SOIL PROPERTIES, CHARACTERIZATION AND CLASSFICATION OF SOILS ALONG THE BONEYA KETO TOPOSESEQUENCE AND LAND USE TYPES OF SILTE ZONE, SOUTHERN ETHIOPIA

MSc. THESIS

BY

SALYA HASSEN

JANUARY, 2020

WOLKITE UNIVERSITY

SOIL PROPERTIES, CHARACTERIZATION AND CLASSIFICATION OF SOILS ALONG THE BONEYA KETO TOPOSESEQUENCE AND LAND USE TYPES OF SILTE ZONE, SOUTHERN ETHIOPIA

A THESIS SUBMITTED TO THE SCHOOL OF NATURAL RESOURCES MANAGEMENT

WOLKITE UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE (SOIL SCIENCE)

BY

SALYA HASSEN

JANUARY, 2020

WOLKITE UNIVERSITY,WOLKITE, ETIHOPIA

SCHOOL OF GRADUATE STUDIES

WOLKITE UNIVERSITY

As Thesis research advisors, we hereby certify that we have read and evaluated the thesis entitled "soil properties, characterization and classification of soils along the Boneya Keto toposequence and land use types of Silte Zone, Southen Ethiopia" prepared under our guidance by Salya Hassen and we recommend that it be submitted as fulfilling the thesis requirement.

Alemayehu Kiflu(PhD)	_______________	________________
Name of Major Advisor	Signature	Date
Fanuel Laekemariam (PhD)	_______________	________________
Name of Co-advisor	Signature	Date

As members of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Salya Hassen and examined the candidate. We recommended that the Thesisbe accepted as fulfilling the requirement for the degree of Master of Science in Agriculture (Soil Science).

___________________	_____________	_______________
Name of Chairperson	Signature	Date
______________________	_____________	______________
Name of Internal Examiner	Signature	Date
________________________	_____________	_____________
Name of External Examiner	Signature	Date

Final approval and acceptance of the Thesis is contingent upon the submission of the final copy to the Council of Graduate Studies through the School/Department Graduate Committee of the candidate's major School/Department.

DEDICATION

This thesis is dedicated to my father Mr. Hassen Abdella and my mother Mrs. Kedija Shifa, who through the last several years, celebrated the best of days with me and ceaselessly encouraged and strengthened me on the worst of days.

STATEMENT OF THE AUTHOR

I declare that this thesis is my authentic work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an MSc degree at Wolkite University and is deposited at the University Library to be made available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgment of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department/school or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

Name: Salya Hassen Abdela Signature______________

Place: Wolkite University

Date of Submission:_______________

ACKNOWLEDGEMENTS

The author extends his deepest gratitude to Dr. Alemayehu Kiflu, my major advisor, for his ever-unforgettable warm welcome at his office, adding valuable comments, giving directions, suggestions and moral encouragement starting from the inception to the accomplishment of the study. I also extend my deepest gratitude to Dr. Fanuel Laekemariam, my co-advisor, for his guidance in the field study, laboratory arrangement and technical comments. The author likes to express his gratitude to all his friends, Mr.Hassen Sebre and Bedru Surur, Mr. Rahmato Wabela, Mr. Bishri Mohammed, Terefa Shewangizew and Nureddin Kemal and Nurato Hassen, who helped me in many ways during my study. The author would also like to thank the administration of Lenfaro and Misrek Silti district and Hawassa University Plant and soil analysis laboratory.

My heartfelt gratitude and deepest appreciation also goes to my lovely partner Siti Ahmed, for her incredible moral supports and initiation to continue my study. Above all, the author would like to be grateful for His loving and kindness of the Almighty Allah in bestowing him health, strength, patience and protection throughout his postgraduate studies and thesis work.

LIST OF ABBREVIATIONS

Av. P	Available Phosphorus
AWHC	Available Water Holding Capacity
Bd	Bulk Density
C: N	Carbon to Nitrogen Ratio
CEC	Cation Exchange Capacity
DTPA	Diethylene Triamine Pentaacetic Acid
ECEC	Effective Cation Exchange Capacity
EC	Electrical Conductivity
EMA	Ethiopian Mapping Agency
Exch. Al	Exchangeable Aluminum
EC	Electrical Conductivity
FAO	Food and Agriculture Organization of the United Nations
FC	Field Capacity
MA	Ethiopian Mapping Agency
m.a.s.l.	Meters above sea level
OC	Organic carbon
OM	Organic Matter
PWP	Permanent Wilting Point
PBS	Percent Base Saturation
RSG	Reference Soil Group
SNNPR	South Nation Nationality and People’s Region
TN	Total nitrogen

WRB	World Reference Base for soil resources
YR	Yellow, Red

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN THE APPENDIX

Soil Properteis, Characterization and classification of Soils along the Boneya Keto toposequence and Land Use Types of Silte Zone, Southern Ethiopia

By: SalyaHassen

Major advisor: Alemayehu Kiflu (PhD.)

Co-advisor: Fanuel Laekemariam (PhD)

ABSTRACT

Characterizing and classifying the behavior of soil based on differences in topography and land use systems practiced is useful for sound soil management. To this effect, the influence of topographic positions (lower, middle, and upper) and land uses (cultivated land and grassland) on soil physicochemical characteristics were assessed and thereby classify the major soil types of the study area. Accordingly, a total of three pedons, one at each topographic position, were freshly opened and described for their morphological properties in the field. The soil samples from each of the identified horizons and surface composites (0-20cm) were collected from each land use at each topographic position and physicochemical properties of the soils were characterized in the laboratory following standard procedures. The result revealed that clay, silt, sand, EC, exchangeable potassium, CEC, and Fe were significantly ($P \leq 0.05$) affected by topographic positions. Accordingly, the significantly highest concentration of clay and silt fraction, soil EC and exchangeable potassium were observed at lower topographic positions whereas, significantly higher sand content, CEC, Fe and Mn were recorded at upper topographic positions. Similarly, EC, Mg, K, Na, CEC, Fe, Mn and Zn were significantly ($P \leq 0.05$) affected by land uses in which significantly highest of these parameters recorded under grassland. The observed relationship between topographic features, soil characteristics, and land use types will help to advance the understanding of soil-land use-landscape relation in the study area, and showed a less costly way of acquiring soil information. The results of the in-situ morphological description of the soil pedons followed by the laboratory analysis of the sampled horizons, soils were classified as Phaezomes Cambisols and Luvisols at upper, middle and lower topographic positions, respectively. Generally, surrounding landform and land use influenced soil properties, suggesting the need for different management practices for varying slope gradients and land uses for sustainable agricultural production.

Keywords: land use; pedon; physicochemical properties; topographic positions

1. INTRODUCTION

Soil is an important natural resource for agriculture, the basic economic source of Ethiopia. Agriculture is the mainstay of the national economy (Shimeles, 2012), on which livelihoods of the majority has been highly dependent on natural resources for centuries (Amsalu *et al.*, 2007). Agriculture, accounting for about 45% of gross domestic product (GDP) and 85% of total employment, is the dominant sector in the national economy of Ethiopia (CSA, 2010). Increasing population pressure expanded farming from gently sloping surfaces in the highlands to steeper slopes and marginal lands (Demel, 2001) which in turn have brought disturbance to the ecosystems, particularly soils that are the determinant factors of agricultural production and productivity.

In developing countries like Ethiopia where research funds are limited, the availability of pedogenic information and proper classification of soils will be greatly important in adopting well tested management technologies and landscape positions without going through the whole process of time consuming and expensive technology selection field trials as this will provide the basic information for sustainable agricultural planning. Nevertheless, sustainable soil managements that are based on the understanding of soil systems are not available for most parts of the country (Fikre, 2003).

Characterizing of soil physical and chemical properties is essential for proper use of soil resources on different topographic positions and speeding up technology transfer (Seid *et al*., 2017). A study conducted by Daniel and Tefera (2016) in Aba Midan Sub Watershed in Bambasi Wereda, West Ethiopia concluded that increasing extent of continuous and intensive cultivation with minimum conservation practices and erosion due to slope effect can further deteriorate soil properties and the control of such damaging effects would require proper soil conservation strategies such as proper land leveling, afforestation, crop rotation, fallowing, terracing and inclusion of restorative crops in cropping systems on these lands.

Several studies have been conducted to determine dominant controlling factors on soil properties within landscape (Fantaw et al., 2006; Mulugeta and Sheleme, 2010; Dinku et al., 2014). Dinku et al. (2014) regarded topography as the dominant factor influencing soil property variation along a toposequence due to its influence on runoff, drainage and soil erosion, and consequently on soil development along a toposequence of Ele watershed, Southern Ethiopia. Many soil properties including particle-size distribution, pH, organic carbon, total nitrogen, available phosphorus, exchangeable cations and cation exchange capacity vary with slope position (Mulugeta and Sheleme, 2010; Dinku et al., 2014; Teshome et al., 2016). On the other hand Teshome *et al* (2018) carried out study on characterization and classification of soils of Wolkite University research sites, Ethiopia argued that soils of the research sites were acidic with low status of available phosphorus, which need amelioration of soil acidity and nutrient management. Within the same context Endalkachew *et al* (2018) conducts study on the characterization and classification of soils of Yikalo Subwatershed in Lay Gayint District, Northwestern Highlands of Ethiopia stated that optimum rates of organic and inorganic amendments should be applied to reduce the level of soil acidity, and improve the fertility level of the soils for better crop production and productivity.

On the other hand study carried out by Lawal *et al.* (2013) reported that sand dominated the mineral fraction and its content in the surface horizon decreased down the slope, whereas silt content increased down the slope due to sorting by geological and pedogenic processes. Although organic carbon (OC), total nitrogen (TN) and available phosphorus (P) were rated high, TN and available P decreased down the slope. High cation exchange capacity (CEC) was an indication that the soils have high potential for plant nutrients retention.

The farmers in and around Siltie woreda, practices traditional land management and soil conservation with mixed farming systems. Despite their long standing traditional land management and soil conservation practices, which are still in use, the toposequance of their agricultural lands were not studied in the woreda. The information on characterization and classification of soil along the toposequance of Boneya Keto in relation to agricultural productivity were not well documented. Therefore, the present study was aimed to characterize and classify the soils of toposequance of Boneya Keto as well as to these the study provided detailed information on the morphological, physical and chemical characteristics. It is hoped that the study will provide valuable and baseline information on the soils and other land resources of the study area in developing a sound management plan for agricultural activity of toposequance of Boneya keto.

1.1.Statement of the Problem

vital role to understand the soil environment and its service (Nahusenay*et al.*, 2014). Soil fertility decline remains one of the most serious problems facing the world. Ethiopia has diverse soil resources largely because of its diverse topography, climatic conditions and geology (Abayneh, 2001). Due to these higher variations of soil, regional and small-scale studies seem to be inadequate in providing basic soil data that can help manage soils according to the local variability. Soil survey reports (FAO, 1984) have indicated that soil conditions show great variations across the regions, and that different soils require specific management practices. Several studies were indicated that characterization and classification of soils along the toposequence in small scale could not be enough to draw development planning at watershed level (Alemu and Tadele, 2018). Consequently, sustainable soil management practices that are based on the understanding of soil system are not available for most parts of the country.

However, the farmer's productivity constrained and continued decline of soil fertility and land degradation on smallholder farmers is partly attributed to inappropriate land use as a results of poor understanding of the soil resource base. Hence, there is a need to commence detailed soil characterization and classifications along the toposequence of toposequence of Boneya Keto. Lack of data to show the characteristics and classification of soil along the toposequence of the study site is an important limitation to the characterization and classification of soils. Unfortunately, the expected knowledge from farmers regarding to the characteristics and classification of soil along the toposequence is not considered for sustainable soil management practices that are based on the understanding of the soil system. Perhaps this study was carried out to identify the morphological, physical and chemical properties of the soil along the toposequence and classify the soils of the toposequence of Boneya Keto according to WRB Classification systems.

1.2.Objective

1.2.1. General Objective

The overall objective of this study is to characterize and classify soil along the toposequence of Boneya keto.

1.2.2. Specific objective

- To determine the influences of topography and land uses on physicochemical properties of the soil.
- To examine the morphological, physical and chemical properties of the soil along the top sequence of the study area.
- To classify the soils of the top sequence of Boneya Keto according to WRB Classification systems.

2.LITERATURE REVIEW

2.1. Overview of Soil

Soil is slowly renewable dynamic natural resource that determines the ultimate sustainability of any agricultural system. Water movement, water quality, land use, and vegetation productivity all have relationships with soil. Soils provide food, fodder and fuel for meeting the basic human and animal needs (Schoonover and Crim, 2015). Soils have diverse morphological, physical, chemical and biological properties. As a result, they differ in their responses to management practices, their inherent ability to deliver ecosystem services, as well as their resilience to disturbance and vulnerability to degradation (FAO, 2017). 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, 2004).

2.2. The Effect of Topography on Soil Properties

Topography influences soil properties through its effects on geomorphological, hydrological and biogeochemical processes (Webster *et al.,* 2011). It determines both the vertical redistribution of elements within soil profiles through leaching and laterally along slope gradients (Laekemariam *et al.*, 2016). Topography plays a vital role in biogeochemical processes which performs key environmental, economic and social functions (Griffiths *et al.*, 2009).Any spatial patterns depend on soil forming processes, our understanding of which is still limited, especially in regards to topographic effects. Soils vary in their characteristics primarily because of topography (Amhakhian and Achimugu, 2011) which modifies soil water relationships and large extent influences on rainfall, drainage, soil erosion, textural composition and other soil properties that affect plant growth within a field (Atofaratiet *et al.,* 2012). Topographic variability associated with crop production is an integrated reflection on soil properties and factors affecting agricultural productivity (Dinaburga *et al.,* 2010).

According to Buol *et al.* (2011), specific statements about the relationship between slope and soil property can be made only within specified geographic areas. This is probably due to variation in intensity and nature of soil forming factors. Within a specific geographic region, the following soil properties are commonly found to be relief related. These are depth of solum, thickness and organic matter content, relative wetness of the profile, color of the profile, degree of horizon differentiation, soil reaction, soluble salt content, kind and degree of "pan" development, temperature and characteristics of the materials. In similar study topographic attributes are also central to many ecological characteristics through their influence on both soil moisture and soil chemistry and there by affecting plant communities and their distribution on the landscape (Yimer *et al.,* 2006).

Study conducted by Amuyuo and Kotingo (2015) reported that Cultivation and slope gradients have marked influence in soil Properties as expressed in the distribution in soils along slope positions in the Obudu Mountains. However, the variation in soil properties in the area was not remarkable. Sand fractions were relatively uniform across the upper, middle and foot slope positions of the catena. But silt and clay were observed to record high values (22.14 %) and (28.75 %) in the lower segment of the slope within top layers while they exhibited irregular distribution at 15-30 cm of soil depth. In any case, sand particle fraction was the dominant inorganic fragment across the different slope complex.

Also, the distribution of soil pH across the upper, middle and foot slope positions was moderately acidic. But soil pH value was relatively high in the upper slope segment compared to other segments of the catena. The pH value at the upper slope position could probably be attributed to the site being covered with grasses. Since there is limited change in the vegetation and turning of the soil as compared to cultivated fields; this mean the pH is likely remain unaffected (Fungo *et al.,* 2011). On the contrary, the frequency of cultivation may result in a more repaid decomposition of organic matter and weakening of soil structure which later results in lowering of soil pH.

2.3. Soil Landform Relationships

Soils that vary with landscape are due to some combinations of microclimate, Pedogenesis and geological processes. In a given geographical location the landform, indirectly control most of the soil forming processes. Erosion processes are more intensive on the steeper slopes and convex landform; accumulation processes are concentrated on the flatter areas and concave landforms (Weigel, 1986). The same author described that due to the longer periods of high soil moisture, weathering processes are much more intensive in flatter and concave areas.

The most obvious relationship of soil properties to landform/topography probably occurs in humid regions where soils on nearly level areas reflect to have thicker solum than on sloppy land (Buol *et al.*,2011). Soils on the uplands commonly are well drained, whereas those in depressions are poorly drained and rich in clay and organic matter, with signs of various degrees of gleying.

2.4. Soil Characterization

Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005).

Previous studies indicated that made so far were mostly at small scale, which could not be applicable for site specific land use and soil management. Therefore, adequate knowledge on soil characteristics at large scale and or local watershed or farm level is essential in tackling specific and local problems of agricultural production (Hailu *et al.*, 2015). As the landscape is undulating, soil characteristics at different topographic positions differ.

2.4.1. Morphological Properties

Soil morphology, characterized by soil structural analysis in toposequence, facilitates the understanding of the topographic influence on the chemical, physical, hydrological and micro morphological attributes of soils. Micromorphology combined with other soil analyses helps in the integration and synthesis of soil processes, covering several hierarchical levels, from the landscape to the soil microstructure (Balasubramanian, 2017). In order to place a soil in its correct position in the classification system, a thorough knowledge of the morphological characteristics is necessary. Morphology of soil is the most important tool than physical and chemical properties of soil in soil classification because it is observed under natural undisturbed condition (Balasubramanian, 2017).

2.4.1.1. Soil Color

Soil color is one of the important basic properties which help to identify the kinds of soils and recognize the successions of soil horizons or layers in soil profiles. It has long been used for soil identification and qualitative measurements of soil properties and is a helpful field soil property for characterizing soil types (Noshadi *et al.*, 2013). According to Mohammed *et al*. (2005), in Jelo micro- catchments of the Chercher highlands of eastern Ethiopia, color characteristics showed a gradient pattern of variation from dark in up slope uncultivated soils through brown in foot slope, to black and/or dark brown in toe slope cultivated soils.

Nuga *et al.* (2006) reported that the variation in color matrix of soils could be attributed to the sequence of drainage condition and physiographic position. Hossain *et al*. (2011) stated that the alternate wetting and drying conditions in the soils resulted in the reduction and subsequent release of iron oxides, which were accumulated in the form of brown, light olive brown, dark brown and dark yellowish brown mottles in the middle zone of the profiles. In a similar way, Dinku *et al*. (2014) identified the color variation in the toposequence of Ele watershed southern Ethiopia thatvaried from dark red at upper slope to very dark gray at depression and indicating the influences of topography on soil color patterns through its effect on the rates of surface runoff, erosion and deposition.

Organic matter, water content and the presence and oxidation states of iron and manganese oxides influence soil color. Soils on hilly slopes are usually characterized by coarse-textured and are lighter in color while soils at lower slopes are fine in texture and darker in color due to the removal of organic matter and finer soil particles from the upper slopes in the case of the former, and their deposition at the lower slopes in the case of the latter (Dinku *et al* 2014; Sheleme, 2017).

2.4.1.2. Soil Structure and Consistence

The term structure relates to the arrangement of primary soil particles in to aggregates or peds. Soil structure is one of the soil physical properties, which is very sensitive to soil management practices. Ashenafi *et al.* (2010) reported that higher clay content could be reason for better development of soil structure. The soils at the foot slope had strong to moderate, fine to medium, sub angular blocky structure on the surface that changed to moderate to strong, medium to coarse angular blocky in the subsurface horizons (Mohammed *et al.,* 2005). According to the same authors, the toe slope soils dominantly consisted of strong to very strong, medium sub angular blocky on the surface and very strong, coarse to very coarse angular blocky in the subsurface horizons. The structure of the soil along the toposequence exhibited wide variability. The structure of the soil at the summit areas was weak to moderate, fine to medium, crumb while that of the soil at the toe slope was moderate to very strong, fine to very coarse blocky structure at the surface (Mebit, 2006).

Soil consistence refers to the manifestations of the physical forces of cohesion and adhesion acting within the soil at a range of soil moisture contents (Lal and Shukla, 2004). Most of time consistence is described for three moisture levels; wet, moist, and dry (Buol *et al.,* 2011). It is a term used to describe the action of physical forces of cohesion and adhesion on the attributes of soil material at these moisture contents that determines the resistance of soil material to crushing or rupture and its ability to change the shape or to be molded. Ashenafi *et al.* (2010)

stated that friable consistency of soils indicates soils are workable at appropriate moisture content and lack of very sticky and very plastic consistency.

2.4.2. Physical Properties

The physical properties of the soil are influenced by the size, proportion, arrangement and mineral composition of the soil particles. Soil physical properties also largely determine the manner in which it can be used, water and air supplying capacity to plants. Some morphological and physical properties of the soils are highly influenced by the land use system and its management, whereas others by differences and/or the origin (geology) from which they were formed. For example, many soil physical properties changed with cultivation, intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses (Mesifin, 1998).

2.4.2.1. Soil Texture

The soil solid phase as a whole can be characterized in terms of the relative proportions of its particle size groups called soil separates. The relative size range of the soil particles is expressed by the term texture, which, qualitatively, refers to the fineness or coarseness of the soil. Quantitatively, it refers to the relative proportions of the different particle size fractions, specifically referred to as sand, silt and clay (with organic and cementing materials removed) (Chaudhary, 2002; Hillel, 2004). Soil texture affects a number of physical and chemical properties of soils including infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Gupta, 2004).

According to Samuel (2006), the texture of the surface soil at the back slope profile was sandy loam in back slope areas at which sand was the dominant soil separate (61%), whereas it was clay in texture throughout the profile except loam soil texture (23% clay) occurred at the depth of 131-194 cm of the foot hill slope soil. However, textural classes of the surface horizons were clay for all the landforms except for the back slope, which was clay loam. Clay percentage increased and sand decreased from the summit area to the toe slope. Although texture is an inherent soil property, slope may contribute directly for the change in particle size distribution particularly in the summit area as a result of clay removal through erosion and deposition at the toe slope (Mebit, 2006). On the other hand study carried out by Mohammed *et al*. (2005), the soil textural class varied with positions of soils in the landscape. It ranged from silt clay loam in the upper slopes to clayey in the lower slope positions; suggesting that amount of clay increases down slope.

2.4.2.2. Particle and Bulk Densities

The fact that the bulk density is lower at the surface than the under-lying horizons observed in the toe slope and lower foot slope area soils were in agreement with the established fact that bulk density is lowest at the surface due to high organic matter content (Mebit, 2006; Samuel, 2006). According to the same author, in the toe slope, lower foot slope and upper foot slope areas, bulk density increased with depth. According to Ahmed (2002), bulk density showed greater variation with profile depth and higher bulk density was obtained at the sub-soil horizons under all the elevation zones and land use types.

Soil particle density is defined as the mass per unit volume of the soil solids. Particle density isaffected by mineralogical composition and crystal structure of mineral and OM content. However, it is not affected by structure of the soil and it is less affected by management practices (Brady and Weil, 2002; Hillel, 2004). As a result, soil particle density is relatively a permanent property. The presence of iron oxides and various heavy minerals increases the average value of particle density whereas the presence of OM lowers it. However, in most mineral soils, the mean particle density is about 2.6 to 2.7 g cm^{-3} (Hillel, 2004). For general calculation purposes, a particle density of 2.65 g cm^{-3} is used if the actual particle density is not determined.

2.4.2.3. Porosity

The pore spaces exist because of the particle and the disturbance including those due to roots, soil animals, swelling, cracking on shrinking and tillage that alter the spacing of aggregates or particles (Rose *et al.,* 1996). Considering only the surface soil layers, the lowest total porosity (55.07%) was observed on the toe slope, followed by (58.77%) the lower foot slope, and the highest total porosity (66.07%) was observed at the 0-25 cm depth of the Mollic Leptosols of the back slope area (Mebit, 2006).For soils with the same particle density, the lower the bulk density, the higher is the percent pore space (total porosity). Total porosity of soil usually lies between 30 to 70% and may be used as a very general indication of the degree of compaction in a soil in the same way as bulk density is used. As is the case with bulk density, management exerts a decisive influence on the pore space of soils (Brady and Weil, 2002).

2.4.3. Soil Chemical Properties

Soil chemical properties are those soil properties which are responsible and take part in the chemical reactions and processes of the soil and are the results of weathering of their mineral Components, decomposition of organic materials and the activity of plants and animals pertaining to plant and animal growth and human development (Kimmins, 1997).

2.4.3.1. Reaction (pH)

Soil reaction (pH) is the degree of soil acidity or alkalinity, which is caused by particular Chemical, mineralogical and/or biological environment. It is the simplest and the most important Chemical parameter measured in soils Teferi (2008). The degree and nature of soil reaction are influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials, application of commercial fertilizers and other farming practices (Brady and Weil,2002; Havlin *et al.,*2002). Soil organic matter, or humus, contains reactive carboxylic and phenolic hydroxyl groups that behave as weak acids releasing H^+ to the soil solution. As described by Mebit (2006), the highest pH (H_2O) value (5.7) was observed on the Mollic Leptosols of the back slope followed by the same soil unit of the summit area (pH=5.6) when the surface horizons were considered. This is due to the higher buffering capacity attributed to the relatively higher organic matter content of the areas. As reported by Tadesse (2002) and Solomon (2006) in the middle and high altitude areas, pH of the soil decreases with depth of the soil.The soils in high altitude and those with higher slopes had low pH values, probably suggesting the washing out of solutes from these parts (Belay, 1996, 1998; Abayneh, 2001; Mohammed *et al.,* 2005).

2.4.3.2. Organic Matter and Total Nitrogen

Organic matter is a weathering material from plants and animals and their degradation compounds containing carbon with the exception of carbon dioxide, carbonates, carbides and metal cyanides (Kordel *et al.,* 1997). Soil OC is sometimes used synonymously with OM as C is the main building block of all organic molecules; and the amount in the soil is strongly related to the OC (Magdoff and Van, 2000). Soil OM controls many soil physical and chemical properties. It improves aggregate stability, structure of soils and is a source of several essential plant nutrients, especially N, S and P (Prasad and Power, 1997). As reported by Abayneh (2001), soil OM depends on the rates of renewal (source) and loss (removal) of carbon from the soil and it decreases with depth of the soil.

According to Mengistu *et al.* (2017), fertile soil has an adequate supply of OM as grassland and forest land significantly higher OM content as compared to arable land owning to intensive cultivation of arable land and the total removal of crop residues for animal feed and source of energy. Altitude increases, OM content of the soil increases due to its low decomposition rates due to lower air as well as soil temperature with increasing altitude. Demelash (2010) states that higher OM content in the surface horizons of the low-lying areas could be related to its foot slope position. This position could allow the profile to receive OM from upper slope areas through processes of erosion and deposition. In general, organic matter is the primary source of nitrogen, phosphorus and sulphur and a temporary sink for most plant nutrients. Moreover, organic matter is important in maintaining soil filth, aiding the infiltration of water and air circulation, promoting water retention, reducing erosion and controlling the efficiency and fate of applied pesticides (Gregorich *et al*., 1994).

Nitrogen is the most limiting nutrient in the tropics and critical shortage of this nutrient brings significant grain/biomass yield reduction (Yihenew, 2002). According to Demelash (2010) N was high in the surface horizons and showed a systematic decrease with depth of the profiles. Sheleme (2011) found out that OC and total N contents were not influenced by land-use systems, possibly due to the complete removal of crop residues, and continuous heavy grazing in the case of grasslands. The C: N ratio was optimal, indicating the mineralization stage of soils and the availability of N to plants. The low content of OC and N could be attributed to the effects of intensive cultivation, which aggravated the oxidation of OC. Another finding also revealed that cultivation of land results in the reduction of OC and N (Wakene and Heluf, 2003). On the other hand authors reported that the highest (0.56%) content of total nitrogen corresponded to the profile having high value of organic matter content. The lowest amount of total nitrogen (0.04%) was recorded in the pedon which also had the lowest organic matter content (1.7%). Considering the surface soil layers, the highest total nitrogen (0.446%) was recorded under the Mollic Leptosol of the backslope, whereas, the lowest total nitrogen (0.12%) was recorded under the Dystric Nitisols of the lower foot slope (Mebit, 2006).

2.4.3.3. Cation Exchange Capacity

Cation exchange capacity (CEC) is the ability of the soil solid phase to attract or store and exchange cationic nutrients with the soil solution and render them available to plants through exchange reactions (Muller-Samann and Kotschi, 1994).The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil (Brady and Wevil, 2002). Both clay and colloidal OM are negatively charged and therefore can act as anions (Kimmins, 1997). As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to absorb and hold positively charged ions (cations). Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM. In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while in the subsoil particularly where Bt horizon exist, more CEC is contributed by the clay fractions than by OM due to the decline of OM with profile depth (Brady and Weil, 2002). Soil solutions contain dissolved chemicals, and many of these chemicals carry positive charges (cations) or negative charges (anions) (Fisher and Binkley, 2000). According to, Mohammed *et al.* (2005) 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.

2.4.3.4. Available Phosphorus

The term available phosphorous (Av.P) refers to the inorganic form, occurring in soil solution, which is almost exclusively orthophosphate. This orthophosphate occurs in several forms and combinations, and only a small fraction of the total amount present may be available to plants, which is of direct relevance in assessing the P fertility level. Soluble Phosphate may be adoptively retained at the surface of colloidal particles. In most soils, the main source of orthophosphate is organic matter (Buruah and Barthakur, 1997). As reported by Mohammed *et al.* (2005) the levels of plant available P in soils vary depending on land use system, altitude, slope position and other characteristics, such as contents of clay and calcium carbonates. According to Demelash (2010), available P showed variation along the toposequence and within the horizons in the studied profiles of Dilla zuria District of Gedeo Zone. Apart from that, its level was also low in most of the soils; thus it is one of the major crop production limiting nutrient elements in the study area.

Another author reported that 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 former. However, soil phosphorus content varies with parent material, extent of

Pedogenesis, soil texture, and management factors such as rate and type of phosphorus applied and soil cultivation (Tekalign *et al*., 1998).

2.4.3.5. Exchangeable Bases

Exchangeable bases including Ca, Mg, K and Na are important in soil classification and genesis (Buol *et al.,* 2011). Their levels in a given soil are more important than CEC because they not only indicate the existing nutrient status, but can also be used to assess balances among cations. Moreover,they influence other soil properties, such as soil structure and nutrient uptake by crops (Landon, 1991). According to Ahmed (2002), different land management affects the amount of exchangeable calcium and magnesium. Leaching caused preferential losses of Na+ and K+. Higher values of Ca/Mg indicated the decrease in extractable magnesium content in soils (Satyavathi and Suryanarayan, 2003).

All soils are naturally variable with their properties changing across landscape and vertically down the soil profile (Sheleme, 2011). Several studies shows topography is the dominant factor influencing exchangeable base variation due to its influence on runoff, drainage and soil erosion, and consequently on soil development along a toposequence (Fantaw *et al.,* 2006; Mulugeta and Sheleme, 2010; Dinku *et al.,* 2014). They indicated that most of the important soil quality indicators were affected by different landscape positions, particularly at surface horizons. On steep slope, exchangeable bases are washed away from upper and steeper slopes and as consequence; soils of these parts tend to have lower content of Ca, Mg and Na, which may lower pH values (Buol *el al*., 2011). On other hand, soils of lower slope positions and foot slopes receive all forms of materials removed from their counter upper position and steeper slopes and resulted in higher contents of exchangeable Cation (Buol *et al*., 2011).

Exchangeable sodium (Na) alters soil physical and chemical properties mainly by inducing swelling and dispersion of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (decrease solubility and availability of calcium (Ca) and magnesium (Mg) ions) (Buol *et al.*, 2011). According to (Brady and Weil, 2002), exchangeable Mg commonly saturates only 5 to 20% of the effective CEC, as compared to the 60 to 90% typical for Ca in neutral to somewhat acid soils. Research works conducted on Ethiopian soils indicated that exchangeable Ca and Mg cations dominate the exchange sites of most soils and contributed higher to the total percent base saturation particularly in Vertisols (Eyelachew, 2001). Different crops have different optimum ranges of nutrient requirements. The response to calcium fertilizer is expected from most crops when the exchangeable Ca is less than 0.2 cmol/kg of soils, while 0.5 cmol (+)/kg soil is reported to be the deficiency threshold level for Mg in the tropics (Landon, 1991).

2.4.3.7. Percent Base Saturation

The percent base saturation (PBS) is as much a measure of the actual percentage of cation exchange sites occupied by exchangeable bases. It is influenced by the pH of the CEC determination. The denominator includes oxide-mineral complexes between the initial soil pH and the reference pH (7.0 or 8.2) (Bohn *et al*., 2001). Percent base saturation (PBS) is also directly related to soil pH and represents the relative availability of many positively charged nutrients (Cations) such as calcium, magnesium, and potassium (Bandle and Meisinger, 2002). Bierman and Rosen (2005) as indicated that cation exchange is the major nutrient reservoirs of K+, Ca2+ and is also important in holding N in the ammonium (NH4+) form. Major causes of soil acidity are leaching and plant up take of basic cations (Ca and

Mg). The primary issues and from fertility standpoint, the actual amount of exchangeable Ca or Mg in soil, rather than the ratio between them, is the most critical factor.

According to same author, since neither the content of exchangeable Al nor exchangeable H is appreciable above pH 5.5, the effective CEC of the soil above this pH should be essentially 100% base saturated. However, soils in the pH range of 5.5 to 7.0 or 8.2 generally still have measured base saturations well below 100%. Such base saturation values are particularly low for minerals that have a high proportion of PH dependent charge, such as kaolinite clays.

2.4.3.8. Available Micronutrients (Fe, Mn, Zn and Cu)

Micronutrients are just as important in plants as the major nutrients except that they simply occur in plants and soils in much smaller concentrations. However, the information available about the status and limitation of micronutrients particularly in soils of sub-Saharan Africa is not adequate and is currently difficult for users to access (Haque, 1988).The same authors study conducted that, the first attempt of diagnosing the micronutrients status in Ethiopian soils showed that Fe and Mn were adequate, Zn varied between low to high, and Cu was deficient throughout the investigation sites (Haque, 1987).

According to Brady and Weil (2002), intensive cropping, in which large amount of plant nutrients are removed in the harvest accelerates the depletion of micronutrient reserves in the soil and increases thelikelihood of micronutrient deficiencies. Erosion of topsoil carries away considerable soil organic matter, in which much of the potentially available micronutrients are held on steep slope land.

Study conducted by Mulugeta and Sheleme (2010) reported that, micronutrients contents decreased with increasing depth of the profile in order of micronutrient concentration in the profile was Mn > Zn > Fe > Cu. The trend of Mn concentration under different slope position was similar to that of Fe distribution indicated that these two elements have similar chemical behavior in tropical soil. The distribution of Cu was consistently decreased from the surface to the subsurface horizons, which might be attributed to strong association of soil organic matter. Positive correlation between Cu and organic matter showing that Cu is strongly complexed with organic matter as describe by (Wakene and Heluf, 2003).

2.5. Soil Classification

Soil classification is the categorization of soil into groups at varying levels of generalization according to their physical, mineralogical and chemical properties. According to Buol *et al*., (2011), classification and categorization of natural phenomena like, soils are generally done for one or more of the following purposes. These are to organize knowledge of subjects, provide maximum knowledge with least cognitive effort, provide a map or organization chart of the structure of the world we perceive and live in, to satisfy our natural curiosity and for ease in communication, reveal and understand the relationship among individuals and classes, identify and learn new relationship and principles not previously perceived, provide objects or classes as subjects for research and experimentation and /or research and, establish group or subdivisions of the objects classified to enable particular application. Soil classification is one of the most important stages in natural resources assessment and soil map is one of the basic tools for planning any agricultural development (Rabia *et al*., 2013).

There are several soil classification schemes in the world. The classification schemes differ because they are based on different appreciation of soil formation, use different criteria, and different hierarchical sub-divisions. But, according to Buol *et al.* (2011), the most common classification systems used worldwide are the WRB Legend and Soil Taxonomy of the United States. These two classification systems attempt to include all naturally occurring soils in different parts of the world.

Currently the WRB legend classification has 32 major soil units of the higher level and 153 sub units as a secondary level (IUSS Working Group, 2015). According to Fikre (2003), the criteria used by Soil Taxonomy are objective and based on properties that are determined quantitatively as well as seasonally dynamic soil temperature and moisture regimes. The system contains six levels or categories order, suborder, great order, subgroup, family, and series from the highest to the lowest level of generalization (Buol *et al*., 2011).

2.6. Effects of Land Use Systems on Soil Chemical Properties

Soil chemical properties are those soil properties that are responsible for the chemical reactions and processes of soil and are the result of soil mineral component weathering, decomposition of OM in the soil and the activity of plants and animals about plant and animal growth and human development (Sims, 2000). The chemical reactions that arise in the soil highly affects processes leading to soil improvement and soil fertility build -up (Amelework, 2017). Sheleme (2017) reported that, chemical properties of the surface soils including organic carbon, available P, exchangeable bases and CEC were significantly affected by land use.

The land-use system causes differences in pH and nutrient concentrations in the surface layers (Materechera and Mkhabela, 2001). Alemayehu and Assefa (2016) noted that the soil's pH of forestland were higher than cultivated and grazing lands soils and cultivated land were more acidic than those of the forestland and grazing lands owning to intensive farming over several years with nitrogen fertilizers on cultivated land.

Managing SOC is indispensable for enhancing soil physical, chemical, and biological processes and properties (Shapro *et al*., 2013). The author also stated that an increase in SOC can increase soil aggregate stability, water retention capacity, water infiltration, plant available water, soil microbial and macro fauna biomass and activity, and cation exchange. Wondimagegn *et al.* (2018) indicate that the SOC concentration showed significant difference with land use types in which highest was observed under natural and mixed forest and lower under cultivated land compared with other land uses. On the other hand, soil organic carbon content exhibits considerable variability spatially, both horizontally according to land use and vertically within the soil profile. The variability of soil organiccarbon stock could be due to input from fresh material decomposition of some partsof above-ground foliage, which is the main pathway of input of new soil organic carbon into the soil; i.e., input from material decomposition was relatively lower in communal and cultivated land use types owing to removal by grazing (Addis *et al*., 2019).

Nitrogen occurs in the soil in both organic and inorganic compound form of which plants absorb N in its cationic form (NH4+) and anionic form (NO3-) and get readily available N forms from various sources (Amelework, 2017). Wasihun (2015) illustrated that when the values of OM content increased, the contents of total N also increased and vice versa showing the direct relationship between them. On the other hand, the total N content of the soils was significantly affected by land use. Accordingly, the average value of total N was highest in the forest land and lowest under the cultivated land (Mamo, 2011). The considerable reduction of total N in the continuously cultivated fields could be ascribed to the usually anticipated rapid mineralization of soil organic matter following frequent tillage operations, which increase aeration and microbial accessibility to organic matter (Jobira, 2018).

Phosphorus is generally available as phosphate, an anion that is not bindable by the cation exchange complex and thus can be easily leached from the soil by rain or runoff (Wiedenhoeft and Alex, 2006). The study by Berhanu (2016) indicated that, available phosphorus (P) content was significantly affected by land uses. The highest available Pcontent recorded in the surface soils of the cultivated land could be attributed to carryover effects from the continuous application of P fertilizers.

The CEC is a property of a soil that describes its capacity to supply nutrient cations to the soil solution for plant uptake (Sonon *et al*., 2014). There was great variation in cation exchange capacity (CEC) of the soils under the differentland uses in both the surface and subsurface layers of the profiles (Brady and Weil, 2002). The highest mean CEC value was recorded for soils of the HL followed by FL, while the lowest was recorded for soils of the GL followed by CL (Jobira, 2018). This is due to the higher clay and OM can absorb and hold positively charged ions (cations) at HL and FL land uses.

Mulugeta *et al.* (2019) reported that percent base saturation (PBS) was significantly affected by land-use types. The highest mean value of PBS was recorded from the surface layer (0-30 cm) of the GL, while the lowest was in the surface layer of the CL. This is due to the PBS have a strong correlation with SOC, TEB, and pH (Jobira, 2018). Similarly, exchangeable base contents of soils showed differences in response to variations in land uses (Jobira, 2018). Wakene and Heluf (2003) reported that the surface soil horizon contained the highest exchangeable Ca in all management system except for current abandoned and fallow land for fifteen years as compared to their respective surface horizon, similarly exchangeable Mg was the highest in the surface soil on the intensive cultivated research field.

The concentrations of the micronutrients (Fe, Mn, Zn, and Cu) of the soil were affected by different land uses, except Cu and Zn (Berhanu, 2016). Mamo (2011) also reported that the contents of micronutrients (Fe, Mn, Zn, and Cu) were significantly affected by land use and soil depth. With this regard, Brady and Weil (2002), intensive croppingin which large amounts of plant nutrients are removed in the harvest product accelerates the depletion of micronutrient reserves in the soil and increases the likelihood of micronutrient deficiencies.

3.MATERIALS AND METHODS

3.1. Study Area and Description

Boneya Keto toposequence is found in SNNPR of Siltie zone Misrak Silti woreda which is located at 225 Kilometers away from the capital city of Addis Ababa and 160 km in north direction of the regional capital city of Hawassa. Boneya Keto toposequence also located at 28 km from east of worabe town to border line of Tinishu Abaya Lake. Geographically, Boneya keto toposequence is located at $7^0$56'43''N to $7^0$56'55'' N latitude and $38^0$23'12'' E to 38^0 22'54''E Longitude. Its altitude ranges from 1834 - 1902 m.a.s.l. According to relative location, the boundary of Boneya Keto toposequence shares Tinishu Abaya Lake in the East, Mirhab silti woreda in the North, Dalocha Woreda in the South and Mirhab silti Woreda in the West. The Boneya keto toposequence total area covers 4596 ha.

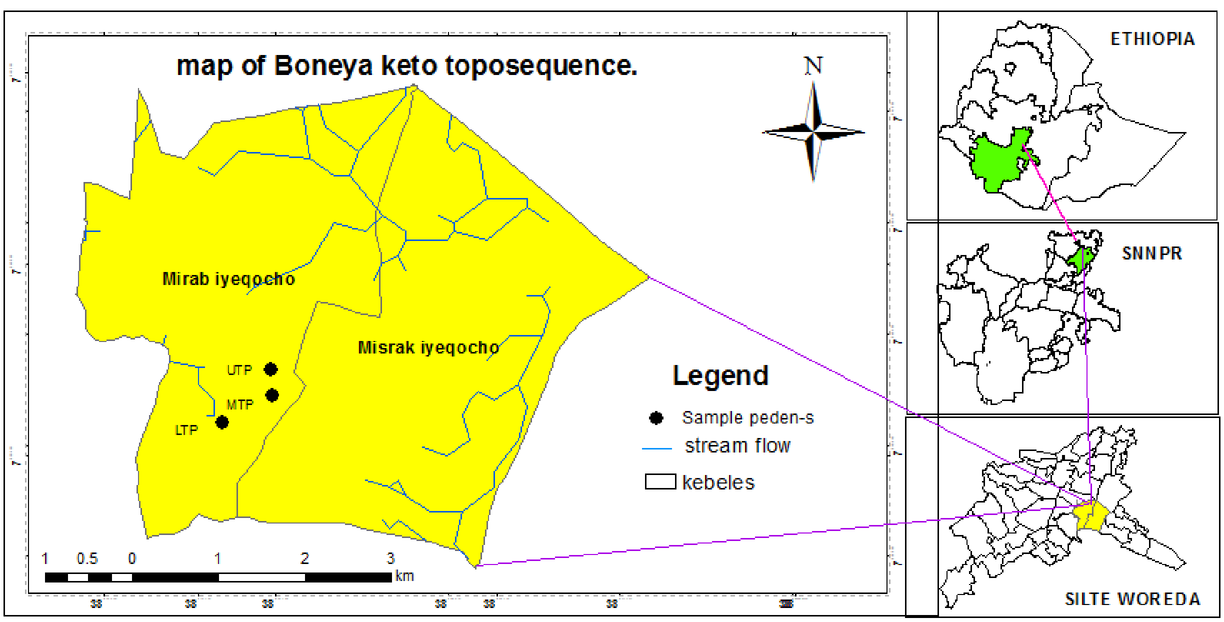

Figure 1. Map of the study area(Boneya Keto toposequence)

The dominant land use of study area are cultivated land and followed by the grazing land with scattered trees and the remaining area coverage of the Boneya keto toposequences constitute settlement areas and others. Mixed crop-livestock agriculture is a common farming system in the study area. The major crops grown during the main rainy season are maize (*Zea mays L.*), wheat (*Triticum aestivium*), sorghum (*Sorghium bicolor*) and pulses like bean (*Vicia faba*), haricot bean (*Phaseolus vulgaris*), chickpea (*Cicer arietimum*). The natural vegetation of Boneya Keto toposequence area consists of scattered trees and mainly covered with grasses. The trees include species such as Eucalyptus camel dullness and Acacia.

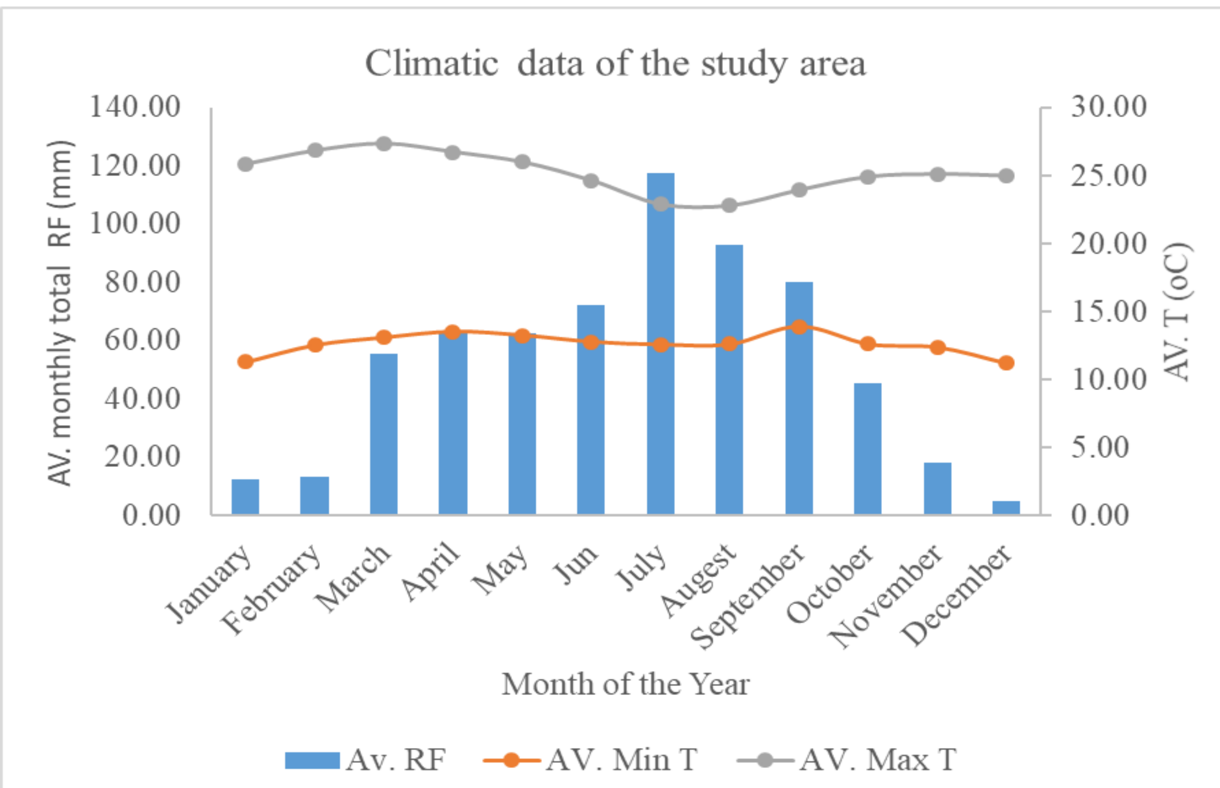

Figure 2. The mean annual temperature and the rainfall of the study area

3.2. The Research Design

At the beginning, a general visual field survey of the study area was carried. According to the natural topography and slopes the toposequence of study area were divided into different topographic positions (UTP, MTP and LTP). Then after general site division, representative Pedon were selected from each topographic position by random auger sampling in transect walk at distance. The soil samples were collected from every identified horizon of the Pedons and random surface composite samples was collected from all directions around each Pedon. During collection of samples furrow, manures, wet spots, areas near trees and compost pits were excluded to minimize differences among the pedon. To determine influences of land use and topographic position on soil properties, two dominant land use of the area namely; cultivated and grass land were selected and 9 sub-surface random composite soil sample was collected and triplicates at each topographic position identified.

3.3. Soil Profile Description and Sampling

The topographic map (scale 1:50,000) Ethiopian Mapping Authority (EMA) was used for locating the study area important land features. Toposequences were selected along south-north facing slopes (toposequence) encompassing landform components spanning from upper top to nearly level lower in Boneya Keto toposequence. 24 Auger samples were taken to select representative soil pedons along the toposequence. Each toposequence were divided into topographic positions, upper position, middle position and lower position. A total of three pedons 2 m length, 2 m width and 2 m depth were excavated on every topographic position. The Pedons were described for the soil morphological properties in the field following the

Guidelines for Field Soil Description (FAO, 2006). Physico-chemical properties of the soils were also characterized in the laboratory through the analysis of soil samples collected from every identified soil horizons.

3.4. Soil Sample Preparation

Soil samples collected from each horizon/layer of the soil profiles and surface soil samples were bagged, labeled and transported to Hawassa Soil laboratory for preparation and analysis of the selected soil physicochemical properties following standard laboratory procedures. In preparation for laboratory analysis, the soil samples were air dried in shade (house), grinded with pestle and mortar and made to pass through a 2 mm size sieve for the analysis of the selected soil properties except OC and total N in which case the soil samples were passed through 0.5 mm sieve to avoid coarser material. The bulk densities of the soils were determined from samples collected using core sampler.

3.5. Laboratory analysis of soil samples

3.5.1. Physical properties

The particle size distributions of the soils were analyzed by the Bouyoucos hydrometer method (Day, 1965). Total porosity was estimated using the following formula:

$$\text{Total porosity} = 1 - \frac{\text{Bd}}{\text{Pd}} \text{x} 100$$

3.5.2. Chemical properties

The major chemical properties of soil such as pH, CEC, exchangeable bases (Ca, Mg, Na, K), organic matter, total nitrogen content, available P and micronutrients (Fe, Cu, Zn, Mn,) were analyzed following the standard procedures. Soil pH was measured potentiometrically using a digital pH meter in the supernatant suspension of 1:2.5 soils to water ratio. Cation exchange capacity (CEC) of the soil was determined from ammonium-saturated samples that are subsequently replaced by sodium (Na) from a percolating sodium chloride solution. The excess salt was removed by washing with 96% ethanol alcohol and the ammonium that is displace by sodium was measured by the Kjeldahl (Chapman, 1965) procedure and reported as CEC. Exchangeable bases were extracted with 1M-ammonium acetate at pH 7 (Sahlemeden and Taye, 2000). Exchangeable Ca and Mg were measured from the extract with atomic absorption spectrophotometer while exchangeable K and Na were determined from the same extracts with flame photometer as described by Rowell (1994).

Percent base saturation (PBS) was computed as the percentage of total exchange bases to CEC of the soil. The CEC of clay was determined by dividing the values of CEC of soil to percentage of clay and multiplying by 100 (Landon, 1991).The organic carbon content of the soils were analyzed following the wet digestion method described by Walkley and Black (1934), which involves digestion of the organic carbon in the soil samples with potassium dichromate ($K_2Cr_2O_7$) in sulfuric acid solution. The Kjeldahl procedure was followed for the determination of total nitrogen as described by Sahlemeden and Taye (2000) by oxidizing the organic matter with concentrated sulfuric acid and converting the nitrogen in the organic compounds into ammonium sulphate during the oxidation.

Available phosphorus was determined by the Olsen methods. Available soil P was analyzed according to the standard procedure of Olsen *et al.* (1954) extraction method when the average pH of the study area is neutral and pH of 8.5. In the Olsen procedure, the soil samples were shacked with 0.5 M sodium bicarbonate at nearly constant pH of 8.5 in 1:2 soils to solvent ratio for 30 minutes and the extract was obtained by filtering the suspension as indicated by Olsen *et al*. (1954). The available phosphorus extracted was measured by spectrophotometer following the procedure outlined by Murphy and Riley (1962).

Available Fe, Mn, Zn and Cu are extracting from the soil samples with DTPA as described by Lindsay and Norvell (1978). All micronutrients extract with different methods will be measured by atomic absorption spectrometry.

3.6. Soil classification

Soil classification was consisted of three steps. First, the expression of thickness and depth of layers were checked against the requirements of WRB diagnostic horizons, properties and materials, which were defined in terms of morphology and/or analytical criteria. Where a layer fulfilled the criteria of more than one diagnostic horizon, property or material, they were regarded as overlapping or coinciding (FAO/WRB, 2014).

Second, the described combination of diagnostic horizons, properties and materials were compared with the WRB Key in order to find the Reference Soil Group (RSG), which was the first level of WRB classification, and it was going on through the Key systematically, starting at the beginning and excluding one by one all RSGs for which the specified requirements were not met (FAO/WRB, 2014).

Third, for the second level of WRB classification, qualifiers were used. Prefix qualifiers comprise those that was typically associated to the RSG and then intergraded to other RSGs. All other qualifiers were listed as suffix qualifiers. For classification at the second level, all applying qualifiers were added to the name of the RSG. Redundant qualifiers (the characteristics of which are included in a previously set qualifier) were not added. Specifiers were used to indicate the degree of expression of qualifiers (FAO/WRB, 2014).

3.7. Statistical Analysis

The data obtained from physical and chemical analyses were subject to using the general linear model procedure of the statistical analysis system and Correlation analysis of soil properties in different pedons along toposequence by using (SAS, 2008). Analysis of variance arranged by factorial (2*3) experiment and laid down in RCBD design was computed using statistical analysis system. Whenever significant, LSD test was used to compare means.

4.RESULT AND DISCUSSION

4.1. Site characterization

The site characteristics of the pedons indicated differences in slope, permeability and extent of water erosion (Table 1). The pedons on the upper and middle topographic position classes were well drained, whereas the pedon on the lower topographic position was poorly drained. Evidence of slight to accelerated water erosion were observed at the sites and surrounding upper topographic position and middle topographic position, whereas the pedon on lower position, showing the susceptibility of soils to very slight erosion. The UTP showed signs of accelerated water erosion as evidenced by gullies on the surrounding landscape, while MTP experiencing slight water erosion and lower very slight erosion. Consequently, the soil of pedon LTP was developed from continuous deposition of material originating from the surrounding slopes including the studied toposequence on which the other pedons are located. On the other hand, the soils of pedons USP and MSP were developed from in situ weathering of basaltic parent material, although influence of material deposition was noted on the surface layer of LTP pedon.

The slope and parent materials are the major contributing factors for the differences in the site characteristics, that is, erosion, deposition and drainage. The parent materials determine certain soil properties and drainage condition such as clay mineralogy, which is among other factors to determine the type of soil (Dinku *et al.,* 2014). The observed well-drained condition and water erosion on UTP and MTP pedons could be attributed to relatively gently slope gradients and subsequent downslope movement of water. Farmers apply contour plowing and terracing to reduce removal of surface soils on these landscapes. The LTP pedon poorly drained with only slight erosion owing to the nearly flat slopping conditions at these positions. The results are coherent with topographic impact on soil quality through direct soil and water movement and indirect profile development as documented earlier (Thompson and Troeh, 1993).

Table 1. Site characteristics and land use of the pedons.

Pedons	Geographic position		Altitude(m)	Slope (%)	Drainage	Land use	PM
	Latitude	Longitude					
USP	8°64′43”N	38°23′12’’E	1902	7	WD	Cultivated	basaltic
MSP	7°56′50’’N	38°23′4’’E	1855	6	WD	Cultivated	sedimentary
LSP	7°56′55’’N	38°22′54’’E	1834	3	SP	Cultivated	Colluvium

USP, MSP and LSP refer to pedons on upper slope position, middle slope position and lower slope position, respectively; WD = Well-drained; PD = poorly drained; S = Slight; PM = Parent material.

4.2. Soil Morphological Properties

4.2.1. Soil depth

The morphological properties of soils; depth, horizon, color, structure, consistency and horizon boundary varied along the toposequence at the study site. All the pedons had a very deep profile (>200 cm). The USP was characterized by A, AC and C sequence of horizons, while the MSP pedon consisted of 5 horizons (A-AB-B-BC-C). The pedon at the LSP had 2 horizons (A-B1-B2-B3) sequence of horizons showing deposition of materials from the topographically higher pedons and surrounding slopes. The described profile at upper topographic positions showed that the thickness of Ap (surface) horizons was 15cm. This thickness generally increases with depth, probably indicating diminishing of differences in morphological properties with depth of the profile (Shimeles, 2006; Seid *et al.,* 2017). The thickness of identified sub-surface horizons of upper topographic position varied from 16-200 cm. Below the Ap horizon 16-32 cm thick subsoil was identified and designated to be AC horizon. Next to AC horizon 33-200 cm subsoil was identified and assigned as C horizon. Within the C horizon there was C1, C2, and C3 horizons were identified and the thickness varied from 32-67, 67-110, and 110-200^{+} respectively (Table 2).

The depth of the middle profile was very deep (> 200 cm), indicating that the slope gradient could be the main factor influencing the depth of the soils. The identified genetic horizons had variable thickness in middle topographic position. Surface horizon (AP) had about 30 cm thick. Below AP horizon, about 25 cm thick subsoil horizon (AB) was identified. Under AB horizon, about 30 cm thick another sub-soil horizon (B) was recognized below which BC horizon with having 51 cm thickness was observed (Table 2). At last fifth horizon which had about 64 cm thick subsoil horizon was also identified and designated as C horizon.

The lower profile, the total depth was observed to be greater than 200 cm. The thickness of Ap horizon had about 45 cm. The genetic horizon underlying the topsoil was thick for 40 cm (B1), which changed to a 45 cm thick the sub surface horizon (B2). The remaining horizon changed to a 70 cm (B3) thick (Table 2). Generally, the depths of different surface horizons vary from deep to very deep (Table 2). Along the toposequence, the pedon at the lower topographic position has relatively the deepest surface horizon (45 cm) followed by the middle pedon (30 cm) whereas the upper pedon has a shallow (15 cm) surface layer. The variation in soil depth is most likely attributed to the topographic position that influenced soil formation and development through its effects on erosion, infiltration and the percolation of water deep into the soil.

The relatively shallow thickness of the surface layers of USP and MSP pedons as compared to that of LSP pedon could be attributed to the influence of runoff, which might have removed soil particles from the upper and middle topographic positions and partly deposited on the lower topographic landscape. Dinku *et al.* (2014) indicated that steepness, shape and length of slope are important in influencing the rate at which water enters into or runoff the soil. The running water, if the site is unprotected, may erode soils on slopes and form thinner surface layer because the surface soil is consistently removed by erosion. On the other hand, the increment in the thickness of surface layers at LSP can be attributed to soil deposition at lower landscape position corroborating the previous findings (Mulugeta and Sheleme, 2010; Sheleme, 2011; Dinku *et al*., 2014). The slightly slope situation at LSP could be the result of accumulation of the soil deposits eroded from the upper and middle slope positions.

4.2.2. Soil color

The color is a property that is easy to observe and measure, but its interpretation must be made in interference with soil mineralogy, alteration stage, organic matter content, seasonal fluctuations in water and several other aspects of land use and performance (Olson, 1981). This is a very important criterion to study because it provides information on the properties and behavior of the soil. The surface horizon of profile at upper topographic position had black (7.5YR 2.5/1) moist, and dark reddish gray (5 YR 4/2) dry color. The color of sub-surface soils of AC to C3 horizon varied only in their value from 7.5YR 4/3 to 7.5YR 3/4 (moist); but there were no variations when dry, due to they showed similar color behavior which had dark brown (7.5YR 4/4) (Table 2). The moist and dry color of the topsoil of middle profile was very dark gray (7.5YR 3/1) and dark brown (7.5YR 3/2) respectively, while the moist and dry colors of sub-soil horizons ranged from very dark brown to dark brown (10YR 2/2 to 7.5 YR 3/3) and very dark grayish brown to dark brown (10YR 3/2 to 7.5 YR 3/4) (Table 2). The topsoil horizons of lower profile had reddish brown (2.5YR 2.5/1) and dusky red (2.5YR 3/2) under moist and dry color, respectively while, the moist and dry colors of sub-soil horizons ranged from black to very dusky red (5YR 2.5/1 to 2.5 YR 2.5/2) and dark reddish brown to very dusky red (5YR 3/2 to 2.5 YR 2.5/2). In general, the moist color of surface horizons varied from black (7.5YR 2.5/1) to very dark gray (7.5YR 3/1), whereas the surface horizon of dry color varied from brown (7.5YR4/2) to dark brown (7.5YR 3/2).

All of the pedons (USP, MSP and LSP) had darker color in the surface as compared to subsurface horizons owing to the relatively higher organic matter contents in the surface horizons. The results show that soil color is highly influenced by organic matter content whereby the color is getting darker with an increase in organic matter content (Haviln *et al.*, 1999; Teshome *et al*., 2016). The surface horizons of the upper and middle profile were darker as compared to the subsurface horizons that mainly could be due to the accumulation and decomposition of organic materials, as it was also discussed by previous studies (Mulugeta and Sheleme, 2010), while the lower profile of surface and subsurface horizons was red, strongly suggesting the presence of iron compounds in the different states of oxidation and hydration as was also suggestions (Foth, 1990) and Alemayehu *et al*. (2016). All profiles horizon dry color “value” and “chroma” were higher due to that the soil color lighter compare to moist soil color. The upper and middle profiles had surface color black and brown whereas, the lower profiles color had red due to the presence of iron oxide.

4.2.3. Soil structure

The surface structure of profile at the upper topographic position had weak, fine, granular that changed to moderate, medium, subangular blocky structure in its underlying horizon. The remains underlying horizon had strong, coarse, massive structure. The surface structure of profile at middle topographic position among the four AP, B1, B2 and B3 horizons moderate, very fine and sub-angular blocky changed to weak, very fine, sub-angular blocky.

The surface horizon of lower slope position Profile had weak, fine, sub-angular blocky structure which was more similar to all underlying horizon. The surface horizons varied from weak, fine and granular structure at upper profile to weak, very fine, subangular block of middle and lower profile, whereas the subsurface horizons varied from moderate, medium, sub angular blocky at upper profile to weak, fine, sub-angular blocky of middle and lower profile. In general, a better structural development down the profile was observed in all pedons except upper slope position due to the relatively higher clay content of the subsurface horizons than their respective surface horizons (Ashenafi *et al*., 2010; Alemayehu and Sheleme, 2013).

4.2.4. Soil consistency

The surface horizon of upper profile had hard (dry), friable (moist), sticky and plastic (wet) consistency. For some of the cases, there were changes inconsistency at least by one grade with depth of the profile. The horizon underlying the Ap horizon (AC) had extremely hard (dry), very friable (moist), slightly sticky and slightly plastic (wet) consistency. The horizon underlying the AC horizon (C) had extremely hard (dry), very friable (moist), non-sticky and non- plastic (wet) consistency. The change related to consistency characteristics may be related to a change in texture. That is, the increase in clay content with depth except the C horizon of a profile may result in changing the consistency of the soil at different moisture levels. The topsoil of middle Profile had soft (dry), loose (moist), very sticky and very plastic (wet) consistency. The horizon underlying the Ap horizon (AB and B sub-surface horizons) had slightly hard (dry), very friable (moist), very sticky and very plastic (wet) consistency. The horizon underlying the B horizon (BC and C sub-surface horizons) had hard (dry), very friable (moist), slightly sticky and slightly plastic (wet) consistency. The lower profile had loose (dry), very friable (moist), very sticky and very plastic (wet) consistency. The horizon underlying the B horizon (B sub-surface horizons) had loose (dry), very friable (moist), very sticky and very plastic (wet) consistency.

In all cases the consistency was loose to friable, slightly sticky and slightly plastic to very sticky and very plastic. On the other hand, the moist consistency of the subsurface horizons ranged from firm to friable; whereas the range was from non-sticky/non-plastic to very sticky/very plastic when wet (Table 2). The hard and non-sticky/non-plastic consistency observed in the subsurface of C horizons whereas, the friable and slightly sticky/slightly plastic to very sticky/ very plastic consistency observed in the surface horizons of all pedons could be attributed to the relative higher organic matter content of the surface than subsurface layers. These results were in agreement with that of Wakene (2001) who argued that although consistency is an inherent soil characteristic and mainly a reflection of the particle size composition of the soil, high organic matter content changed stickiness and plasticity of surface soil layer. These are main constituent of highly plastic soils, which experience periodic swelling and shrinkage during alternate wet and dry periods (Dinku *et al.*, 2014).

4.2.5. Horizon boundary

The boundary of upper profile, the Ap horizon was characterized by clear and smooth and AC had gradual and smooth horizons boundary, but the lower C1 and C2 horizon which had changed to diffuse to smooth, whereas middle profile was characterized by diffuse and smooth boundary in the surface horizon Ap and sub-surface horizons AB, which changed to gradual and smooth in the subsoil B and BC and horizons. The horizon boundary of lower profile indicate that Ap was diffuse and smooth and B1 horizon was characterized by clear and smooth, whereas there were gradual and smooth in B2 horizon boundary. This implies that, whereas there were clear morphological differences between overlying and sub-soil horizons, such differences become slope gradient with depth of the profile. The gradual and smooth boundaries in the lower horizons reflect absence of distinct morphological differences between the subsequent subsoil horizons of such soils.

Table 2. Selected morphological characteristics of the soils under different topographic positions

Depth (cm)	Horizon	Color		Structure	Consistence	Horizon Boundary
		Moist	Dry			
Upper						
0-15	AP	7.5YR 2.5/1	7.5YR 4/2	WE,F,GR	VER,S,P	C,S
15-32	AC	7.5YR 4/3	7.5YR 4/4	MO,M,SAB	VER,SS,SP	G,S
32-7	C1	7.5YR 3/3	7.5YR 4/4	ST,C,MA	VFI,SS,SP	D,S
67-110	C2	7.5YR 2.5/3	7.5YR 4/3	ST,VC,MA	EFI,SS,SP	D,S
110-200^{+}	C3	7.5YR ¾	7.5YR 4/4	ST,VC,MA	EFI,SS,SP	
Middle						
0-30	AP	7.5YR 3/1	7.5YR 3/2	WE,F,SAB	VER,VS,VP	D,S
30-55	AB	10YR 2/2	10YR 3/2	WE,F,SAB	VER,VS,VP	D,S
55-85	B	7.5YR 3/2	7.5YR 4/2	WE,F,SAB	FR,VS,VP	G,S
85-136	BC	7.5YR ¾	7.5YR 5/3	MO,C,MA	VFI,SS,SP	G,S
136-200^{+}	C	7.5YR 3/3	7.5YR 3/4	ST,C,MA	EFI,SS,SP	

4.3. Soil Physical Properties

The study revealed that physical characteristics of the soil such as texture and bulk density were influenced by the difference in slope characteristics along the toposequence.

4.3.1. Particle size distribution

The texture of upper profile is clay in top soil horizon, whereas the sub-surface horizons showed loam (AC), sandy loam (C1), loam (C2 and C3) texture from upper sub-surface horizon to the deeper lower horizon, respectively. The particle size analysis indicates that, the proportions of clay and sand showed an irregular variation with depth of this profile. On the other hand, the regular allocation in amounts of silt except (15-32cm) depth could indicate equal weathering of materials among the horizons of the profile (Table 2). The irregular variation in amounts of clay and sand could implicate unequal weathering of materials among the horizons in the profile.

The texture of middle profile was clay in the surface horizon, whereas the sub-surface horizons showed clay, clay, clay loam and loam texture from B sub-surface horizon to the deeper lower horizon, respectively. The proportions of sand and silt increased in the sub-soil horizons except 30-85cm profile depth, whereas thus depth the proportion of clay increase the presence of clay migration from upper to the lower horizon. The proportion of clay showed an even variation in all the horizons with the exception of the BC and C sub-soil horizon (85-200^{+} cm) which showed lower clay content but, higher silt content those horizons (Table 2). The increase in sand and silt content with depth of subsurface horizons (85-200^{+} cm) may be attributed to the C horizon as well as its transformations from other particle sizes. On the other hand, the regular allocation in amounts of silt could indicate equal weathering of materials among the horizons of the profile. A lower silt/clay ratio was identified in the sub-surface horizon. However, it increased unsystematically down the profile. Higher silt/clay ratio was recorded from the lower horizon. Higher silt/clay ratio in the sub-surface C horizon also indicates less nutrient reserve and water retention capacity than the Ap, AB and B horizon.

The texture of lower profile is silt clay in the surface horizon, whereas the sub-surface horizons showed clay throughout lower depth. The irregular variation in amounts of silt and sand could implicate unequal weathering of materials among the horizons in the profile. The proportions of clay increased in the sub-soil horizons the presence of clay migration from upper to the lower horizon (Table 3).

The textural class of the surface horizons ranged from clay to silt clay, whereas the subsurface horizons of most of the layers were clayey except for the C horizons of both the upper and middle pedons, which were sandy loam and loam, respectively. However, the soils at all slope positions showed discernible increase in clay content with depth indicating high rates of clay formation in subsoil horizons. From the three profiles, clay content in the lower slope position increased with increasing soil depth and forming argillic horizons. According to Boul *et al.* (2011), the accumulation of clay in the subsurface horizon could be also contributed by the insitu synthesis of secondary clays, and the weathering of primary minerals in the B horizon.

Generally, proportion of clay increased consistently down the profile due to attributed to clay migration with slop position. Along the toposequence there is difference in the depth of clay texture soil. The lower slope has relatively deep (45 cm) clay textured soil, while the upper and middle slope had 15 and 30 cm respectively.

4.3.2. Bulk density and total porosity

The bulk density of upper profile showed an increasing pattern with depth of the profile. It varied from 1.1 g/ cm^3 in the surface horizon 1.28 g/ cm^3 in the sub-surface horizon. The values of bulk densities indicate that there was slight to strong relation with depth in contents of organic carbon. On the other hand, the total porosity decrease from surface (58.5%) to the last sub-surface (52%) horizon (Table 3). Bulk density in the middle profile showed an increasing pattern with depth. It varied from 0.85 g/ cm^3 in the surface horizon to 1.16 g/ cm^3

in the lower sub-surface horizon. On the other hand total porosity (TP) of the soils showed decreasing trends from 68 % at surface layer to 56 % at subsurface layer (Table 3). The bulk density value of lower Profile in the surface horizon varied from 0.97g/cm^3 to 1.2 g/cm^3 to the lower sub-surface horizon. However the total porosity varies from surface horizon 63% to 55% in sub surface with depth. According to (Brady and Weil, 2002), ideal total pore space values, which are acceptable for crop production, are around 50%. Hence, the soils have an acceptable range of total porosity values for crop production.

Generally, the highest bulk density (1.28 g/cm3) was noticed at the C- horizon of the middle pedon, whilst the lowest (0.85 g/cm3) was found at surface horizon of the middle pedon (Table 3). In all pedons, the lowest bulk densities were found at the surface horizons. Moreover, bulk densities in the pedons increased with depth from surface to sub-surface horizons. Lower bulk density in Ap horizon could be due to the fact that organic matter makes soils loose, porous and well aggregated, and thereby lower bulk densities (Celik, 2005). Besides, the density of organic matter is very low as compared to the mineral soil and hence higher organic matter content results in lower density. Moreover, higher compaction due to the weight of the overlying layers also increases the bulk density of the subsurface layers (Shiferaw, 2004).

Table 3. Selected physical characteristics of the soils under different topographic positions

Depth (cm)	Horizon	Particle size (%)			Texture	Bulk density (gm/cm3)	Total porosity	Silt/Clay
		Clay	Silt	Sand				
Upper								
0-15	AP	42.16	28	29.84	Clay	1.1	0.58	0.67
15-32	AC	24.16	29	46.84	Loam	1.14	0.57	1.20
32-7	C1	18.16	14	67.84	Sandy Loam	1.17	0.56	0.77
67-110	C2	20.16	30	49.84	Loam	1.24	0.53	1.50
110-200$^+$	C3	22.16	38	39.84	Loam	1.28	0.52	1.7
Middle								
0-30	AP	56.16	22	21.84	Clay	0.85	0.68	0.39
30-55	AB	60.16	26	13.84	Clay	0.91	0.66	0.40
55-85	B	56.16	30	13.84	Clay	0.95	0.64	0.54
85-136	BC	32.16	40	27.84	Clay Loam	1.13	0.57	1.25
136-200$^+$	C	26.16	40	33.84	Loam	1.16	0.56	1.5
Lower								
0-45	AP	50.16	40	9.84	Silt Clay	0.97	0.63	0.80
45-85	B1	64.16	21	14.84	Clay	1.1	0.58	0.32
85-130	B2	58.16	28	13.84	Clay	1.16	0.56	0.50
130-200$^+$	B3	56.16	27	12.84	Clay	1.2	0.55	0.45

4.4. Soil Chemical Properties

The pH-H_2O of soils in the study area ranged from 5.69 to 7.89 which were rated as moderately acidic to slightly alkaline reaction according to Foth and Elias (1997) and was within the preferred range for most crops. The pH-H_2O of pedon at all topographic positions, showed inconsistent relations with soil depth. Generally, the soil pH increased with depth of soil profile and relatively high soil pH was observed at subsoil horizons at all physiographic positions. The relatively high soil pH observed at subsoil horizons may be attributed to vertical movements of exchangeable bases which is evidenced by their positive correlation (r=0.36). On the other hand, the probable reason for high pH at subsurface layers of soil could be due to less H^+ ions released from decomposition of organic matter at subsurface layers. The result is in agreement with the findings of Abay and Sheleme (2012) who reported increasing of pH with depth might be due to decreaseing of organic matter content as was also supported by significant and negative correlation (r=-0.68**) with organic carbon.

Due to the moderately acidic to neutral nature of most soils of the study area, the electrical conductivity (EC) values were below 1 dS m^{-1}. The relatively higher value of electrical conductivity of the extract was recorded at the sub surface horizon of upper profile which was 0.26 dS m^{-1} (Table 4). Electrical conductivity values in all profiles were rated as very low as rated in Shaw (1999). Generally, the EC values measured throughout the depths of the soils in the study area indicated that the concentrations of soluble salts are below the levels at which growth and productivity of most agricultural crops are affected due to soil salinity (US Salinity Laboratory Staff, 1954; Landon, 1991).

The organic carbon of soils (%) was in the range between 0.59 and 2.73, and was generally between low and medium rate as adapted from Tekalign (1991) who rated the values of OC as extremely very low (<0.5%), low (0.5-1.5%), medium (1.5-3%) and high (>3%). The organic carbon contents of the soils decreased with soil depth (Table 4) which might be due to the concentration of most of the root activities and incorporation of organic materials in the surface layers. This finding is in agreement with several research finding who reported that organic carbon contents of the soils decreased with soil depth, which might be due to the concentrations of most of the root activities and incorporation of organic materials in the surface layers (Tilahun and Asefa, 2009; Lalisa *et al*., 2010; Beyene, 2017; Mulugeta *et al*., 2019). In general, the higher OC were recorded at the surface layer of lower topographic position as compared to the upper topographic position where located on sloppy land. There is a general increasing in the distribution of surface OC from upper to lower physiographic positions. This indicates the influence of the slope gradient, which could be attributed to the transport of organic materials and other nutrient from areas having higher slopes to landscapes with gentle or flat gradient corroborating the previous findings (Beyene, 2017; Dessalegn *et al*., 2014).

The content of total nitrogen also showed an decreasing trend with depth of the profile in line with variations in the level of organic carbon at all topographic positions which was also evidenced by their significant and positive correlation (r=0.98***). It varied from 0.05% in the sub surface horizon of upper topographic position to 0.23% in the surface horizon of lower topographic profile. This finding is in agreement with several research finding who reported that total nitrogen contents of the soils decreased with soil depth, which might be due to the concentrations of most of the root activities and incorporation of organic materials in the surface layers (Tilahun and Asefa, 2009; Lalisa *et al.*, 2010; Beyene, 2017; Mulugeta *et al.*, 2019). This decrease of TN with depth generally parallels to a decrease in contents of organic matter, suggesting that the main source of total nitrogen was organic matter. According to ratting set by Havlin *et al.* (1999), TN content of the soils are categorized <0.15 as low, 0.15 to 0.25 as medium and > 0.25 as high, thus the TN content of surface soils are categorized as medium (0.23%) at lower physiographic position and low at middle and upper physiographic positions. Regarding to the level of carbon to nitrogen ratio of study area, its varied from 10.25 to 12.4. Foth and Elias (1997) reported that soils with C: N ratios in the range of 10- 12 provide nitrogen in excess of microbial needs. Therefore, the result obtained in all pedons, showed optimum range for active microbial activities for humification and mineralization of organic residues (Table 4).

Table 4. Chemical properties of the soils in the pedon of Boneya Keto toposequence

Pedon	Depth	Horizon	pH(H_2O)	ECdSm^{-1}	OC	TN	C/N	Av.P
					%			
	0-15	AP	5.79	0.08	1.56	0.143	10.87	1.98
	15-32	AC	6.85	0.09	1.09	0.098	11.09	2.95
	32-7	C1	6.55	0.12	0.58	0.052	11.24	2.95
	67-110	C2	7.45	0.16	0.58	0.051	11.46	6.05
Upper	110-200+	C3	7.38	0.26	0.58	0.050	11.60	1.89
	0-30	AP	5.78	0.05	1.95	0.156	12.43	3.22
	30-55	AB	6.08	0.09	1.36	0.127	10.69	1.89
	55-85	B	6.88	0.04	1.36	0.116	11.70	1.54
	85-136	BC	6.35	0.09	0.81	0.072	11.36	1.36
Middle	136-200+	C	7.89	0.18	0.58	0.051	11.46	1.54
	0-45	AP	5.87	0.03	2.73	0.227	12.01	4.10
	45-85	B1	6.03	0.03	1.75	0.171	10.25	1.45
	85-130	B2	6.28	0.04	1.65	0.136	12.11	1.28
Lower	130-200+	B3	5.69	0.09	0.97	0.087	11.15	0.84

Available P content of surface layers ranged from 1.98 mg kg^{-1} at the upper topographic position to 4.1 mg kg^{-1} on lower topographic positions. According to Olsen *et al.* (1954), the available soil P level of < 5 mg/kg is rated as low, 5-10 mg/kg as medium and > 10 mg/kg is rated as high, showing available P of study soils were in low ranges at all physiographic positions of study area. Available phosphorous has generally shown an inconsistent relationship with depth in upper topographic pedon and the irregular trend observed was not explained. Whereas, consistently decreasing pattern of available P from the surface to sub-surface horizon were observed at middle and lower topographic pedons. This decreasing trend down the profile might be attributed to the increasing in clay content as evidenced by their negative correlation (r=-0.45) and decreasing of organic carbon. Phosphorus fixation tends to be more pronounced and ease of phosphorus release tends to be lowest in those soils with higher clay content and lower organic carbon (Brady and Weil, 2002). There is also a general increasing in the distribution of surface available P from upper to lower physiographic positions. The variation in the distribution of available phosphorous observed among topographic positions might be attributed to variations in slope gradient, which could be due to the transport of organic materials from areas having higher slopes to gentle or flat landscapes position.

The very low availability of P at study area might be attributed to the inherent P deficiency of the soils, the fixation of P with Fe and Al and by Ca and Mg, inaducate application of external P sources and continues cultivation of the land. As represented by all profiles, crop cultivation in these soils would be limited by very low P status in addition to other limiting factors, as a result application and management of P may be required. In fact, low availability of P is a common characteristic of soils in different areas of Ethiopia as in the present study area

(Tamene *et al.*, 2017). Wakene and Heluf (2003) have also suggested that the existence of low contents of available P is a common characteristic of most Ethiopian soils. Consequently, very low available P of the soils could form one of the major soil fertility limiting factors in the study area. Therefore, to increase any economical agricultural production would require raising of available P through various P management practices, such as fertilization and/or organic manure application (Tamene *et al.*, 2017).

Exchangeable calcium followed by magnesium formed the dominant cation in the exchange complex throughout the horizons of the all representative profiles (Table 5). The two cations relatively showed increasing pattern from the surface to sub-surface horizon at all topographic positions. Considering the surface horizons, the highest concentrations (23.85 and 2.98 cmol (+) kg^{-1} of exchangeable Ca and Mg respectively, were recorded at the upper topographic pedon. Among the different layers of horizon, the highest values of exchangeable Ca (31.37 cmol (+) kg^{-1}) was obtained at the subsurface layers (15-32 cm) of upper topographic pedon. This could be due to the presence of Ca and Mg bearing parent materials at the site of soil sampling that has contributed much to the high exchangeable Ca and Mg contents on the soil exchange complex. In accordance with that of Landon (1991) rating, exchangeable Ca and Mg of the study areas were categorized as high at lower to very high at upper and middle topographic positions and medium at upper to high level at lower and middle topographic positions respectively.

Exchangeable K and Na were found in high to very high and high concentration ranges in all soils studied in accordance with Landon (1991) ratting. Among the surface horizons, the highest (1.83 cmol(+) kg^{-1}) of exchangeable K was recorded at the upper and lower topographic positions. According to Berhanu (1980) rating of soil characteristics, the high to very high status of exchangeable K obtained in all pedons were in agreement with the common idea that Ethiopian soils are reach in K. But it disagrees with Alemayhu (1990), Belay (1996) and Wakene (2001) who reported K deficiency in Eutric Vertisols of Melbe (Tigray) and Dystric Nitisols of Bako area, respectively. On other hand, despite high exchangeable Na contents of the study soils, the exchangeable Na concentration along the toposequence were generally medium as compared to the critical level. The critical level that causes deterioration of soil structure and Na toxicity could be when the exchangeable Na percentage (ESP) is greater than 15% as indicated by Miller and Donahue (1990). Apparently, this is due to the high amount of annual rainfall at the study area which causes enough leaching of basic cations and finally soil acidity. At all topographic positions, the analytical values of cations are in the order: Ca > Mg > Na > K. Mesfin (1998) and Yihenew (2002) reported a similar order (Ca > Mg > Na > K) for Alfisols of Debre Markos and Bahir Dar area and different major soil groups of Adet Research Center and its testing sites, respectively.

Balance between the basic cations on the exchange complex has an important effect on their availability for crop production. The ratios of Ca: Mg were 7.99, 8.18 and 5.48 in surface layers of upper, middle and lower topographic pedons, respectively (Table 5) suggesting that magnesium may become progressively less available to plants with increasing calcium. According to Landon (2014), Ca: Mg > 5:1 possibly cause Mg deficiency and inhibition of P uptake, particularly at high pH; the ration between 3-5:1 could be considered as normal range and if < 3:1 it possibly inhibit P and cause Ca deficiency. Accordingly, nutritional disorder might be expected at sub surface layer of middle and upper topographic positions.

Table 5. Chemical properties of the soils in the pedons of Boneya Keto toposequence

Pedon	Depth	Horizon	Ca	Mg	K	Na	CEC	PBS	Fe	Mn	Zn	Cu
			(cmol(+)/kg of soils					%	(mg/kg soil)			
Upper	0-15	AP	23.9	3.0	1.8	1.2	39.0	77	12.5	0.65	0.85	1.3
	15-32	AC	31.4	3.1	2.7	1.2	39.4	98	12.0	0.26	0.82	1.2
	32-7	C1	31.0	3.0	3.0	1.3	35.0	109	11.8	0.11	0.85	1.1
	67-110	C2	28.3	2.8	2.4	1.3	37.4	93	10.0	0.21	0.80	1.0
	110-200+	C3	30.8	1.9	1.1	1.3	34.6	101	10.1	0.23	0.88	1.0
Middle	0-30	AP	23.6	2.9	1.7	1.2	39.4	74	13.3	8.19	1.22	1.2
	30-55	AB	27.0	3.0	0.8	1.1	39.0	81	10.1	4.11	0.94	1.2
	55-85	B	23.7	3.1	1.3	1.2	39.6	74	12.0	0.55	0.70	1.2
	85-136	BC	22.5	2.9	1.8	1.2	39.4	72	9.6	0.43	0.95	1.1
	136-200+	C	24.7	2.5	2.5	1.3	37.0	84	12.7	0.77	1.16	1.3
Lower	0-45	AP	14.8	2.7	1.8	1.2	37.0	55	17.4	7.90	1.13	1.4
	45-85	B1	25.2	3.8	1.3	1.1	36.2	87	13.0	8.60	1.36	1.1
	85-130	B2	20.8	3.4	1.1	1.2	38.4	69	13.0	1.95	0.83	1.3
	130-200+	B3	27.8	4.1	2.5	1.2	38.4	93	11.3	8.45	0.77	1.3

The cation excheange capacity (CEC) of the soils in both surface and sub-surface layers were ranged from 34.6 $cmol_c kg^{-1}$ to 39.6 $cmol_c kg^{-1}$ and was generally in very high range according to Landon (1991). The high amount of CEC in the soils of the study area may due to the presence of active clay mineralogy. The CEC of upper profile ranged from 34.6 $cmolckg^{-1}$in the subsurface horizon to 39 $cmolckg^{-1}$ in the surface horizon. CEC varied from 37 to 39.6 $cmolckg^{-1}$in middle profile, and varied from 36.2 $cmolckg^{-1}$to 38.4 $cmolckg^{-1}$in lower profile, respectively. In all profiles, CEC showed irregular variation with depth of the profiles. A relatively lower value of CEC was recorded for horizons where all total exchangeable cations were found to be low. Similarly, Seid *et al*. (2017) also reported lower CEC of soil were recorded from horizons of lower total exchangeable bases.

The PBS of upper Profile ranged from 77% on the surface to 109% in the underlying subsurface horizon. The high PBS at subsurface horizon of upper topographic positions were attributed to high effervesces of subsurface horizon observed at field characterization which belong to calcareous nature of soil. The very high PBS of the profiles indicates the presence of CaCO3, which would be dissolved during CEC determination using 1M NH_4AOc ammonium acetate of pH 7, and contributes to the values exchangeable Ca. A similar result was also reported by Serkalem and Sosena (2019) who obtained high PBS above 100% and attributed to the very high contents of exchangeable Ca and Mg dissolved from calcium carbonates in the process of extraction. Therefore, it would not be possible to make a generalization on PBS of the soils based on these values. It varied from 74% to 84% at middle profile, and 55% to 93% at lower topographic positions profile respectively. At all topographic position the PBS of the soil were greater than 50% and showed unsystematic variation with depth of Profile (Table 5). The PBS values in both surface and sub-surface horizons ranged from high (60-

80%) to very high (> 80%) based on the rating of Metson (1961). Accordingly, the PBS of soils of the study area could be characterized as very weakly leached (50-70%) and weakly leached (70-100%).

The highest Fe (17.4 mg kg^{-1}) and Cu (1.4 mg kg^{-1}) contents were registered at the lower topographic pedon. Relatively the decreasing pattern of Fe, Mn and Cu with soil depth were observed at all topographic positions. Significant variation was also observed along the toposequence in available Fe and Cu concentrations between the surface and subsurface horizons of the study area. In general, available Fe in the surface horizons increased consistently along the toposequence from the lowest at the upper topographic pedon to the highest at lower topographic positions (Table 5).

The trend and distribution of available Mn concentration in the profile and along the toposequence was nearly similar to that of Fe distribution (Table 5), indicating that these two elements have similar chemical behavior in tropical soils. The highest concentration of available Mn (8.6 mg kg^{-1}) was observed at the sub surface soil of the lower topographic positions. Sims and Johnson (1991) indicated that the critical or threshold levels of available Fe and Mn for crop production are 2.5-4.5 mg $kg^{-1}$and 1-50 mg kg^{-1}, respectively. Therefore, the results observed in this study revealed that the average mean values of available Fe and Mn were greater than an adequate range for Fe and in adequate range for Mn for the production of most crop plants. In connection with this, the status of available Fe and Mn of sudy area were categorized as low and very low range following the rating adopted by EthioSIS, (2016) respectively.

The trend of extractable Zn concentration shows irregular pattern with depth of all Profile, and varied from 0.7 mg kg^{-1}in to 1.36 mg kg^{-1}in the profile of study area. Whereas, extractable Cu decreased consistently with increasing of depth at all topographic positions and varied from 1 mg $kg^{-1}$to 1.4 mg kg^{-1}in Profile of study area. The decreasing of Cu concentration with depth of profile might be attributed to decreasing of organic carbon contents of the soil (Table 5). The higher value of available Cu recorded at surface layers of all profile could be due to higher organic carbon contents of surface horizon as was supported by significant and positive correlation (r=0.66**) for which copper is strongly complexed with organic matter which were also discussed by Kiflu and Beyene (2013). With this regard, the status of surface available Zn content of upper profile soils was categorized as very low, while at middle and lower topographic positions were in low range following the rating adopted by EthioSIS, (2016). Similarly, the status of surface available Cu content of study soils were categorized as optimum range following the rating adopted by EthioSIS, (2016).

4.5. Soil Classifications based on WRB legend

The soils were classified based on both morphological and analytical data following the FAO World Reference Base for soil resources (WRB, 2014). The results revealed that there are differences in soil types (Table 6) between profile that might be attributed to diversity of geographical, morphological and ecological conditions (Piccolo and Huluka, 1986; Fritzsche *et al*., 2007; Shimelis *et al*., 2007; Ashenafi *et al*., 2010; Rabia *et al*., 2013). The surface horizon (0-15cm) soils of the upper topographic position pedon had OC 1.56%; base saturation (by 1M NH_4OAc, pH 7) of 77%; structure that was not massive and hard when dry; had color values of 2.5(moist), chroma of 1(moist). These criteria qualify the surface layer for mollic diagnostic surface horizon. The profile has base saturation (by 1 *M* NH4OAc, pH 7) of

≥ 50% throughout to a depth of 100 cm which can be classified as Phaeozems. The soil fail to meet the criteria's listed under principal qualifier and grouped as Haplic. The soil is being ploughed to a depth of ≥ 20 cm from the soil surface. It also is having a texture class of loam, sandy loam and loam in a layer ≥ 30 cm thick, within 100 cm of the mineral soil surface to qualify loamic supplemental qualifier. Therefore, soils of the upper topography are classified as Haplic Phaeozems (Aeric, Loamic).

The surface horizon (0-30 cm) soils of the middle topographic position had OC 1.95%; base saturation (by 1M NH_4OAc, pH 7) of 74%; structure that was not massive and hard when dry; had color values of 3(dry) and 2(moist), chroma of 1(moist). These criteria qualify the surface layer for mollic diagnostic surface horizon. Subsurface horizon was meeting the criteria for abrupt textural difference and base saturation greater than 50 percent. It had evidence of pedogenic alteration; not meeting the criteria of diagnostic horizons that indicate stronger alteration or accumulation processes. With these set of characteristics, the soils at the middle topographic position could be classified as Cambisols according to the WRB (IUSS, 2014). The profile had a texture of clay in a layer more than 30 cm thick within 100 cm of the soil surface and clay coatings on B horizon, which qualify for Clayic and Cutanic qualifiers and support the Cambisols classification. Thus, the soils were classified as Abruptic Cambisols (Clayic, Cutanic).

The soils of the surface horizon (0-45 cm) of the lower topographic position pedon had color values of 3 (dry) and 2.5(moist), chroma of 1 (moist); structure that was not massive and hard when dry; contained 2.73% OC; base saturation (by 1M NH_4OAc, pH 7) greater than 50 percent and hence fulfill the requirements of mollic diagnostic surface horizon. The subsurface horizon (45-200 cm) had more than double clay as compared to the surface layer; clay increment throughout the horizons and the ratio of clay in subsurface horizon to surface horizon greater than 1.2 indicating argic subsurface diagnostic horizon. The argic subsurface horizon had CEC greater than 24cmol (+) kg^{-1} and base saturation greater than 50 percent qualifying the soils as Luvisols. The soil had a textural class of clay in a layer more than 30 cm thick within 100 cm of the soil surface; clay coatings in B horizon, which qualify it for Clayic and Cutanic qualifiers. Additionally, the argic horizon had an overlying coarser textured horizon that was not separated by lithic discontinuity and had 26% less clay as compared to the argic horizon, which meet the criteria for Differentic qualifier. So, the soils at this topographic position could be classified as Abruptic Luvisols (Clayic, Cutanic, Differentic).

Table 6. Diagnostic horizons and soil types of Boneya Keto sites according to WRB (FAO, 2014)

Pedon	**Digonstic horizon**	**Soil type**
Upper	Mollic	Phaeozems
Middle	Cambic	Cambisols
Lower	Argic	Luvisols

4.6. Influences of topography and land use on physicochemical properties of soil

The analysis of variance on physicochemical properties of studied soil showed the presence of significant varations among different topography and land uses along the toposequences (Table 7 and Appendix Table 1). Accordingly, the clay, silt and sand fractions, EC, exchangeable potassium, CEC, Fe and Mn were significantly ($P \leq 0.05$) affected by the topographic positions (Table 7 and Appendix Table 1). Similarly, the contents of EC, exchangeable Mg, exchangeable K, exchangeable Na, CEC, Fe, Mn and Zn were also significantly ($P \leq 0.05$) affected by different land uses. Whereas, the contents of pH, EC, Mg, K, Na, CEC, PBS, TEB, Fe, Mn and Zn were sinificanly affected by the interaction effect of topography and land uses (Table 7 and Appendix Table 1). The details of each parameters are presented and discussed in the following sections.

Table 7. Analysis of Variance on effects of Topography and land use on physicochemical properties of soils at Boneya Keto toposequence.

Source of variation	DF	P value									
		Clay	Silt	Sand	BD(gm/cm3)	pH	ECdSm^{-1}	OC	TN	Av. P	CEC
								%			
TP	2	0.0012	0.0012	0.0032	0.49	0.109	0.001	0.06	0.1	0.29	0.0026
LU	2	0.06	0.54	0.15	0.84	0.107	0.003	0.39	0.4	0.67	0.03
TP x LU	4	0.45	0.07	0.13	0.035	0.006	0.002	0.72	0.7	0.06	0.0017

Table 7 continued.

Source of variation	DF	P value							
		Ca	Mg	K	Na	Fe	Mn	Zn	Cu
		(cmol(+)/kg of soils							
TP	2	0.31	0.0511	0.012	0.067	0.0054	0.023	0.78	0.07
LU	2	0.74	0.007	0.022	0.044	0.0158	0.017	0.02	0.07
TP x LU	4	0.057	0.026	0.005	0.032	0.003	0.004	0.037	0.65

4.6.1. Effect of topography on physicochemical properties of soil

The significantly higher clay content (Table 8) was observed at lower slope position where the clay moved down the slope and accumulated to the gentle and level slope position. Similarly, the significantly higher silt content was recorded at lower slope position which are attributed to the influences of slope on soil erosion. On other hand, significantly higher sand content was noted at the upper topographic position which might be attributed to the removal of fine soil particles from steeper slope and their deposition at lower slope positions.Besides, the loose aggregate structure of the upslope soils has enhanced easy transportation of the fine soil particles downslope along with the water movement. In support of this, Dinku *et al*. (2014) and Sheleme (2017) reported differences in transport for each sediment particle-size, whereby transport of course-size particles (sand) was low whilst that of fine- and medium-size particles was high. To this effect, decreasing of sand content down the toposequence implicate an existence of sheet erosion in topsoil horizons ascribed to easy transportation of fine soil particle and whereby transport of course particle size was low.

Table 8. Effect of topography on physicochemical properties of soil of Boneya Keto topo sequence.

Topographic position	**Physical properties**			**Chemical properties**				
	Clay	**Silt**	**Sand**	**ECdSm^{-1}**	**K**	**CEC**	**Fe**	**Mn**
					(cmol(+)/kg of soils			
UTP	46.2^{b}	33^{a}	20.8^{a}	0.04^{b}	1.5^{b}	38.8^{a}	19.7^{a}	12.9^{a}
MTP	57.2^{a}	26.5^{b}	16.3^{a}	0.04^{b}	1.7^{b}	37.2^{a}	11.2^{b}	4.8^{b}
LTP	55.2^{a}	34.8^{a}	10^{b}	0.06^{a}	2.3^{a}	34.8^{b}	14.2^{b}	7.5^{ab}
LSD $_{t0.05}$	**5.13**	**3.83**	**5.39**	**0.01**	**0.48**	**1.91**	**4.61**	**5.56**
CV (%)	**7.73**	**9.69**	**27.26**	**19.93**	**21.01**	**4.11**	**24.41**	**25.36**

Mean followed by the same letters was not significant at the probability level of 0.05; UTP, MTP and LTP =Upper, middle and lower topographic position respectively.

With regard to exchangeable potassium, the significantly highest content of exchangeable potassium (K) was recorded at lower topographic positions (Table 8). The higher exchangeable potassium of the soils at lower topographic positions as compared to those on upslope positions were influence of slope classes. This could be attributed to the transport of soil materials from upslope positions and their deposition on the lower slope and depression corroborating previous finding by Dinku *et al*. (2014) and Sheleme (2017). Concerning the CEC of the soil, the significantly lower CEC of the soil was recorded at lower topographic position where the transport of soil materials from upslope positions and their deposition on the lower slope are expected, although this could not explain the low soil CEC obtained at lower slope positions (Table 8). Incontrast to this study, the highest values of CEC, were recorded at the topographic position with the low slope gradient indicating the accumulations of OC and bases from steep slope areas (Sheleme, 2017; Dinku *et al*., 2014). Similaly, the significantly highest available Fe and Mn were recorded at upper topographic position (Table 8). This variation could be due to the removal of exchangeable bases from upper slope position and deposition at lower and depression area. Mengistu *et al.* (2017) also discussed the reason of higher available micronutrient at the surface layer of soil are because of removal of basic cations from surfaces to subsurface layer through leaching.

4.6.2. Effect of land uses on physicochemical properties of soil

The significantly lower contetns of exchangeable magnesium, exchangeable potassium and exchangeable sodium were observed under cultivated land (Table 9). The significantly lower contents of exchangeable Mg, K and Na observed under cultivated land could related to removal of exchangeable bases through harvested product, continuous cultivations and inorganic farming practices in the study area. The result is supported by previous study findings that indicate intensity of weathering, cultivation and use of acid forming inorganic fertilizers affect the distribution of exchangeable bases in the soil system and enhance its depletion (Mengistu *et al*., 2017). Where as, the significantly higher CEC contents were recorded under grass land (Table 9). The higher CEC values recorded under grass land soil could be attributed to the effect of the relatively higher organic matter content of the grassland, since organic matter is strongly associated with CEC as was also discussed by Sheleme (2017).

Table 9. Effect of land use on soil chemical properties of Boneya Keto toposequence

Land use	**Chemical properties**							
	EC	**Mg**	**K**	**Na**	**CEC**	**Fe**	**Mn**	**Zn**
		(cmol(+)/kg of soils)						
Cultivated	0.04b	2.6^{b}	1.6^{b}	1.1^{b}	36.1^{b}	12.6^{b}	5.5b	1.3b
Grassland	0.06a	3.1^{a}	2.1^{a}	1.2^{a}	37.8^{a}	17.4^{a}	11.3a	1.9a
LSD $_{t0.05}$	0.01	0.28	0.39	0.07	1.55	3.76	4.53	0.52
CV (%)	19.93	9.59	21.01	6.24	4.11	24.41	25.36	31.33

Mean followed by the same letters was not significant at the probability level of 0.05

With regard to extractable micronutrient, the significantly highest available micronutrient (Fe, Mn and Zn) were recorded under grassland (Table 9) which might be attributed to absence of their removal though harvested crop product. The result corroborating previous study finding by Alemayehu and Sheleme (2013) and Mengistu *et al*. (2017) who reported that micronutrient status was significantly influenced by different land use systems, whereby the higher extractable micronutrient cations were available in grazing land as compared to cultivated land uses.

4.6.3. The interaction effect of land uses and topography on physicochemical properties of soils

Considering the interaction effects of land use and topographic position, the significantly lowest pH was recorded at lower topographic position under cultivated land (Table 10). The significantly lower pH at lower topography under cultivated land might be attributed to lower total exchangeable bases which evidenced by significant and positive correlations (r= 0.47*). Continuous cultivation practices and application of inorganic fertilizers could also be some of the factors which are responsible for the low pH in the under cultivated land of lower topographic position soil. The other studies also reported continuous cultivation practices, and application of inorganic fertilizers could be some of the factors which are responsible for the variation in pH in the soil profiles (Ahmed, 2002; Mengistu *et al*., 2017).

Wih regards to exchangeable bases, the significantly highest exchangeable magnesium, potassium and sodium were recorded under grass land at lower topographic position (Table 10). The possible reason could be due to the transport of soil materials from upslope positions and their deposition on the lower slope and absence of removal of exchangeable bases through harvested crop product under grassland soil. Inadition to this, the varation observed might be related to varations in their OC contents between land uses and removal of OC from upslope and accumulations on the lower slope positions corroborating other study (Sheleme, 2017) who reported higher contents of exchangeable bases under grass land and ascribed to higher organic carbon contents of grass land soil. Similarly, the signifficanly higher CEC was notedunder grass land soil and could be attributed to the effect of the relatively higher organic matter content of the grassland, since organic matter is strongly associated with CEC as was also discussed by Sheleme (2017).

Table 10. The interaction effect of topography and land use on soil chemical properties of of Boneya Keto toposequence

Topographic position	**Land use**	**Chemical properties**										
		pH	**EC**	**Mg**	**K**	**Na**	**CEC**	**PBS**	**TEB**	**Fe**	**Mn**	**Zn**
UTP	**Cultivated**	6.4^{a}	0.05^{b}	2.2^{c}	2.0^{b}	1.2^{a}	38.5^{a}	77.2^{a}	29.7^{a}	11.8^{b}	1.7^{b}	0.9^{c}
	Grassland	5.8^{bcd}	0.04^{bc}	3.0^{ab}	1.1^{c}	1.1^{a}	39.1^{a}	61.4^{b}	23.9^{ab}	27.5^{a}	24.2^{a}	2.4^{a}
MTP	**Cultivated**	5.6^{cd}	0.03^{c}	3.1^{ab}	1.1^{c}	0.9^{b}	38.1^{a}	68.6^{ab}	26.1^{ab}	11.6^{b}	6.5^{b}	1.6^{abc}
	Grassland	6.1^{ab}	0.04^{bc}	2.9^{ab}	2.4^{ab}	1.2^{a}	36.4^{a}	82.2^{a}	29.9^{a}	10.8^{b}	3.1^{b}	1.4^{bc}
LTP	**Cultivated**	5.4^{d}	0.03^{bc}	2.6^{bc}	1.8^{b}	1.1^{a}	31.6^{b}	70.4^{ab}	22.3^{b}	14.3^{b}	8.5^{b}	1.4^{bc}
	Grassland	6.1^{abc}	0.1^{a}	3.1^{a}	2.8^{a}	1.2^{a}	38.1^{a}	75.1^{ab}	28.7^{ab}	13.9^{b}	6.6^{b}	2.1^{ab}
LSD $_{t0.05}$		0.49	0.02	0.48	0.69	0.13	2.70	15.5	6.74	6.52	7.86	0.91
CV (%)		4.72	19.93	9.59	21.01	6.24	4.11	12	14.14	24.41	25.36	31.33

mean followed by the same letters was not significant at probability level of 0.05; UTP, MTP and LTP =Upper, middle and lower topographic position respectively.

Regarding to the interactions effect of topography and land uses on extractable miconutrients, the significantly higher available micro nutrient (Fe, Mn and Zn) were observed under grassland soil at upper topographic positions (Table 10). This variation might be attributed to removal of exchangeable bases from upper slope position though erosion and absence of microntrrient removal through harvested crop product as was also discussed by Mengistu *et al.* (2017).

5. CONCLUSIONS AND RECOMMENDATION

Soils of BoneyaKeto toposequence, Southern Ethiopia, could differ as a result of erosion, transport and deposition of surface materials as well as leaching, translocation and deposition of chemicals and particulate constituents in the soil. Topography plays a major role in these processes and thereby influences the development and characteristics of the soils along the toposequence. Soil color and particle-size distributions were influenced by topography such that the upper and middle slope position soils were black to dark red and course texture, whereas the lower slope position soils were black to very dark grayish and clayey texture. The topography has also influenced site characteristics (i.e., drainage, susceptibility to erosion and land use types) and soil morphological properties (i.e., soil depth, root ability and profile development). Soil depth, root ability and profile development improved from the upper to the lower slope positions, whereas the drainage conditions decrease from upper slope to lower slope position. Moreover, the upper and middle slope position were enhanced the surface erosion due to that the surface horizon of the upper and middle slope position shallow. Whereas, the lower slope position had thick surface horizon. The most of the important soil quality indicators such as bulk density, structure, OC, soil pH, CEC, total N, available P, exchangeable bases, and available micronutrients were influenced by the different landscape positions, particularly at the surface horizon. Consequently, three soil types, Phaezomes, Cambisols and Luvisols were identified in upper, middle and lower slope position respectively.

The land use types of the BoneyaKeto toposequence, Southern Ethiopia have also controlled the chemical properties of the soils, particularly soil organic carbon, exchangeable bases and CEC. Grassland soils had higher amount of organic carbon, exchangeable bases and CEC, as compared to their cultivated counterparts. Thus, reducing intensive cultivation, implemented soil management practices to control erosion and integrated use of inorganic and organic fertilizers could replenish the degraded soil quality parameters for sustainable productivity as well as reduce runoff and surface soil removal. However, further study of the areas is recommended especially with respect to soil landscape land management relationships so as to give sound conclusion for the sustainable use of the land.

6. REFERENCES

Abay Ayalew and Sheleme Beyene. 2012. Characterization of soils and response of potato (Solanum tuberosum l.) to application of potassium at Angacha in southern Ethiopia. *Int. Res. J. Biochem. Bioinform*, 2(2): 046-057.

Abayneh Esayas. 2001. Application of Geographic Information System (GIS) for soil resource study in Ethiopia. Proceedings of the National Sensitization Workshop on Agro metrology and GIS, 17-18 December 2001, Addis Ababa, Ethiopia.

Abayneh Esayas. 2001. Some physicochemical characteristics of the Raya valley soils, Ethiopia. *Ethiopian Journal of Natural resource*, 3(2); 155-171.

Addis Shiferaw, Fantaw Yimer and Samuel Tuffa. 2019. Changes in soil organic carbon stockunder different land use types in semiarid Borana rangelands: Implications for CO2Emission Mitigation in the Rangelands. *J Agri Sci Food Res*, 10(1): 254.

Ahmed Hussein. 2002. Assessment of spatial variability of some physico-chemicalproperties of soils under different elevations and land use systems in the western slopes of Mount Chilalo, Arsi. MSc Thesis Submitted to the School of Graduate Studies, Alemaya University, Ethiopia. 111p.

Alemayehu Adugna and Assefa Abegaz. 2016. Effects of land use changes on the dynamics ofselected soil properties in northeast Wollega, Ethiopia. Copernicus Publications onbehalf of the European Geosciences Union.2: 63–70.

Alemayehu Tadesse. 1990. Soil and irrigation management in the state farms. In: Proceedings of the First Natural Resources Conservation Conference. Natural Resource Degradation:

A Challenge to Ethiopia, 7-8 Feb 1989, Pp. 47-52. Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.

Alemayehu, K. and Sheleme, B. 2013. Effects of different land use systems on selected soil properties in Southern Ethiopia. *J. Soil Sci. Environ. Manage*. 4(5):100-107.

Alemayehu, K., Sheleme, B. and Schoenau, J. 2016. Characterization of problem soils in and around the south central Ethiopian Rift Valley. *J. Soil Sci. Environ. Manage*. 7(11):191-203.

Alemu Lelago and Tadele Buraka. 2018. Soil classification and Agricultural potentials of soil of tembero district,kembata tembero zone ,southern Ethiopia.civil and environmental research vol 10 no 6

Amelework Kindihun. 2017. Assessment of Farmers ‘Perception on the Status, Classificationand Management Practices of Soil Fertility in Comparison to Scientific Practices: inthe case of Ada‘a district, central highlands of Ethiopia. MSc. Thesis, Submitted tothe College of Social Sciences, Addis Ababa University. Addis Ababa.113pp.

Amhakhian, S.O. and Achimugu, S. 2011. Characteristics of soil on toposequence in Egume, Dekina Local Government Area of Kogi State. Production Agriculture and Technology, 7(2), 29-36.

Amsalu, A., Stroosnijder, L. and de Graaff, J. 2007. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. J. Envir. Manag. 83, 448–459.

Amuyou, U. A. and Kotingo, K. E. 2015. Toposequence analysis of soil properties of an agricultural field in the Obudu Mountain slopes, cross river state-Nigeria. European journal of physical and agricultural sciences, 3(1).

Ashenafi, A., Abayneh, E. and Sheleme, B. 2010. Characterizing soils of DelboWegen watershed, Wolayita zone, southern Ethiopia, for planning appropriate land management. *J. Soil Sci. Environ. Manage*. 1(8):184-189

Atofarati, S. O., Ewulo, B. S. and Ojeniyi, S. O. 2012. Characterization and classification of soils on two toposequence at Ile-Oluji, Ondo State, Nigeria. *International Journal of Agricultural Science*, 2(7), 642-650.

Balasubramanian .2017. Soil Morphology Centre for Advanced Studies in Earth Science, University of Mysore, Mysore DOI: 10.13140/RG.2.2.14083.91686.

Bandel, V.A. and J.J. Meisinger. 2002. Basic principles of soil Fertility II: Soil properties. College of Agriculture and Natural Resources. University of Mary land, FS- 640.

Belay Tegene, 1998. Pedogenesis and soil-geomorphic relationships on the piedmont slopes of Wurgo Valley, Southern Welo, Ethiopia. SINET: Ethiop. J. Sci. 21(1): 91-111.

Belay Tegene. 1996. Characteristics and landscape relationships of Vertisols and Vertic Luvisols of Melbe, Tigray, Ethiopia. SINET: Ethiop. *J. Sci*. 19(2): 93-115.

Berhanu D (1980). The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Berhanu Seyoum. 2016. Assessment of soil fertility status of Vertisols under selected three landuses in Girar Jarso District of North Shoa Zone, Ethiopia. *Environmental System Research Journal*. 5(18):1-16.

Bierman, P.M., and C. J. Rosen. 2005. Nutrient cycling and maintaining soil fertility, fruit and vegetable crop systems. University of Minnesota Extension service, 24p.

Bohn H.L., McNeal B.L. and OConnor G.A. 2001. Soil Chemistry. 3 rd ed. John Wiley and Sons. Inc. USA.

Boul, S.W., Southard, R. J., Graham, R. C. and McDaniel, P. A. 2011. Soil genesis and classification.6th ed. Iowa State University Press. Ames, USA.

Brady, N. C. and Weil, R. R. 2002. The Nature and Properties of Soils, 13th Ed. Prentice-Hall Inc., New Jersey, USA. 960p.

Buruah, T.C. and H.P. Barthakur. 1997. A Text Book of Soil Analysis. Vikas Publishing house PVT LTD. India.

Celik, I. 2005. Land use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil and Tillage Research 83: 270-277.

Central Statistical Agency. 2010. Agricultural Sample Survey. Statistical Bulletin 468Addis Ababa.

Chapman, H.D. 1965. Cation Exchange Capacity. pp. 891-901, In: Black, C.A. (Ed), Methods of Soil Analysis. American Society of Agronomy, Wisconsin USA.

Chaudhary, B. D. 2002. Fundamentals of Soil Science. Division of Soil Science and Agricultural Chemistry, Indian Agricultural Institute, New Delhi.

Daniel Adhanom and Tefera Toshome. 2016. Characterization and Classification of Soils of Aba Midan Sub Watershed in Bambasi Wereda, West Ethiopia, *International Journal of Scientific and Research Publications* Volume 6, Issue 6 pp. 390-399 www.ijsrp.org

Day, P.R., 1965. Hydrometer Method of Particle Size Analysis. pp. 562-563. In C.A. Black (Ed.). Methods of Soil Analysis. Agron. Part II, No .9 Am. Soc. Agron. Madison, Wisconsin, USA.

Demel Teketay. 2001. Vegetation Type and Forest Fire Management in Ethiopia, pp 1-35. Proceedings of Round-Table Conference on Integrated Forest Fire Management in Ethiopia. September 19-21.

Demelash Wendemeneh. 2010. Characterization and classification of the soils of upper sala watershed in Dilla zuria District of Gedeo Zone, Southern Ethiopia. MSc Thesis, Haramaya University, Haramaya.

Dereje Tilahun Tamirat. 2004. Soil fertility status with emphasis on some micronutrients in vegetable growing area of Fofele, Addi Ababa, Ethiopia. M.Sc. Thesis Submitted to School of Graduate Studies of Alemaya University, Ethiopia. 78p.

Dinaburga, G., Lapins, D. and Kopmanis, J. 2010. Differences of soil agrochemical properties in connection with altitude in Winter Wheat. Engineering for Rural Development, 79-84.

Dinku, D., Sheleme, B., Nand Ram, Walley, F. and Gala, TS. 2014. Effects of Topography and land use on soil characteristics along the toposequence of Ele watershed in southern Ethiopia. Catena, 115:47-54.

Endalkachew, F., Kibebew, K., Bobe, B. and Asmare, M. 2018. Characterization and classification of soils of Yikalo Subwatershed in Lay Gayint District, Northwestern Highlands of Ethiopia. *Eurasian Journal of Soil Science* vol 7 issue(2) pp. 151 - 166DOI: 10.18393/ejss.376267

EthioSIS. 2016. Soil Fertility Status and Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples' Regional State, Addis Ababa, Ethiopia.

Eylachew, Z. 2001. Study on the physical, chemical and mineralogical characteristics of some Vertisols of Ethiopia. pp.87-102. In: Wondimagegn Chekol and Engida Marsha (eds.), Proceedings of the 5th Conference of the Ethiopian Society of Soil Science/ESSS, March 30-31, 2000. The ESSS. Addis Ababa.

Fantaw, Y., Ledin S. and Abdelkadir A. 2006. Soil property variations in relation to topographic aspect and vegetation community in the southeastern highlands of Ethiopia. *Forest Ecology and Management.* 232 (1): 90–99.

FAO. 2017. Voluntary Guidelines for Sustainable Soil Management. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 16p.http://www.fao.org/3/a-bl813e.pdf

Fikre, M. 2003. Pedogenesis of ma jor volcanic soils of the south central rift valley Region, Ethiopia. MSc Thesis. University of Saskatchewan. Saskatoon, Canada. pp. 128.

Fisher, R. F. and Binkley, D. 2000. Ecology and Management of Forest Soils. John Wiley & Sons, New York. Pp.489.

Food and Agricultural Organization (FAO), 2006. Guidelines for soil profile description. Soil Resources, Management and Conservation Service, Land and Water Development Division, FAO, Rome.

Food and Agricultural Organization/United Nat ions Development Program (FAO/UNDP), 1984. Ethiopian geomorphology and soils (1:1,000,000 scales). Assistance to land use Planning. Addis Ababa, Ethiopia.

Foth, H. D. and Ellias, B.G. 1997. Soil Fertility, 2nd Ed. Lewis CRC Press LLC., USA. 290p.

Foth, H.D., 1990. Fundamentals of Soil Science. 7th Edition. John Wiley and Sons, Inc., USA.

Fritzsche, F., W. Zech and G. Guggenberger, 2007. Soils of Ethiopian Rift valley escarpment: A transect study, Volume 70, issue 2, pp. 209-219.

Fungo, B., Grunwald, S., Tenywa, M., Vanlauwe, B. and Nkedi-Kizza, P. 2011. Lunnyu soils in *European Journal of Physical and Agricultural Sciences* Vol. 3 No. 1, pp. 15 -24

Gregorich, E.G., Carter, M.R., Angers, D.A., Monereal, C.M. and Ellert, B.H. 1994. Towards a minimum data set to Asses, soil organic matter quality in agricultural soils. Can. *Journal of soil science* 74: 367-385.

Griffiths, R. P., Madritch, M. D. and Swanson, A. K. 2009. The effects of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): Implications for the effects of climate change on soil properties. Forest Ecology and Management, 257, 1-7. http://dx.doi.org/10.1016/j. foreco.2008.08.010

Gupta P.K. 2004. Soil, plant, water and fertilizer analysis. Shyam Printing Press. Agrobios, India. 438pp.

Hailu, A.H., Kibret, K. and Gebrekidan, H. 2015. Characterization and classification of soils of Kabe Subwatershed in South Wollo Zone, Northeastern Ethiopia. *African Journal of Soil Science* 3(7): 134-146.

Haque, I. 1987. Molybdenum in soils and plants and its potential importance to livestock nutrition with special reference to Sub Saharan Africa. International Livestock Center for Africa (ILCA) Bull. No. 26: 41p.

Haque, I. 1988. Bibliography on Micronutrients in Soils, Plants and Animals in Sub-Saharan Africa. Plant Science Division Working Document Number B8. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. 138p.

Havlin, J. L., Tisdale, S. L., Nelson, W. L., and Beaton, J. D. 2002. Soil fertility and fertilizer. 7th Ed. Prentice-Hall of India, New Delhi. 633p.

Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nilson, W.L. 1999. Soil fertility and fertilizers: an introduction to nutrient management. 6th ed. Prentice-Hall. Upper Saddle River. New Jersey.

Hillel, D. 1980. Fundamentals of Soil Physics. Academic Press, Inc., London.

Hillel, D. 2004. Introduction to Environmental Soil Physics. Elsevier Academic Press.

Hossain, M.M., Khan, Z.H., Hussain, M.S. and Mazumder, A.R. 2011. Characterization and classification of some intensively cultivated soils from the Ganges river floodplain of Bangladesh. Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh. Biol. Sci. 20(1): 71- 80.

IUSS Working Group WRB. 2015. World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Jobira Defera. 2018. Assessment of Physicochemical Properties of Soil under Different LandUse Types at Wuye Gose Sub- Watershed, North Shoa Zone of Oromia Region,Ethiopia. MSc. Thesis, School of Natural Resources Management and EnvironmentalSciences, Haramaya University. Haramaya.70pp.

Kimmins, J. P. 1997. Forest ecology: A foundation for sustainable management, 2nd Edition. New Jersey.

Kordel, W., Dassenakis, M., Lintelmann, J. and S. Padberg. 1997. The importance of natural organic material for environmental processes in waters and soils. Technical Report. International Union of Pure and Applied Chemistry. Pure and Applied Chem. 69(7): 1571-1600.

Laekemariam, F., Kibret, K., Memo, T., Karltun, E. And Gebrekidan, H. 2016. Physiographic characteristics of agricultural lands and farmers' soil fertility management practices in Wolaita zone, Southern Ethiopia. Environ Syst. Res. 5: 24.

Lal, R. and M.K. Shukla. 2004. Principles of soil physics. Marcel Dekker, Inc. New York, USA.699p.

Lalisa, A., Herbert, H. and Monika, S. 2010. Effects of Land Use Types on Soil Chemical Properties in Smallholder Farmers of Central Highland Ethiopia. Ekológia (Bratislava) 29: 1–14.

Landon, J.R. 2014. Booker Tropical Soil Manual. A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Taylor and Frances.

Lawal, B. A., Ojanuga, A. G., Tsado, P. A. and Mohammed, A. 2013. Characterization, classification and agricultural potentials of soils on a toposequence in southern guinea savanna of Nigeria, *International Journal of Agricultural and Bio systems Engineering*Vol:7, No:5, pp. 330-334.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science. Soceity. American. Journal*. 42: 421-428.

London, J.R. 1991. Booker tropical soil manual: Handbook for soil survey and agricultural land evaluation in tropics and subtropics. Longman London.

Magdoff, F. and H. Van. 2000. Building soils for better Crops Sustainable Agriculture Network 2nd Edition. Handbook Series 4. Beltsville, MD: National Agricultural Library

Mamo Yalew. 2011. Influence Of Land Use Systems on Selected Soil Physical and ChemicalProperties at Agedit Watershed, South Gondar Zone, Amhara Regional State. MSc.Thesis, College of Agriculture, Haramaya University, Ethiopia.83 pp.

Materechera, S. A.and Mkhabela, T.S. 2001. Influence of land-use on properties of a ferralitic soilunder low external input farming in Southeastern Swaziland. Soil & TillageResearch. 65:15-25.

Mebit Kebede. 2006. Physico-chemical Properties and Classification of Soils along the Toposequence at Woreta Agricultural Technical Vocational Education and Training College Research Farm. MSc Thesis, Haramaya University. Haramaya, Ethiopia.

Mengistu, C., Kibebew, K. and Tarekegn, F. 2017. Influence of Different Land Use Types and Soil Depths on Selected Soil Properties Related to Soil Fertility in Warandhab Area, HoroGuduruWallaga Zone, Oromiya, Ethiopia. *Int J Environ Sci* Nat Res.4(2): 555634. DOI: 10.19080/ IJESNR.2017.04.555634.

Mesfin Abebe. 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Metson, A.J., 1961. Methods of Chemical Analysis for Soil Survey Samples. Soil Bureau Bulletin No. 12, New Zealand Department of Scientific and Industrial Research, pp. 168–175.

Miller, P.W. and R.L Donahue, 1995. Soils in Our Environment. 7th Edition. PrinticeHall Inc, USA. 649p. Janzen.

Mohammed Assen. P.A.L., Leroux, C.H., Barker, and Heluf Gebrekidan. 2005. Soils of Jelo micro catchment in the Chercher highlands of eastern Ethiopia: I. Morphological and Physiochemical Properties. *Ethiopian Journal of Natural Resources*, 7(1): 55-81.

Muller, S., M. Karl and K. Johannes. 1994. Sustaining the soil: soil fertility management in the tropical smallholdings. Margraft Verlag. Germany.

Mulugeta T., Asmare M. and Wondwosen T. 2019. Effects of land use types on selected soil physical and chemical properties: The case of Kuyu District, Ethiopia. *Eurasian J Soil Sci.*
8: 94 – 109.

Mulugeta, D.and Sheleme B.2010. Characterization and classification of soils along the toposequence of Kindo Koye Watershed in Southern Ethiopia. *East African Journal of Sciences* 4 (2): 65–77.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal.Chim.Acta 27: 31-36.

Nahusenay Abate,Kibebew Kibret,Heluf Gebrekidan and Abayneh Esayas.2014. characterization and classification of the soil along the toposequence at the wadla Delenta massif, North centeral highlands of Ethiopia *journal of ecology and the natural environment*, vol 6, issue 9 pp-304-320

Noshadi, E., A. Hossein and S. Alavipanah.2013. Prediction of surface soil color using ETM+satellite images and artificial neural network approach. International Journal of Agriculture. 3(1): 87-95.

Nuga, B.O., N.C. Eluwa, G.E Akinbola and C.C. Wokocha. 2006. Characterization and classification of soils along a toposequence in Ikwuano Local Government Area of Abia State

Ogunkunle A.O.2005. Soil Survey and Sustainable Land Management. Invited paper at the 29th annual conf. of SSSN held at University of Nigeria, Abeokuta, from 6th to 10th Dec. 2004.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean.1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA, Circular, 939: 1-19

Olson, G.W., 1981. Soil and the environment. A Guide to Soil Survey sands their applications. Chapman and Hall, 178 p.

Piccolo, A. and G. Huluka, 1986. Phosphorus status of some Ethiopian soils, Trop.Agric. (Trinidad) 63 (2).

Prasad, R., & James F. P. (1997). Soil Fertility management for sustainable Agriculture. Lewis Publisher, New York Printed-Hall Inc. U.S.A.

Rabia, A. H., Afifi, A.R., Gelaw, A. M., Bianchi, S., Figueredo, H., Huong, T. L., Lopez, A. A., Damiao, S., Matta, M.E., Ronchi, M., Solomon, H. W., Tine, A. K., Youssef, M. S., Gutierrez, M. G.,Yusuf, M. M. and Alessandro, V. 2013. Soil mapping and classification: a case study in the Tigray Region, Ethiopia, Journal of Agriculture and Environment for International Development – JAEID 107 (1): 73 – 99.

Rose, C.W, J.W. Holmes & T.J. Marshall., 1996. Soil physics, 3rd Edition. Cambridge. 453p.

Rowell D.L., 1994. Soil Science: Methods and Applications. Addison Wesley Longman Singapore Pub. (Pvt) Ltd., UK, 350p

Sahlemeden Serstu and Taye Bekele. 2000. Procedure for soil and plant analysis. National Soil Research Center, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. 110p.

Samuel Feyissa. 2006. Characterization and Classification of Soils of Maichew Agricultural Technical and Vocational Education and Training College, Tigray, Ethiopia. Msc Thesis, Haramaya University, Haramaya.

Satyavathi, P. L. and A. Suryanarayan M. Reddy. 2003. characterization and classification of shallow, medium deep and deep red and black soils of northern telangana zone in andhra pradesh. *Journal of Tropical Agriculture* 41: 23-29

Schoonover, J.E and Crim, J.F. 2015. An introduction to soil concepts and the role of soils in watershed management. *Journal of Contemporary Water Research and Education* 154(1): 21-47.

Seid Mohammed ,Kibebew Kibret and Mukter Mohammed .2017. Charactrization and classification of soil along toposequence of gobeya sub-water shed , south wello zone, Ethiopia. AJSSPN:4:1-17.

Serkalem Tamiru and Sosena Amsalu.2019. Soil characterization and evaluation of blended (yaramila cereal) fertilizer for bread wheat (triticum aestivum L.) production at Aleltu areas North shewa of oromia region. JSSEM; 10: 114-123.

Shapro C. A., Wortmann C., Drijber A. R. and Martha M. 2013. Soil organic carbon: The valueto soil properties. *Journal of Soil and Water Conservation*. 66 (5):129-134pp.

Shaw, R.J., 1999. Soil Salinity, Electrical Conductivity and Chloride. In 'Soil analysis: An interpretation manual ' . (Eds. K.I. Peverill, L.A. Sparrow and D.J. Reuter.) pp. 129-144 (CSIRO Publishing: Melbourne).

Sheleme Beyene. 2017. Topographic positions and land use impacted soil properties along humbo larena-ofa sere toposequence, southern Ethiopia. Journal of Soil Science andEnvironmental Management. 8: 135-147.

Sheleme Beyene. 2011. Characterization of Soils along a Toposequence in Gununo Area, Southern Ethiopia. *Journal of Science and Development* 1(1): 31-41.

Shiferaw Boke. 2004. Soil phosphorus fractions as influenced by different cropping systems in Andosols and Nitosols in Kembata-Tembaro and Wolayta Zones, SNNPRS. MSc Thesis. Alemaya University, (AU). 131p

Shimeles Damene. 2012. Effectiveness of soil and water conservation measures for land restoration in the Wello area, northern Ethiopian highlands. *Ecology and Development Series* No. 89.

Shimeles, D. 2006. Characterization and classification of soils at Tenocha catchment. MSc Thesis. Alemaya University. P. 39

Shimelis, D., Mohamed, A., Abayneh, E., 2007. Characteristics and classification of the soils of Tenocha -Wenchacher micro-catchment, South-West Shewa, Ethiopia. Ethiopian Journal of Natural Resources 9(1): 37-62.

Sims, J.T. 2000. Soil fertility evaluation. In: Sumner, M.E. (Ed.), Handbook of Soil Science.CRC Press, Boca Raton, Florida. pp. D-113– D-127.

Solomon Yilma. 2006. Characteristics, Classification and Agricultural Potentials of Soils of Gonde Micro catchment, Arsi Highlands, Ethiopia. MSc Thesis, Haramaya University. Haramaya, Ethiopia.

Sonon L. S., Kissel D. E and Saha U. 2014. Cation Exchange Capacity and Base Saturation.UGA Extension Circular 1040.Wakene Negassa and Hiluf Gebrekidan.2003. Influence of land management on morphological,physical and chemical properties of some soils of Bako, Western Ethiopia.Agropedology. 13 (2):1-9.

Statistical Analysis System (SAS). 2008. Institute Inc,2008.SAS/STAT 9.2 User's Guide, SAS Institute, Cary, NC, USA, 2008.

Tadesse Kippe. 2002. A Case Study on Gedeo Land Use (Southern Ethiopia). PhD Thesis, University of Wageningen, the Netherlands.

Tamene L; Amide T; Kihara J; Tibebe D; Schuls S.(eds). 2017. A reviwof soil fertility management and crop response to fertilizer application in Ethiopia : towards development of site and context –specific fertilizer recommendation .CIAT publication NO.443. International center for tropical agriculture (CIAT), addis ababa,Ethiopia. 86p. available at: httpillhdi. Handle. net /10568/ 82996.

Teferi, T. 2008. Soil fertility assessment and mapping in selected Highland areas of Kuyu district in north Shoa Zone of Oromia Region. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Tekalign Mamo, I. Haque, and C.S. Kamara. 1998. Phosphorus status of Ethiopian Vertisols: Management of Vertisols in Sub-Saharan Africa. pp. 232-252.

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Teshome Y, Sheleme B and Kibebew, K .2016. Characterization and classification of soils of Abobo area, western Ethiopia. Applied and Environ. Soil Sci. 1-16.

Teshome Yitbarek *, Abdeta Jembere and Habtamu Kerebeh.2018Characterization and classification of soils of Wolkite University research sites, *Ethiopia Eurasian Journal of Soil Science* vol 7 issu(4) pp. 292 - 299DOI: 10.18393/ejss.436186

Thompson, L.M and Troeh, RF. 1993. Soils and Soil Fertility, 5th ed., Oxford University Press, NY, USA. P 462.

Tilahun C. and Asefa T. 2009. Assessment of soil organic matter under four land use systems in Bale Highlands, Southeast Ethiopia. World Appl. Sci. Journal. 6: 1231–1246.

United States Salinity Laboratory Staff, 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Agriculture Handbook No. 60, U. S. Govt. Printing Office. Washington, D. C, USA.

Wakene Negassa and Heluf Gebrekidan. 2003. Forms of phosphorus and status of available nutrients under different land use systems of Alfisols in Bako area, Ethiopia. *Ethiopian Journal of Natural Resources* 5(1): 17-37.

Wakene Negassa. 2001. Assessment of Important Physicochemical Properties of Nitosols under Different Management Systems in Bako Area, Western Ethiopia. M.Sc. Thesis, Alemaya University, Alemaya. pp 109.

Walkley,A. and C.A. Black. 1934. An Examination of Different Methods for Determining Soil Organic Matter and the Proposed Modifications by the Chromic Acid Titration Method. Soil Sci: 37:29-38.

Wasihun Mengistu. 2015. Evaluation of the effect of land use types on selected soil physicochemical properties in Itang-Ker Area of Gambella Regional State of Ethiopia. MSc.Thesis, Haramaya University, Ethiopia.58pp.

Webster K.L., Creed I.F. Beall F.D. And Bourbonnière R.A. 2011. A topographic template for estimating soil carbon pools in forested catchments. Geoderma. 160: 457–467.

Weigel, G., 1986. The Soils of Maybar Area, Wello Research Unit, Ethiopia. Soil Conservation Research project, Research Report (7). 104p.

Wiedenhoeft and Alex C.2006. Plant Nutrition. An imprint of InfoBase Publ.132 West 31stStreet, New York NY 10001.

Wondimagegn Amanuel, Fantaw Yimer and Erik K. 2018. Soil organic carbon variation inrelation to land use changes the case of Birr watershed, upper Blue Nile River Basin,*Ethiopia. Journal of Ecology and Environment*.42:16.

World reference base for soil resources. 2006. A framework for international classification, correlation and communication Web site: http://www.fao.org

Yihenew Gebreselassie. 2002. Selected chemical and physical characteristics of soils of Adet Research Centre and its testing sites in northwestern Ethiopia. *Ethiopian Journal of Natural Resources.* 4(2): 199-215.

7. APPENDIX

Appendix Table 1: Profile Description Sheet

Profile No 1	
Location	Bonia Misrak silitiee
Date of examination	
Surveyor	Salya Hassen
Coordinates	N 07^{o} 56'43'' E 38^{o}23'12''
Elevation	1902m a.s.l
Human influence	Have influence
Surrounding landform	Steep slope
Physiographic position	upper slope
Slope	7%
Moisture condition	Moist
Drainage	Well drained
Soil type	Sanch afer
Groundwater table	Not observed up to 200+ cm depth
Parent materials	Basaltic Type
Erosion	Water and sheet erosion
Rock outcrops/stoniness	None
Present land use	Agriculture
Rootable depth	67 cm

Horizon	Depth (cm)	Description
AP	0-15	Black (7.5YR2.5/1) moist; clay; weak, fine, granular; very friable, sticky and plastic; few, fine roots; clear and smooth boundary.
AC	15-32	Brown (7.5YR4/3) moist; loam; moderate, medium, sub angular blocky; very friable, slightly sticky and slightly plastic; very few, fine roots; gradual and smooth boundary.
C1	32-67	Dark brown (7.5YR3/3) moist; sandy loam; strong, common, massive; very firm, slightly sticky and slightly plastic; very few, very fine roots; gradual and smooth boundary.
C2	67-110	Very dark brown (7.5YR2.5/3) moist; loam; strong, very common, massive; extremely firm, slightly sticky and slightly plastic; diffuse and smooth boundary.

C3	110-200+	Dark brown (7.5YR3/4) moist; loam; strong, very common, massive; firm, slightly sticky and slightly plastic.

Profile No 2	
Location	Kito Misrak silitiee
Date of examination	
Surveyor	Salya Hassen
Coordinates	N 07^{o} 56’50’’ E 38^{o}23’04’’
Elevation	1855m a.s.l
Human influence	Have influence
Surrounding landform	gently slope
Physiographic position	middle slope
Slope	5%
Moisture condition	Moist
Drainage	Well drained
Soil type	Lem
Groundwater table	Not observed up to 200+ cm depth
Parent materials	Basaltic Type
Erosion	Water and sheet erosion
Rock outcrops/stoniness	None
Present land use	agriculture
Rootable depth	85 cm

Horizon	Depth (cm)	Description
AP	0-30	Very dark gray (7.5YR3/1) moist; clay; weak, fine, granular; very friable, very sticky and very plastic; few, fine roots; diffuse and smooth boundary.
AB	30-55	Very dark brown (10YR2/2) moist; clay; weak, fine, sub angular blocky; very friable, very sticky and very plastic; few, fine roots; diffuse and smooth boundary.
B	55-85	Dark brown (7.5YR3/2) moist; clay; weak, fine, sub angular blocky; very friable, very sticky and very plastic; very few, very fine roots; gradual and

		smooth boundary.
BC	85-136	Dark brown (7.5YR3/4) moist; clay loam; weak, fine, sub angular blocky; very firm, slightly sticky and slightly plastic; very few, fine; gradual and smooth boundary.
C	136-200^{+}	Dark brown (7.5YR3/3) moist; loam; strong, common, massive; extremely firm, slightly sticky and slightly plastic.

Profile No 3	
Location	Rabaka Misrak silitiee
Date of examination	
Surveyor	Salya Hassen
Coordinates	N 07^{o} 56'55'' E 38^{o}22'54''
Elevation	1834m a.s.l
Human influence	Have influence
Surrounding landform	nearly slope
Physiographic position	lower slope
Slope	1%
Moisture condition	Moist
Drainage	poor drained
Soil type	Tem afer
Groundwater table	Not observed up to 200+ cm depth
Parent materials	colluvium Type
Erosion	Water and sheet erosion
Rock outcrops/stoniness	None
Present land use	agriculture
Rootable depth	130 cm

Horizon	Depth (cm)	Description
AP	0-45	Reddish black (2.5YR2.5/1) moist; silt clay; weak, fine, granular; very friable, very sticky and very plastic; few, common roots; diffuse and smooth boundary.
B1	45-85	Black (5YR2.5/1) moist; clay; weak, fine, sub angular blocky; friable, very sticky and very plastic; few, fine roots; clear and smooth boundary.
B2	85-130	Very dusky red (2.5YR2.5/2) moist; clay; weak, fine, sub angular blocky; friable, very sticky and very plastic; very few, very fine roots; gradual and smooth boundary.
B3	130-200^{+}	Very dark brown (10YR2.5/1) moist; clay; weak, fine, sub angular blocky; very firm, very sticky and very plastic.

Appendix table2. Analysis of variance on the effect of topography and land use on physicochemical properties of soil

Parameters	Source of variation	DF	Square sum	Mean square	F	P Value
Clay	TP	2	412	206	12.4	0.0012
	LU	1	72	72	4.32	0.06
	TP*LU	2	28	14	0.84	0.45
	Error	12	200	16.7		
Silt	TP	2	230.1	115.1	12.4	0.0012
	LU	1	3.55	3.55	0.38	0.54
	TP*LU	2	61.4	30.7	3.31	0.07
	Error	12	111.3	9.3		
Sand	TP	2	355.4	177.7	9.66	0.0032
	LU	1	43.55	43.55	2.37	0.15
	TP*LU	2	12.11	6.1	0.33	0.13
	Error	12	220.7	18.4		
BD	TP	2	113.3	56.6	0.75	0.49
	LU	1	3	3.1	0.04	0.84
	TP*LU	2	674.1	337.1	4.45	0.035
	Error	12	908.6	75.7		
pH	TP	2	0.42	0.21	2.68	0.109
	LU	1	0.23	0.23	3.04	0.107
	TP*LU	2	1.24	0.62	7.99	0.006
	Error	12	0.93	0.08		
EC	TP	2	0.0027	0.0013	13.1	0.001
	LU	1	0.0025	0.0025	24.4	0.003

	TP*LU	2	0.0041	0.0021	19.8	0.002
	Error	12	0.0012	0.0001		
OC	TP	2	2.3	1.15	3.58	0.06
	LU	1	0.24	0.24	0.77	0.39
	TP*LU	2	0.22	0.11	0.34	0.72
	Error	12	3.85	0.32		
TN	TP	2	0.017	0.008	3.57	0.1
	LU	1	0.002	0.002	0.8	0.4
	TP*LU	2	0.002	0.001	0.34	0.7
	Error	12	0.03	0.002		
Av. P	TP	2	20.9	10.4	1.35	0.29
	LU	1	1.41	1.41	0.18	0.67
	TP*LU	2	53.9	26.9	3.49	0.06
	Error	12	92.6	7.72		

Appendix table2 continued

Parameters	Source of variation	DF	Square sum	Mean square	F	P Value
Ca	TP	2	30.5	15.3	1.28	0.31
	LU	1	1.32	1.32	0.11	0.74
	TP*LU	2	87.67	43.83	3.67	0.057
	Error	12	143.3	11.94		
Mg	TP	2	0.57	0.28	3.85	0.0511
	LU	1	0.78	0.78	10.55	0.007
	TP*LU	2	0.74	0.37	4.99	0.026
	Error	12	0.89	0.07		
K	TP	2	1.98	0.99	6.58	0.012
	LU	1	1.03	1.03	6.83	0.022
	TP*LU	2	4.64	2.32	15.4	0.005
	Error	12	1.81	0.15		
Na	TP	2	0.034	0.017	3.42	0.067
	LU	1	0.025	0.025	5.03	0.044
	TP*LU	2	0.047	0.023	4.61	0.032
	Error	12	0.061	0.005		
CEC	TP	2	47.05	23.52	10.21	0.0026
	LU	1	13.86	13.86	6.02	0.03
	TP*LU	2	52.2	26.1	11.32	0.0017
	Error	12	27.65	2.3		
Fe	TP	2	223.2	111.6	8.32	0.0054
	LU	1	105.8	105.8	7.89	0.0158

	TP*LU	2	265.8	132.9	9.91	0.003
	Error	12	160.9	13.4		
Mn	TP	2	205.2	102.6	5.26	0.023
	LU	1	148.4	148.4	7.6	0.017
	TP*LU	2	636.2	318.1	16.3	0.004
	Error	12	234.3	19.52		
Zn	TP	2	0.13	0.065	0.25	0.78
	LU	1	1.85	1.85	7.11	0.02
	TP*LU	2	2.27	1.14	4.38	0.037
	Error	12	3.12	0.26		
Cu	TP	2	0.124	0.062	3.2	0.07
	LU	1	0.073	0.073	3.76	0.07
	TP*LU	2	0.017	0.008	0.45	0.65
	Error	12	0.23	0.019		

Appendix table3. Pearson correlation matrix for pedon at different topographic position.

	Ph	EC	Fe	Mn	Zn	Cu	Ca	Mg	K	Na	TEB	CEC	PBS	Clay	Silt	Sand	OC	TN	A.P
pH	1																		
EC	0.72^{**}	1																	
Fe	-0.36	-0.53^{*}	1																
Mn	-0.66^{*}	-0.46	0.51	1															
Zn	-0.16	-0.15	0.46	0.59^{*}	1														
Cu	-0.46	-0.62^{*}	0.75^{**}	0.39	0.11	1													
Ca	0.41	0.62^{*}	-0.71^{**}	-0.36	-0.33	-0.64^{*}	1												
Mg	-0.55^{*}	-0.69^{*}	0.06	0.43	-0.07	0.34	-0.06	1											
K	0.26	0.28	-0.06	-0.19	-0.15	-0.09	0.42	0.07	1										
Na	0.62^{*}	0.74^{**}	-0.21	-0.52^{*}	-0.37	-0.28	0.44	-0.45	0.67^{**}	1									
TEB	0.36	0.55^{*}	-0.65^{*}	-0.33	-0.34	-0.58^{*}	0.98^{***}	0.05	0.55^{*}	0.47	1								
CEC	-0.34	-0.54^{*}	-0.05	0.02	-0.25	0.36	-0.26	0.33	-0.12	-0.37	-0.22	1							
PBS	0.42	0.64^{*}	-0.59^{*}	-0.31	-0.25	-0.62^{*}	0.96^{***}	-0.04	0.53^{*}	0.53^{*}	0.96^{***}	-0.47	1						
Clay	-0.71^{**}	$-0.74*^{*}$	0.33	0.71^{**}	0.19	0.58^{*}	-0.51	0.63^{*}	-0.57^{*}	-0.79^{**}	-0.49	0.41	-0.55^{*}	1					
Silt	0.37	0.34	0.04	-0.18	0.03	-0.02	-0.34	-0.52^{*}	-0.07	0.25	-0.37	0.04	-0.36	-0.23	1				
Sand	0.55^{*}	0.60^{*}	-0.36	-0.63^{*}	-0.21	-0.58^{*}	0.65^{*}	-0.41	0.61^{*}	0.69^{**}	0.66^{*}	-0.43	0.72^{**}	-0.9^{***}	-0.2	1			
OC	-0.68^{**}	-0.76^{**}	0.81^{**}	0.64^{*}	0.41	0.66^{*}	-0.78^{**}	0.21	-0.46	-0.62^{*}	-0.77^{**}	0.26	-0.77^{**}	0.67^{**}	-0.04	-0.66^{*}	1		
TN	-0.70^{**}	-0.72^{**}	0.78^{**}	0.65^{*}	0.44	0.62^{*}	-0.72^{**}	0.26	-0.47	-0.67^{**}	-0.72^{**}	0.24	-0.73^{**}	0.69^{**}	-0.08	-0.66^{*}	0.98^{***}	1	
A.P	0.22	0.17	0.11	-0.06	0.03	-0.28	0.07	-0.35	0.36	0.35	0.08	-0.15	0.11	-0.45	-0.01	0.46	0.02	-0.1	1

Appendix table4. Pearson correlation matrix for land use and topographic position.

	pH	EC	Fe	Mn	Zn	Cu	Ca	Mg	K	Na	TEB	CEC	PBS	Clay	Silt	Sand	OC	TN	A.P
pH	1																		
EC	0.72**	1																	
Fe	-0.36	0.02	1																
Mn	-0.31	-0.1	0.94***	1															
Zn	-0.15	0.23	0.77**	0.81***	1														
Cu	0.36	0.31	0.66**	0.53*	0.55*	1													
Ca	0.45	0.03	-0.47*	-0.47*	-0.33	-0.26	1												
Mg	-0.23	0.11	0.19	0.31	0.56*	0.05	0.15	1											
K	0.49*	0.63**	-0.38	-0.52*	-0.17	0.04	0.37	0.03	1										
Na	0.54*	0.51*	0.09	-0.11	0.02	0.52*	0.12	-0.13	0.68**	1									
TEB	0.47*	0.16	-0.46	-0.49*	-0.27	-0.22	0.98***	0.23	0.53*	0.24	1								
CEC	0.46	0.17	0.18	0.16	0.26	0.31	0.54*	0.31	-0.12	-0.07	0.50*	1							
PBS	0.31	0.07	-0.63**	-0.64**	-0.45	-0.41	0.84***	0.11	0.66**	0.31	0.88***	0.05	1						
Clay	-0.24	-0.06	-0.74**	-0.55*	-0.35	-0.5*	0.07	0.15	0.14	-0.37	0.09	-0.26	0.23	1					
Silt	-0.09	0.07	0.41	0.37	0.19	0.28	-0.4	-0.25	0.06	0.41	-0.36	-0.38	-0.21	-0.45	1				
Sand	0.33	0.01	0.45	0.29	0.21	0.34	0.25	0.08	-0.21	0.06	0.19	0.58*	-0.07	-0.7**	-0.32	1			
OC	-0.1	0.38	-0.39	-0.32	-0.22	-0.04	-0.03	-0.01	0.47*	0.26	0.05	-0.24	0.18	0.44	0.23	-0.6**	1		
TN	-0.21	0.39	-0.37	-0.36	-0.28	-0.03	-0.02	-0.1	0.46*	0.28	0.09	-0.17	0.27	0.43	0.21	-0.7**	0.99***	1	
A.P	-0.32	-0.21	-0.25	-0.11	-0.04	-0.44	0.26	0.58*	-0.13	-0.46	0.25	0.25	0.14	0.41	-0.27	-0.21	0.25	0.31	1

Appendix table5. Average monthly annual rainfall of study area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	NA	0	5	15.4	95.6	124.7	130.7	201.4	109.7	13.9	158.5	0
2009	3	1.5	90.8	7.6	26	39.5	178.9	132.5	66	138.9	0	23
2010	7.2	59.5	105.9	154.2	136	125.3	113	137.8	184.3	83.7	25	23
2011	NA	6.2	59.1	NA	NA	NA	138.4	122.2	NA	0	0	0
2012	0	0	66.3	44.5	63.5	93	276.9	64.1	105.7	0	0	0
2013	56.3	0	NA	99.4	23.5	122.3	104.9	73.2	56.1	116.1	0	0
2014	0	45.3	50	45.6	78	72.1	94	47.6	NA	NA	NA	NA
2015	0	0	10	NA	64.7	29.2	60.2	53	28.9	1.3	0	0
2016	NA	20	47	NA	14.9	2.1	67	71	82.8	16	0	NA
2017	33	17	33	32	75	33	73	52	57	19	0	0
2018	NA	NA	89.8	107.6	48	81	56	68	33	66	0	0
2019	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
AV.AN.RF	12.43	13.59	55.69	63.28	62.52	72.22	117.54	92.98	80.38	45.49	18.35	5.11

Appendix table6. Average monthly annual minimum temperature of study area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	NA	NA	NA	13.50	14.1	13.37	13.36	13.43	13.10	13.50	13.26	11.69
2007	11.95	13.62	13.67	14.02	13.64	12.23	12.62	12.29	12.74	12.64	NA	9.75
2008	10.86	11.58	13.49	12.35	13.67	13.54	12.85	13.30	13.23	13.37	12.10	10.6
2009	11.56	12.92	12.72	14.52	13.33	13.30	12.91	13.3	NA	11.92	11.96	12.72
2010	11.57	12.33	12.53	13.02	13.06	11.66	12.39	13.08	12.33	13.05	12.30	10.63
2011	11.72	12.74	13.36	14.02	13.58	NA	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	NA	NA	12.75	13.26	12.46	12.19	NA	11.85	NA	NA	11.90	NA
2014	11.83	12.35	13.18	13.78	13.42	12.85	12.58	11.83	12.12	12.12	NA	10.02
2015	10.48	12.33	13.56	14.04	12.65	13.03	11.53	11.41	12.87	14.21	13.28	12.76
2016	13.35	13.09	NA	13.89	13.49	12.45	12.88	12.75	12.97	12.43	12.77	11.82
2017	NA	12.55	14.07	13.33	13.7	13.48	13.11	13.26	24.74	NA	NA	NA
2018	9.31	12.43	12.26	12.68	13.02	12.75	11.70	12.32	12.14	11.80	12.15	11.00
2019	10.52	12.12	12.5	13.49	12.32	12.60	12.57	12.62	12.78	11.13	11.77	11.23
AV.M.ANU. MIN.T	11.32	12.55	13.10	13.53	13.26	12.79	12.59	12.62	13.90	12.62	12.39	11.22

Appendix table7. Average monthly annual maximum temperature of study area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	NA	NA	NA	25.05	25.44	24.06	22.39	21.43	23.61	25.27	25.68	25.22
2007	25.62	26.00	27.54	26.44	26.32	23.21	22.45	22.00	23.05	24.32	24.84	24.55
2008	26.43	26.23	28.26	27.31	25.36	23.74	21.62	21.77	23.26	24.38	23.39	24.43
2009	24.71	26.24	28.06	27.35	27.10	26.48	22.74	22.94	NA	23.97	25.48	24.29
2010	26.06	25.41	25.27	25.57	24.85	24.81	21.82	22.36	23.28	25.59	25.07	24.66
2011	26.07	27.59	26.49	28.06	25.62	NA	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013	NA	NA	27.60	26.22	25.40	23.64	NA	21.72	NA	NA	23.87	NA
2014	25.62	25.93	26.81	26.79	26.14	25.96	23.92	23.52	23.17	23.88	NA	24.61
2015	25.36	27.74	27.9	28.56	26.99	24.97	24.73	24.76	24.72	26.26	26.14	25.88
2016	26.35	27.80	NA	25.61	25.44	23.99	23.23	23.22	24.40	25.39	25.82	25.23
2017	NA	27.12	27.96	28.02	26.38	26.67	23.34	24.30	24.74	NA	NA	NA
2018	26.01	26.91	25.76	25.16	25.22	24.13	22.90	23.27	25.16	25.70	25.23	25.73
2019	26.40	28.29	29.17	27.43	27.72	24.31	23.26	23.05	24.50	24.69	25.83	25.52
AV.M.AN.MAX.T	25.86	26.84	27.35	26.73	26.00	24.66	22.94	22.86	23.99	24.94	25.14	25.01

8. BIOGRAPHICAL SKETCH

The author was born in July 1982 at the Gerbiber town, Silte Zone, SNNP Ethiopia. He attended his primary education in the Gerbiber Primary School and his secondary and preparatory school in the Kibet. After completion of his secondary and preparatory school education, he joined the Wolaita Sodo Agricultural college in March 2007 and graduated with BSc Degree in Plant Sciences in 2009. After that, he was employed as administrative member of Lanfaro worada at the Silte Zone and served for two year before joining the School of Graduate Studies at the Wolkite University in September, 2011 in the regular program to pursue his MSc study in soil science.