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EFFECTS OF DIFFERENT LAND USE TYPES, SOIL DEPTH AND TOPOGRAPHY ON SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SOIL AT WUNKE WATERSHED OF GETO WOREDA, SOUTHERN ETHIOPIA

MSc Thesis

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EFFECTS OF DIFFERENT LAND USE TYPES, SOIL DEPTH AND TOPOGRAPHY ON SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SOIL AT WUNKE WATERSHED OF GETO WOREDA, SOUTHERN ETHIOPIA

MSc Research Thesis Submitted to College of Agriculture and Natural Resource Management Department of Natural Resource Management in Partial Fulfillment of the Requirements for Degree of Master of Science in Agriculture (Soil Science)

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SCHOOL OF GRAUATE STUDIES

WOLKITE UNIVERSITY

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DEDICATION

This thesis is dedicated to my father Ato Woldeyesus who was eager to see my success but passed at the beginning of my journey to it. Oh! My God would keep his soul in the abode and to my lovely families Workenesh Nissa, Eyob Habtu, Nahom Habtu, Kerod Habtu and all my family members dedicated to the success of my life.

STATEMENT OF AUTHOR

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BIOGRAPHICAL SKETCH

The author was born on March 13, 1989, in Gurage Zone of Southern Nation, Nationalities and Peoples Regional State. He attended his primary and secondary education at Quante Junior Secondary School and Arekit Comprehensive Senior Secondary School, respectively between 1996 and 2002.

After successfully passing the Ethiopian School Leaving Certificate Examination (ESLCE), he joined Hawassa College of Teacher Education for studying tertiary education in 2005 and graduated with a diploma with a specialization in chemistry, mathematics, and physics in June 2007. Soon after his graduation, he was employed by the Geto woreda education sector and after serving one year, he joined Dilla University in 2009 for the next level of studying and graduated with a BSc degree in October 2012 with studied chemistry major and mathematics in minor until he left for Wolkite University in September 2018 to pursue his Graduate Studies after serving for six years in different sectors.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectro Photometer
ANOVA	Analysis of Variance
CEC	Cation exchange capacity
CSA	Central Statical Agency
FAO	Food and Agricultural Organization
GLM	General Linear Model
GPS	Global position system
LSD	Least Significant Difference
Masl	Meter above sea level
OC	Organic Carbon
pH	The degree of soil Acidity or Alkalinity
SAS	Statical Analysis System
SNNPRG	Southern Nation Nationalities Peoples Regional Government
UNESCO	United Nations, Educational, Scientific and Cultural Organizations

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EFFECTS OF DIFFERENT LAND USE TYPES, SOIL DEPTH AND TOPOGRAPHY ON SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SOIL AT WUNKE WATERSHED OF GETO WOREDA, SOUTHERN ETHIOPIA

ABSTRACT

The study of soil's physical and chemical properties is critical for the sustainable management of agricultural resources and economic growth. The purpose of the study was to look into the effects of different land use types, soil depth and topography on selected physical and chemical properties of soil in the Wunke watershed of Geto woreda in southern Ethiopia. This study considered three land uses (cultivated, grazing, and enset land), two soil depths (0-20 and 20-40cm), and three topographic positions (upper, middle, and lower) in three replications. For laboratory analysis, a total of 54 composite samples were collected. A three-way analysis of variance (ANOVA) was performed using the general linear model (GLM) procedure of the statistical analysis system (SAS, 2008) to determine whether or not variations in soil their interaction were significant. The findings revealed that the majority of the soil's physical and chemical properties varied with, the interaction effect of land use, soil depth and topography. The interaction effects of land use and soil depth affected particle size distribution, BD, AP, OC, TN CEC, exchangeable bases and PBS. Exchangeable bases and PBS were all significantly influenced by the interaction effect of land use and topography. The interaction effect of soil depth and topography affected sand, silt, pH, AP, OC, TN, and Ca. The interaction effect of land use, soil depth, and topography affected CEC, exchangeable bases and PBS. The highest bulk density (1.17gcm-3) was found grazing land of lower depth, while the lowest (1.0 gcm-3) was found on enset land of lower depth. Soils on enset land had consistently higher pH values, followed by grazing and cultivated lands. , higher (4.1%) mean organic carbon content was found upper depth of lower topographic position and lower (2.4%) mean TN content values were found in cultivated land of lower depth. The effects of soil depth on soil properties revealed that the surface soil layer had the highest sand fraction, TN, OC, and CEC. The subsurface soil layer had the highest clay fraction and the lowest values of TN, OC, and CEC. The interaction effect of land use, soil depth, and topography on soil properties revealed that the lowest layers of soils with the highest exchangeable bases and CEC were found at the lower topographic position under the three land use types. Soil fertility in cultivated lands was lower than in enset and grazing lands. Most of the measured soil properties were better in enset land than in other land use soils, and lower topographic positions were better than upper and middle topographic positions.

Keywords: *TP=Total porosity, AP=Available phosphorous, TN=Total Nitrogen, CEC=Cation exchange capacity, BD=Bulk Density, Cultivated land ,Enset Land, Grazing Land, Topographic Position.*

1. INTRODUCTION

Soil and water are essential components of agriculture and natural resources, as well as basic economic factors in every country. It is a living, dynamic, natural body that plays a variety of important roles in terrestrial ecosystems. It is the essence of life and health for humankind and animals, as well as the primary source of the majority of our food production. Every soil is made up of different horizons, each with its own set of physical and chemical properties. Chemical properties are mostly determined by the clay fraction and soil organic carbon, whereas physical properties are determined by the mineral particle size distribution Alemayheu Kiflu and Sheleme Beyene, (2013).

Many factors contribute to spatial variability in soil properties, including vegetation type, cultivation history (fertilizer application and crop species), and differences in field management (Iqbal et al., 2011; Wang et al., 2009). Increasing demand for food, feed, fiber, and fuel has accelerated global agricultural expansion (Foley et al., 2011), putting additional strain on natural resources, particularly soil. Agriculture's environmental impacts include those caused by expansion (when croplands and pastures spread into new areas, replacing natural ecosystems) and those caused by intensification (when existing lands are managed to be more productive, frequently using irrigation, fertilizers, biocides, and heavy mechanization) (Foley et al., 2011). Under small catchment scales, land use may be the dominant factor influencing soil properties. Land use and soil management practices have an impact on soil nutrients and soil processes such as erosion, oxidation, mineralization, and leaching, among others (Celik, 2005; Liu et al., 2010). As a result, it has the potential to alter nutrient transport and re-distribution processes.

Land use changes, particularly the conversion of natural forests to agricultural land and settlement, are the most common activities in Ethiopia (Eyayu et al., 2010).Such changes, combined with centuries of continuous use of land for cultivation and grazing, resulted in a disastrous loss of soil nutrients, particularly in the highlands, where erosion is more severe (Eyayu et al., 2010). Soil properties also change as soil depth changes. So far, very few quantitative studies have been conducted in Ethiopia to assess the effects of soil depth on soil properties. Fantaw et al. (2007) and Eyayu et al. (2009) conducted studies in the southeastern and northwest parts of Ethiopia, respectively, and found variations in soil parameters with soil depth under different land uses. Several studies support the idea that soil properties vary with depth across different land use types and topography. Land use type, soil depth and topography can have a significant impact on soil organic matter stock. It has a significant impact on SOC stocks (Gruenberg et al., 2010). Furthermore, the relationships between soil properties change as soil depth changes. Cation exchange capacity (CEC) is more strongly associated with organic matter (OM) than clay in the surface soil layer. Because clay content is higher in subsoil and organic matter is lower, CEC is strongly correlated with clay rather than organic matter (Jin et al., 2011).

These findings lend credence to the notion that soil properties vary in response to depth across land use types. Topography is critical in biogeochemical processes that perform critical environmental, economic and social functions (Griffiths et al., 2009). Any spatial pattern is dependent on soil formation processes, which we still have a limited understanding of, particularly in terms of topographic effects. According to Nahusenay and Kibebew (2016), increasing topography/elevation increased soil moisture, precipitation, soil organic matter, and liable carbon. However, as elevation increases, bulk density, pH, and soil temperature decrease. Conversion of forestland to other land uses has been ongoing in the Wunke watershed.

As a result of uncontrolled farming and settlement distributions, the size of agricultural land grows even more. However, no research has been conducted to investigate the effects of soil depth on soil properties within the watershed. Understanding the effects of soil depth on the dynamics of soil properties under different land covers, on the other hand, is critical for establishing appropriate management options aimed at restoring the area's degraded soils to normal or previous condition, and sustaining its health. Evaluating the effects of land use changes and soil depth on soil properties in various parts of the watershed is critical for understanding the effects of agro-ecosystem transformation on soil productivity and developing appropriate and sustainable soil and land management options. Such studies will help to better understand the relative dynamics of soil properties to changes in land use because assessing soil quality involves measuring physical and chemical properties of a soil under different land use scenarios with soil depth. Furthermore, no quantitative evidence on the extent of soil property variation associated with land use types, soil depth, and topography in the study area has been reported. Therefore, assessing the interaction effects of different land use systems, soil depth and topography on soil physical and chemical properties in the study area was needed.

1.1. Objectives of the study

1.1.1. General objective

- The general objective of this study was to investigate the interaction effects of different land uses types, soil depth, and topography on selected physical and chemical properties of soils at Wunke watershed of Geto Woreda.

1.1.2. Specific objectives

- To identify the effects of different land use types on selected physical and chemical properties of soils
- To evaluate the effect of soil depth on selected physical and chemical properties of soils
- To identify the effect of topography on selected physical and chemical properties of soils
- To investigate the interaction effects of land use by soil depth, land use by topography, soil depth by topography and the interaction effects of these indicated three parameters on selected physical and chemical properties of soils.

2. LITERATURE REVIEW

2.1. Over view of Land Use Types, Soil Depths and Topography

Ethiopia is a country of great geographical diversity with mountains, highlands, extensive plateaus, valleys, deep gorges and lowlands. Being located within the tropics, such physical conditions and variations in elevations have resulted in the greatest diversity of climate, vegetation and soils (Dereje, 2016). Soils have many variables, which have multiple types of characteristics that ultimately affect crop production and land productivity. Therefore, in order to understand the similarity, dissimilarities and relationships among different land uses, it is important to study the effects of land use, depth and topography on the vital physical and chemical properties of soil. Land is use defined as the arrangements, activities and inputs people undertake in a certain land cover type (Ufot *et al.*, 2016).

Changes of forests to rangeland and agricultural lands are one of the most concerns in environmental degradation and world climate change. Land use types develop depending on the soil properties, the climate, and the socio-political factors and the interest of the society or the landowner. Now a day, due to population growth, forestlands are degraded and converted to agricultural lands. By and large, land use change is more frequent in the highlands due to population pressure, government policy, market demand, climate change and urbanization (Valentin *et al.*, 2008).

2.2. Effects of Land Use on Soil Physical Properties

Physical properties play an important role in determining soil's suitability for agricultural and environmental uses. The supporting capability; movement, retention and availability of water and nutrients to plants; easy in penetration of roots, and flow of heat and air are directly associated with the physical properties of the soil. Soil physical properties profoundly influence how soils function in an ecosystem and how they can be managed. The physical properties of soil such as soil color, texture, structure, density, porosity and water content are the dominant factors affecting the use of soil and they have a crucial role in describing several productivity levels of a given area (Ahmed and Sharma, 2002). Some physical properties of the soils are highly influenced by the land use system and its management, whereas others by differences or the origin from which they were formed. Different studies shows that soil bulk density (BD), gravimetric soil moisture content, soil porosity and proportion of sand, silt and clay contents were significantly different under different land use types. Physical characteristics of the soils on land under continuous cultivation could vary from the land that remains uncultivated for a long period of time (Gebreyohannes, 2001; Wakene, 2001).

Moreover, the transformation of one land use system into another system practices can affect soil structure, soil organic carbon and other nutrients. The different land use and land management systems could also significantly contribute to the variation in soil physical properties. Biro *et al.* (2013) observed that the expansion of cultivated areas can substantially affect soil nutrient content by reducing the composition of plant species, net primary productivity, above- and belowground allocation in plants, and nutrient cycling. Land use changes from forest cover to cultivated land may reduce the input or organic residues that lead to a decline in soil fertility (Muñoz- Rojas *et al.,* 2015), increases rates of erosion (Biro *et al.,* 2013), the loss of soil organic matter and nutrient, Saha D., and kukal LP., 2015), and an accelerated rate of soil degradation (Barua and Haque, 2013).

2.2.1. Effects of Land Use on Particle and Bulk Densities

Saha and Kukal (2015) found a higher bulk density and lower macro porosity and water retention in cultivated soils than in soils of grassland and forests. This indicates the degradation of soil properties due to the conversion of natural ecosystems to agricultural systems. In addition, Continuous cultivation of land results in an increase in sand fraction and bulk density, reduced soil nutrient status and water retention capacity while increasing soil acidity as against bush fallow land (Malgwi and Abu, 2011).Land use practices have a strong effect on soil properties, especially on soil aggregation and bulk density. Soils having low and high bulk densities exhibit favorable and poor physical conditions, respectively. Bulk density normally decreases as mineral soils become finer in texture.

Bulk densities of soil horizons are inversely related to the amount of pore space and soil organic matter (Brady and Weil, 2002; Gupta, 2004). Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity Infiltration capacity which is an important soil hydrological property is influenced by soil structure, aggregate stability, particle size distribution, land use type (Fu *et al.,* 2000), vegetation (including plant and litter cover and type, and soil organic content), and climatic influences However, land use change, especially from native vegetation to cultivation and grazing, soils have undergone important changes in their properties, including loss of organic matter and increases in bulk density.

2.2.2. Effects of Land Use on Total Porosity

The effects of land use change on soil physical proprieties are broadly known, especially the conversion of tropical forest to pasture or croplands. Changes in soil bulk density, penetration resistance, porosity, near-surface hydraulic conductivity, in filterability and saturated hydraulic conductivity are described as possible consequences of the land use change. Soil porosity characteristics are closely related to soil physical behavior, root penetration and water movement (Pagliai and Vignozzi, 2002). Macro pores can occur as the spaces between individual sand grains in coarse textural soils. Thus, although sand soil has relatively low total porosity, the movement of air and water through such soil is surprisingly rapid because of the dominance of macro pores.

Fertile soils with ideal conditions for most crops have sufficient pore space, more or less equally divided between large (macro) and small (micro) pores. Sands with a total pore space of less than about 40% are liable to restrict root growth due to excessive strength with l^{st} in clay soils limiting total porosities are higher, and less than 50% can be taken as the corresponding value (Landon, 1991).

2.2.3. Effects of Land Use on Soil Structure and Texture

Assessing land-use-induced changes in soil properties is essential for addressing the issue of agro ecosystem transformation and sustainable land productivity (Yao et al., 2010). Sustainable land-use systems are therefore needed to prevent further soil degradation and to maintain soil fertility. The fertility status of most soils, particularly under low input agricultural systems, depends largely upon some soil physical properties such as texture, soil aggregates, hydraulic conductivity and soil organic matter. It is one of the soil physical properties, which is very sensitive to soil management practices. Consequently, changes in soil structure because of different management systems have pronounced effects on bulk density, porosity, aeration, infiltration, water storage capacity, water characteristics, erosion and runoff water (Wakene, 2001). Soil texture is one of the inherent soil properties less affected by management. Since the proportion of each size group in a given soil (the texture) cannot be easily altered, it is considered as a basic property of a soil. According to Wakene and Heluf (2004), intensive cultivation contributed to the variation of particle size distribution at the surface horizons. This could be due to the removal of soil particles through sheet and rill erosion and mixing of the surface and subsurface horizons during deep tillage activities.

2.3. Effects of Land Use types on Soil Chemical Properties

Land use practices influence the chemical properties of soils. Changing land use from forests to croplands leads to a change in the chemical properties of the soil (Zhang *et al.,* 2004; Viollete *et al.,* 2009). Moreover, land use changes from forest cover to cultivated land may reduce the input or organic residues that lead to a decline in soil fertility (Muñoz- Rojas *et al.,* 2015), increased rates of erosion (Biro *et al.,* 2013), the loss of soil organic matter and nutrients (Saha and Kukal, 2015), and an accelerated rate of soil degradation (Barua and Haque, 2013). Several studies in the past have shown poor soil management, deforestation, and continuous cultivation of virgin soils often lead to depletion of nutrients and high soil erosion rate (Nigussie and Fekadu, 2003; Seibert *et al.*, 2007; Tilahun, 2015).

Land-use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing biological transformations in the rooting zone. Soil chemical characteristics are the most important factors that determine the nutrient supplying power of the soil to the plants and microbes. Various studies have been conducted to assess the effect of land use changes in chemical properties in Ethiopia (Fantaw *al.,* 2007, 2008, Mulugeta *et al.,* 2006). Soil pH, CEC, TN and OC, different forms of P, exchangeable bases, were affected due to intensive cultivation and use of acid-forming fertilizers (Wakene and Heluf, 2004).

Similarly, Tesfahunegn (2016) showed that soil quality indicators varied across the land use and soil management systems, among which natural forestland and protected afforestation areas are the most important systems in maintaining soil quality, whereas cultivated and marginal lands seriously deteriorated the soil system. The same author showed that soil organic carbon (SOC), pH, TN, available phosphorous (AP), and clay are significantly higher in natural forest and protected afforestation areas.

Such type of conversion increased soil organic carbon, microbial biomass and potential nitrogen mineralization rate, and reduced the soil bulk density (Chen 2003; Yang *et al*., 2005; Mao *et al*., 2010). Soils under grass cover have shown better chemical properties than soils under forest cover (Pavlu *et al*., 2007). Moreover, in the sub-humid highlands of South-western Ethiopia, the shift of land use changes from natural forest to cultivation led to the depletion of P. Because of the study area are facing agricultural challenges such as shortage of land for crop cultivation and livestock grazing, the decline of soil fertility and rainfall variability resulting in low yield production, determining the soil property is crucial for further soil management and improvement.

2.3.1. Effects of Land Use Types on Organic Carbon and Total Nitrogen

Organic carbons are considered as one of the most important factors among soil quality indexes and have a positive effect on soil properties. The conversion of natural forest into cultivated and grazing lands caused losses of soil nutrients. As per cultivation periods, various scholars (Mulugeta *et al.,* 2006; Eyayu *et al.,* 2009; Mojiri *et al.,* 2012) revealed that as the cultivation period increase the bulk density also increase, whereas soil organic carbon and total nitrogen contents are reduced. Soil organic carbon (SOC) of terrestrial ecosystems is important for the biochemical cycle of major nutrients and soil structure.

Another study by Alemayheu and Sheleme (2013) also found comparable higher organic carbon (OC), total nitrogen (TN) under grassland as compared to cultivated land use types. Similarly, according to Yihenew and Getachew 2013), human managed land uses like cultivated and grazing land use types had more deleterious effects on soil electric conductivity (EC), pH, soil organic carbon (SOC), TN and on the overall activities of soil macro faunal in the soil. In tropical environments where forest ecosystems are usually converted to agricultural systems, OM and total nitrogen content of soils tend to turn down quickly. Meanwhile, many factors that change soil organic matter levels and forms are controlled by management, and the processes governing its dynamics are complex. There is a strong positive relationship between soil nitrogen and soil organic matter content. Low total nitrogen content and therefore N deficiency is visible in highly weathered soils .

2.3.2. Effects of Land Use types on Soil pH

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and biological environment. Land use changes from forest to crop land resulted in a reduction of soil pH. Continuous cultivation practices, excessive precipitation, and application of inorganic fertilizer could have attributed as some of the factors which are responsible for the reduction of pH in the soil. Mohammed (2003) also concluded that the lowest value of pH under the cultivated land could be due to the depletion of basic cations in crop harvest and leached to streams in runoff generated from accelerated erosions.

The other reason could be higher microbial oxidation that produces organic acids, which provide H^+ to the soil. Soil pH is one of the attributes sensitive to changes in the natural environment and soil management processes because of human activity. In tropical and sub-tropical environments two major reasons cause changes in pH and acidification process. There is a generally decreasing trend in soil pH with an increasing number of years in cultivation as soils tend to be slightly leached and become acidic in reaction (Jaiyeoba, 2003). The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil (Tilahun, 2015). The values of pH less than 5.5 may lead to aluminum toxicity, and hence unavailability of phosphorus and some of the soil micronutrients such as molybdenum and reduced biological activity (Gachene, 2003).

2.3.3. Effect of Land Use Types on Cation Exchange Capacity

Land use practices and land use shifting lead to soil erosion, leading to negative changes in the soil chemical properties, especially soil aggregate stability (SAS), soil organic carbon (SOC) and cation exchange capacity (CEC). The cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). Cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. The CEC is strongly affected by the nature and amount of mineral and organic colloids present in soil.

Soils with a large amount of clay and organic matter have higher CEC than sandy soil low in organic matter. As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to adsorb and hold positively charged ions (cations). Soil solutions contain dissolved chemicals, and many of these chemicals carry positive charges (cations) or negative charges (anions) (Fisher and Binkley, 2000). Soils with CEC less than 16meq/100g are considered not to be fertile. Such soils are usually highly weathered. Fertile soils have a CEC of more than 24meq/100g (Brady and Weil, 2002). On the contrary, Mohammed *et al.* (2003) reported that the values of CEC were uniformly high throughout most profiles and did not show any clear pattern of variability among horizons of the profiles except two pedons, which showed slight decrease with depth.

2.3.4. Effects of Land Use Types on Available Phosphorus

Phosphorus (P) is a fundamental macronutrient. P is important when considering the availability of P to known as the master key to agricultural soils. This is because low crop production in acidic soil is mainly due to lack of P than any other element Following N, AP has a more wide spread influence on both natural and agricultural ecosystems than any other essential elements. The shift of land use changes from natural forest to cultivation led to a significant decline in available P content of soils in the sub-humid highlands of the south-western Ethiopia (Solomon *et al*., 2002) and in tropical farmlands of Hainan, China.

Soils under different land use types and related management practices have also been shown to differ markedly in pool sizes and distribution of P within soil profiles. Variability of the level of available P is related to land use, altitude, slope position and other characteristics, such as clay and calcium carbonate content (Mohammed *et al.,* 2000). Many studies shown that soil devoted to crop production lost far more P to steams than do those covered by relatively undisturbed forest or natural grass land (Brady and Weil, 2002).

In most natural ecosystems, such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002).Phosphorus (P) is one of the less mobile plant nutrients in soil and it can be rendered unavailable to plants by fixation and precipitation as insoluble P compounds in most soils. Soils have significant amount of P, which is not immediately available to crops and only a small fraction becomes available during crop season (Barber, 1984).

2.3.5. Effects of Land Use Types on Exchangeable and Available Potassium and Sodium

Potassium (K) is the third most important plant growth-limiting nutrient just next to N and AP. The variation in the distribution of K depends on the mineral present, particle size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soils formed. Available K exists in soils in solution while exchangeable K is adsorbed on the soil colloidal surfaces from where it is slowly released to soil solution so as to be available to plants. Plants directly absorb K from the soil solution where it is found in the most readily available form for plant absorption (Brady and Weil, 2002).

According to Havlin *et al*. (2002), low sodium (Na) indicates that weathering of Na-containing minerals. Very little exchangeable and mineral Na occurs in humid region soils, whereas Na is common in most arid and semi-arid soils. It is an essential nutrient for halophytic plant species that accumulate salt in vacuoles to maintain turgor and growth. Sodium (Na) constitutes an appreciable fraction (2.8%) of the earth crust. Its presence in the soils in any but very small amount is restricted to those of arid and semiarid regions. In soils of humid regions, long continued application of sodium nitrate will result immeasurable quantities of this element in an exchangeable form but Na is one of the most loosely held of the metallic ions and is readily lost in leaching waters. The lack of large soil pores in the dispersed soil gives rise to an extremely low level of hydraulic conductivity and water infiltrations. The deleterious effect of high exchangeable sodium percentage (ESP) is greater in the soils with 2:1 lattice clay than in soils with 1:1 clay. The infiltration rate reduces so much that water tends to form puddles rather than soaked into the soils (Brady and Weil, 2002).

2.3.6. Effects of Land Use Types on Exchangeable Calcium and Magnesium

Calcium in acidic, humid region soils occurs largely in the exchangeable form and as primary minerals. Soils having 2:1 layer silicates have higher CEC and thus retain larger amount of calcium or magnesium. Research works conducted on some Ethiopian soils indicated that exchangeable Ca and Mg cations dominate the exchange sites of most soils and contributed higher to the total percent base saturations particularly in the Vertisols.

2.3.7. Effects of Land Use Types on 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. The denominator includes oxide-mineral complexes between the initial soil pH and the reference pH (7.0 or 8.2) (Bohn *et al.,* 2001). According to the same authors, 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.

2.3.8. The interaction Effects of Land Uses and Soil Depth on Soil Physical Properties.

Soil depth is an important factor to consider when evaluating crop production on different land uses. We can express soil depth in different ways soil depth is the root space and the volume of soil from where the plants fulfill their water and nutrient demands. It is very critical for plant growth, any discontinuities in the soil profile from layers of sand or gravel to even bed rocks; it can physically limit root penetration. It can also create problem using irrigation, soil macro and mesobiota need enough soil to grow and increase physical fertility (Louis, 2011). Soils on different land uses and depths produced different kinds and amounts of vegetation.

The study results of Woldeamlak and Stroosnijder (2003) and Mulugeta (2005) revealed that the bulk density of cultivated soils was higher than the bulk density of forest soils. Similarly, Ahmed (2002) reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth. Moreover, Wakene (2001) reported that bulk density was higher at the surface than the subsurface horizons in the abandoned and lands left fallow for twelve years. The availability of soil moisture to plants is a function of water input, moisture retention and root depth of a given soil, which is governed by the inherent soil properties and management practices. Furthermore, soil water content at field capacity, a permanent welting point and available water holding capacity increase with depth for the soils under different management practices (Wakene, 2001; Ahmed, 2002).Human management system such as frequent plowing and tillage for the purpose of cultivation, grazing or similar uses also changes the proportions of many soil properties with changing depths (McCarthy *et al.*, 2013).

Wakene (2001) reported that the highest (526 mm/m) and the lowest (275 mm/m) of soil water content at FC were observed in the deeper subsoil (90-140 cm) layer of the continuously cultivated farmer's field and the surface (0-16 cm) soil layer of the abandoned research field respectively. Sheet erosion and intensive leaching process leads to higher concentration of clay content and lesser concentration of calcium, magnesium, potassium and sodium in the subsoil than the topsoil (Adeboye *et al.,* 2011). However, silt and clay fractions are higher in forest land than the contents in cultivated land in both depths. It has also been reported that various nutrient elements such as N, P, Ca^{2+}, Mg^{2+} and K^{+} showed 3 to 43% declining trend as soil depth increases.

2.3.9. The Interaction Effects of land use and Soil Depth on Soil Chemical Properties

Soil chemical properties are those that are mainly influenced by the chemical components of soil. The more important chemical characteristics that influence soil fertility and plant growth are soil reaction, cation exchange property (CEC), available nutrients, organic matter content and salt concentration. Various studies have been conducted to assess the effect of land use types on soil chemical properties in Ethiopia (Mulugeta *al.,* 2006; Fantaw *et al.,* 2008). Mulugeta *et al.* (2006) showed that afforestation of farmland with various trees specious increased total nitrogen (TN), exchangeable potassium (K), and exchangeable calcium (Ca) on the surface soil layer than subsurface soil layer.

Fantaw *et al.* (2008) also compared croplands, forest lands and grazing lands and found that soil organic carbon (OC) and TN decreased in croplands as compared to forest lands. He also suggested that the OC was abundant of surface soil layer compared to the lower soil horizon. Topsoil phosphorus is usually greater than that in subsoil due to sorption of the added phosphorus and greater biological activity and accumulation of organic material in the top soil. In the subsoil, since there is higher clay and relatively lower OM, CEC was strongly correlated with clay than organic matter (Jin *et al.*, 2011).

These observations have supported the thought that soil properties react to depths across the various land use types. Therefore, depth of soil is an important factor in agriculture and land evaluation. Lalisa *et al*. (2010) also reported that OC, TN and Tp declined with depth for cereal farm; but these nutrients increase across the depth in the pasture land. Exchangeable cations decreased with depth except Ca^{2+} in wood lots, K^+ in homesteads and Na^+ in cereal farms. CEC, however, decreased in all the land uses with depth. As the interaction between natural and anthropogenic management system persists (Assefa and van Keulen, 2009).The reasons for these are the addition of organic matter from plant growth to the top soil, weathering of rocks and minerals, decomposition of organic matter, and translocation of soluble components by leaching, which in turn responsible for the differentiation of soil layers.

Soil pH increases with depth of the soil profiles and relatively higher pH values were observed at the subsoil horizons in Alfisols of Bako area (Wakene, 2001), Mount Chilalo (Ahmed, 2002) and in the Vertisols of the central highlands of Ethiopia (Tamirat, 1992). In strongly acid soil, Al^{3+} becomes soluble and increase soil acidity, while in alkaline soils exchangeable basic cations tend to occupy the exchange site by replacing H^+ and Al^{3+}ions resulting in strongly alkali soils. Nega and Heluf (2013) indicated that deforestation has resulted in deterioration of SOM in the soil. Similarly, Tesfahunegn (2016) showed that soil quality indicators varied across the land use and soil management systems, among which natural forestland and protected afforestation areas are the most important systems in maintaining soil quality, whereas cultivated and marginal lands seriously deteriorated the physical soil system. The same author showed that soil organic carbon (SOC), pH, TN, available phosphorous (AP), and clay are significantly higher in natural forest and protected afforestation areas. On the other hand, Yihenew *et al.* (2005) found that SOC and TN at (0–20cm) depth remained the same after natural forest conversion into eucalyptus plantations in Munesa, Ethiopia. Fantaw *et al.* (2007) in his study in the Bale Mountains of Ethiopia found no variation in soil organic carbon content after natural forest was converted into grazing land. These conflicting findings suggest that the conversion of forestland into cultivated or grazing land leads to changes in soil chemical properties.

2.3.10. The Interaction Effects of Topography on Soil Chemical Properties.

The highest exchangeable Ca was at the lower topographic position, while the lowest values were recorded at the upper and middle topographic positions by Nahusenay & Kibebew (2016). This shows the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system. The lowest pH-H_2O was registered in the upper topographic position, while the highest was at the lower topographic position and the lowest pH at the high organic matter content, while the highest pH in the accumulation of basic cations reported by Eyayu *et al*. (2009) and Mojiri *et al*. (2012).

2.3.11. The Interaction Effects of land use and topography on spatial variety of soil Properties

Environmental factors are found to be useful in reducing uncertainties by improving estimations of the spatial distribution of SOC. First, SOC varies among different land use types (Chuai *et al.* 2012) because of differences in land cover, soil conditions and micro-organisms (Guo and Gifford 2002; Ayoubi *et al.*2012). Second, topographic factors, such as elevation, slope and topographic wetness index (TWI), also affect the spatial distribution of SOC because these topographic factors can affect the processes of soil erosion and sediment transport(Zhong and Xu 2009; Schwanghart and Jarmer 2011) and thus the distribution of SOC attached to soil particles. In addition, topographic factors affect patterns of land cover and decomposition of plant litter by affecting environmental conditions, such as the amount of water available and temperature (Seibert *et al.* 2007; Schwanghart and Jarmer 2011).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Wunke watershed which is located in Geto Woreda, Gurage Zone of the Southern Nation, Nationalities and Peoples Regional State (SNNPRS). It is situated at 240 km northwest of Addis Ababa and 68 km northeast of Wolkite town which is the capital city of Gurage zone. The geographical location of Wunke watershed extends from 7^0 26' 08" to 7^0 59' 56"N latitude and from 37^0 08' 23" to 37^0 56' 59" E longitude Geto Woreda Agriculture Sector (GWAS, 2019). The study area lays an altitude ranging from 2472 – 2818 meters above sea level (m.a.s.l).

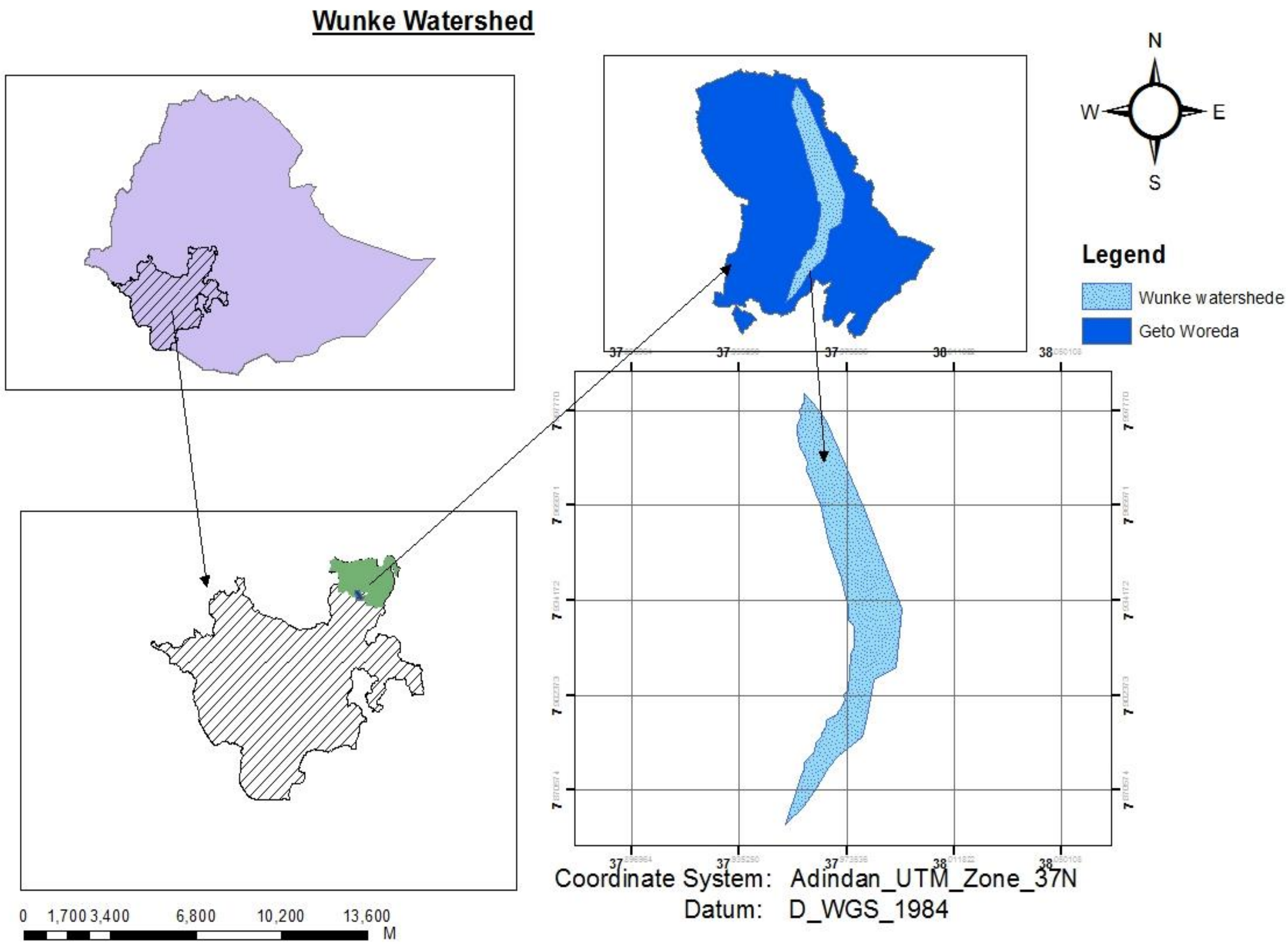

Figure 1. Location Map of the Study Area

3.2. Climate and Hydrology

The Watershed is divided into two agro-ecological zones locally called Dega (highland) and Woyna Dega (Mid Highland). The watershed experiences alternating wet and dry season. The wet season is ranges from June to October and the dry season ranges from November to May. The area receives mean annual rainfall which is varying from around 1001 to 14000 mm and the temperature ranges from 8.2 – 23.6ºc. Temperature also appears to decrease with a rise in altitude of the study area, as observed from crops and vegetation types grown in the area woreda agriculture sector (GWAS, 2018).

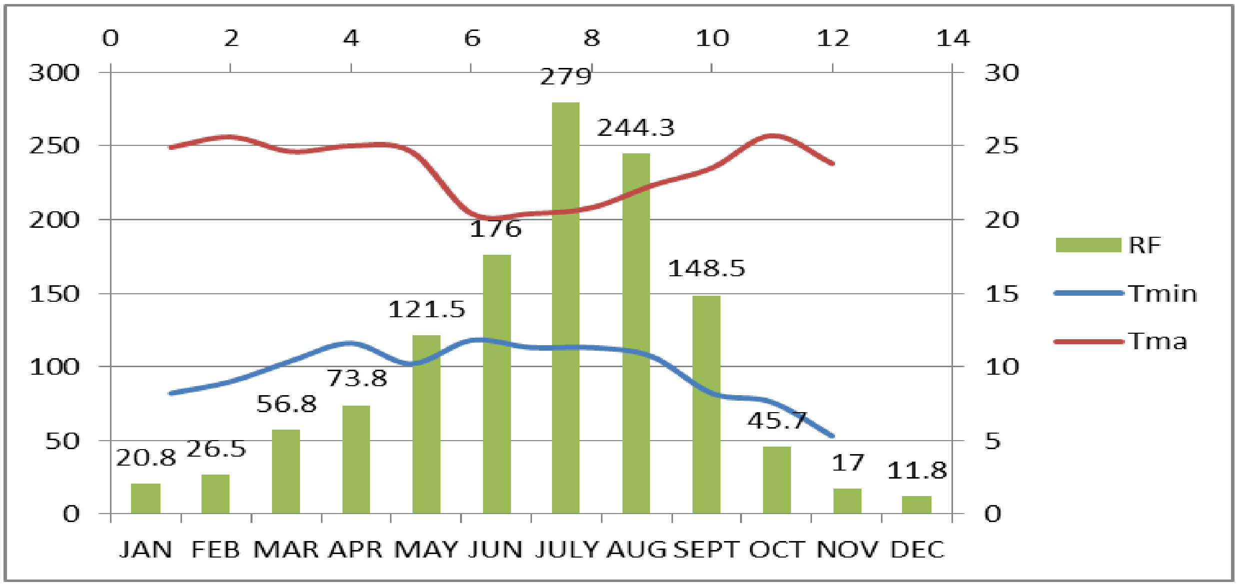

Figure2. Mean Monthly Rainfall (mm), Mean Monthly Maximum and Minimum Temperature ($^{o}{}_{C}$).Source (GWAS, 2018).

3.3. Land Use System, Soil and Vegetation of the Watershed

According to my personal observation and communication with elders, the land use type in Wunke watershed is changing historically. This could be due to the rapid expansion of settlements and the associated needs for cultivated land and deforestation activities. The high population pressure, high and intensive rainfall and the traditional farming practices seriously damaged the productivity and sustainability of the agricultural lands. There have been no studies carried out to quantify the effects of land use types, soil depth and topography in the watershed. Moreover, the different anthropogenic and other manmade problems caused reduction in productivity of crops in the study area. This implies that there is a need to have watershed specific information on soil properties to support timely information for decision makers and land managers that plan accurate soil conservation planning. The common type of soil in the watershed is Vertisols (GWAS, 2019). According to CSA, (2007), Geto Woreda has a total population of 101,834 out of which 53,814 are men and 48,020 are women. Specifically, the watershed has a population of approximately 39,500 people of which 49 percent are women. Out of the total population, about 95 percent of the population in the watershed depends on agriculture (CSA, 2007) and the remaining percent live near the town.

In Wunke watershed the mainly produced crops are enset (Enset ventricosum), barely (Hordeum vulgaris), beans (Vicia faba), and wheat (Triticum aestivium). Therefore, evaluating the influence of land use types, topography and soil depth on soil physical and chemical properties for major crops of soils in Wunke watershed is one of the important practices for formulating the management alternatives on soil and selecting the type of suitable crops to be cultivated in order to get high amounts of yields. For better management and protection, tree and shrub species are primarily concentrated around the homestead. Eucalyptus (Eucalyptus globulus), habesha tid (Junipers procera), yfrenge tid (Cupressus lusitanica), sholla (Ficussycomours), kosso (Hagezia Abyssinia), and other fodder trees and shrub species are among the common tree species covering the forest land in the study area.

The research area is suitable for a variety of crop production. The main crops are enset, barely, and beans. Farmers use chemical fertilizers, primarily di-ammonium phosphate and urea, to increase crop yield. Manure is also applied to homestead plots. Crop residues are used as livestock feed and fuel and animals are free to graze on cultivated land after crops have been harvested. The Wunke watershed covers 5417 hectares in total. Cultivation land (1942 ha), enset land (917 ha), individual and common grazing land (815 ha), and others are among them (1743 ha). In general, the soils of the study area require soil and water conservation practices, as well as the addition of inputs that improve soil fertility (GWAS, 2019).

3.4. Soil Depth and Topographic Selection

The watershed was divided in to three different topographic positions (FAO, 2006). Upper middle and lower topographic positions were identified. After a reconnaissance survey, in each topographic position three major land use type: enset land (organic), grazing land (areas with degraded temporary or permanent grass cover), and cultivated lands (areas used for rain-feed and irrigated agriculture) was selected in the watershed. Information on previous land use history was documented from oral histories communicated by local elder farmers who are the owners of the lands. In addition, two different soil depths i.e., 0-20cm (topsoil layer) and 20–40cm (subsoil layer) were selected.

The two depths were deliberately selected for two main reasons. Firstly, the 0–20cm represents the average plough layer in the area while the 20–40 cm depth is the layer where the clay particles leached from the topsoil accumulate. Secondly, samplings at these predetermined depths enhance the comparability of soil properties with depth among the studied land uses. Wunke watershed was purposively selected for this study because higher land degradation and soil erosion problems were commonly observed in this area which has a deleterious impact on soil physical and chemical properties under different land use types.

3.5. Methods of Soil Sampling and Analysis

3.5.1. Methods of Soil Sampling

Soil samples were collected from representative sites of each of the three land use types in the three topographic positions in three replicates. Soil samples (disturbed and undisturbed) was collected. From each LUT, adjacent sampling site plots (20m×20m) were identified considering slope gradient and topography variations for each land use types were located. Before sampling, plant and grass litter including any other material on the soil surface was removed. Then, in each plot soil, samples were collected in three corners and at center in two different soil depths i.e., 0-20cm (topsoil layer) and 20–40cm (subsoil layer) using soil auger. Each of the soil samples from the two depths consisted of 10-15 sub-samples that have been bulked to make a single composite soil sample for the respective soil depths.

Consequently, a total of 54 composite samples were collected from the three land use types (3 land uses x 2 depths x 3 replications and 3 topographic positions). Additionally, undisturbed soil core samples of known volume were collected in all plots of each land use type and sample depths in three replications for bulk density determination. At every sampling plot, soil samples were collected from depth and within the land use and composite samples were prepared by hand mixing depending on depth strata.

3.5.2 Laboratory Analysis

All samples were analyzed following standard laboratory procedures as outlined by Sahlemedhin and Taye (2000). The collected soil samples were air-dried and ground to pass through 2mm sieve for determination of selected soil physical and chemical properties except for TN and OC which were determined after passing the soil through a 0.5 mm sieve.

Particle size distribution was determined using hydrometer method (Bouyoucos, 1962). Bulk density (bρ) was determined by core-sampling method (Baruah and Barthakur, 1997). TP was computed from the measurements of soil dry bulk density (b ρ) and soil particle density (ρP) as: Total porosity (%) = [1-(Bulk density/Particle density)] x 100.

Soil pH was measured from soil suspension solution prepared with soil water using a glass electrode pH meter at the ratio of 1:2.5 soils to solution (Mclean, 1982). Organic carbon was analyzed by the wet digestion method (Walkley and Black, 1934). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method (Bremner and Mulvney, 1982). Available phosphorous was analyzed using the Olsen sodium bicarbonate extraction solution (pH 8.5) method (Olsen *et al*., 1954) and the amount of available P was measured by Spectro photo meter. The CEC and exchangeable cations were extracted using a 1M ammonium acetate (pH 7) solution (Van Reeuwijk, 1993). Percent base saturation was calculated by adding the cations that form bases (Ca, Mg, Na, and K), dividing by the soil's CEC, and multiplying by 100.

3.5.3. Data Analysis

The various data on soil physical and chemical parameters were subjected to a three-way analysis of variation (ANOVA) procedure of statistical analysis system (SAS) software, version (SAS, 2008) to determine whether or not variations in soil attributes among land uses, soil depths, topography, and their interaction were significant. At a 5% level of probability, the mean comparison was performed using Fisher's least significant difference (LSD) test.

4. RESULTS AND DISCUSSION

4.1. Interaction Effect of Different Land Use Types, Soil Depths and Topography Physical and Chemical Properties

The results regarding interactions effects of land use, soil depth and topography on physical and chemical properties of soil are shown in (Table 1). In this study, the interaction effect of land use and topography had significant influences on particle size distribution, BD, TP, available P, soil pH, OC, TN, exchangeable bases and PBS. Sand, silt, soil pH, AP, OC, TN, CEC, and exchangeable bases were affected by the interaction effect of soil depth and topography. Exchangeable bases and CEC were affected by the interaction effect of the three parameters.

The interaction effect of land use, soil depth and topography on soil properties indicated that the highest exchangeable bases and CEC were observed in the bottom layers of soils under the three land use types at the lower topographic position. This might be due to the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system

Table 1. Analysis of Variance on effects of land use, soil depth and topography and their interaction effect on physical and chemical properties of soils at Wunke Watershed (P –value).

Source	Df	Sand	Silt	Clay	BD	TP	pH	OC	TN	AP	CEC	Na	K	Mg	Ca	PBS
LU* depth	2	0.001	0.001	0.003	0.001	0.896	0.001	0.001	<0.001	<0.001	0.431	0.001	<0.001	0.023	0.002	0.001
LU*Top	4	<0.001	0.001	<0.001	0.569	0.600	0.002	<0.001	0.001	0.001	0.002	<0.001	0.001	0.001	0.001	0.001
Top* depth	2	0.001	<0.001	0.315	0.568	0.622	0.001	<0.001	<0.001	<0.001	0.001	0.563	0.001	0.892	0.731	0.001
LU*Depth *Top	4	0.208	0.243	0.261	0.901	0.895	0.431	0.231	0.241	0.007	0.001	0.001	0.001	0.001	<0.001	0.001

LU=Land use, TOP= Topographic position, SD=Soil depth

4.2. Interaction Effects of Land Use and Soil Depth on Soil Physical and Chemical Properties

The result of the analysis of variance indicated that the interaction effect of land use and soil depth significantly (P< 0.05) affected bulk density of soil. The highest (1.17 gcm^{-3}) bulk density value of soil was recorded from the sub surface layer (20-40 cm) of the grazing land, but it was statistically not different from that that was recorded in the surface layer of grazing Land (1.16 g cm^{-3}). On the other hand, the lowest (1.00 gcm^{-3}) values of BD were recorded from both surface and sub-surface layers of the enset land (Table 2). The highest value of BD in grazing land might be due to the effects of high compaction by grazing animals.

In contrast, the lowest bulk density in the case of enset land might be due to the accumulation of organic matter. The current result of BD in grazing land is in agreement with Muche *et al.* (2015), who reported higher bulk density value for soils of grazing land due to the trampling effect of livestock during free grazing activities. In addition, Wakene and Heluf (2003) reported the highest bulk density in the abandoned land which was due to soil compaction and organic matter degradation. As per the classification rating suggested by Pam and Brian (2007), bulk density of the soil is rated as very low (< 1 gcm^{-3}), low (1-1.3 gcm^{-3}), medium (1.3-1.6 gcm^{-3}), high (1.6 -1.9 gcm^{-3}) and very high (> 1.9 gcm^{-3}). Accordingly, the result of the study area could be categorized as low in grazing and enset land.

pH of soil (H_2O) was significantly (P< 0.05) affected by the interaction of land use and soil depth (Table 2). The highest value of pH of soil (6.6) at 20-40 cm depth of soil and the lowest value of pH of soil (4.7) were recorded under the enset and the cultivated lands. In addition, the soil pH of the study area increased with depth of soil (Table 2) Agoume and Birang (2009) also reported that pH of the soil could be affected by land use systems in their study conducted in Oxisol of the humid forest zone of the Southern Cameroon. Other study conducted by Nega and Heluf (2013) in Western part Ethiopia indicated that pH of the soil was affected by the interactions of land use changes and the soil depths. Alemayheu and Sheleme also found an increment of soil pH with depth under enset and cultivation lands. Malo *et al.* (2005) also reported that soil pH values were significantly lower on the surface layer for cultivated soils when compared to non-cultivated soils due to the application of NH_4^+sourced fertilizers to cultivated lands that nitrifies NH_4^+ and its uptake by the crops. The difference observed in pH of soil among different land uses in this study is further corroborated with the findings of Tilahun (2015), who found significant differences in pH values among land uses and indicated the lower value of pH under the cultivated land. A pH value of less than 5.5 is considered as a problematic for most microbial activities, and this directly influences availability of nutrients to plant (Solomon, 2008). Therefore, application of lime could be very important in the study area s to amend acidity problem for crop production.

The interaction effect of land use by soil depth, on the variability of OC was significantly ($P< 0.05$) higher OC (4.5%) at surface layer of the enset land and lower OC (2.4%) at subsurface layer of cultivated land and enset land (Table 2). The soils of the study area could be ranged from medium in cultivated land to very high in enset land. Comparatively the higher value of OC on surface soil of enset land could be due to falling of plant materials which could in turn increase organic carbon in the soil. In contrary, the lower organic carbon content of cultivated land might have resulted from removal of crop residues for animal feed and source of energy as well as removal of organic carbon through oxidation as a result of intensive cultivation and erosion which could deplete organic carbon. This result is in agreement with Eylachew who reported that SOC content under grazing and cultivated soils were lower than the content obtained from enset land. Nega and Heluf (2013) also reported less organic carbon in the cultivated soils than grassed soils and higher in the surface soils of forest land while least in subsurface layers of the cultivated soils.

Results of the statistical analysis revealed that total nitrogen content of soils was significantly ($P\leq 0.05$) affected by the interaction effect of land use and soil depth (Table 2). Accordingly, the highest content of TN (0.37%) was recorded at the surface layer of the enset land followed by 0.34% which was recorded at the surface layer of grazing land whereas the lowest TN content (0.24%) was recorded in the subsurface layer of the cultivated land. The mean TN content of the surface soils of the study area was within the range of low in soils of cultivated land to very high in soils of enset land. The available phosphorus (AP) was significantly ($P\leq 0.05$) affected by the interaction of the two factors (Table 2). The content of available P in the cultivated land appeared to be significantly higher than the other two land use types. The higher in available (P) content in soils of cultivated land might be due to continuous application of mineral P fertilizer for few years as indicated by different farmers in the area. This result is in conformity with Van der Eijk *et al.* (1993) who reported the high content of P under maize farms than of grass land soils due to the continuous application of phosphorus fertilizer.

Similarly, Boke (2009) also reported high availability of P under enset farms due to rapid mineralization and additions of manure and crop residue. The available P content of the study area could be ranged into the ranges of very low to medium. Murphy (2007), Tekalign *et al.* (2002), and Abebe and Endalkachew (2012) also reported low availability of P in most Ethiopian soils including Vertisols as results of effects of copious crop harvest, erosion, fixation and low accumulation of soil organic carbon. Exchangeable calcium was significantly ($P< 0.05$) affected by the interaction of land use and soil depth (Table 2). The highest value of exchangeable Ca (13 cmol $_{(+)}$ kg^{-1}) at the sub-surface layer soil (20-40 cm) and the lowest value of exchangeable Ca (7.5 cmol $_{(+)}$ kg^{-1}) at surface layer (0-20 cm) of soil were recorded in enset and cultivated land, respectively.

Besides, the contents of exchangeable calcium increased with soil depth. These might be due to higher leaching of basic cations in the crop field than in the other land use practices. Similar observation was also reported by Mamo (2011). The lowest value obtained on the cultivated land could also be related to the influence of intensity of cultivation and abundant crop harvest with little or no use of input as reported by Singh *et al*. (1995) and He *et al*. (1999).

Exchangeable magnesium was also highly significantly ($P< 0.05$) affected by the interaction effect of land use and soil depth. Accordingly, the highest (8.3 cmol $_{(+)}$ kg^{-1}) value of Mg was observed in the sub-surface layer of enset land and the lowest (5.7 cmol $_{(+)}$ kg^{-1}) value of Mg was recorded on the surface layer of cultivated land (Table 2). The possible reason for this might be low organic matter content and high leaching of exchangeable magnesium from the cultivated land. The current finding is corroborated by He *et al*. (1999), who reported the lowest exchangeable magnesium content in cultivated land due to the high intensity of cultivation and abundant crop harvest with little or no use of inputs. Mamo (2011) also found that the contents of exchangeable magnesium decreased with soil depth. Exchangeable potassium was significantly ($P< 0.001$) affected by land use and soil depth interactions (Table 2). The highest (3.35 cmol $_{(+)}$ kg^{-1}) value of K was recorded on the sub- surface layer of enset land while the lowest (0.09 cmol $_{(+)}$ kg^{-1}) value of K was recorded in the surface layer of cultivated land. Possible reason for higher value of exchangeable K in enset land compared to cultivated land might be high organic matter content on the surface layer soils of enset and relatively lower status in cultivated land.

This result is in agreement with Baker *et al*. (1997), who found lower exchangeable potassium contents in cultivated and grazing lands than in the forestland. Barber (2001), reported that the critical level of exchangeable K in the soil for most crops for potassium fertilizer requirement is 0.38 cmol$_{(+)}$kg^{-1} and therefore, the content of exchangeable potassium was above the threshold level in the soils of the study area for crop growth with no potassium fertilizer requirement in the plow layer of cultivated lands. Similarly, Smaling *et al*. (2000) also reported that crop responses to potassium fertilization are rare in Africa due to high exchangeable potassium contents in many parts of Africa. Exchangeable sodium was significantly ($P< 0.05$) affected by the interaction effect of land use and soil depth (Tables 2).

The highest (0.33 cmol $_{(+)}$ kg^{-1}) value of exchangeable Na was recorded on the subsurface layer of enset land and the lowest (0.05 cmol $_{(+}$ kg^{-1}) value of exchangeable sodium recorded surface layer of cultivated land Similar result was reported by Mamo (2011) who indicated that deforestation, leaching, limited recycling of dung and crop residues, declining fallow periods and soil erosion have contributed to depletion of basic cations and reduction of CEC in cultivated land as compared to adjacent forest land. In addition, Foth (1990) also reported that as a result of small energy of adsorption of K and Na, it is more likely to exist in soil solution than colloidal sites and be removed from soil by leaching. The exchangeable Na content was low in cultivated and grazing lands but medium in forest land according to FAO (2006) rating, in which the exchangeable Na contents of the soil in cmol$_{(+)}$kg^{-1} < 0.1, 0.1-0.3, 0.3-0.7, 0.7-2 as very low, low, medium, high and very high, respectively.

Percentage Base Saturation was significantly ($P < 0.05$) affected by the interaction of land use and soil depth (Table 2 and Appendix Table 5). In this study, the highest (69.3%) value of PBS was observed in the surface layer of enset land where as the lowest (39.7%) value of percent base saturation was observed on the subsurface layer of cultivated land. Relatively high organic matter and clay contents of soil colloidal sites and storehouse of exchangeable bases in the surface layer of enset land compared to the subsurface layers of cultivated and grazing lands might have possibly contributed for the results recorded in the study site.

The lowest percent base saturation recorded in the sub surface layer of the cultivated land could be attributed to the low sum of bases, pH and low soil organic carbon content in this layer (Table 2). Apparently, Kedir (2015) suggested that variation in percentage base saturation could also be because of variation in pH, soil organic carbon content, soil texture, parent materials, intensity of cultivation, and soil management practices.

Table 2. The Interaction Effect of Land Use and Soil Depth at Wunke Watershed.

Land Use	Soil Depth (cm)	Physical Properties					Chemical Properties									
		Sand	Silt	Clay	BD (g cm-3)	TP (%)	pH- (H2O)	AP (ppm)	OC	TN	CEC	Na	K	Mg	Ca	PBS (%)
		(%)							(%)		Cmol(+) kg-1					
Cultivated	0-20	31.7^{bc}	33.3^{ab}	35.0^{ab}	1.11^{b}	66	4.7^{f}	5.3^{a}	3.4^{b}	0.28^{c}	33.2^{a}	0.05^{b}	0.39^{e}	5.7^{b}	7.5^{b}	43.1^{cd}
	20-40	28.1^{bc}	39.1^{a}	32.8^{bc}	1.13^{b}	66	5.9^{b}	4.6^{b}	2.4^{d}	0.24^{de}	35.6^{a}	0.13^{ab}	0.46^{de}	6.2^{ab}	8.2^{b}	39.7^{d}
Grazing	0-20	45.2^{a}	22.1^{c}	32.7^{bc}	1.16^{a}	62	5.1^{e}	4.2^{cd}	3.6^{b}	0.32^{b}	34.8^{a}	0.31^{ab}	0.80^{d}	6.0^{b}	8.1^{b}	44.5^{cd}
	20-40	36.0^{ab}	38.0^{a}	26.0^{c}	1.17^{a}	61.4	6.3^{b}	3.7^{e}	2.93^{c}	0.24^{de}	37^{a}	0.30^{a}	1.19^{c}	7.3^{ab}	9.3^{b}	50.8^{bc}
Enset	0-20	29.0^{bc}	28.8^{b}	42.2^{a}	1.0^{c}	61.2	5.4^{d}	4.3^{c}	4.5^{a}	0.37^{a}	32.3^{a}	0.21^{ab}	1.85^{b}	6.2^{ab}	8.2^{b}	58.9^{ab}
	20-40	22.5^{c}	34.7^{ab}	42.8^{a}	1.0^{c}	63.3	6.6^{a}	4.0^{d}	2.8^{cd}	0.27^{cd}	35.3^{a}	0.33^{a}	3.35^{a}	8.3^{a}	13^{a}	63.2^{a}
LSD (0.05)		**9.3**	**6.1**	**5**	**0.01**	**NS**	**0.2**	**0.2**	**0.52**	**0.04**	**NS**	**0.03**	**0.19**	**2.3**	**2.53**	**10.5**
CV (%)		30.9	29.8	20.4	22.7	13.3	4.8	29.8	16.7	17.1	16.5	27	28	29	30.6	30.7

Means within a column followed by the same letter are not significantly different at 5% level of probability.

CV = Coefficient of variation, LSD = Least significant difference. UTP= Upper topographic position, MTP= Middle topographic position, LTP=Lower topographic position.

4.3. Interaction Effects of Land Use and Topography on Soil Physical and Chemical Properties

Data analysis revealed that particle size distributions were varied significantly at ($P < 0.05$) due to the interaction effect of land use and topography (Table 3). Accordingly, the highest sand (47.01%) and silt (39.6%) contents were recorded in soils of grass land in the upper and lower topography, respectively. Moreover, the highest clay content (44.5%) was found in soils of the enset land at the lower topographic position. This could be due to the mixing of soil during tillage activities as was also reported by Heluf and Wakene (2006). Similarly, the highest clay fraction at the lower landscape position of cultivated land compared with others could also be attributed to selective removal of fine earth fractions during water erosion leaving behind the coarser ones (Fantaw, 2017).

The analysis of variance revealed that the Ap were varied significantly ($P < 0.05$) due to the interaction effect of land use and topography (Table 3).The highest (5.68%) and the lowest(3.6%) values of AP were recorded at cultivated land of lower altitude and grazing land of upper topography, respectively. The analysis of variance revealed that the soil pH were varied significantly ($P < 0.05$) due to the interaction effect of land use and topography (Table 3).The highest (6.1%) and the lowest(5.0%) values of pH were recorded at enset land of lower altitude and cultivated land of upper topography, respectively.

The analysis of variance revealed that exchangeable bases and percent base saturation were varied significantly ($P < 0.05$) due to the interaction effect of land use and topography (Table 3). Accordingly, the highest (13.16cmol $_{(+)}$ kg^{-1}) and the lowest (6.16cmol $_{(+)}$ kg^{-1}) values of Ca were recorded at enset land of lower altitude and cultivated land of upper topography, respectively. Similarly, the highest (8.83cmol $_{(+)}$ kg^{-1}) and the lowest (4.5cmol $_{(+)}$ kg^{-1}) values of Mg were recorded under enset land of middle topography and cultivated land of upper topography, respectively. This shown the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system. The highest (3.96 cmol $_{(+)}$ kg^{-1}) and the lowest (0.27 cmol$_{(+)}$ kg^{-1}) values of K were recorded under enset land of lower topography and cultivated land of upper topography, respectively. The ranges of mean exchangeable K values observed in this study indicated that K^+ was above the critical levels (0.38 cmol (+)/kg) for the production of most crop plants as indicated by Barber (1984). In general, the amount of K in soils of study area could be enough for the crop production. The highest (0.40cmol $_{(+)}$ kg^{-1}) and the lowest (0.05cmol $_{(+)}$ kg^{-1}) values of Na were recorded under enset land of lower topography and cultivated land of upper topography, respectively.

The variation in cation exchange capacity as a result of the interaction effect of land use and topographic position were significant at ($P< 0.05$). The highest mean CEC (39.6 cmol (+) kg^{-1}) was found under grazing land followed by enset land at the lower topographic positions, whereas the lowest value (30.2 cmol (+) kg^{-1}) was observed under cultivated land of upper topographic position (Table 3). The highest CEC in the middle topographic positions could be the result of high pH, while the lowest CEC at upper topographic position could be the result of downward movement of clay particles and leaching of basic cation as was also reported by Fassil and Yamoah (2009) and Nega *et al.* (2009).

Table 3. The Interaction Effect of Topography and Land-use on Soil Physical and Chemical Properties at Wunke Watershed.

TOP	LU	Physical Properties					Chemical Properties									
		Sand (%)	Silt (%)	Clay	BD (gcm^{-3})	TP (%)	pH-(H_2O)	AP (ppm)	OC	TN	CEC	Na	K	Ca	Mg	PBS (%)
		(%)							(%)		Cmol$_{(+)}$kg^{-1}					
UTP	Cultivated	29.3^{bc}	35.1^{abc}	35.6^{abc}	0.93^{a}	64.8^{a}	5.0^{f}	4.1^{d}	2.7^{d}	0.24^{e}	30.2^{c}	0.05^{d}	0.27^{e}	6.16^{d}	4.5^{d}	38.7^{de}
	Grazing	47.0^{a}	25^{e}	28.0^{c}	0.92^{a}	62^{a}	5.98^{bc}	3.6^{f}	3.13^{cd}	0.26^{cde}	30.6^{bc}	0.11^{cd}	0.58^{e}	8.16^{bcd}	7.5^{abc}	57.1^{bc}
	Enset	31.8^{bc}	32.6^{abcde}	35.6^{abc}	0.87^{a}	67^{a}	6.0^{a}	4.06^{de}	3.8^{a}	0.31^{b}	31.3^{bc}	0.32^{abc}	2.69^{b}	8.3^{bcd}	8.1^{ab}	73.3^{a}
MTP	Cultivated	33.6^{bc}	32.6^{abcde}	33.8^{bc}	0.92^{a}	67^{a}	5.1^{f}	5.06^{b}	2.99^{d}	0.26^{de}	36.3^{ab}	0.09^{cd}	0.59^{e}	7.0^{d}	5.8^{bcd}	44.4^{cde}
	Grazing	37.5^{ab}	35.4^{abc}	27.1^{c}	1.07^{a}	61^{a}	5.6^{de}	4.5^{c}	3.04^{d}	0.26^{de}	37.6^{a}	0.18^{abcd}	0.58^{e}	7.1^{cd}	5.83^{bcd}	35^{e}
	Enset	32.3^{bc}	32.6^{abcde}	35.1^{abc}	1.02^{a}	59^{a}	5.8^{cd}	3.78^{ef}	3.65^{ab}	0.36^{a}	35.3^{abc}	0.08^{d}	1.17^{d}	8.1^{bcd}	8.83^{a}	44.6^{cde}
LTP	Cultivated	29.0^{bc}	39.6^{a}	31.4^{bc}	1.10^{a}	66^{a}	5.93^{bc}	5.68^{a}	3.18bcd	0.28^{bcde}	38^{a}	0.14^{bcd}	0.56^{e}	10.8^{ab}	8.0^{ab}	41.0^{de}
	Grazing	37.1^{ab}	32.4^{abcde}	30.5^{bc}	1.08^{a}	57^{a}	5.85^{cd}	3.78^{ef}	3.7^{a}	0.32^{b}	39.6^{a}	0.36^{ab}	2.10^{c}	10.9^{ab}	6.0abcd	50.5^{cd}
	Enset	24.5^{c}	31.0^{bcde}	44.5^{a}	1.0^{a}	59.6^{a}	6.1^{a}	4.73^{c}	3.5^{abc}	0.30^{bc}	39.3^{a}	0.40^{a}	3.96^{a}	13.16^{a}	8.5^{a}	65.3^{ab}
LSD (0.05)		**7.2**	**7.1**	**8.7**	**NS**	**NS**	**0.24**	**0.29**	**0.48**	**0.03**	**5.8**	**0.2**	**0.3**	**2.7**	**2.6**	**7.9**

CV (%)		29.35	32.8	23.9	24	27	12.3	9.3	25.3	21.2	15.36	23	19	23	27	23.9

Means within a column followed by the same letter are not significantly different at 5% level of probability.

CV = Coefficient of variation, LSD = Least significant difference. UTP= Upper topographic position, MTP= Middle topographic position, LTP=Lower topographic position.

4.4. Interaction Effect of Soil Depth and Topography on Soil Physical and Chemical Properties

The analysis of data is indicated in (Table 4). Accordingly, except clay, both sand and silt were significantly affected at ($P< 0.05$) due to the interaction effect of soil depth and topographic position. The highest sand (39.7%) and silt (40.0%) values were recorded at surface layer of upper topographic position and middle topographic positions, respectively. The lowest sand (24.7%) was recorded at subsurface layer of lower topographic position whereas the lowest silt (22.2%) content was recorded at surface layer of upper topographic position. Similar to the interaction effect of soil depth and topography on clay, the interaction effects on BD and TP were also not significant at ($P< 0.05$).

The interaction effect of soil depth and topography was also significant at ($P< 0.05$) on pH of soil in the study area (Table 4).The lowest pH (H_2O) was registered at surface layer of soil in the upper topographic position while the highest was recorded at the subsurface layer of soils in the lower topographic position. In addition, the interaction effects of soil depth and topography on soil organic carbon and total nitrogen were also significant at ($P< 0.05$) (Table 4). The highest organic carbon (4.1%) content was recorded at the upper depth of lower topography, while the lowest (2.71%) was observed at bottom layer of middle and lower topographic positions.

Furthermore, the effect of soil depth and topography on available phosphorus was also at ($P< 0.05$) (Table 4).The highest (4.97 ppm) available P was obtained from the surface layer of lower topographic position and the lowest (3.7 ppm) available P value was obtained from the sub surface layer of upper topographic position. This clearly shown the significant contributions of the soil organic matter content to the P pool of the soils in the study area. Exchangeable K was significantly affected at ($P<0.05$) by the interaction effect of topography and soil depth (Table 4).n. The highest exchangeable K (2.88cmol $_{(+)}$ kg^{-1}) was found in the bottom layer of the lower topographic position, whilst the lowest value (0.58 cmol kg^{-1}) was recorded at the upper layer of soils at the middle topographic position.

In contrary, exchangeable Na and Mg were not significantly affected by the interaction effect of topography and soil depth at ($P<0.05$) (Table 4). The highest (0.52cmol $_{(+)}$ kg^{-1} and the lowest (0.07cmol $_{(+)}$ kg^{-1}) exchangeable Na were obtained from the bottom and top layers of the lower topographic position, respectively. In the meanwhile, the highest exchangeable Mg content was recorded from the sub-surface of middle topographic position whereas the lowest content of it was also recoded from sub-surface but lower topographic position. This might be the indication of the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system.

The trends observed for the other exchangeable bases, however, not consistent. The variation in cation exchange capacity as a result of the interaction effect of soil depth and topographic position was significant at ($P<0.05$). The highest (40cmol (+) kg^{-1}) value of mean CEC was found under the lower depth of the lower topographic position whereas the lowest (26.9cmol (+) kg^{-1}) value of CEC was observed at upper depth of upper topographic position (Table 4). The highest CEC in the lower topographic positions could be the result of high pH, while the lowest CEC at upper topographic position could be rated as high in accordance with Landon (2014).

The CEC of the soils did not follow consistent trend across topography. Generally, the lower topographic positions had higher CEC value than those on the upper and middle topographic positions. The high CEC results obtained in the study area suggested that the soils of the study area have good nutrient retention and buffering capacity as was also suggested by Mulugeta *et al. (*2018).

Table 4. Interaction Effect of Topography and Soil Depth.

TOP	Soil Depth (cm)	Physical Properties					Chemical Properties									
		Sand	Silt	Clay	BD (g cm^{-3})	TP (%)	pH- (H_2O)	AP (ppm)	OC	TN	CEC	Na	K	Ca	Mg	PBS (%)
		(%)							(%)		Cmol $_{(+)}$ kg^{-1}					
UTP	0-20	39.7^{a}	22.2^{d}	38.1	1.01	62	5.1^{c}	4.1^{c}	3.7^{b}	0.30^{b}	26.9^{c}	0.164	1.07^{bc}	6.6^{c}	6.4	60.3^{a}
	20-40	29.6^{bc}	35.3^{b}	35.1	0.92	65.4	6.4^{a}	3.7^{d}	2.7^{c}	0.24^{c}	34.0^{b}	0.16	1.2^{bc}	9.4^{b}	7.3	52.5^{ab}
MTP	0-20	31.4^{abc}	40.0^{a}	28.6	0.98	62.2	5.05^{c}	4.7^{a}	3.6^{b}	0.32^{b}	34.2^{b}	0.15	0.58^{d}	6.8^{c}	6.0	39.6^{c}
	20-40	32.2^{abc}	30.4^{bc}	37.4	1.05	60	6.03^{b}	4.1^{c}	2.71^{c}	0.27^{c}	38.6^{ab}	0.08	0.91^{cd}	8.4^{bc}	7.4	43.4^{bc}
LTP	0-20	35.6^{ab}	28.8^{c}	35.6	0.93	64	5.1^{c}	4.97^{a}	4.1^{a}	0.36^{a}	38.7^{ab}	0.07	1.40^{b}	10.3^{b}	7.1	46.6^{bc}
	20-40	24.7^{c}	35.3^{b}	40	0.91	65.4	6.5^{a}	4.4^{b}	2.71^{c}	0.24^{c}	40^{a}	0.19	2.88^{a}	12.6^{a}	5.5	57.9^{a}
LSD (0.05)		**5.0**	**4.0**	**NS**	**NS**	**NS**	**0.20**	**0.24**	**0.39**	**0.03**	**4.8**	**NS**	**0.38**	**2.23**	**NS**	**10.1**
CV (%)		26.7	29	20.4	14.4	12	6.76	14.9	19.7	19.1	12.8	21	16	28.9	25	29.9

Means within a column followed by the same letter are not significantly different at 5% level of probability.CV = Coefficient of variation, LSD = Least significant difference. UTP= Upper topographic position, MTP= Middle topographic position, LTP=Lower topographic position.

4.5. Interaction Effect of Land Use, Soil Depth and Topography on Soil Physical and Chemical Properties

The analysis of the variance showed that exchangeable bases and cation exchange capacity were significantly ($P< 0.05$) affected by the interaction of land use, soil depth and topographic position (Table 5). The highest mean exchangeable value of Ca (16 cmol (+) kg^{-1}) was found in the bottom layer of soils under the enset land use at the lower topographic position, while the lowest value (6cmol (+)kg^{-1}) was recorded at the surface layers of soils under the cultivated and enset land use types of the upper topographic position.

In this study, exchangeable calcium showed significant ($P< 0.05$) and positive correlation (r = 0.17, 0.52, 0.44*, and 0.63***) with sand OC and CEC, Na and K, respectively **(**Table 5) which might be due to its source from organic matter and it is one of the most abundant basic cations surrounding the colloidal soil surface with higher charge density. The highest mean exchangeable Mg (10.3cmol (+)kg^{-1}) was found in the bottom layers of soils under the enset land use of the lower topographic position while the lowest value (4.3cmol (+)kg^{-1}) was recorded at the surface layer of soils under the cultivated land use types at the upper topographic position. The value of exchangeable magnesium in the study area was significantly ($P< 0.05$) and strongly positively correlated (r = 0.05, 0.33*** and 0.21**) with, CEC, Na and K, respectively (Table 5).

The highest mean exchangeable K (5.85 cmol (+) $kg^{-1}$was found in the bottom layers of soils under the enset land use under the lower topographic position, while the lowest value (0.28cmol (+) kg^{-1}) was recorded at the surface layers of soils under the cultivated land use types at the upper topographic positions. The highest Na content (0.7 cmol (+) kg^{-1}) was recorded at sub-surface layer of the enset land under lower topographic position. However, the lowest Na content (0.01cmol (+) kg^{-1}) was recorded at the surface layers of cultivated and grazing lands under upper topographic position. Similar value of Na (0.01 cmol (+) kg^{-1}) was recorded at surface layer of enset land under middle topographic position. This shows the existence of some erosion from the upper topographic position and subsequent deposition mainly at the lower position and downward leaching of this cation within the soil system. Similar trends were observed for the other exchangeable bases. In the study area, Ca and Mg were the dominant cations in the soil. This agrees with the finding of Fassil and Yamoah (2009) who indicated that in neutral Vertisols the exchangeable sites are mainly occupied by Ca and Mg and to small extent by K and Na.

Following exchangeable bases ratings suggested by FAO (2006), the soils were high to very high in their K, Ca, and Mg contents and rated from low to medium in exchangeable Na. The ranges of mean exchangeable K values observed in this study shown that K^+ was above the critical level (0.38 cmol (+)/kg) for the production of most crop plants as indicated by Barber (1984). In general, this indicated that there was no deficiency of K for production of crops in the study area. The variation of mean cation exchange capacity (CEC) as a result of the interaction effect of land use, soil depth and topographic position were significant ($P \leq 0.05$) (Table 5).

Following this, the highest mean CEC (41 $cmol_{(+)}$ kg^{-1}) was registered in the bottom layer of soils of grazing land use type at the lower topographic position followed by(40.3$cmol_{(+)}kg^{-1}$which was registered in bottom layer of cultivated land use in lower topographic position whereas the lowest value (25 $cmol_{(+)}$ kg^{-1}) was observed at the surface layers of soils under the enset land use type in the upper topographic position. The highest CEC in the bottom layers of all land uses at the lower and middle topographic positions could be the result of the high clay content accumulation, whilst the lowest CEC at the surface layers of all land uses at the upper topographic position could be the result of leaching and downward movement of clay particles as was also reported by Fassil and Yamoah (2009), Nega and Heluf (2009) and Deekor (2012). As per the ratings suggested by FAO (2006), the CEC of the soils of study area qualified the range of high to very high across the different land uses and soil depth along the toposequnce.

Results of the statistical analysis revealed that percent base saturation varied significantly ($P \leq 0.05$) as a result of the interaction effect of land use, soil depth and topographic position (Table 5). The base saturation of the soils also varied following the trends exhibited by the exchangeable bases. Accordingly, the highest (86%) of PBS was recorded at enset land of lower topography in (20-40 cm) depth of soil and the lowest (31%) value of

PBS was recorded at grazing land of middle topography at (0-20 cm) depth of soil. The trends showed for the percent base saturation, however, were not constant due to the effects of exchangeable bases and cation exchange capacity.

The factors that affect the basic cations could also affect the percent base saturation. The percent base saturation values ranged from 31 to 53.5% at the surface layers and 36 to 86% at the bottom layers. The trends showed for the percent base saturation, however, were not constant due to the effects of exchangeable bases and cation exchange capacity. The value of percent base saturation in the study area was highly significantly ($P \leq 0.05$) and strongly positively correlated ($r = 0.61^{***}$, 0.51^{***}, 0.21^{**} and 0.38^{***}) with K, Mg, Na and Ca, respectively.

Table 5. The Interaction Effects of Land Use, Soil Depth and Topography.

TOP	LU	Soil Depth	Physical Properties				chemical Properties								
		(cm)	Sand	Silt	Clay	BD (g cm^{-3})	pH (H_2O	OC	TN	CEC	Na	K	Mg	Ca	PBS
			(%)					(%)		cmol$_{(+)}$ kg^{-1}					(%)
UTP	Cultivated	0-20	32.1	31	36.9	0.98	5.4^{de}	3.4	0.31^{cde}	26.5^{de}	0.01^{d}	0.28^{g}	4.3^{d}	6.0^{f}	36de
		20-40	28.8	35.8	36	0.89	5.2^{de}	3.29	0.3^{cde}	33.8^{abcd}	0.07^{cd}	0.42^{g}	5.3^{bcd}	6.3^{ef}	41.3^{cd}
	Grazing	0-20	32.4.	33.6	34	1.1	5.2^{de}	3.36	0.31^{cde}	29.2^{cde}	0.01^{d}	0.32^{g}	8.0^{abcd}	7.3^{cde}	53.5^{bc}
		20-40	32.3	33.7	34	1.05	5.3^{de}	3.16	0.29^{cde}	31.9^{bcde}	0.18^{cd}	0.45^{g}	8.3^{abc}	9.0^{ab}	61^{b}
	Enset	0-20	35.6	31.4	33	0.96	5.6^{de}	3.4	0.31^{cde}	25.0^{e}	0.41^{abc}	2.61^{bc}	6.6^{abcd}	6.0^{f}	47^{bcd}
		20-40	29.6	36.4	34	0.82	5.7^{de}	3.5	0.3^{cde}	37.6^{ab}	0.24^{cd}	2.77^{b}	8.3^{abc}	10^{bc}	61^{b}
MTP	Cultivated	0-20	33.9	33.1	33	0.83	5.7^{de}	3.4	0.3^{cde}	33^{abcd}	0.10^{cd}	0.55^{g}	8.0^{abcd}	6.7^{cde}	45.6^{cd}
		20-40	36	29	35	1.01	5.5^{de}	3.3	0.28^{cde}	39.3^{ab}	0.0.08^{cd}	0.60^{g}	9.7^{ab}	7.3^{c-f}	43.3^{cd}
	Grazing	0-20	33.9	33.9	32.2	0.98	5,0^{de}	3.26	0.3^{cde}	36.6^{abc}	0.12^{cd}	0.30^{g}	4.6^{cd}	6.3^{ef}	31^{e}
		20-40	35.4	32.6	32	1.1	5.2^{de}	3.18	0.29^{cde}	38.6^{ab}	0.24^{cd}	0.70^{g}	7.0^{abcd}	8.0^{cde}	40de
	Enset	0-20	33.7	33.3	33	1.13	5.4^{de}	3.32	0.31^{cde}	32^{abcde}	0.1^{d}	0.90^{fg}	5.3^{bcd}	7.6^{cde}	42^{cd}
		20-40	33.1	35.9	31	1.06	5.4^{de}	3.29	0.29^{cde}	38^{ab}	0.04^{d}	1.44^{ef}	6.3^{bcd}	13.0^{a}	47^{bcd}
LTP	Cultivated	0-20	33.2	32.8	34	0.98	5.9^{de}	3.2	0.29^{cde}	35.6^{abc}	0.01^{d}	0.34^{g}	4.6^{cd}	10^{bc}	40de
		20-40	29.4	34.6	36	0.8	5.2^{de}	3.07	0.28^{cde}	40.3^{a}	0.26^{bcd}	0.36^{g}	4.6^{cd}	11^{bc}	42.3^{cde}

	Grazing	0-20	32.4	33.6	34	0.9	5.2^{de}	3.39	0.3^{cde}	39^{ab}	0.12^{cd}	1.79^{de}	5.3^{bcd}	10^{bc}	49.3^{bcd}
		20-40	32.4	33.6	34	0.91	5.4^{de}	3.2	0.29^{cde}	41^{a}	0.6^{ab}	2.42^{bcd}	6.6^{abcd}	11^{bc}	52^{bcd}
	Enset	0-20	32.3	33.5	34.2	0.9	5.3^{de}	3.4	0.3	39.3^{ab}	0.09^{cd}	2.06^{cde}	6.6^{abcd}	10.3^{bc}	48.3^{bcd}
		20-40	34.6	34.3	31.1	1.03	5.8^{de}	3.06	0.29	39.3^{ab}	0.71^{a}	5.85^{a}	10.3^{a}	16^{a}	86^{a}
LSD (0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**4.8**	**0.3**	**0.08**	**3.7**	**3.7**	**7.6**
CV (%)			29	19	23	19	21	12.7	11.7	14.2	14	30.5	28	21.5	22.3

Means within a column followed by the same letter are not significantly different at 5% level of probability.CV = Coefficient of variation, LSD = Least significant difference. UTP= Upper topographic position, MTP= Middle topographic position, LTP=Lower topographic position.

Table 6. Simple Linear Correlation Coefficient on Selected Soil Physical and Chemical Properties Measured with Each Other, Between Land Uses, Soil Depths and Topographic Positions.

	Sand	Silt	Clay	BD	TP	PH	OC	OM	TN	CEC	Na	K	Mg	Ca	AP	PBS
Sand	1	-.107	-.702**	-.349	-.037	-.067	-.064	.173	-.109	-.160	-.137	.036	-.002	.145	.132	.191
Silt		1	-.632**	-.033	-.144	-.053	-.046	.016	.125	-.137	-.148	-.333	-.160	-.144	.217	.152
Clay			1	.295	.132	.090	.083	-.146	-.005	.223	.213	.210	.116	-.010	-.258	-.257
BD				1	-.045	-.588**	-.589**	-.431*	-.425*	-.222	-.101	.088	.153	-.257	-.106	-.319
TP					1	-.090	-.093	-.152	-.272	.631**	.738**	.298	.800**	.777**	-.747**	-.759**
pH						1	.999**	.712**	.828**	.256	-.033	-.072	-.326	.116	.059	.424*
OC							1	.718**	.834**	.253	-.032	-.072	-.325	.116	.064	.428*
OM								1	.677**	-.122	-.361	-.302	-.253	-.190	.018	.269
TN									1	-.009	-.195	-.405*	-.439*	-.098	.367	.586**
CEC										1	.665**	.500**	.563**	.681**	-.650**	-.485*
Na											1	.585**	.556**	.891**	-.590**	-.494**
K												1	.232	.574**	-.535**	-.341
Mg													1	.556**	-.681**	-.780**
Ca														1	-.574**	-.408*
AP															1	.885**
PBS																1

DF = Degrees of freedom; * = Significant at (P = 0.05); ** = high Significant at P = 0.01;***= highly significant

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. SUMMARY AND CONCLUSION

Successful agriculture requires the sustainable use of soil resource, because soils can easily lose their quality and quantity within a short period of time for many reasons. A success in soil management to maintain the soil quality depends on the understanding of how the soil responds to agricultural practices over time. Therefore, this research was conducted with the objective to investigate the effect of different land use types and soil depth on selected physical and chemical properties of soil along different topographic positions. Before soil sample collection, field observation and reconnaissance survey were carried out in order to observe the general nature of the relief of the watershed and major land use types.

Accordingly, the entire watershed area was divided into three topographic positions (upper, middle, and lower) and major adjacent land use types (cultivated land, grazing land and enset land) were identified. The farmers categorization of the topography was based soil fertility status, monoculture crop farming; Ansewa (higher elevation), Gbeteder (middle elevation), Yegrema (lower elevation).A total of 54 composite surfaces (0-20 cm) and subsurface (20-40 cm) soil samples and undisturbed samples were collected from the three land use types and topographic positions and their replications for laboratory analysis of selected physical and chemical properties of the soils of the watershed for analysis of pertinent soil properties.

The interaction effects of land use, soil depth and topography indicated that the highest (6.8) and lowest (4.46) pH (H_2O) value were recorded at the grazing land of lower depth at lower topographic position and cultivated land of upper depth of soils at upper topographic position, respectively. Available phosphorus of soils in the study area showed variations as a result of different land use types, soil depth practiced on different topographic positions. The highest mean exchangeable potassium, (5.85cmol $_{(+)}$ kg^{-1}) and sodium (0.7cmol $_{(+)}$ kg^{-1}) were found in the bottom layers of soils under the enset land use at the lower topographic position, while the lowest values K (0.28(cmol $_{(+)}$ kg^{-1}) and Na (0.04cmol$_{(+)}$ kg^{-1}) were recorded at the surface layers of soils under the cultivated land use types at the upper topographic Positions. This indicated the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system.

The highest mean CEC (41 $cmol_{(+)}$ kg^{-1}) was registered in the bottom layers of soils of enset land use types at the lower and middle topographic positions, whereas the lowest values (25 $cmol_{(+)}$ kg^{-1}) were observed at the surface layers of soils under the enset land use types at the upper topographic position. The base saturation of the soils also varied following the trends exhibited by the exchangeable bases. Accordingly, the highest (86%) and the lowest (30 %) value of PBS were recorded enset and grazing land of lower upper and middle topography, respectively. The trends showed for the percent base saturation, however, were not constant due to the effects of exchangeable bases and cation exchange capacity. The factors that affect the basic cations also affect percent base saturation.

Soil fertility was low in cultivated lands than enset and grazing lands. Therefore, the soils of the cultivated land in all topographic positions require more attention in order to sustain the agricultural activity in the area. These studies reinforce the sustainable crop production on these soils will require the maintenance of the productive potentials of the soils by continuous use of fertilizers and continuous use of compost, crop rotation, fallowing and intercropping leguminous crops with cereals. In general, most of the measured soil properties were measured better in enset than in other land use soils and the lower topographic positions than the upper and middle ones.

5.2. RECOMMENDATION

From this research result the following recommendations could be forwarded.

There should be an improvement of the fertility status of cultivated lands by applying nutrient rich amendments (indigenous practices) such as traditional agro forestry, composting, crop rotation, intercropping leguminous crops with cereals biomass transfer, Amendment of lime and improved practices such as chemical and organic fertilizers, improved fallows, improved crop variety etc. Therefore, reducing the intensity of cultivation and adopting integrated soil fertility management could maintain the

Finally, to increase the soil fertility techniques complemented with strong land use policy and alternative rural energy sources should be integrated into a strategy for sustainable agricultural development in the region, governmental and non-governmental rural development programs and strategies should be flexible in responding to the various agro-ecological zones, local resource endowment and farmers capacity to invest in affordable integrated soil fertility management technique

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7. APPENDIX

Appendix Table 1. Ten Years (2003-2012 EC.) Monthly Total Rains Falls (Mm) And Mean Annual Minimum And Maximum Temperature (^{O}C) Indibir Station 47 Km Away From Study Area.

Rainfall												
Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2003	13.9	30.4	45.9	108.9	12.8	147.0	169.4	89.6	41.0	7.0	2.4	18.3
2004	35.1	11.8	37.1	71.4	50.2	105.6	243.3	267.5	169.3	104.6	7.8	13.9
2005	35.4	0.0	31.7	34.6	30.8	181.7	334.5	227.9	181.2	50.3	21.0	2.6
2006	7.7	33.8	143	89.0	140	177.6	253	296.7	186.5	75.8	6.0	7.4
2007	43.5	89.9	98.4	68.4	148	146.3	249.8	256.4	298.7	46.5	0.0	0.0
2008	2.5	6.8	7.3	94.3	235	183.0	319.8	226.0	117.0	69.0	80.5	0.0
2009	41.7	34.2	50.2	63.2	56.9	82.8	327.4	248.6	73.8	57.3	2.8	51.0
2010	25.8	58.2	68.0	103.7	252	196.0	375.4	285.9	131.7	18.9	7.4	20.1
2011	0.0	0.0	77.9	58.4	238	314.6	257.6	323.1	117.4	8.3	41.3	0.0
2012	2.0	0.0	7.4	46.9	49.5	224.5	256.5	221.1	168.8	19.3	0.0	4.2
Ave	20.8	26.5	56.8	73.9	121	176.0	279.0	244.3	148.5	45.7	17.0	11.8

Temperature

Temperature													Ave
T.Max	24.9	25.6	24.6	25.0	24.6	22.4	20.4	20.8	22.3	23.5	25.2	23.8	23.6
T.Min	8.2	9.0	10.4	11.6	10.2	11.8	11.3	11.0	10.7	8.2	7.6	5.3	9.6

Source: Geto woreda AGP (agriculture gross production) from Hawassa Metrology Station 2009 E.

Appendix Table 2. Co-ordinate Points of Soil Sampling Point

	X (Easting)	Y (Northing)	Z (elevation (m)
1	7^{0}54'301"	37^{0}59'764"	2818
2	7^{0}54'302"	37^{0}59'765"	2816
3	7^{0}54'303"	37^{0}59'767"	2817
4	7^{0}54'305"	37^{0}59'769"	2815
5	7^{0}54'306"	37^{0}59'768"	2813
6	7^{0}54'307"	37^{0}59'771"	2812
7	7^{0}55'309"	37^{0}59'774"	2808
8	7^{0}55'311"	37^{0}59'784"	2805
9	7^{0}55'310"	37^{0}59'785"	2806
10	7^{0}56'709"	37^{0}58'233"	2676
11	7^{0}56'710"	37^{0}58'234"	2675
12	7^{0}56'711"	37^{0}58'231"	2674
13	7^{0}56'716"	37^{0}58'235"	2672
14	7^{0}56'717"	37^{0}58'236"	2671
15	7^{0}56'719"	37^{0}58'237"	2667
16	7^{0}57'720"	37^{0}57'231"	2659
17	7^{0}57'721"	37^{0}57'234"	2655
18	7^{0}57'722"	37^{0}57'233"	2654
19	7^{0}59'753"	37^{0}56'781"	2472
20	7^{0}59'755"	37^{0}56'783"	2472
21	7^{0}59'757"	37^{0}56'784"	2471
22	7^{0}58'754"	37^{0}55'785"	2470
23	7^{0}58'753"	37^{0}55'786"	2468
24	7^{0}58'752"	37^{0}55'787"	2467
25	7^{0}59'885"	37^{0}56'780"	2479
26	7^{0}59'886"	37^{0}56'777"	2478
27	7^{0}59'863"	37^{0}56'782"	2472

Appendix Table 3. Mean square values for Particle Size Distribution

Source of variation	Degree of freedom	Mean squares		
		Sand	Clay	Silt
		(%)		
LU*SD	2	35.9 *	34.7 ns	134.5*
LU*TOP	4	65.04***	53.47***	81.1*
SD*TOP	2	191 *	82.5ns	418.9***
TOP*SD*LU	4	147.04ns	95.54 ns	340ns
Error	34	96.29	72.59	38.16
CV (%)		30.41	24.3	19.01

DF = Degrees of freedom; * = Significant at (P = 0.05); ** = high Significant at P = 0.01;***= highly significant, Ns = Non-significant; CEC = Cation exchange capacity; SD =Soil Depth, LU= Land Uses, TOP= Topography

Appendix Table 4 Mean square values for pH-H_2O

Source of variation	Degree of freedom	Mean squares		
		pH-H_2O		
		(%)		
LU*SD	2	**0.012***		
LU*TOP	2	**0.06ns**		
SD*TOP	2	0.195*		
TOP*SD*LU	4	0.130ns		
Error	34	0.045		
CV (%)		3.73		

DF = Degrees of freedom; * = Significant at (P = 0.05); ** = high Significant at P = 0.01;***= highly significant ,Ns = Non-significant; CEC = Cation exchange capacity ;SD =Soil Depth , LU= Land Uses ,TOP= Topography

Appendix Table 5. Mean square values for Organic Carbon, Total Nitrogen, Available Phosphorus and Percent of Base Saturation

Source of variation	Degree of freedom	Mean squares OC	TN	AP	PBS
		%	%	ppm	%
LU*SD	2	1.11*	0.005***	0.12***	116*
LU*TOP	4	0.32***	0.006*	1.79*	519*
SD*TOP	2	0.19***	0.005***	0.024***	414*
LU*TOP*SD	4	1.60ns	0.009ns	0.265ns	456*
Error	34	0.16	0.001	0.073	131.5
CV (%)		12.4	11.4	6.18	22.89

DF = Degrees of freedom; * = Significant at(P = 0.05); ** = high Significant at P = 0.01;***= highly significant ,Ns = Non-significant; CEC = Cation exchange capacity ;SD =Soil Depth , LU= Land Uses ,TOP= Topography

Appendix Table 6 Mean square values for Ca, K, Mg, Na, and CEC

Source of variation	Degree of freedom	Mean squares Ca	K	Mg	Na	CEC
		(cmol$_{(+)}$ kg^{-1})				
LU*SD	2	22.3ns	2.5***	3.12ns	0.08**	21.6ns
LU*TOP	4	2.01**	4.04**	24.04*	0.05***	4.5ns
SD*TOP	2	1.72ns	2.36*	0.57ns	0.3ns	32.5*
LU*TOP*SD	4	3.11***	1.85*	2.26*	0.04*	15.5*
Error	34	0.16	0.001	0.073	131.5	0.19
CV (%)		25	29.79	28	27	14

Appendix Table 7. General rating of some chemical and physical properties

Organic matter, organic carbon, total nitrogen ,available phosphorus and CEC

	Very low	Low	Medium	High	Very high
OM %	< 1.0	1.0-2.0	2.1-4.2	4.3-6.0	> 6.0
OC %	< 0.6	0.6-1.25	1.26-2.5	2.51-3.5	> 3.5
TN %	< 0.1	0.1-0.2	0.21-0.5	> 0.5	
AP mg/kg (Bary-Kurtz)		< 7	7-20	>20	
CEC Comlc/kg	< 6.0	6.0-12	12.1-25.0	25.1-40.0	> 40

Source: Msanya *et al.* (1996) and Kileo (2000).

pH- H2O< 7.0, determine AP by Bary-Kurtz method and pH H_2O >7.0, use Olsen method.

pH<7.5, determine CEC using 1M ammonium acetate and pH >7.5 use 1M sodium acetate.

C/N Ratio is an indication of quality of OM (8-13: good quality, 14-20: moderate quality, >20: poor quality).

Appendixes 8. Ratings of exchangeable Ca, Mg, Na, K, CEC and PBS in the soil

CEC($cmolkg^{-1}$)		Ca ($cmol_{(+)}$ kg^{-1}	Mg ($cmol_{(+)}$ kg^{-1}	Na ($cmol_{(+)}$ kg^{-1}	K ($cmol_{(+)}$ kg^{-1}	PBS (%)
Rating		Rating	Rating	Rating	Rating	
V/ Low	> 13	< 2	< 0.3	< 0.1	<50	0-20
Low	13-15	2-5	0.3-1	0.1-0.3	50-100	20-40
Medium	15-25	5-10	1-3	0.3-0.5	100-250	40-60
High	25-40	10-20	3-8	0.5-1	250-400	60-80
V/High	>40	>20	>8	> 1	>400	> 80

Source Beernaert (1990), Tekalign (1991), FAO (2006), Hazelton and Murphy (2007

2. Soil reaction (pH)

Extremely acid	< 4.5	Neutral	6.6-7.3
Very strongly acid	4.5-5	Mildly alkaline	7.4-7.8
Strongly acid:	5.1-5.5	Moderate alkaline	7.9-8.4
Medium acid	5.6-6	Strongly alkaline	8.5-9.0
Slightly acid	6.1-6.5	Very strongly alkaline	> 9.0

Source: Msanya *et al.* (1996) and Kileo (2000).