage, as well as biological activity, such as the tunneling of earthworms and others soil microorganism (Brady and Weil, 2008).

Particle density is determined similarly to bulk density, but it is the mass of the dry soil divided by the volume of the solid soil components only that is, excluding the volume of the pore space. Therefore, particle density will be greater than bulk density and represents the average density of all the solids composing the soil (Easton *et al*., 2015). The particle density of most soils is around 2.65 g cm^{-3} because quartz, feldspar, and the colloidal silicates are within this range usually making up the major portion of mineral soils and is usually one of the dominant minerals in soils. However, clay has a particle density of 2.83 g cm^{-3}, and organic matter has a particle density of

0.8 g cm^{-3}, so soils with significant amounts of either clay or organic matter particle density will deviate from the 2.65 g cm^{-3} particle density estimate (Eyayu *et al*., 2009).

Even though the mean particle density of most mineral soils is about 2.60 to 2.75 g cm^{-3}, the presence of iron oxide and heavy minerals increases the average value of particle density and the presence of soil OM decreases it (Tilahun and Asefa, 2009). According to Abad *et al*. (2014), the surface soil layer had lower particle density value than the subsoil horizons and the higher particle density (2.93 g cm^{-3}) was obtained at the subsoil horizons in different land use systems at different elevations. This is attributed to the lower OM content in the subsoil than in the surface horizons.

2.3.3. Total porosity

The porosity of a soil is defined as the volume percentage of pores in a soil, i.e. the inverse of the volume percentage of solids. Within a soil of similar texture, a compacted soil has lower porosity and thus a greater bulk density, while a loose soil has a greater porosity and a lower bulk density (Teshome *et al*., 2013). The total porosity of the soils usually lies between 30% and 70%, and may be used as a very general indication of the degree of compaction in a soil in the same way as bulk densities are used. The soils which have the same particle density, the lower bulk density and the higher percent total porosity it have (Nega and Heluf, 2013). Apart from quantities and distribution, the tortuosity and continuity of pores are important features influencing aeration, water movement and root penetration in soils, but they are less easily measured and in most surveys, only qualitative observation is made (Mengistu *et al*., 2017). The arrangement of soil particles determines the amount, shape and direction of pore space. As soil particles vary in size and shape, pore spaces also vary in size, shape and direction. Coarse textured soils tend to be less porous than fine texture soils, though the mean size of individual pores is greater in the former than in the latter (Onweremadu, 2007).

Pores can be grouped into macro, meso and micro-pores, depending on their size. The macro-pores characteristically allow readily movement of air and drainage of water. Macro pores, those larger than 0.08 mm, are primarily the pore spaces between aggregates, and they promote free drainage of water (which can transport dissolved nutrients and agrochemicals), aeration, evaporation, and gas exchange in the soil profile (Ross, 2009). This free drainage, also referred to as preferential flow because the water preferentially bypasses the bulk soil, is enhanced by wet soil conditions and lack of soil disturbance such as is often found in no-till or pasture systems (Easton *et al*., 2015). Preferential flow can cause rapid leaching and bypass flow of nutrients and agrochemicals, even those that otherwise could be strongly bound to the soil, thereby potentially reducing the effectiveness of fertilizer and agrochemical applications (Lorencova *et al*., 2013). Macrospores are most prevalent in loamy and well-aggregated soils, but can be converted to micro pores by compaction through tillage and vehicle traffic (Zhang and Zhang, 2005).

Attah (2010) stated that the presence of close relationship between relative compaction and macro-porosity of soils. Tillage reduces the macro-pore space and produces a discontinuity in pore space between the cultivated surface and the subsurface soils. Generally, intensive cultivation has the greater compaction and degradation of the soil properties through expose the soil for heavy load and trampling which in turns reduce macro or meso pore space into micro pore space (Yihenew and Getachew, 2013). Macro-pores can occur as the space between individual sand grains in coarse textural soils. Thus, even though a sand soil has relatively low total porosity, the movement of air and water through such a soil is surprisingly rapid because of the dominance of macro-pores. The ideal fertile soils for most agricultural crops have sufficient pore space, more or less equally divided between large and small pores (Alemayehu and Sheleme, 2013).

The decrease in organic matter and increase in clay that occur with depth in many profiles are associated with a shift from macro-pores to micro-pores. In contrast to macro-pores, micro-pores are usually filled water in the soils (Lechisa *et al*., 2014). Even if not water filled, they are too small to permit much air movement. Fine textured soils, especially those without a stable granular structure may have a dominance of micro-pores, thus allowing relatively slow gas and water movement, despite the relatively large volume of total pore space (Geissen *et al*., 2009). According to Landon (1991), sands with a total pore space of less than 40% are liable to restrict root growth due to excessive strength, whilst in clay soils, limiting total porosities is higher and less than 50% can be taken as the corresponding value.

2.4. Soil Chemical Properties

Soil chemical properties are the result of different soil minerals disintegration, decomposition and weathering of soil parent materials over the geological period (Ufot *et al*., 2016). Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes (Kizilkaya and Dengiz, 2010). Minerals inherited from the soil parent materials over time release chemical elements that undergo various changes and transformations within the soil (Gebeyaw, 2007). Like that of soil physical properties, soil chemical properties are also playing an indispensable role in the soil resources function via showing how soil response to agrarian activities. This implication has happened through positively modifying the availability of different nutrient in the soil, the degree of soil reaction and nutrient retention of the soil (Zeng *et al*., 2009).

2.4.1. Soil reaction (pH), electrical conductivity and calcium carbonate

Soil pH or soil reaction is an indicator of soil acidity or alkalinity and is measured in pH units. The pH scale goes from 0 to 14 with pH 0 to 7 is acid, 7 to 14 basic and 7 as the neutral Point. A pH range of 6 to7 is generally more favorable for plant growth because most plant nutrients are readily available in this range. However, some plants have soil pH requirements above or below this range (Fageria and Baligar, 2008). The pH value(s) of soil helps to identify the kinds of chemical reactions that are likely taking place in the soil and the possible agricultural practice carried on (Mengistu *et al*., 2017). Soil reaction affects nutrient availability and toxicity, microbial activity which in turn reduces degradation and decomposing rate of organic matter, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment (Shimeles, 2006).

The degree of acidity or alkalinity of a soil is a very relevant property, which can influenced and fluctuated by natural phenomena as well as human induced problem including leaching of exchangeable bases, acid rains, decomposition of organic materials**,** application of commercial fertilizers and other farming practices (Brady and Weil, 2008). This in turns affect many other physico-chemical and biological properties, agricultural activities, crop production and food security. Deforestation followed by the cultivation of the same land with resulting export of basic cations in agricultural products, and leaching due to adequate rainfall, forms the major cause for the change in pH and acidification process in the tropics. Various studies in Ethiopia (Tsehaye and Mohammed, 2013; Lechisa *et al*., 2014 and Mulugeta and Kibebew, 2016) again noted a significant reduction in soil pH among soils cultivated for several years. Excessive disturbance of the soil due to cultivation caused high rates of OM turn over and decomposition releases both organic (H_2CO_3) and inorganic acids (H_2SO_4 and HNO_3) result in reduction of soil pH (Nega and Heluf, 2013).

Electrical conductivity is a measure of salinity present in the soil and thus to measure the total dissolved salts in the soil, the electrical conductivity measurement is sufficiently accurate for most purposes in agricultural practices (Alemayehu and Sheleme, 2013). Excessive accumulation of soluble salts converts soils to salt affected soils and the process leading to accumulation of salts in arid and semi-arid regions where rainfall amount is insufficient to leach soluble salts (Qadir *et al*., 2014). Electrical conductivity (EC) of the soil is heavily dependent on climatic conditions of the area in consideration. In soils of sub-humid tropics, where there is sufficient rainfall to leach out base forming cations from the root zone, EC is found too low, usually, less than 4 dS/m (Landon, 1991). Accordingly, owing to the high soil acidity levels (slightly acidic to very strongly acidic), the EC values are negligible and there were no apparent differences in electrical conductivity among the different soil management systems in the soils of Bako area, western Ethiopia (Heluf and Wakene, 2006).

Problems derived from acidic soils or acidification of agricultural soils can be overcome by increasing base saturation and pH with soil amendments such as liming materials (Asmare *et al*., 2015). Basic or alkaline soils are the consequence of the buffering of soil pH by base elements or by the presence of buffering compounds such as carbonates. Calcareous soils are those with an appreciable concentration of $CaCO_3$, which buffers soil pH near 8.5; the presence of other carbonates (Na in sodic soils) can buffer soil pH well above 8.5. The pH of a calcareous soil cannot be changed due to its high buffering capacity and its limitations for agricultural use, mainly related to restrictions in nutrient uptake and in plant nutrition, may be overcome with special fertilizer products and fertilization strategies (Abad *et al*., 2014).

2.4.2. Soil organic matter

Soil organic matter (OM) consists of dead plants, animal, microbes and fungi or their parts, as well as animal and microbial waste products in various stages of decomposition. Eventually, all of these break down into humus, which is relatively stable in the soil (Getahun and Bobe, 2015). Soil organic matter (OM) is considered to be a key attribute of soil quality and is usually considered as one of the most important properties of soils because of its impact on ecosystem sustainability and its effects on other soil physical, chemical, and biological characteristics (Abebe and Endalkachew, 2012). Organic matter improves soil structural stability in addition to providing mineral nutrients for plants and microorganisms through the mineralization process or biochemical oxidation of organic substrates (Tilahun and Asefa, 2009). For this reason, soil OM content is the result of equilibrium between the processes supplying new organic inputs and the rate of mineralization of the existing OM (Nega and Heluf, 2013). Mineralization and immobilization are thus soil microbial processes governed by carbon availability, closely linked to soil OM content.

Variability in the levels of soil OM relates to land use scenario, soil depth, slope position and climatic characteristics (Abiyot and Alemayehu, 2016). In arid and/or semi-arid regions, low and irregular rainfall together with high evapotranspiration rates leads to a low crop biomass production and thus, a limited residue input into the soil. Impacts of tillage on soil OM in surface soils have been well documented, but results vary due to soil type, cropping systems, residue management, and climate. Habtamu *et al*. (2009) obtained that higher value of OM at the upper elevation under the natural vegetation than cultivated land soils. Research results of Fantaw and

Abdu (2011) indicated that continuous cultivation practices and low return of plant biomass to the soil system had significantly reduced the OM contents of soil under the cultivated land as compared to the uncultivated counter part of the same site.

2.4.3. Total nitrogen and carbon to nitrogen ratio (C:N)

Nitrogen (N) is one of the most essential elements that is taken up by plants in greatest quantity after carbon, oxygen and hydrogen, and considered to be one of the key crop growth limiting factors (Solomon *et al*., 2006). Soil total N composed of inorganic (NH_4^+ and NO_3^-) and organic forms, is subject to change due to various factors. Management (cropping, fertilization, erosion and leaching) and climatic conditions (temperature and moisture) determine the level and dynamics of N found in soils (Ashenafi *et al*., 2010). Previous investigations on soil properties along landscapes affected by long-term tillage indicate that soil total N and OC contents are lower in areas of soil removal than in areas of soil accumulation (Shimeles, 2006).

According to Heluf and Wakene (2006) reported that there was a 30% and 76% depletion of total N from agricultural fields cultivated for 40 years and abandoned land, respectively, compared to the virgin land in Bako area, Ethiopia. Average total N increased from cultivated to grazing and forest land soils, which again declined with increasing depth from surface to subsurface soils (Nega, 2006). 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 (Mulugeta and Kibebew, 2016). 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 (Mulugeta, 2004). The same author also stated that the levels of soil OC and total N in the surface soil layer (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 to nitrogen 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 ((Nega and Heluf, 2013). 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 (Getahun and Bobe, 2015). They further noted that as decomposition proceeds, carbon is released as CO_2 and the C:N of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients (Liu *et al*., 2010). Plant residues with C:N of 20:1 or narrower has sufficient N to supply the decomposing microorganisms and also to release N for plant use. Residues with C:N 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 (Abad *et al*., 2014). Residues with C:N 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 (Tilahun and Asefa, 2009). They have further stated that the wider the C:N of organic materials applied, the more is the need for applying N as a fertilizer to convert biomass into humus. Microbial respiration (soil respiration) is defined as oxygen uptake or CO_2 evolution by bacteria, fungi, algae and protozoans, and includes the gas exchange of aerobic and anaerobic metabolism (Lechisa *et al*., 2014).

According to the same authors, soil respiration results from the degradation of organic matter for instance mineralization of harvest residues. This soil biological activity consists of numerous individual activities; the formation CO_2 being the last step of carbon mineralization. Conditions that favor growth of microorganisms will favor fast decomposition rates: continuous warm temperature, wetness, clay types of texture, suitable soil pH (slightly acidic), and adequate nutrients and absence of other decomposition inhibitors such as toxic levels of elements (aluminum, manganese, boron and chloride), soluble salts, shade, and organic phytotoxines (Mengistu *et al*., 2017).

2.4.4. Available phosphorus

Phosphorus (P) is the most critical essential element next to nitrogen, in influencing plant growth and production across the world (Nega and Heluf, 2013). Unlike nitrogen, it is not supplied through biochemical fixation, but must come from other sources to meet plant requirements. Hence, its deficiency is directly related to food security issues, especially in the tropics, where severe soil degradation is responsible for serious deterioration in soil quality (Solomon *et al*., 2006).

Several research results in Ethiopia indicated that most of the soils are known to have low P contents not only due to the inherently low available P content, but also due to the high P fixation capacity of the soils (Mishra *et al*., 2004; Wondwosen and Sheleme, 2011; Asmare *et al*., 2015). According to Mishra *et al*. (2004) studies in most of Ethiopian soils, Oxisols, Ultisols, Vertisols and Alfisols are generally low in total P content. The solubility and availability of P are largely determined by soil chemical characteristics such as, soil reaction (pH), cation contents (Fe, Al, and Ca) and the total phosphate reserves of the soil. For instance, in acidic soils (pH <5.5), inorganic Phosphorous precipitates as Fe/Al-P secondary minerals and/or is adsorbed to the surfaces of Fe/Al oxides and clay minerals, finally P became less available. Based on the levels of Olsen extractable P in the soil, Olsen *et al.* (1954) has indicated that available P below 5 mg/kg is considered as low between 5 to 10 mg/kg as a medium; and above 10 mg/kg as high level. However, the available P was low in calcareous soil since P can more available under the soil pH of 5.5 to 6.5.

2.4.5. Cation exchange capacity

Probably the most important and distinctive property of soils is that they can retain ions and release them slowly to the soil solution and to plants. The cation exchange capacity (CEC) implies the capacity of a soil for ion exchange of cations between the soil solid and the soil solution (Ross *et al*., 2008). CEC strongly influences nutrient availability, thus widely used in the soil fertility evaluation and soil classification projects (Ufot *et al*., 2016). The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil because both clay and colloidal OM are negatively charged and hence can act as anions to adsorb and hold positively charged ions (Teshome *et al*., 2013). Higher CEC values are usually associated with humus compared to those exhibited by the inorganic clays (Lechisa *et al*., 2014). According to Hazelton and Murphy (2007) classification, soils consisting of CEC values greater than 40 $cmol_c$/kg are rated as very high, while the CEC values between 25 to 40, 12 to 25 and 6 to 12 $cmol_c$/kg are rated as high, moderate and low, respectively.

2.4.6. Exchangeable bases

The amounts of exchangeable bases (Na, K, Mg and Ca) are important properties of soils as these are not only indicate the existing nutrient status, but can also be used to assess balances amongst cations (Abiyot and Alemayehu, 2016). They relate information on a soil's ability to sustain plant growth, retain nutrients, buffer acid deposition or sequester toxic heavy metals (Landon, 1991). Exchangeable sodium (Na) is found in very small amount in humid regions, but it can be a major component of soils in arid and semiarid regions. The concentration of Na in the soil varied from 0.1 to 1% (Landon, 1991). The presence of excess exchangeable Na in the soil exchange site alters soil physical properties mainly by inducing swelling and dispersion of soil colloidal particles resulting restriction in water and air movement, root penetration and nutritional disorders.

According to Landon (1991) classification, soils are considered as Sodic or Saline-sodic, when exchangeable Na occupies more than 15% of the CEC. Such soils contain exchangeable Na great enough to interfere with the growth and production of most crop plants which affects soil fertility and productivity. Based on its nature of availability, K exists as unavailable, slowly available (exchangeable) and readily available forms. The largest portion (90 - 98%) of the total K present in the soil is found in a relatively unavailable form to plants, whereas only 1 to 2% of the soil K is readily available to plants. In general, K content of a given soil depends on climatic condition, degree of weathering, intensity of cultivation and the parent material from which the soil is formed. The response to K fertilizer is expected from most crops when the exchangeable K contents of the soil are below the critical (0.38 $cmol_c$/kg) range, although different crops have different ranges of nutrient requirements. It is commonly believed that Ethiopian soils contain sufficient K and no deficiency problem for crop production. However, several research works of Shimeles (2006), Sintayehu *et al*. (2006) and Wondwosen and Sheleme (2011) revealed that K was deficient in various soil types (Umbrisols, Nitsols and Plinth sols), which were subjected to intensive cultivation.

Exchangeable calcium (Ca) and magnesium (Mg) are the dominant exchangeable cation in many soils, except alkaline soil that contain excess Na and acidic soils that contain higher amounts of hydrogen and aluminum. Exchangeable Ca and Mg usually account for more than 60% of the exchangeable cations of soil at pH 5.5 or higher. The concentration of Ca in the soil varies from 1% or less (in non-calcareous soils) to 10% or more (in calcareous soils), whereas the content of Mg is about 2.2% in lithospheres (Getahun *et al*., 2014). However, the contents of Ca and Mg of a given soil depend on its parent material, degree of weathering and land use/management practices. Similarly, continuous cultivation and inorganic fertilizers application result in declining of soil pH and caused loss of basic cations especially soils inherently poor in Ca and Mg sources (Papiernik *et al*., 2007).

2.4.7. Percent base saturation

The percent base saturation (PBS) is as much a measure of the actual percentage of cation exchange sites occupied by exchangeable bases. It is influenced by the pH of the CEC determination (Abebe and Endalkachew, 2012). The denominator includes oxide-mineral complexes between the initial soil pH and the reference pH (7.0 or 8.2) (Bohn *et al*., 2006). According to the same author, since neither the content of exchangeable Al nor exchangeable H is appreciable above pH 5.5, the effective CEC of the soil above this pH should be essentially 100% base saturated. However, soils in the pH range of 5.5 to 7.0 or 8.2 generally still have measured base saturations well below 100%. Such base saturation values are particularly low for minerals that have a high proportion of pH dependent charge, such as kaolinite clays (Fageria and Baligar, 2008).

The PBS of the lower B and upper C-horizons are especially diagnostic of the extent to which exchangeable basic cations have been removed from the soil and replaced by exchangeable acidity (Yacob, 2012). Therefore, this characteristic is extensively used in soil classification, soil fertility evaluation, and mineral nutrition studies. The differences between two soil orders are separated from each other by differences in PBS of the subsoil. Those soils in regions of higher rainfall, warmer temperatures, and an older landscape surface has been observed to have PBS less than 35 in their B-horizons (soils with argillic horizons only), or PBS is decreasing from B to C horizons (Shimeles, 2006).

An experiment conducted at a vegetable growing area of Kolfe showed that the PBS of soils is more than 50%. However, the soils of the new farmland indicate higher values of base saturation as compared to the soils of old farms (Dereje, 2004). In tropical regions under rainforest, the base saturation in humus-rich topsoil is usually in the order of 50 to 80%, while below the humus-rich layer, it drops very sharply to the levels of less than 20%. Getachew and Heluf (2007) reported that the PBS values throughout the two soil profiles and composite surface soil samples near these profiles described at the Ayehu Research Substation in northwestern Ethiopia were less than 50%. This could be due to the intensive cultivation and continuous use of the inorganic fertilizer in the study site that enhanced loss of basic cations through leaching, erosion and crop harvest.

2.4.8. Micronutrients

Micronutrients include boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). These elements required in very small amounts for plants, but their role is equally as important as the primary or secondary macronutrients (Attah, 2010). A deficiency of one or more of the micronutrients can lead to severe depression in growth, yield, and crop quality (Vijayakumar *et al*., 2011). The main source of micronutrient elements in most soils is the parent material, from which the soil is formed. However, the availability of micronutrients largely depends on soil texture, soil OM, CEC and soil pH. For instance micronutrients such as Cu, Fe, Mn and Zn are higher under acidic conditions (pH < 6.5), whereas, Mo deficiency is likely to occur in soils with a pH of less than 5.5 (Nazif *et al*., 2006). Some soils do not contain sufficient amounts of these nutrients to meet the plant's requirements for rapid growth and good production. In such cases, supplemental micronutrient applications in the form of commercial fertilizers are important (Tuma *et al*., 2014).

According to Yifru and Mesfin (2013), the overall assessment of micronutrients on Ethiopian soils and plant samples, the status varied considerably from one micronutrient element to another mictonutrients. Accordingly, the contents of Fe and Mn were considered adequate; Mo and Zn were thought to be highly variable and ranged from very low to high, while Cu was considered to be the micronutrient most likely to be deficient at several locations. The recent research findings by Ashenafi *et al.* (2010) and Wondwosen and Sheleme (2011) also indicated that Cu was most likely deficient, Zn contents were variable and man was sufficient for major soil groups in the south and west Ethiopia.

Heluf and Wakene (2006) reported that the status of micronutrients (B, Cu, Fe, Mn and Zn) of the Bako area soils revealed the effects of different soil management practices on the concentration of each micronutrient element. Significant variation was observed among the different soil management practices in available Fe and Mn concentrations, particularly in the surface horizons and to a lesser extent in the subsurface horizons. Adsorption of micronutrients, either by soil OM or by clay-size inorganic soil components is an important mechanism of removing micronutrients from the soil solution (Yifru and Mesfin, 2013). Thus, each may be added to the soils pool of soluble micronutrients by weathering of minerals, by mineralization of OM, or by addition as a soluble salts. Micronutrients have positive relation with the fine mineral fractions like clay and silt while negative relations with coarser sand particles. This is because of their high retention of moisture induces the diffusion of these elements (Kumar and Babel, 2011).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

The study was conducted on Jila Kerensa kebele, Kuyu district, north Shewa zone, the Oromia National Regional State. It's located on the main road of Addis Ababa to Bahir Dar on the 150 km in north direction. Geographically, it is located at about $9^{0}36'34''$ N latitude and $38^{0}05'00''$-$38^{0}34'13''$ E longitude with an altitudinal range of 1200-2800 meters above sea level (masl) (KWAO, 2017).

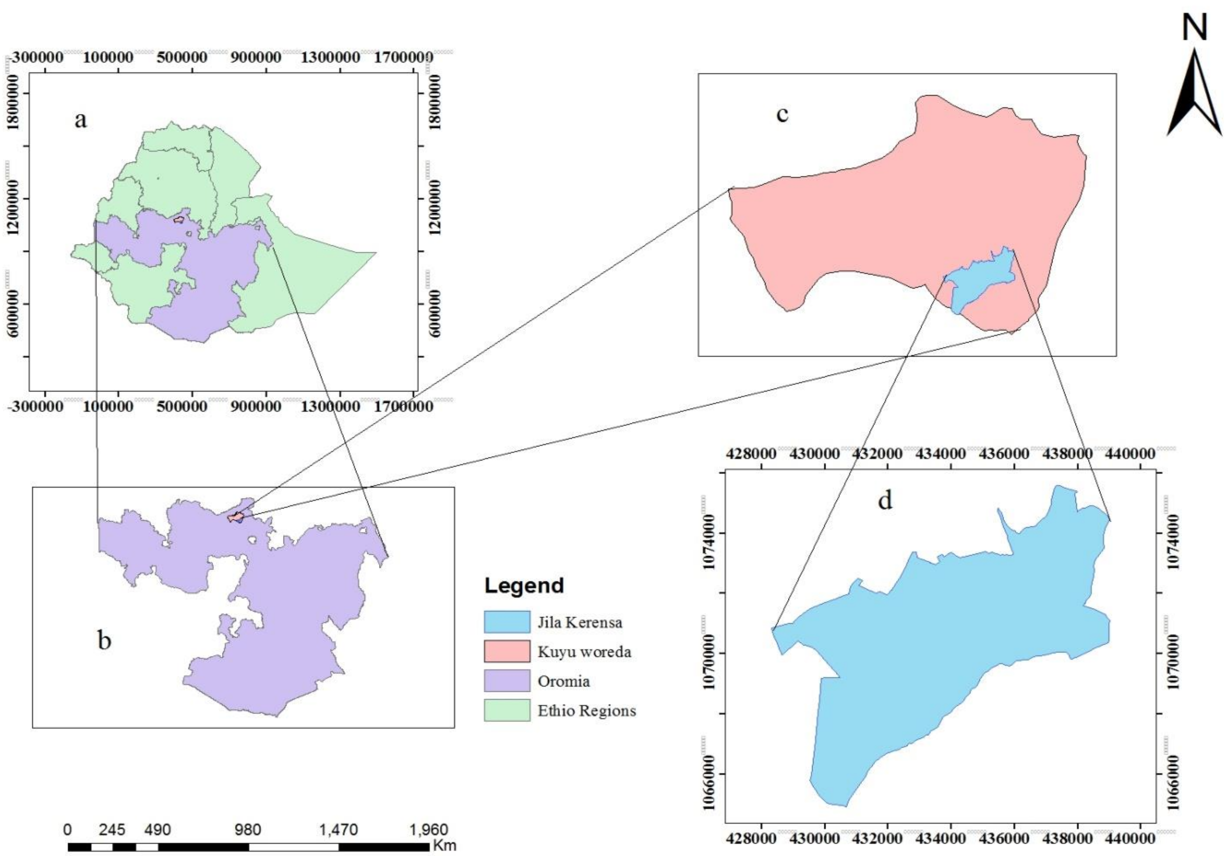

Figure 1. Location map of the study area: (**a**) Map of Ethiopia showing Oromia Regional State, (**b**) Oromia Regional State showing Kuyu woreda, (**c**) Kuyu woreda and (**d**) Jila Kerensa kebele.

3.1.2. Climate

The vast majority part of the study area is *badda daree* (*woinadega*) (1500-2500 masl) which accounts 75%, followed by *gammoojjii* (*qolla*) (below 1500 masl) (20%). The rest 5% of the area is constituted by *baddaa* (*dega)* (above 2500 masl) agro-climatic zone. The average annual rainfall of the study area was 1475.3 mm per year, where the maximum is obtained during summer (*kremt*) season from June to September and the minimum is obtained during spring (*belg*) season from March to June. The mean monthly minimum and mean maximum air temperature of the study area were 8.0 and 20.0 ^{o}C, respectively (KWAO, 2017).

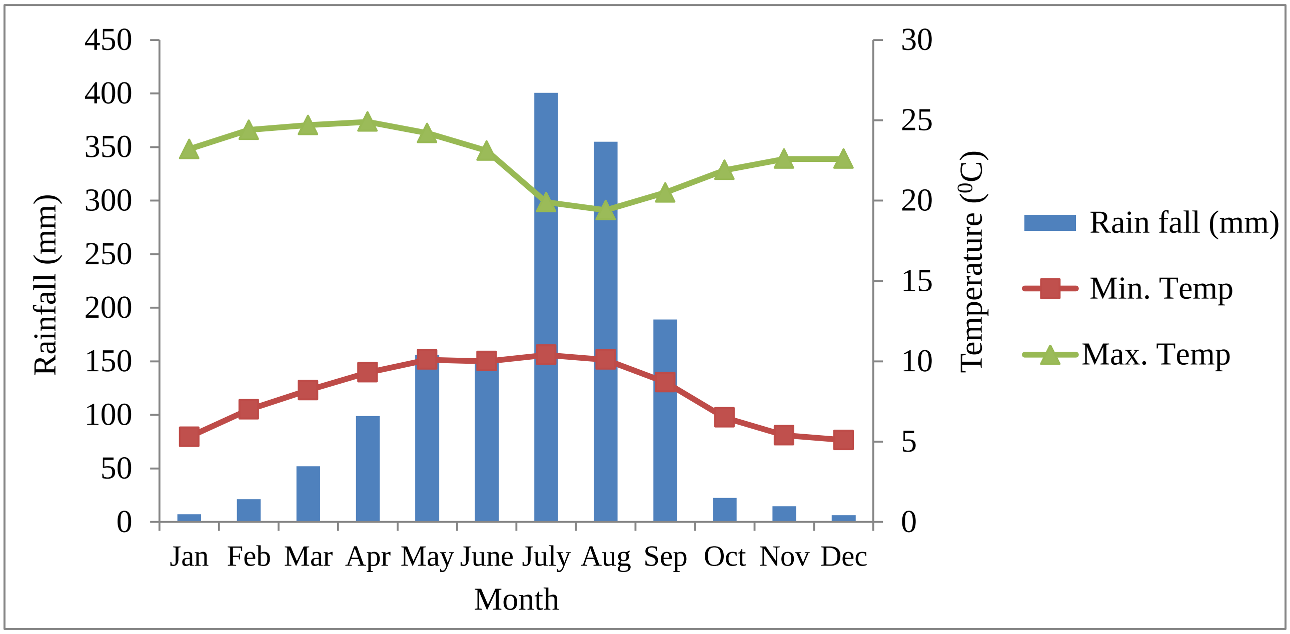

Figure 2. Mean monthly rainfall and mean monthly minimum and maximum temperatures of the study area for eight years (2010-2017).

3.1.3. Soils

According to FAO (1984), the dominant soil type of the study area is Vertisols. Its vernacular or local name is "Biyyee Gurraacha" meaning black soil and clay is the dominant soil texture. Additionally, the data obtained from the Woreda Agricultural Office reveals that soil erosion in the area is so severe. This is mainly because the vast proportion of the land is uncovered by vegetation and steep slopes are widely available in *woinadega* part of the study area (KWAO, 2017).

3.1.4. Vegetation

According to the Forestry Development and Protection Department of the Kuyu district Agricultural Office, the study area has the scarcity of natural forest in different land use types. However, plantation forests such as eucalyptus trees are found scattered in *dega* and *woinadega* regions of the study area. Eucalyptus trees are mostly restricted to around community settlements. As it is true for most areas of Ethiopia deforestation has been one of the serious problems in the study area. Vegetation has been cleared for the purpose of timber production, firewood, construction materials and for expansion of cultivation lands. As a result, the fertile soils have been lost and the wild animals have been endangered. Almost all flat-topped plateaus have small form of natural vegetation, whereas the valleys and sloppy lands are covered with scattered bushes and shrubs (KWAO, 2017).

The study area was contained both native and exotic plant species. There are the several diversity of native plant species such as, *Birbirsa* (*Zigba)* (*Podocarpus talacta*), *Waddeessa* (*Wanza*) (*Cordia Africana*), *Ejersa* (*Weira)* (*Olean Africana*), *Sombo* (*Ekebcrgia capensis*) and *Laaft*oo (*girar*) (*Acacia's*) species are commonly found in most parts of the study area. Additionally, there are the others some exotic species such as *Gravillia*, *Juniperus procera* and *Eucalyptus* species. *Eucalyptus* species such as *globulus* and *camaldulensis* are the major species planted in the study area. *Gravillia* species are only planted and found around the homestead area while *Juniperus procera* are sparsely found in large areas (KWAO, 2017).

3.1.5. Land use and farming system

According to the data obtained from Kuyu district Agricultural Office and Rural Development, in the study area there are different land use types: cultivated lands, forest lands, bush and shrubs, grasslands, and grazing lands (Table 1). The total land coverage areas of Jila Kerensa kebele is 4973.341 ha, where cultivated land is (3673.077 ha), grazing land (362.46 ha), grassland (308.23 ha), forest land (274.68 ha), settlement (228.059 ha), bush and shrubs (114.84 ha), institution (6.275 ha) and urban area was (5.72 ha) (KWAO, 2017).

Regarding to agricultural practice, the community of the study area is practicing mixed farming system that is sowing and producing a variety of crops as well as rearing animals that ensure their livelihoods and their income. All crops are annual and rain feed crops, such as teff (*Eragrostis tef*), maize *(Zea mays* L.*)*, wheat (*Triticum spp)*, sorghum (*Sorghum bicolor*), barley (*Hordeum spp)*, chickpea (*Cicer arietinum)*, grass pea *(Lathyrus sativus)*, lentil (*Lens culinaris*), bean (*Fabaceae spp,)* pea (*Pisum sativum*), niger seed *(Guizotia abyssinica)*, linseed *(Linus usitatissiumum)*, and sunflower *(Helianthus annus)* are the common one. From the fruit, sugar cane *(Saccharum officinarum* L.), banana (*Musa spp*.) and mango *(Mangifera indica* L.*)* are found in some specific study area of the small scale level. The livestock of study area includes cattle, sheep, goats and equine (donkeys, mules and horses) (KWAO, 2017).

Table 1. Description of land use types identified on Jila Kerensa kebele central highland of Ethiopia

Land use types	Description
Grass land	The type of land use which was protected and purposely allocated only for grass throughout a year, and this grass is only cut-carry based on its annual maturity period and used as animal feeding and for home as thatch and hay.
Cultivated land	The land which allocated for sowing of rain fed annual crops includes teff, wheat, niger seed, linseed and sorghum.
Forest land	This is a land use types that contain and characterized by indigenous natural trees and shrubs.
Grazing land	This is one of the land use types which is allocated for cattle grazing and contains some scattered trees, bush and shrubs.

3.2. Site Selection

For this study, Jila Kerensa kebele was purposively selected from Kuyu district because higher land degradation and soil erosion problems are commonly observed in this area, which has a deleterious impact on soil physico-chemical properties under different land use types. Prior to the collection of soil samples, discussions was made with the woreda agricultural office expertise in order to get the prehistory and current information about the utilization of land use types and lifestyle of the local community in the study area regarding to their handling and managing method of various land use types.

Then after, a reconnaissance field survey was carried out in order to have a general view of land use types in the study area. Throughout the visual observation of the study area its geographic coordination (latitudes and longitudes) and elevation were recorded by global positioning system (GPS). Then after for the addressing the intended objective, the treatments were stratified into four land use types viz: cultivated, grazing, forest and grasslands.

3.3. Soil Sampling

Composite soil samples were collected from the four land use types (cultivated, grazing, forest and grasslands) by two soil depths (0-20 cm and 20-40 cm) with three replications. The whole factors were situated on the same slope, climatic, geologic and topography. Both undisturbed and disturbed soil samples were taken from two soil depths from ten to fifteen sampling point based on the heterogeneity of land unit in a zigzag manner. Undisturbed soil samples were taken by core sampler to measure the soil bulk density, whereas the disturbed soil samples were taken by using an auger to measure the rest selected soil physico-chemical properties.

During the collection of soil samples, gravel materials, dead plants, old manures, areas near trees and compost pits were excluded. This is to minimize the differences variation, which may arise because of the dilution of soil OM due to mixing through cultivation and other factors. After these materials and areas were separated, 24 composite soil samples were collected from representative land use types. Then after, about one kilogram (1kg) of the soil samples from 24 composite soil samples were sub-sampled and packed by plastic bags. After the composite soil sub-samples were taken and packed, it was air dried and finally ground and sieved by 2 mm sieve to the analysis of physico-chemical properties of soil. However, organic carbon (OC) and total nitrogen (N) analyses were ground to pass 0.5 mm size sieve and then brought to the laboratory for the analysis of selected soil physico-chemical properties.

3.4. Soil Laboratory Analysis

Selected soil physico-chemical properties were analyzed at Addis Ababa, National Soil Testing Center. Standard laboratory procedures were followed in the analysis of the selected physico-chemical properties of the soils.

3.4.1. Analysis of soil physico-chemical properties

Soil texture was analyzed by the Bouyoucous hydrometer method (Bouyoucous, 1962), after OM was destroyed or burned by using hydrogen peroxide (H_2O_2), soil particles dispersed and disintegrated by sodium carbonate (Na_2CO_3) and sodium hexametaphosphate ($NaPO_3$) in distilled water and finally using amyl alcohol to destroy the soil solution foam. After the particle size distributions were determined in percent, the textural class of the soil could obtained by using USDA soil textural triangle classification system (USDA, 2008).

The bulk density (BD) of the soil was measured from undisturbed soil samples collected using a core sampler after drying the core samples in an oven at 105 ^{o}C (Black, 1965). A core sampler containing an inner core sampler cylinder and external driver cylinder was used to take a sample from the field. The inner cylinder was driven into the soil with a drop hammer dropping through the external cylinder. The inner sampler containing an undisturbed soil core is removed and trimmed on the end or rim of core with a sharp knife to yield a core whose volume can easily be calculated from the height and diameter of a cylinder. The core sampler that was used in these sampling procedures has 5 cm diameters (2.5 cm radius) and 5 cm height. After oven drying the soil sample at 105 ^{o}C and weighing its mass would be known.

The total porosity of soil samples was estimated from the values of bulk density (BD) and particle density (PD) (assuming an average particle density of mineral soil is 2.65 g cm^{-3}). Then the total porosity (TP) was calculated as, TP (%) = (1-Bulk density/Particle density) * (100) %.

The pH of the soils was measured in water (H_2O) suspension in a 1:2.5 (soil: liquid) potentiometrically using a glass-calomel combination electrode whereas electrical conductivity was measured by a conductivity meter (Van Reeuwijk, 1992). Calcium carbonate content of the soil was determined by an acid neutralization method in which the soil carbonate was neutralize by standard 0.1M HCl solution and back titrated with standard NaOH (Van Reeuwijk, 1992).

To determine organic carbon, the Walkley and Black (1934) method was used in which the carbon was oxidized under standard conditions with potassium dichromate ($K_2Cr_2O_7$) in sulfuric acid solution. Finally, the organic matter content of the soil was calculated by multiplying the organic carbon percentage by 1.724 following the assumptions that OM is composed of 58% carbon i.e. 100/58 = 1.724. The total nitrogen content in soils was determined using the Kjeldahl digestion, distillation and titration method by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO_4) as described by Black (1965). Then after, C:N was calculated by dividing organic carbon to total nitrogen. The available P was calculated by the Olsen method using sodium bicarbonate (0.5M $NaHCO_3$) as an extraction solution (Olsen *et al*., 1954).

Exchangeable bases (Na, K, Mg and Ca) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Na and K were analyzed by flame photometer while Ca and Mg in the extracts were analyzed using atomic absorption spectrophotometer (AAS) as described by Rowell (1994). Cation exchange capacity was estimated titrimetrically by distillation of ammonium that could be displaced by sodium from NaCl solution (Chapman, 1965). Percent base saturation would be calculated by dividing the sum of the charge equivalents of the base forming cations (Na, K, Mg and Ca) by the CEC of the soil and multiplying by 100.

3.5. Statistical Analysis

After all the data collected and organized, the two way analysis of variance (ANOVA) was used to test differences in soil physical and chemical properties across land use types and soil depths. For statistically different parameters at probability 5% ($p \leq 0.05$), means were separated by the Duncan's Multiple Range Test (DMRT) using SAS software version 9.4 (SAS, 2013).

4. RESULTS AND DISCUSSION

4.1. Selected Soil Physical Properties under Different Land Use Types

4.1.1. Soil texture

According to the results of analysis of variance (ANOVA) revealed that there was no significant ($P > 0.05$) different on the sand particle under land use types, soil depths and in the interaction of the land use types by the soil depth. But, silt and clay particles were significantly ($P \leq 0.05$) affected by land use types. However, sand, silt and clay particles were not significantly ($P > 0.05$) affected by soil depths and by the interaction of land use types by the soil depth (Tables 2 and 4). Although there was no statistical disparity on soil sand particles amongst land use types, there was the numerical variation across the land use types.

Considering the interaction of land use types with soil depth, the highest (34.3%) and the lowest (21.3%) value of sand was found on the surface (0-20 cm) soil layer of cultivated and forest lands, respectively. Whereas the highest (51.0%) and lowest (36.7%) values of clay content were found in the subsurface (20-40 cm) soil layer of the cultivated and forest lands, respectively (Table 2). In the case of soil depth, the higher sand content was obtained at the surface (0-20 cm) soil layer, whereas the higher silt and clay were recorded in the subsurface (20-40 cm) of soil layer (Table 4). Generally the clay content was higher in the subsurface layer of cultivated land as compared to the adjacent forest, grass and grazing lands. The reason might be due to the preferential removal of clay particles by erosion agents from the surface layer of cultivated land and downward clay migration into the subsurface soil layer.

Similarly, Mengistu *et al*. (2017) stated that the clay content of cultivated land was increased from the surface to subsurface soil layer due to the long period of cultivation. Additionally, Tsehaye and Mohammed (2013) reported that lower clay and higher sand content was found in the surface layer and higher clay contents was found in the subsurface layer of cultivated land than the others adjacent natural forest, plantation forest and grazing lands. This might be attributed to the selective removal of clay particles by processes of erosion, leaving behind the sand fraction in situ and its downward migration through soil profile. The study area was in parallel with the above researchers in which cultivated and grazing lands are more vulnerable to erosion agents as they have little or no protective vegetation cover. Thus, when erosion occurs, the finer and lighter materials are selectively removed. Generally, the absence of protective vegetation cover on the cultivated land and grazing lands also indirectly contributes to the removal of finer particles as it reduces the soil OM that disturbs soil aggregates and accelerates soil loss via erosion (Abbasi *et al*., 2007).

Table 2. Interaction effects of land use types and soil depth on soil texture on Jila Kerensa kebele

	soil texture					
	Sand (%)		Silt (%)		Clay (%)	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
Land use types	0-20	20-40	0-20	20-40	0-20	20-40
Grass	25.0	24.7	26.0	25.0^{b}	49.0	50.3^{a}
Cultivated	34.3	26.3	26.7	22.7^{b}	39.1	51.0^{a}
Forest	21.3	25.3	32.7	38.0^{a}	46.0	36.7^{b}
Grazing	27.7	25.0	28.7	30.7^{ab}	43.7	44.3^{ab}
CV (%)	19.62	18.24	20.55	16.05	17.05	12.51
P - values	ns	ns	ns	*	ns	*

Interaction means within a columns followed by the different letter(s) are significantly different from each other at $P \leq 0.05$; ns = not significant; * = significant at $P \leq 0.05$; CV = Coefficient of variation.

4.1.2. Bulk densities

The soil bulk density value was significantly ($P \leq 0.001$) affected by land use and by their interaction effects, whereas it was significantly affected by soil depth at $P \leq 0.01$ (Tables 3 and 4). Considering the main effects, the highest (1.37 g cm^{-3}) mean value of bulk density was recorded on the cultivated land and the lowest (1.10 g cm^{-3}) mean value was found under the grassland (Table 4). The reason for the lowest soil bulk density of the grassland could be due to the higher clay content and less disturbance of the soil under grassland. The higher bulk density of soil in cultivated land might be due to the practice of ploughing in cultivated soil, which tends to lower the quantity of OM of that soil and leads to high bulk density through animal trafficking and expose the soil surface to direct strike by rain drops. This finding is in agreement with Teshome *et al.* (2013) who found the highest bulk density under cultivated land compared to the adjacent grazing and forest lands at a soil depth of 0-20 cm. Additionally, Gebeyaw (2007) and Lechisa *et al.* (2014) suggested that the bulk density of soil was highest under cultivated land compared with the adjacent forest and grazing lands.

Furthermore, it is in agreement with the findings of Abad *et al.* (2014) in their findings they found that the bulk density of cultivated land was higher than that of adjacent grazing land and forest lands at soil depth of 0-30 cm. Paradoxically, Abiyot and Alemayehu (2016) found that the higher bulk density in the grassland compared to the adjacent bare land and rehabilitated land at a soil depth of 0-10 cm, 20-30 cm and 30-40 cm. Generally, the ranges of bulk density values observed in this study are within the ranges expected value in most mineral soils as indicated by Gupta (2004). Since the bulk density of this study area was within the expected values the aeration and water movement within the soil structure is in conducive situation that attain plant growth and determine the numbers and diversity of soil microbes thereby they furnish the versatile function in agrarian activities.

The bulk density of the soil was insignificantly and negatively correlated with silt and clay particles values at r = -0.13, -0.21, respectively. But it was significantly and negatively ($r = -0.99^{***}$) correlated with the total porosity (Table 11). This might be due to the reciprocal relationship between soil bulk density and total porosity, which shows the degree of soil compaction.

Table 3. Interaction effects of land use types and soil depth on soil bulk density and total porosity of soil on Jila Kerensa kebele

	BD (g cm^{-3})		TP (%)	
	Soil depth (cm)		Soil depth (cm)	
Land use types	0-20	20-40	0-20	20-40
Grass	1.09^{c}	1.10^{d}	58.8^{a}	58.50^{a}
Cultivated	1.38^{a}	1.36^{a}	47.8^{c}	48.56^{d}
Forest	1.15^{b}	1.16^{c}	56.5^{b}	55.90^{b}
Grazing	1.39^{a}	1.34^{b}	47.6^{c}	49.40^{c}
CV (%)	0.64	0.67	0.61	0.55
P - values	***	***	***	***

Interaction means within a columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; *** = significant at P ≤ 0.001; BD = Bulk density; TP = Total porosity

Table 4. Main effect of land use types and soil depth on selected physical properties of soil on Jila Kerensa kebele

Treatments	Sand (%)	Silt (%)	Clay (%)	BD (g cm^{-3})	TP (%)
			Land use types		
Grass	23.3	25.33^{b}	51.33^{a}	1.10^{d}	58.7^{a}
Cultivated	30.3	24.70^{b}	45.00^{ab}	1.37^{a}	48.2^{c}
Forest	23.3	35.33^{a}	41.33^{b}	1.16^{c}	56.2^{b}
Grazing	26.3	29.70^{ab}	44.00^{ab}	1.36^{b}	48.5^{c}
			Soil depth (cm)		
0-20	27.6	28.5	43.92	1.25^{a}	52.70^{b}
20-40	24.1	29.0	46.90	1.24^{b}	53.11^{a}
Land use	ns	*	*	***	***
Depth	ns	ns	ns	**	**
Land use * depth	ns	ns	ns	***	***
CV (%)	22.4	22.54	14.32	0.62	0.54

Main effect means within a columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001.

4.1.3. Total porosity

The result of the analysis of variance (ANOVA) showed that the total porosity of soil was significantly ($P \leq 0.001$) affected by land use types and by their interaction. But it was significantly affected by soil depth at $P \leq 0.01$ (Tables 3 and 4). Considering the interaction of land use types with soil depth, the highest (58.8%) and the lowest (47.6%) values of total porosity was recorded on surface (0-20 cm) soil layer of grass and grazing lands, respectively (Table 3). The higher value of soil total porosity in grassland was implied that the low bulk density.

Regarding to the mean values of total porosity under different land use types, the mean total porosity of grass, cultivated, forest land and grazing lands were 58.7, 48.2, 56.2 and 48.5%, respectively (Table 4). In the case of both soil depths, the higher value of total porosity was recorded at subsurface (20-40 cm) soil layer. The higher and lower of total porosity across the adjacent land use types was implies the lower and higher bulk density values of that soil, respectively.

The soil total porosity was insignificantly and positively correlated with soil OM and clay at $r = 0.04$ and at $r = 0.22$, respectively. This is because of the soil contained OM and clay particles have meso or microspores, which has low soil aeration and water percolation. But it was significantly and positively correlated with $CaCO_3$ and CEC of the soil at $r = 0.76^{***}$ and at $r = 0.75^{***}$, respectively (Table 11).

Generally, the optimal level of total porosity of soil is ranges from 30 to 70%, which indicates the degree of compactness in the soil. According to Landon (1991) the favorable total porosity of sand particles was about 40% whereas that of clay content soil is about 50% and above to sustain and regulate the activities of soil biota. Therefore, having this as departure the findings of this study is in agreement with these ideas and confirms inexistence of soil properties problems via water infiltration and soil aeration under adjacent different land use types in the study area.

Moreover, the high total porosity of the soil implies that the less problem of water logging and surface runoff.

4.2. Selected Soil Chemical Properties under Different Land Use Types

4.2.1. Soil reaction (pH), electrical conductivity and calcium carbonate

The ANOVA results indicated that the soils pH-H_2O was not significantly ($P > 0.05$) affected by land use types, soil depth and their interaction (Tables 5 and 7). Even though there was no statistical variation of soil reaction under different land use types and in their interaction, there was a numerical variation on its values. Considering the interaction of land use types with soil depth, the highest (8.1) and the lowest (7.6) values of soil reaction were recorded on the surface (0-20 cm) soil layer of grass and cultivated lands, respectively (Table 5). The higher pH value was recorded at surface soil layer than the subsurface soil layer (Table 7).

Compared with the others adjacent land use types ⁻ forest, grass and grazing lands, in the main effect of land use types, the lowest mean value of soil reaction was observed under the cultivated land. This might be due to the depletion of basic cations through crop harvesting and surface runoff, which generated from accelerated water erosions since there was no or little protective vegetation on the surface soil layer of cultivated land. Additionally, it might be due to its highest microbial oxidation that produces an organic acid, which contribute H ions to the soil solution and that lowers soil reaction. In line with these results, Getahun and Bobe (2015) also found that the lower soil reaction under cultivated land compared to the adjacent forest land and grazing land at a soil depth of 0-20 cm.

These results are also in agreement with others authors' findings Gebeyehu (2007) and Lechisa *et al.* (2014) who suggested that the soil reaction was lower under cultivated land compared to forest and grazing lands at a soil depth of 0-20 cm and 20-40 cm. As per rating of soil pH by Tekalign (1991), the soil pH of the study area under grass and forest lands was rated as moderately alkaline whereas the pH values of cultivated and grazing lands were in the range of slightly alkaline. By and large, the result of high pH values of soil in the study area was indicated that the presence of calcareous soil, which is characterized by high contents of calcium carbonate compounds which occupied the exchangeable complex instead of exchangeable Al and Fe cations.

Table 5. Interaction effects of land use types and soil depth on soil pH, EC and $CaCO_3$ on Jila Kerensa kebele

	Soil parameters					
	pH-H_2O (1:2.5)		EC (dS/m)		$CaCO_3$ (%)	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
Land use types	0-20	20-40	0-20	20-40	0-20	20-40
Grass	8.1	7.9	0.32^b	0.24^b	8.13^b	9.13^a
Cultivated	7.6	7.7	0.31^b	0.33^{ab}	6.80^c	7.20^b
Forest	7.8	7.9	0.57^a	0.48^a	11.50^a	9.06^a
Grazing	7.7	7.7	0.30^b	0.35^{ab}	5.10^d	5.86^c
CV (%)	4.24	4.82	20.53	25.24	5.44	4.36
P - values	ns	ns	**	*	***	***

Interaction means within a columns followed by the different letter(s) are significantly different from each other at $P \leq 0.05$; ns= not significant; * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$; *** = significant at $P \leq 0.001$; EC = Electrical conductivity; $CaCO_3$ = Calcium Carbonate.

The electrical conductivity (EC) values of soils were significantly ($P \leq 0.01$) affected by land use types, but not significantly ($P > 0.05$) affected by the soil depths and their interaction (Tables 5 and 7). Considering the main effects of land use types, the highest (0.53 dS/m) and the lowest (0.26 dS/m) EC of the soils were obtained in the forest and the grasslands, respectively (Table 7). The highest EC value under the forest land might be due to the higher exchangeable bases since there was no or little disturbance of erosion, which remove basic cation from upper surface layer of soil that triggered by torrential rainfall. The lowest EC value under the grassland could be associated with the loss of base forming cations through high water percolation since grassland had a low bulk density and higher total porosity.

Similarly, this result is in agreement with findings of Sintayehu *et al.* (2006) who found the lower electrical conductivity under grassland compared to the adjacent croplands, bush lands and bushed-grasslands at 0-20 cm of soil depth. The EC of soil was going increased with depth i.e. it increased from the surface layer (0-20 cm) to subsurface layer (20-40 cm) except in forest land in which it was decreased from surface (0.57 dS/m) to subsurface layer (0.48 dS/m) (Table 5).

According to the standard classification of EC values by Landon (1991), the EC values measured under all land use types in the study area indicated that the concentration of soluble salts is below the levels at, which growth and productivity of most agricultural crops are affected. This implies that the presence of enough precipitation to evaporation ratio on the study area. Therefore, it is not the limiting factor regarding to plant growth and agricultural crop productivity.

The calcium carbonate ($CaCO_3$) of soils was significantly ($P \leq 0.001$) affected by land use types and by the interaction of land use types with soil depths, but not significantly ($P > 0.05$) affected by the soil depths (Tables 5 and 7). Considering the interaction of land use types by soil depths, the highest (11.50%) and the lowest (5.10%) $CaCO_3$ values were observed on the surface (0-20 cm) soil layer of forest and grazing lands, respectively. The more existence of $CaCO_3$ across land use types could be related to the trends of calcium contents of the soil. According to Landon (1991) classification, the soil classified as none calcareous soil when $CaCO_3$ contents are less than 0.5% and considered as calcareous soil when it is 0.5% and above. Based on this classification, the study area was characterized by high content of $CaCO_3$ in all land use types and both soil depths, which indicates that the presence of calcareous soil in the study area. This in turn causes for phosphorous precipitation in the form of Ca-phosphate and ultimately decreases the availability of P in the soil.

The soil pH was insignificantly and positively correlated with soil OM and available P at r = 0.10 and at r = 0.08, respectively, whereas soil EC was significantly and positively correlated with the total N and soil OM at r = 0. 78*** and at r = 0.73***, respectively. Similarly, the soil $CaCO_3$ was significantly and positively (r = 0.93***) correlated with the CEC of the soil (Table 11). This is because of the presence of more OM in the soil leads to the more pH in the soil and exchangeable basic cations on exchangeable complex. Besides, the more exchangeable Ca in the soil, the probability of more $CaCO_3$ present in the soil.

4.2.2. Soil organic matter

The ANOVA results revealed that the soil OM contents were significantly ($P \leq 0.001$) affected by land use types, soil depth and the interaction of land use types by soil depth (Tables 6 and 7). Considering the interaction effects, the highest (5.60%) value of soil OM content was recorded on the surface (0-20 cm) soil layer of forest land and the lowest (2.73%) value of soil OM was found under the subsurface (20-40 cm) soil layer of grazing land (Table 6). The decline of soil OM content in the grazing land might be due to the overgrazing and the heavy compactness of the soil by livestock trampling. This could be in turns hamper an accumulation of soil OM at both surface and subsurface soil layer. Compared to the grazing lands, cultivated land had relatively higher soil OM at the surface and subsurface soil layer. This could be due to rooting systems in, which grass and grazing lands have fine, short and dense roots while cultivated land has large, long and sparse roots of crops, which can play a great contribution in the enhancement of soil microorganism as well as reinforce their function (Tsehaye and Mohammed, 2013).

However, the highest value of soil OM on the surface layer of forest land was attributed to the excessive amount of plant residues and biomass on surface land. With no exception, the soil OM of the study area was going decreased while soil depth was going increased, i.e. the soil OM decreased from the surface (0-20 cm) to subsurface (20-40 cm) soil layer (Table 6). The decreased of soil OM to downward through the soil profile and increased upward is implies the soil OM across the adjacent different land use types was suffice on surface soil layer where both animal and plant residues are present to accommodate several diversity of soil micro and macro-organisms. This in turns play an indispensable role in mineralization and immobilization processes. Therefore, the analysis of variance results confirms that regarding to a soil depth of the study area, the soil OM value was higher (4.4%) on the surface (0-20 cm) soil layer than that of subsurface (3.5%) soil layer (Table 7).

This finding is in agreement with different individuals' findings Tilahun and Asefa (2009), Lalisa *et al*. (2010), Iqbal, *et al*. (2012) and Lechisa *et al*. (2014) in which they proposed that the soil OM decrease with increasing soil depth, with more accumulation on the upper surface soil layer. Similarly, it is in line with the other authors Alemayehu and Sheleme (2013), in their findings they found that soil OM become decreasing with increasing of soil depth and it was higher in grassland compared with adjacent maize and enset land at the soil depth of 0-15 cm and 15-30 cm. This might be due to roots of the grass and fungal hyphae in the grassland soils are probably responsible for the higher amount of total organic matter. Generally, based on classification clue cited by Tekalign (1991), soil OM of study area was belonged to medium rate in all land use types except in forest land which is in the high rate.

Soil OM was insignificantly and positively correlated with the soil total porosity, silt and clay at r = 0.40, at r = 0.29 and at r = 0.03, respectively, while it was significantly and positively correlated with the soil total N and CEC at $r = 0.95^{***}$and at $r = 0.68^{***}$, respectively (Table 11). This positive relationship between soil OM and CEC confirm that the more soil OM, the more potential of the nutrient reservoir of the soil and exchangeable basic cations on soil complex site.

Table 6. Interaction effects of land use and soil depth on total N, soil OM, C:N and Av. P of the soils on Jila Kerensa kebele

Land use types	Total N (%) Soil depth (cm)		OM (%) Soil depth (cm)		C:N Soil depth (cm)		Av.P (ppm) Soil depth (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
Grass	0.26^{ab}	0.21^{ab}	4.6^{ab}	3.60^{b}	10.5^{b}	10.0	2.22^{bc}	0.88^{b}
Cultivated	0.21^{b}	0.20^{ab}	3.7^{b}	3.30^{b}	10.2^{b}	10.0	3.03^{b}	1.75^{ab}
Forest	0.28^{a}	0.22^{a}	5.6^{a}	4.30^{a}	11.6^{a}	11.3	7.70^{a}	3.05^{a}
Grazing	0.20^{b}	0.16^{b}	3.5^{b}	2.73^{b}	10.1^{b}	9.9	1.40^{c}	1.13^{b}
CV (%)	13.31	7.83	5.90	16.47	8.77	8.81	21.86	10.33
P - values	***	**	***	*	*	ns	***	*

Interaction means within a columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; Av.P = Available phosphorous; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001.

4.2.3. Total nitrogen and carbon to nitrogen ratio (C:N)

The total nitrogen (N) content of soils was significantly (P ≤ 0.001) affected by land use types. However, it was significantly affected by soil depth at P ≤ 0.01 and by the interaction of land use with soil depth at P ≤ 0.05 (Tables 6 and 7). Regarding to the main effects of land use types and soil depths, the average value of total N was highest (0.26%) on the forest land and lowest (0.18%) on the grazing land (Table 7). The variations of total N content among different land use types are parallel with that of OM content which is decreasing while soil depth was increased (Table 6).

The higher total N content in soils of the forest land could be associated with the high OM contents of the soils, whereas the low content of total N in grazing land might be due to the house consumption of animal dung as fuel instead of leaving in the field. Further, removal of vegetation by livestock grazing and expose the surface layer of grazing land to direct rain drop could be generating more surface runoff, which can remove the animal and plant residues from the surface layer thereby decrease soil OM and eventually cause for total N depletion.

Similarly, the results of this study is in agreement with the findings of Ufot *et al*. (2016) who reported that the total N was higher in the forest land compared to the cultivated and oil palm plantation land at a soil depth of 0-15 cm and 15-30 cm. Additionally, Abebe and Endalkachew (2012) and Mengistu *et al*. (2017) stated that the higher total N was obtained under forest land compared to the adjacent grazing and cultivated lands at a soil depth of 0-20 cm and 20-40 cm. Regarding to the interaction of land use types with the soil depths, the highest (0.28%) total N was recorded on the surface (0-20 cm) soil layer of forest land while the lowest (0.16%) total N was recorded at the subsurface (20-40 cm) soil layer of grazing land (Table 6). However, at two soil depths, the higher total N was found on the surface soil layer. According to the rating of total N by Tekalign (1991), the total N in the study area was in a medium rate under grazing and cultivated lands while it was rated as high in the grass and forest lands.

Table 7. Main effect of land use types and soil depth on selected chemical properties of soil on Jila Kerensa kebele

Treatments	pH-H_2O (1:2.5)	EC (dS/m)	$CaCO_3$ (%)	Total N (%)	OM (%)	C:N	Av. P (ppm)
			Land use types				
Grass	8.00	0.26^{b}	8.73^{b}	0.24^{b}	4.12^{b}	10.30^{b}	1.55^{bc}
Cultivated	7.68	0.32^{b}	7.00^{c}	0.21^{b}	3.51^{b}	10.10^{b}	2.40^{b}
Forest	7.90	0.53^{a}	10.45^{a}	0.26^{a}	5.02^{a}	11.50^{a}	5.37^{a}
Grazing	7.70	0.36^{b}	5.36^{d}	0.18^{b}	3.15^{b}	10.00^{b}	1.26^{c}
			Soil depth (cm)				
0-20	7.82	0.38	7.80	0.24^{a}	4.4^{a}	10.5	3.58^{a}
20-40	7.81	0.36	7.96	0.20^{b}	3.5^{b}	10.3	1.71^{b}
Land use	ns	**	***	***	***	*	***
Depth	ns	ns	ns	**	**	ns	***
Land use * depth	ns	ns	***	**	**	ns	***
CV (%)	4.22	21.30	4.95	9.47	10.03	8.73	28.10

Main effect means within a columns followed by the different letter(s) are significantly different from each other at $P \leq 0.05$; ns= not significant; *= significant at $P \leq 0.05$; **= significant at $P \leq 0.01$; ***= significant at $P \leq 0.001$.

The analysis of variance (ANOVA) results indicated that the carbon to nitrogen ratio (C:N) of the soils in study area was significantly ($P \leq 0.05$) affected by land use types. However, it was not significantly ($P > 0.05$) affected by soil depth and the interaction of land use types by soil depth (Tables 6 and 7). Considering the main effects of soil depth, the higher (10.5) mean value of C:N was found on the surface (0-20 cm) soil layer. This indicates that the rate at which total N decreased with soil depth was much higher than the reduction in carbon.

In all land use types, the C:N decreased with soil depth with no exception (Table 6). In fact the C:N of the soil is decreasing while the soil depth going increase. However, occasionally it can increase with the increment of soil depth in some exceptional cases which might be due the alluvial soil that contain more C:N in subsurface soil layer than surface soil layer through sedimentation processes. Therefore, the finding of this study was indicated the C:N was decreased when the soil depth increased. This is contradicting with findings of Gebeyaw (2007) who reported that the C:N of different land use types was increasing with increasing soil depth. Generally, the C:N was in the narrow range (8:1 to 12:1) under all land use types and in both soil depths.

Considering the interaction effect of land use types by soil depth, the highest (11.6) and the lowest (9.9) C:N values were recorded at the surface (0-20 cm) soil layers of the forest and grazing lands, respectively (Table 6). The higher C:N in forest soil indicates the prevalence of optimum biological activities, whereas the lower C:N in the surface soil of cultivated land might be due to higher microbial activity and more CO_2 evolution and its loss to the atmosphere at the surface (0-20 cm) soil layer than in the subsurface (20-40 cm) soil layer.

The current result is in agreement with the findings of Tsehaye and Mohammed (2013) who found that the higher C:N in forest land compared to the adjacent plantation, grazing and cultivated land up to soil depth of 0-20 cm. Additionally Yihenew and Getachew (2013) found that the higher C:N in natural forest than the adjacent eucalyptus plantation, grazing and cultivated lands at a soil depth of 0-15 cm and 15-30 cm. They also suggested that the optimum range of the C:N is about 10:1 to 12:1 that provides nitrogen in excess of microbial needs.

Accordingly, the C:N of the soil across the land use types under the study area were considered to be within the optimum range in all land use types. This indicates that the presence of suitable and balanced mineralization/immobilization processes of soil microorganisms.

The soil total N and C:N were insignificantly and negatively correlated with the soil bulk density at r = -0.38 and r = -0.28, respectively. The soil total N was significantly and positively ($r = 0.92^{***}$) correlated with the availability P. Similarly, the C: N was significantly and positively ($r = 0.66^{***}$) correlated with the soil OM (Table 11).

4.2.4. Available phosphorus

The ANOVA results was indicated that the available P of the study area was significantly ($P \leq 0.001$) affected by land use ytpes, soil depth and the interaction of land use type by soil depth (Tables 6 and 7). Considering the two soil depths, the available P was higher in the surface (0-20 cm) soil layer than in the subsurface (20-40 cm) soil layer (Table 7). Generally, variations in available P contents in soils could be related to the intensity of soil weathering or soil disturbance under different land use types. Considering the main effects of land use types, the highest (5.37 ppm) available P was recorded on the forest land and the lowest (1.26 ppm) available P was recorded on the grazing land (Table 7).

Considering the interaction effect of land use types with soil depth, the highest (7.70 ppm) and the lowest (1.13 ppm) of available P contents was recorded at the surface (0-20 cm) soil layer of the forest and subsurface (20-40 cm) soil layer of the grazing lands, respectively (Table 6). Generally, all treatments combination were significantly ($P \leq 0.001$) different from each other due to the interaction effects. Although Gebeyaw (2007), Mulugeta and Kibebew (2016) and Mengistu *et al*. (2017) reported that the higher available P was recorded in cultivated land than the adjacent grazing and forest lands, this finding reported that the higher available P was obtained in forest land at both surface and subsurface soil layer.

Relatively the high content of available P in the forest land could be due to the high content of soil OM resulting in the release of organic phosphorus thereby enhances available P under forest land. Similarly, this result is in agreement with the findings of Abad *et al*. (2014) who reported that the available P was high in forest land compared to pasture land and cultivated land at 0-30 cm soil depth. Additionally, it is in line with result of Lechisa *et al*. (2014) whose findings revealed that available P was high in forest land than the adjacent cultivated and grazing lands at a soil depth of 0-10 cm, 10-20 cm and 20-30 cm. Compared with the rest of the adjacent land use types in the study area, the higher the available P was also recorded in the cultivated land next to the forest land. This might be due to the application of diammonium phosphate (DAP) and nitrogen phosphorous sulfur (NPS) fertilizers on the cultivated land since there was an application of inorganic fertilizers in the study area.

As per the ratings of available P by Olsen *et al*. (1954), the available P of the soil under this study was rated as very low in the grass, cultivated and grazing lands whereas it was rated as low in forest land. This implies that the study area has high deficiency of available P thereby the external input of available P through both organic and inorganic sources are strongly likely. The drastically deficiency of available P on the study area could be due to the high $CaCO_3$ content of the soil since the available P can precipitate in the form of calcium phosphate in calcareous soil. Similarly, Asmare *et al*. (2015) reported that in calcareous soil, the available P was low due to the precipitation of P in the form of calcium phosphate.

4.2.5. Cation exchange capacity

The analysis of variance results revealed that the cation exchange capacity (CEC) of the soils in the study area was significantly ($P \leq 0.05$) affected by the land use types (Table 9). The CEC means values under grass, cultivated, forest and grazing lands were 38.5, 33.2, 41.7 and, 30.1 $cmol_c/kg$, respectively (Table 9). The higher and lower of CEC in forest and grazing land might be due to the presence and absence of soil organic matter or high soil organic matter in forest land while it was less in grazing land. Besides, the amount and types of clay particles also the determinant factor on the CEC of soil under different land use types.

This result is in agreement with the findings of Teshome *et al.* (2013) who suggested that the CEC of soil was higher in forest land compared to that of the adjacent grazing and cultivated land at 0 - 20 cm soil depth. Considering the interaction effects, the CEC of the soil under study area was significantly ($P < 0.05$) affected by interaction of land use types by the soil depth (Table 10). The highest (43.40 $cmol_c/kg$) value of CEC was recorded on surface (0-20 cm) soil layer of forest land, whereas the lowest (27.13 $cmol_c/kg$) was recorded at the surface soil layer of grazing land.

Considering the soil depth, like that of the interaction of land use types with soil depth, the CEC values of the soil under different land use types were not significantly ($p > 0.05$) affected by soil depth. But numerically, the higher CEC value was found in subsurface (20-40 cm) soil layer (Table 9). Similarly, Alemayehu and Sheleme (2013) reported that the CEC of the soil was not significantly affected by soil depth at a soil depth of 0-15 cm and 15-30 cm under adjacent maize, enset and grasslands.

Moreover, Gebeyaw (2007) reported that the CEC of soil was higher in the subsurface of soil layer under the adjacent forest, cultivated and grazing lands at 0-20 cm and 20-40 cm soil depth. As per the ratings CEC recommended by Hazelton and Murphy (2007), the CEC value of soil under the grass, cultivated and grazing land were in the range of high rate while it was rated as very high under the forest land. This indicates that the soil of the study area was characterized by high clay particle contents in which probably all of the textural class of its soil was clay.

The CEC of the soil was significantly and positively correlated with the total porosity ($r = 0.75^{***}$), $CaCO_3$ ($r = 0.93^{***}$), total N ($r = 0.67^{***}$), soil OM ($r = 0.68^{***}$), C:N ($r = 0.45^{*}$), available P ($r = 0.63^{***}$) and PBS ($r = 0.61^{**}$), whereas it was insignificantly and positively correlated with the silt ($r = 0.18$), clay ($r = 0.01$), pH ($r = 0.01$) and EC ($r = 0.31$). But it was insignificantly and inversely ($r = -0.15$) correlated with sand while it was significantly and inversely ($r = -0.75^{***}$) correlated with the soil bulk density (Table 11). This is because of the high CEC of the soil the high present of soil OM and clay particles, which has high total porosity, less compaction and eventually leads to low soil bulk density.

4.2.6. Exchangeable bases

The analysis of variance results indicated that the exchangeable Ca was significantly ($P \leq 0.001$) affected by land use types, soil depths and the interaction of land use types by soil depth (Tables 8 and 9). The presence of such significant variation on exchangeable Ca could be triggered from different management practice, way of land utility, and the various imbalances proportional of soil texture and OM. Considering the main effect of land use types, the mean values of exchangeable Ca under grass, cultivated, forest and grazing lands were 23.6, 17.7, 24.1 and 16.2 $cmol_c$/kg, respectively (Table 9).

Regarding to exchangeable Ca at both soil depths, the exchangeable Ca was higher at the surface (0-20 cm) soil depth than at the subsurface (20-40 cm) soil depth (Table 9). This could be the possibility of the high exchangeable Ca was available on surface soil layer with an abundance of animal and plant residues than beneath the soil layer. This is parallel with the work of Alemayehu and Sheleme (2013) in their findings, they revealed that the exchangeable Ca contents of soil was higher on the surface soil layer than the subsurface soil layer due to the association of biological accumulation with biological activity and accumulation from plant residues.

However, Getahun and Bobe (2015) reported that the exchangeable Ca was increasing with increasing soil depth since it is susceptible and possibility of easily leach downward by runoff and water percolation. In terms of the interaction of land use types with the soil depth, the highest (25.4 $cmol_c$/kg) and the lowest (15.2 $cmol_c$/kg) exchangeable Ca was found in the surface (0-20 cm) soil layer of the forest and grazing lands, respectively (Table 8). As per the ratings of FAO (2006), the exchangeable Ca contents of study area soil was categorized as high rate under cultivated and grazing lands whereas categorized as very high rate under grass and forest lands. Therefore, by standing on this view of point, the study area was characterized by high contents of exchangeable Ca, which implies that the presence of calcium carbonate in the soil of study area.

Furthermore, the analysis of variance result indicated that the exchangeable Mg was significantly ($P \leq 0.001$) affected by land use types while it was not significantly ($P > 0.05$) affected by soil depths and the interaction of land use types by soil depth (Tables 8 and 9). Considering the main effect of land use types, the mean values of exchangeable Mg under grass, cultivated, forest and grazing lands were 5.4, 5.8, 8.7 and, 5.3 $cmol_c$/kg, respectively (Table 9). Considering the both soil depths, the higher exchangeable Mg was recorded on surface (0-20 cm) soil layer (Table 10).

Considering the interaction of land use types with soil depth, the highest (9.1 $cmol_c$/kg) exchangeable Mg was recorded on the surface (0-20 cm) soil layer of forest land while the lowest (5.2 $cmol_c$/kg) exchangeable Mg was obtained under the subsurface (20-40 cm) soil layer of grazing land (Table 8). As per the ratings of FAO (2006), the exchangeable Mg contents of the study area under grass, cultivated and grazing lands were in the range of high rate, whereas the exchangeable Mg contents under forest land was in the range of very high rate. The holistic implication of this finding is indicated that like that of calcium, the magnesium content of the study area was high. Additionally, the ratios of exchangeable Ca to Mg were within the critical values (3:1 to 5:1), which may not cause of the nutrient imbalance under different land use types of the study area.

According to the correlation matrix of selected soil physico-chemical parameters, the exchangeable K and Mg were significantly and positively correlated with the soil OM at $r = 0.77^{***}$ and at $r = 0.75^{***}$, respectively. The exchangeable Ca was significantly and positively ($r = 0.48^{*}$) correlated with the available P. Besides, it was also significantly and positively ($r = 0.88^{***}$) correlated with the $CaCO_3$ of the soil (Table 11).

Table 8. Interaction effects of land use types and soil depth on exchangeable Na, K, Mg and Ca on Jila Kerensa kebele

	Exchangeable bases (cmol$_c$/kg)							
	Na		K		Mg		Ca	
	Soil depth (cm)		Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
Land use types	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
Grass	0.43	0.45	0.62[b]	0.65	5.4[b]	5.50[b]	23.2[b]	24.0[a]
Cultivated	0.42	0.47	0.64[b]	0.78	5.8[b]	5.68[ab]	16.8[c]	19.2[c]
Forest	0.44	0.43	1.50[a]	1.00	9.1[a]	8.30[a]	25.4[a]	21.2[b]
Grazing	0.42	0.43	0.35[b]	0.36	5.4[b]	5.20[b]	15.2[c]	15.4[d]
CV (%)	17.61	15.37	23.37	14.40	18.80	21.81	3.62	5.45
P - values	ns	ns	**	ns	*	*	***	***

Interaction means within a columns followed by the different letter(s) are significantly different from each other at P ≤ 0.05; ns = not significant; * = significant at P ≤ 0.05; ** = significant at P ≤ 0.01; *** = significant at P ≤ 0.001.

The exchangeable K of soil under study area was significantly (P ≤ 0.001) affected by land use types. But it was not significantly (P > 0.05) affected by soil depths and the interaction of land use types by soil depth (Tables 8 and 9). Concerning to the main effect of land use types, the mean values of exchangeable K under grass, cultivated, forest and grazing lands were 0.63, 0.72, 1.30 and 0.36 cmol$_c$/kg, respectively (Table 9). Considering the soil depths of the study area, the higher exchangeable K was found on the surface (0-20 cm) soil layer (Table 9).

Considering the interaction of land use types with soil depth, the highest (1.50 cmol$_c$/kg) and the lowest (0.35 cmol$_c$/kg) values of exchangeable K contents was recorded on the surface soil layer of forest and grazing lands, respectively (Table 8). The higher exchangeable K on the surface layer of forest land could be due to the availability of surface biomass through litter falling and little or no surface soil disturbance by rain drops, surface runoff and other severe erosion agents. The derivative of this phenomenon is the reasonable for lower exchangeable K in case of surface layer of grazing land in, which higher disturbance was severe and exacerbate soil erosion.

Similarly, this result is in agreement with the work of Teshome *et al*. (2013) and Lalisa *et al.* (2014) whose findings was reported that the exchangeable K of soil is higher in the forest land than cultivated and grazing lands. According to the rate of exchangeable K cited by FAO (2006), the exchangeable K contents of grass and cultivated lands of the study area were rated as high, whereas that of grazing and forest lands were in the range of medium and very high rate, respectively.

Table 9. Main effects of land use types and soil depth on selected chemical properties of soil on Jila Kerensa kebele

Treatments	Na	K	Mg	Ca	CEC	PBS
			$cmol_c/kg$			%
			Land use types			
Grass	0.45	0.63^{bc}	5.4^{b}	23.6^{b}	38.5^{a}	78.0^{a}
Cultivated	0.44	0.72^{b}	5.8^{b}	17.7^{c}	33.2^{ab}	74.3^{b}
Forest	0.46	1.30^{a}	8.7^{a}	24.1^{a}	41.7^{a}	82.9^{a}
Grazing	0.42	0.36^{c}	5.3^{b}	16.2^{d}	30.1^{b}	74.0^{b}
			Soil depth (cm)			
0-20	0.43	0.75	6.40	20.8^{a}	35.3	78.2^{a}
20-40	0.41	0.71	6.09	19.9^{b}	35.7	77.8^{b}
Land use	ns	**	**	***	*	***
Depth	ns	ns	ns	**	ns	*
Land use * depth	ns	ns	ns	***	ns	***
CV (%)	16.04	21.19	20.50	5.06	6.16	2.37

Main effect means within a columns followed by the different letter(s) are significantly different from each other at $P \leq 0.05$; ns = not significant; * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$; *** = significant at $P \leq 0.001$.

The analysis of variance results indicated the exchangeable Na of the study area was not significantly ($P > 0.05$) affected by land use types, soil depth and interaction of land use types by the soil depth (Tables 8 and 9). This finding is in agreement with that of Tsehaye and Mohammed (2013) who reported that, the exchangeable Na is not indicated the significant variation, neither under land use types nor across the soil depth by the time exchangeable Ca, Mg and K was showing significant variation under adjacent different land use types.

However, Yihenew and Getachew (2013), Mulugeta and Kibebew (2016) and Ufot *et al*. (2016) reported that like that of exchangeable Ca, Mg and K, exchangeable Na also affected by land use types. Although there was no statistical variation on exchangeable Na of the study area, more or less the numerical variation was remarkable on exchangeable Na under different land use types and on the interaction effects. Considering the mean values of exchangeable Na of the study area, 0.45, 0.44, 0.46 and 0.42 $cmol_c$/kg) were found under grass, cultivated, forest and grazing lands, respectively (Table 9). The higher exchangeable Na was observed on the surface (0-20 cm) soil layer than the subsurface (20-40 cm) soil layer (Table 9).

Considering to the interaction of land use types with soil depth, the highest (0.47 $cmol_c$/kg) exchangeable Na was obtained under the subsurface soil layer of forest land, whereas the lowest (0.42 $cmol_c$/kg) exchangeable Na was obtained on the surface soil layer of both cultivated and grazing lands (Table 8). Though there was no statistical variation in its values, the higher exchangeable Na in the forest land might be due to the availability and accumulation of plant residues resulted from an abscissions leaf trees and biological functions thereby enhance exchangeable Na in forest land. On the other hand the lower exchangeable Na in cultivated and grazing lands attributed to the removal of crops and other plant residues on cultivated land through harvesting and cutting by human induced activities, whereas the removal of surface vegetation by livestock grazing may render the lower exchangeable Na on grazing land.

This result is also parallel with the findings of Mengistu *et al*. (2017) who found that the lower exchangeable Na under cultivated and grazing lands compared to the adjacent forest land. Furthermore, Getahun and Bobe (2015) reported that the forest land contains more exchangeable Na than adjacent cultivated and grazing lands at 0-20 cm of soil depth. As per rating of FAO (2006), the exchangeable Na of the study area was in the range of medium rate under all land use types. Therefore the exchangeable Na of soil under this study was not the limiting factor on crop productivity and not surplus that may trigger soil sodicity, which in turns hamper the agricultural practices.

Table 10: Interaction effect of land use types and soil depth on CEC and PBS on Jila Kerensa kebele

	CEC ($cmol_c$/kg)		PBS (%)	
	Soil depth (cm)		Soil depth (cm)	
Land use types	0-20	20-40	0-20	20-40
Grass	36.60^{b}	38.60^{a}	81.6^{a}	79.2^{a}
Cultivated	33.05^{c}	33.42^{b}	69.4^{c}	78.3^{a}
Forest	43.40^{a}	39.40^{a}	84.6^{a}	78.1^{a}
Grazing	27.13^{d}	28.90^{b}	77.0^{b}	73.7^{b}
CV (%)	3.89	6.98	1.88	3.10
P - values	***	**	***	*

Interaction means within a columns followed by the different letter(s) are significantly different from each other at $P \leq 0.05$; ns = not significant; * = significant at $P \leq 0.05$;** = significant at $P \leq 0.01$; *** = significant at $P \leq 0.001$.

4.2.7. Percent base saturation

The Percentage base saturation (PBS) of the study area was significantly ($P \leq 0.05$) affected by land use types and interaction of land use types by soil depth (Tables 9 and 10). Considering the interaction of land use types with soil depth, the highest (84.6% and the lowest (69.4%) value of PBS was obtained in the surface (0-20 cm) soil layer of forest land and grazing land, respectively (Table 10).

Considering the main effects of land use types, the highest (82.9%) and the lowest (74.0%) values of PBS were recorded under the forest and grazing lands, respectively (Table 9). Concerning to the two soil depths ‒ surface and subsurface soil layer, higher PBS was recorded in the surface soil layer than the subsurface soil layer. In general, processes that affect the extent of basic cations also affect percent base saturation of the soil. According to the rate of PBS cited by Hazelton and Murphy (2007), the PBS of the study area was rated as high in the grass, cultivated and grazing lands whereas it was rated as very high in the forest land. This implies that the soil under the study area was contained high exchangeable bases and less susceptible to leaching.

Table 11. Pearson's correlation matrix for selected soil physico-chemical parameters

	Sand	Silt	Clay	BD	TP	pH	EC	$CaCO_3$	TN	OM	CN	Av. P	Na	K	Mg	Ca	CEC	PBS
Sand	1.00																	
Silt	-0.54**	1.00																
Clay	-0.63***	-0.31	1.00															
BD	0.29	-0.13	-0.21	1.00														
TP	-0.28	0.12	0.22	-0.99***	1.00													
pH	-0.58**	0.33	0.35	-0.37	0.37	1.00												
EC	-0.41*	0.52**	-0.02	-0.12	0.12	0.41*	1.00											
$CaCO_3$	-0.29	0.22	0.13	-0.76***	0.76***	0.19	0.41*	1.00										
TN	-0.29	0.28	0.07	-0.38	0.38	0.21	0.78***	0.71***	1.00									
OM	-0.21	0.29	0.03	-0.37	0.4	0.1	0.73***	0.74***	0.95***	1.00								
CN	0.17	0.23	-0.41*	-0.28	0.27	-0.13	0.29	0.56**	0.43	0.66**	1.00							
Av. P	-0.08	0.28	-0.16	-0.27	0.26	0.08	0.69**	0.66***	0.92***	0.95***	0.62**	1.00						
Na	-0.19	0.02	0.21	-0.06	0.06	-0.16	-0.27	0.03	-0.29	-0.22	0.06	-0.29	1.00					
K	-0.25	0.17	0.13	-0.39	0.39	0.27	0.67	0.77***	0.77***	0.77***	0.46*	0.75***	-0.22	1.00				
Mg	-0.11	0.42	-0.27	-0.29	0.28	-0.22	0.54**	0.62**	0.72***	0.75***	0.48*	0.72***	-0.09	0.51*	1.00			
Ca	-0.28	0.03	0.28	-0.88***	0.88***	0.2	0.18	0.88***	0.56**	0.57**	0.35	0.48*	0.02	0.58**	0.48*	1.00		
CEC	-0.15	0.18	0.01	-0.75***	0.75***	0.01	0.31	0.93***	0.67***	0.68***	0.45*	0.63***	-0.01	0.68***	0.7***	0.9***	1.00	
PBS	-0.31	0.03	0.32	-0.66***	0.66***	0.22	0.33	0.62**	0.53**	0.55**	0.36	0.45*	-0.04	0.49*	0.43*	0.78***	0.61**	1.00

*Significant at $P \leq 0.05$; ** significant at $P \leq 0.01$; *** significant at $P \leq 0.001$; BD = Bulk density; TP = Total porosity; EC = Electrical conductivity; $CaCO_3$ = Calcium carbonate; TN = Total nitrogen; OM = Organic matter; Av.P = Available phosphorous; C:N =Carbon to nitrogen ratio; CEC = Cationex change capacity; PBS = Percent base saturation.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.1. Summary and Conclusions

Soil fertility is the decisive issue throughout the worldwide in general and in Ethiopia in particular where the livelihoods of the local communities are mostly depending on the agricultural activities. In spite of this, the decline of soil fertility is the remarkable problem of dwindling the soil quantity and quality, thereby ultimately leads to agricultural problems and environmental deterioration, which is the current formidable issues in all corners of the countries. By considering these problems the objective of the current study was aimed to evaluate the selected soil physico-chemical properties as affected by different land use types on Jila Kerensa kebele, Kuyu district, north Shewa zone, Central Highland of Ethiopia.

Prior to all, the general field survey observation was made in the study area to capture the visual image of different land use types. Then after, the land use types were categorized into four land use types, namely, grass, cultivated, forest and grazing lands those adjacent to each other's and appropriated on similar topography. After the land use types were stratified, the soil samples were collected from two soil depths (0-20 cm and 20-40 cm) by three replications. Finally, the dried and well prepared soil samples were brought to Addis Ababa National Soil Laboratory for analysis of selected soil physical-chemical properties.

In the main effects of land use types the mean value of sand was high in cultivated and low in forest lands, whereas the mean values of clay and silt were high in forest and grasslands, respectively. Considering the soil depths, the higher sand was observed at the surface soil layer while higher silt and clay were observed at the subsurface soil layer. The mean values of soil bulk density under all land use types were low and that of total porosity was high in, which the aeration and water movement in the soil may not limited. The higher bulk density and lower total porosity were recorded on the surface soil layer than subsurface soil layer, which is indicating the higher soil OM and clay soil particles were found on the surface soil layer.

The mean value of soil pH was ranged in between 7.68 to 8.00 in cultivated and forest lands, respectively, which are rated as slightly alkaline to moderately alkaline. This implies that inexistence of soil acidity problems and presence of calcareous soil in all land use types of the study area. The highest mean value of EC was recorded in the forest and the lowest was recorded in grasslands, which ranged in between 0.53 to 0.26. Its value was below the level of salinity problem, which in turns indicate that the soluble salt was below the zone of plant root and the problem of salinity is inconsiderable factor.

The soil OM was significantly ($P \leq 0.001$) influenced by land use types, soil depths and their interaction. The higher soil OM was recorded in the forest land while the lower was found in the grazing land. The declined values of the soil OM on the grazing lands was indicate that higher nitrogen and organic carbon losses from the grazing lands compared to the forest lands due to the heavy grazing impact of livestock and the absence of conservation practices on grazing land. The soil organic matter of the study area under grass, grazing, cultivated and forest lands were in the range of medium in the first three consecutive land use types and rated as high in the later land use type. Considering the main effect of soil depths, the higher soil OM was observed on the surface soil layer and it is decreasing with increasing soil depth.

The C:N ratio was significantly ($P \leq 0.05$) affected by land use types. However, it was not significantly ($P > 0.05$) affected by soil depths and interaction of land use types by soil depths. Relatively, the mean values of total N and available P were low in grazing and high in forest lands in, which it followed the same trends of soil OM. Furthermore, the analysis of variance results indicated that exchangeable basic cations were significantly influenced ($P \leq 0.001$) by land use types except exchangeable Na. The average values of exchangeable basic cations ‒ Ca, Mg, K and Na were ranged from 12.6 to 24.1, 5.3 to 8.7, 0.36 to 1.3 and 0.42 to 0.46 $cmol_c$/kg in grazing and forest land, respectively. The CEC of soil under the study area was categorized in the high rate in grass, grazing and cultivated lands, whereas rated as very high in forest land. Similarly, the PBS of the soil follow the trend of CEC, which was in the range of high rate in the grass, grazing and cultivated lands while it was rated as very high in forest land. The mean values of PBS ranged between 74.0 to 82.9% in grazing and forest lands, respectively.

In conclusion, the conversion of different land use types resulted in the variation of selected physico-chemical properties. The soil properties were relatively low in cultivated and grazing lands than the adjacent grass and forest lands, which implies that the severity of soil erosion problems and decline of soil fertility. The high sand content was observed in cultivated and grazing lands compared to the adjacent grass and forest lands. This indicated that the high bulk density and low total porosity, which in turn implies the low nutrient retention and high probability of leaching problems in these land use types. The soil OM and total N of the study are were in the medium ranges, which may not adversely affect the activities of soil microorganisims and C:N values.

In general, the study area has high pH, clay particles, total porosity, exchangeable basic cations (Na, K, Mg and Ca), CEC and $CaCO_3$, but has low available P. The higher mean values of CEC in the study area indicated that the presence of high exchangeable basic cations and the high capability of the soil for nutrient retention. The high $CaCO_3$ contents of the soil may leads to the fixation of the native and/or applied P, which may be the cause for low available P in the soil.

5.2. Recommendation

Compared to the adjacent grass and forest lands, the cultivated and grazing lands have low soil fertility. Therefore, reduction of intensive cultivation, removal of crop residues, removal of animal manures, and controlling overgrazing should be practiced. Monocroping is the common practice in the study area, therefore, using of crop rotation is highly important in order to use the cultivated land in a sustainable manner.

The available P was the limited nutrient in the study area, which may be due to its fixation by $CaCO_3$. Thus, the supply of high P fertilizers levels are important, which can increase crop productivity. To minimize the P fixation and increase its availability, band or localized application of P fertilizer is highly recommended in the sudy area.

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7. APPENDIX

Table 1. Rating of selected soil chemical parameters

Soil Parameters	Rating					References
	Very low	Low	Medium	High	Very high	
SOM (%)	< 0.86	0.86-2.59	2.59-5.17	> 5.17	–	Tekalign, 1991
TN (%)	< 0.05	0.05-0.12	0.12-0.25	> 0.25	–	"
Av. P (ppm)	-	<5	5-10	>10	-	Olsen *et al.* 1954
Ca ($cmol_c$/kg)	< 2.0	2–5	5–10	10–20	> 20	FAO, 2006
Mg ($cmol_c$/kg)	< 0.3	0.3-1.0	1.0-3.0	3.0-8.0	> 8.0	"
K ($cmol_c$/kg)	< 0.2	0.2-0.3	0.3-0.6	0.6-1.2	> 1.2	"
Na ($cmol_c$/kg)	< 0.10	0.1-0.3	0.3-0.7	0.7-2.0	> 2.0	"
CEC ($cmol_c$/kg)	< 6	6–12	12–25	25–40	> 40	Hazelton and Murphy, 2007
PBS (%)	0-20	20-40	40-60	60-80	>80	"

Table 2. Mean squares (MS) and the results of two-way analysis of variance of selected soil physical properties on the Jila Kerensa area

Physical soil properties	Land use			Soil depth			Interaction		
	MS	F	P	MS	F	P	MS	F	P
Sand (%)	66.00	0.83	0.49^{ns}	73.5	0.93	0.35^{ns}	45.94	0.58	0.63^{ns}
Silt (%)	145.10	3.45	0.045^{*}	1.5	0.04	0.85^{ns}	24.61	0.59	0.63^{ns}
Clay (%)	107.70	2.55	0.041^{*}	54.0	1.28	0.27^{ns}	135.3	3.2	0.056^{ns}
BD (g cm^{-3})	0.12	204.0	0.001^{***}	0.007	11.80	0.004^{**}	0.001	20.04	0.0001^{***}
TP (%)	170.4	2087	0.001^{***}	1.041	12.76	0.003^{**}	1.747	21.39	0.0001^{***}

* Significant at $p \leq 0.05$; ** significant at $p \leq 0.01$; *** significant at $p \leq 0.001$; ns= not significant; BD= Bulk density; TP= Total porosity; P= Probability.

Table 3. Mean squares (MS) and the results of two-way analysis of variance of selected soil chemical properties under four land use types and two soil depths on the Jila Kerensa area

Chemical soil properties	Land use			Soil depth			Interaction		
	MS	F	P	MS	F	P	MS	F	P
pH (H_2O)	0.125	1.15	0.36^{ns}	0	0	1ns	0.014	0.13	0.93^{ns}
EC (dS/m)	0.083	13.46	0.0002^{**}	0.003	0.56	0.46^{ns}	0.004	0.68	0.58^{ns}
CaCO3 (%)	28.84	189.6	0.0001***	0.15	0.99	0.33^{ns}	3.59	23.64	0.0001***
SOM (%)	107.4	45.08	0.0001^{***}	50.17	21.06	0.0004^{***}	25.49	10.7	0.0006^{***}
TN (%)	0.134	23.00	0.0001^{***}	0.066	11.12	0.004^{**}	0.021	3.6	0.04^{*}
C:N	14.04	4.73	0.02^{*}	2.04	0.69	0.42^{ns}	2.375	0.8	0.51^{ns}
Av.P (ppm)	21.3	38.53	0.0001^{***}	21.15	38.25	0.0001^{***}	5.49	9.94	0.0009^{***}
Ca ($cmol_c$/kg)	99.4	275.2	0.0001^{***}	7.393	20.45	0.0005^{***}	16.84	46.58	0.0001^{***}
Mg ($cmol_c$/kg)	16.23	9.85	0.0009^{***}	0.68	0.41	0.52^{ns}	0.163	0.1	0.95^{ns}
K ($cmol_c$/kg)	0.84	11.08	0.0005^{***}	0.03	0.4	0.53^{ns}	0.132	1.73	0.21^{ns}
Na (cmolc/kg)	0.001	0.2	0.89^{ns}	0.01	2.04	0.174^{ns}	0.002	0.38	0.77^{ns}
CEC ($cmol_c$/kg)	318.8	3.61	0.041^{*}	3.466	0.04	0.84^{ns}	20.83	0.24	0.8^{ns}
PBS (%)	75.37	51.3	0.0001^{***}	8.284	5.64	0.032^{*}	87.95	59.87	0.0001^{***}

* Significant at $p \leq 0.05$; ** significant at $p \leq 0.01$; *** significant at $p \leq 0.001$; ns= not significant.

Table 4. Mean monthly rainfall (mm) and mean monthly minimum and maximum temperatures (^{0}C) of the study area for eight years (2010-2017)

Month	Minimum temperature	Maximum temperature	Rainfall
January	5.3	20.0	7.3
February	7.0	20.2	21.4
March	8.2	22.0	52.2
April	9.3	22.4	98.9
May	10.1	23.0	155.8
June	10.0	19.3	151.9
July	10.4	19.0	400.6
Augest	10.1	19.4	354.9
Septemper	8.7	20.1	188.9
October	6.5	20.2	22.4
November	5.4	20	14.7
December	5.1	20.2	6.3
Mean	8.0	20.0	-
Total	-	-	1475.3

Source: KWAO (2017)