ASSESSEMENT OF STATUS OF SOIL ACIDITY UNDER DIFFERENT LAND USE TYPES AND SLOPE GRADIENTS: THE CASE OF WEST AZERNET BERBERE DISTRICT, SOUTHERN ETHIOPIA

MSc. THESIS

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WOLKITE, ETHIOPIA

JUNE, 2022

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THESIS SUBMITTED TO

WOLKITE UNIVERSTY

DEPARTMENT OF NATURAL RESOURCE MANAGEMENT, COLLEGE OFAGRICULTURAL AND NATURAL RESOURCE MANAGEMENT, SCHOOL OF GRADUATE STUDIES, WOLKITE UNIVERSITY

IN PARTILAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN SOIL SCIENCE

WOLKITE, ETHIOPIA

JUNE, 2022

SCHOOL OF GRADUATE STUDIES

WOLKITE UNIVERSITY

ADVISORS' APPROVAL SHEET

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As members of the Board of Examiners of the final Master's degree open defense, we certify that we have read and evaluated the Thesis prepared by Ahmed Asrar Abdella and examined the candidate .We recommend that the Thesis be accepted as fulfilling the thesis requirement forthe degree of Master of Soil Science.

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DEDICATION

This thesis is dedicated to my lovely families for their concern and strong support made for the successful accomplishment of my education.

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BIOGRAPHICAL SKETCH

The author, Ahmed Asrar Adela was born on April 15, 1985 from his father Asrar Abdela kerbege and his mother Mrs.Mehdya Helil Yesuf at Wusho Keble of Gumer Woreda, Gurage Administrative Zone, Southern Nation and Nationality people Regional State. He then, attended his primary school education (Grade 1-6) at Abejay Elementary School., He attends (Grade 7-8) at Koter Gedra Junior School. Then in subsequent year he attended 9-10 at Arekt Secondary School where he sat for the Ethiopian General Schools Leaving Certificate Examination (EGSLCE) in 2001. After successfully passing the examination, he joined Emdber preparatory Secondary School for Preparatory Program. After he successfully passed the ESLCE, joined Hawassa University and studied from 2004 to 2006 and obtained BSc degree in Applied Chemistry in July 2006. Right after graduation, he joined Alicho wurriro woreda and employed under water, mineral, and energy office in the Silte Zone SNNPRS and served as Biogas expertise from October 2007 to 2018. He joined Wolkite University in 2019 to proceed for his Master of Science degree in Soil Science.

ACKNOWLEDGEMENTS

Support and continuous encouragement during completion of this paper at the Wolkite University First the author would like to express his sincere thanks and gratitude to his Major advisor, Achalu Chimdi (PhD) and co-advisor Wondwosen Tena (PhD) for their professional and endless support and patience well from the first planning stage to the finalization of this Thesis. Without their advice and support, this paper would not have come to a successful study.

I am thankful to Alicho Wurriro Woreda administrative office for providing me the study leave and guaranteeing my salary during the study period. I extend my great appreciation to all West Azernet Berbere Woreda agricultural and natural resource office experts for their support during field work and for the information they gave me.

I would like to thank Ato Nesredine my field guide who assisted me by touring all the study sites with me. The author also special thanks SNNPRS for providing financial support for graduate study at Wolkite University. Thanks are also extended to the Alicho Wurriro Woreda Administration office. Then after, thanks go to the Wolkite Soil Laboratory technicians Special Neja Bedru, for offering him all possible helps in all aspects of the laboratory work I take this opportunity to thank my wife, Mrs. Muhabe Adem, for her endless moral.

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ACRONYMS AND ABBREVIATIONS

AASP	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
m.a.s.l	Meters above sea level
BD	Bulk Density
BoA	Bureau of Agriculture
CEC	Cation Exchange Capacity
CL	Cultivated Land
Cmolc/kg	Centimol Charge per Kilogram
CV	Coefficient of Variation
EATA	Ethiopian Agricultural Transformation Agency
Exch.Ac	Exchangeable Acidity
Exch. Al	Exchangeable Aluminum
FAO	Food and Agriculture Organization
FL	Forest Land
GL	Grazing Land
Ha	Hectare
LSD	Least Significance Difference
PD	Particle density

Ppm	parts per Million
PBS	Percent Base Saturation
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SNPRS	Southern Nation Nationalities People Regional State
TN	Total nitrogen

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ABSTRACT

The general purpose of the study was to evaluate the effects of land use types; slope gradient and their interaction on soil acidity and selected physico-chemical properties in West Azernet Berbere Woreda. The experiment was taken as the randomized complete block design (RCBD) with two factors and total of 27 composite samples were taken. For data analysis, general linear model procedure of SAS version 9.4 was used.

Three land uses (natural forest, grazing and cultivated land), and three slope gradients (10-15%, 5-10% and 2-5%) in three replications were considered for this study. Totally 27 composite soil samples were collected from cultivated, forest and grazing lands and slope gradients with three replications for laboratory analysis. Results indicated that the highest mean value of sand was recorded in grazing land and highest mean value of silt and clay were recorded under forest land, cultivated lands and upper slope classes respectively. Soils were strongly acidic (pH =5.2-5.4), whereas natural forest land uses and lower slope classes were moderately acidic2 (pH =5.9-6.0). The total porosity, bulk density and PH, Av.P, OM, CEC,Ca^{+2}, Mg^{+2} K^{+}, Na^{+}, were significantly ($p \leq 0.001$) affected by land use types and slope gradients .Percent base saturation Total nitrogen and except silt, particle size distribution were significantly ($P \leq 0.05$) affected by land use types and slope classes . The mean values of sand ,total porosity, pH, OM, TN, CEC, Ca^{+2}, Mg^{+2}, K^{+}, Na^{+} and PBS were higher in forest and lower slope classes as compared with grazing , cultivated lands and in 10-15% and 5-10% slope classes respectively. The exchangeable acidity and exchangeable Al were significantly ($P \leq 0.05$) affected by under cultivated land and grazing lands and upper slope classes. Generally, land use types and slope gradient have significant effect on their interaction soil acidity and selected physico-chemical properties of soil. Therefore, in order to reduce soil acidity problem, minimize intensive cultivation, over grazing, liming and integrated soil acidity management practice is recommended for study area and further study should be investigated on the rest soil nutrients.

Key words: Soil acidity, Cultivated land, Grazing land, Forest land, Slope gradient

1. INTRODUCTION

1.1. Background and justification

Soil acidity is a worldwide problem and it limits plant production all over the world. About 50% of the worlds' arable soils are acidic and may be subjected to the effect of aluminum (Al) toxicity of which the tropics and subtropics account for 60% of the acid soils in the world (kochian, et al.2015). This mainly located in two belts which are: the northern belt in the cold humid temperate zone covering North America, South Asia and Russia; and the southern belt in humid high rainfall tropical areas including South Africa, South America, Australia and parts of New Zealand. It affects about 56% in Sub-Saharan Africa, 38% of farmland in Southeast Asia, 31% in Latin America, 20% in East Asia and parts of North America (Hoekenga *et a*l., 2006).In Americas 1616 million hectare is affected, mostly in South America.

In Ethiopia, soil acidity affects large surface areas of the highlands located mostly all regional states of the country. According to recent agricultural transformation agency (ATA) report year it was estimated that about 43% of the total arable land in Ethiopia is affected by soil acidity. Soil acidity problem is significantly affect the south-western, north-western, southern and central regions of the country which receive high rain fall to leach down soluble salts and/or basic cations appreciably from the surface layers (root zone) of the soils. Some of the well-known areas seriously affected by soil acidity in Ethiopia are Ghimbi, Nedjo, Hossana, Sodo, Chencha, Hagere-Mariam and Awi Zone of the Amahara Regional State MoARD (2007).

Soil acidity is a problem that has not been addressed in depth. It is observed that most of these soils are found in the highlands receiving high rainfall (Paulos, 2001). The Ethiopian highlands are one of the hotspots on the African continent with regard to food production and in the struggle to preserve the natural resource base cited in (FAO, 2004 Balesh et al., 2005, FAO, 2005 cited in Tesfaye, 2005). The major causes for soil acidity acid are acidic parent material, high rainfall, harvest of high yielding crops, leaching and organic matter decay (Getachew et al., 2019).Even though, in Ethiopia the amount of inorganic fertilizers applied was in small doses repeated use of urea(46N-O-O) and diammonium phosphate(DAP) (18N-46P2O5-O) over long period of times cause for soil acidification in the northwestern and southwestern highlands of Ethiopia(Takele et al,.2018).

Balance of soil acidity or alkalinity (measured by pH) of the soil is very necessary to manage optimum availability of soil nutrients and minimizing potential toxicities. For example, at a very low pH, aluminum (Al) may become more soluble and can be absorbed by roots and becomes toxic. P (phosphorus) and Ca (calcium) may become deficient. At high pH, Fe (Iron) and other micronutrients except (Mo) are become unavailable because they are formed as insoluble hydroxides and carbonates (Getachew et al., 2016).

In land use changes, forests are converted to agricultural and land settlement purpose and it is the most widely common activities in Ethiopia. This changes involve intensive agricultural practices for a long period of time and as consequence loss of nutrients are resulted, specifically in the highlands where erosion is more critical (Mamo, 2018; Eyayu *et al*., 2010). The variation of land use and management systems could significantly contribute to the influence

in soil physico-chemical properties. Most of the time soil physical properties change with changes in land use system and its management such as intensity of cultivation and the nature of the land under cultivation, led to the soil less permeable and more susceptible to runoff and erosion losses (Mesifin, 2007).

Topography is one of the naturally occurring soils forming factor that affect soil properties and control soil erosion process through redistribution of soil properties (Ziadat and Taimeh, 2013). High sloppy area with poor management practices, over grazing and traditional agricultural systems aggregates soil erosion but flat area (low slopping), different soil and water conservation (SWC) measures and management activities and modern agricultural practices by minimizing run off decrease soil loss due to topographic features that influence the process of drainage, run off and soil erosion there by affects physico-chemical analysis. (Farmanullah *et al*., 2013).

Mirab Azernet Berbere woreda in silte zone southern region is most high land area. Its mean annual rain fall is (900mm- 1400mm) and it is mostly affected by soil acidity problem and information on the extent of soil acidity is not well known since recent years. Thus studying soil acidity problem and management of soil acidity problem for three land uses which are: cultivated, grazing and forest lands and comparing the level soil acidity in these land uses is very important for the productivity crops and additionally, clear understanding of the problem is necessary to exercise sustainable land management practice to sustain the soil fertility status by improving soil physical, chemical and biological properties.

1.2. Statement of the problem

West Azernet Berber woreda has severed yield reduction problem. One reason for this reduction is expected due to soil acidity problem. This may result from leaching of nutrient because of high annual rain fall (900-1400mm) and is most high land area (Dega),crop residue and cow dung removal for fire wood consumption. On the other hand farmers use Urea and DAP fertilizers for long period of time, these might have contributed to soil acidity and it may leach of base forming cations. Thus, Impact of soil acidity problem result in deficiency of essential plant nutrients and toxicity of some elements, which have great influence on yield reduction.

The cause, extent and existence of soil acidity have not been studied and not well known by development agents and farmers since recent years in the study area, more over there is no specific symptom on the crop, except decrease in yield reduction.

Hence studying magnitude and extent of soil acidity problem under different land uses is used to improve the productivities of soils and to fill knowledge gap in soil acidity and sustainable land management in study area.

1.3. Objective

1.3.1. General objectives

The general purpose of the study was to evaluate the effects of land use types; slope gradient and their interaction on soil acidity and selected physico-chemical properties in the study area.

1.3.2. Specific objectives

- . To examine acidity related selected physical and chemical properties of soil under different land uses and their interaction effect
- To evaluate extent of soil acidity under different land uses and slope gradients

1.4. Significance of the study

It had developed the knowledge of professionals and development agents and quantify extent and magnitude of soil acidity under different land uses in general and in particular available essential macro nutrients and, CEC, PBS, exchangeable acidity and conversation practice and to improve crop productivity for study area, which is affected by soil acidity.

1.5. Scope of the study

Since there are different factors that determine soil physiochemical property so, the study focused on extent and status of soil acidity by analyzing related physiochemical properties of soil under different land uses.

1.6. Limitation of study

The study was not considered all the areas which are found in Mirab Azernet Berber woreda due to time shortage, transportation and budget.

2. LITERATURE REVIEW

2.1. Concept of soil acidity

Crop management's key soil concerns include deterioration of soil physical qualities, nutritional inadequacies, loss of soil organic carbon, anthropogenic soil erosion and degradation, and a lack of incentives and regulations to adopt improved and ecologically friendly technologies. Because of the enormous range of topography, climate, soil types, and associated vegetation and farming systems, practically all soil-related problems are occurring at alarming rate throughout Ethiopia's highlands, with noticeable differences in magnitude. The most significant soil chemical degradation is fertility decrease, which manifests itself as excessive nutrient exhaustion, followed by acidity. This element of soil chemical deterioration is the most important concern in the majority of Ethiopia's farmed soils, negatively impacting crop yields and agricultural output. As a result of this degradation, the national average yield of cereal crops is less than 1 t/ha, even in the country's prolific highlands. This is exacerbated by intense land use and a high population density (Regassa et al, .2011).It is expected that about 43% of the total Arable land of Ethiopia is affected by soil acidity (ATA, 2014). Acidity of soil resulted from increment of hydrogen ions (H^+) concentration .It is occurred by human-induced natural processes. Acid parent materials ,leaching of basic cations (Ca2+), magnesium (Mg2+), and potassium (K+), hydrolysis reactions within the soil exchange sites, rain fall containing sulphuric and nitric acids, cations uptake by the crop over the long run cultivation, crope residue removal, and cations uptake addition of soluble salts and fertilizers in to the soil which might be cause soil acidification

(Agegnehu et al .2019, R.Alvarez et al 2020)

In the tropics leaching or/and continuous removal of basic cations through crop harvest seriously increase the soil acidity. Soil acidity limits the growth of crop because acidic soil contains toxic levels of aluminum and manganese and characterized by deficiency of essential plant nutrients such as P, K, Ca, Mg, and Mo (*Wang et. al.*, 2006; Tisdale *et. al.*, 1985).

2.2. Extent of soil acidity

Soil acidity is one of the major land degradation problems worldwide. Approximately 30% of the ice-free soils (close to 4 billion ha) in the world are acidic). Soil acidity mostly affects Tropical and sub-tropical regions as well as areas with moderate climatic conditions. Worldwide, 32% of all arable land is acid. Almost two-third of all acidic soils in the world belongs to Ultisols, Entisols and Oxisols (Rengel, 2011). Oxisols (also referred to Ferralsols) occupy about 3.75 million km^2 or 14.3% of the total land area of Africa. About 10.76 million km^2 or 35% of the total area of land in Africa is characterized by P fixation, i.e. from slight to high fixation, and out of this 8.23 million km^2 is typified by high P fixation (Eswaran *et al*., 1997b). Similarly, tropical American soils are largely acid and low in reserves of nutrients available to plants.

The intensive need to increase agricultural production causes great pressure on easily damaged soils and natural resources. Such soils contain toxic levels of Al and Mn, are prone to compaction and erode easily (Thomas, 1995). For example, the ‘Cerado’ (acid savanna soils) affects an area of 207 million ha in Brazil alone (Fageria and Nascente, 2014; Thomas, 1995). The Oxisols (dusk red Latosols, dark red Latosols, red yellow Latosols, and yellow Latosols) are the dominant soils, with about 98 million hectare (Thomas, 1995). They are very weathered deep acid soils with a low availability of nutrients, but with good physical properties due to the predominance of 1:1 clay minerals and Fe and Al oxides in the fraction (de Sant-Anna *et al.,* 2017).As described by (Zeleke et al., 2010) Soil acidity characterized with low nutrient availability are very limiting factor to crop production in acidic soils, mainly Nitisols of Ethiopian highlands. Soil acidity affects approximately 43% of the Ethiopian cultivated land Haile *et al*. (2017). (ATA, 2014) states that about 28.1% of these soils are dominated by strong acid soils (pH 4.5). Strongly acidic soils are usually infertile because of the high availability of Al and Mn toxicities and Ca, Mg, P and Mo deficiencies (Getachew et al., 1984).

2.3. Land use types and soil acidity

The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use aggravates the degradation of soil physicochemical and biological properties (Tesema et al., 2008; Mesifin, 2007).Climate and particularly rainfall is a key element in soil acidification processes. The risk of acidification associated with increase in areas with higher rainfall particularly, with an uneven seasonal distribution. Measurements have shown that there was a marked increase in soil acidification rates in cropping zones with higher rainfall (500-600 mm per annum) (Coventry, 1992), compared to lower rainfall (Young *et al.*, 1999).As observed by (Mokwunye, 1978) intensive cultivation and acid forming fertilizers applications, characterized decline of the soil pH and cause loss in basic cations especially under intensive cropping on inherently poor soils. Thus, intensive agriculture increases the rate of acidifications through the addition of acidifying fertilizers; increased nitrate leaching and the export of product.

Legumes contribute symbiotic N_2 worth several billions of dollars of equivalent N fertiliser each year to agriculture (Hurrison and Demora, 1995). However, by raising the fertility of soil they also raise the risk of acidity unless inorganic N in soil is carefully managed. Legumes can be expected to produce more soil acidification than non-leguminous species such as grasses. This disadvantage of legumes can be attributed to the following factors, Legumes excrete protons (H^+) strongly from their roots as a result of a greater excess of cations (Ca, Mg, K and Na) uptake during N_2 fixation. This can become a problem where legume products (seed or hay) are exported. However, other non-leguminous dicotyledons such as canola may be just as acidifying from this cause (Howieson and Herridge, 2005).Residues of legumes have a high N_2 content, resulting in large amounts of nitric acid ($HNO_{3)}$ being produced during nitrification following ammonification of their residues. This will be a problem where NO^{3-} is available for leaching, particularly in higher winter rainfall areas. In grazing lands nitrate leaching and buildup of soil organic matter are the major causes. Product removal in total is usually low and the use of nitrogen fertilizers not applicable. It should be understood that the leaching of nitrate is potentially higher on annual species than under perennial pasture. Planting trees like pinus and Eucalyptus species invariably alters many soil properties. Soil under plantation typically becomes more acidic, the effect usually being attributed to the uptake of basic cations into the forest biomass. As stated by (Mills and Fey, 2003) acidic organic compounds are released in to the soil are decomposed.

Coniferous forests can produce an acid litter because the tissue of such vegetation contains considerable concentration of soluble organic acid. Dilute acids together with the soluble organic from vegetation can readily leach fulvic acid, in soil humic materials. This can produce strong acidification and weathering of soils leading to podosols formation and low base saturation (Hurrison and Demora, 1995).In many areas soil nutrient is increased by plantation forestry because of greater mineralization under forestry than grasslands(Milles and Foy, 2003).Thus, land use can lead to subtle changes in soil chemistry.

2.4. Effect of soil acidity on nutrient availability and crop yield

The solubility and availability of essential nutrients to plants is associated with the pH of the soil (Marschner, 2011; Somani, 1996). Soil pH affects the availability of essential plant nutrients. Effects of high acidity in a soil are deficiency of available, Ca and Mo and excess of soluble Al, Mn ions in the soil (Agegnehu and Sommer, 2000a; Somani, 1996). Acid soil restricts the availability of essential nutrients such as P, K, Ca and Mg, and limits the movement of soil organisms that used for plants stay healthy. In particular acidic soils plants not grow healthy, thus it is better to raise the PH by applying exchangeable cations. In slightly acidic soil PH is optimum for plant production. At extremes of high (alkaline) and low (acid) pH this delicate balance is disturbed and plant nutrients that were in adequate supply can become either deficient or toxic to plant growth. Some essential nutrients such as phosphorous, calcium, magnesium, and molybdenum become unavailable if the soil pH becomes too acid. Acid conditions will result in a lowering of plant production in farming systems. This will result in reduced profitability and an increased reliance on fertilizers to sustain any form of productive agriculture. Correcting soil pH to a more favorable pH range will increase the availability of essential nutrients. Nutrient toxicity can occur in acid soils when the pH Ca is 4.8 or lower (Slattery *et al.*, 1999).

2.5. Soil pH and acidification

Soil pH is a measure of the number of hydrogen ions in the soil solution; the more acidic the solution the higher the concentration of hydrogen ions. Knowing Soil pH is used for the proper soil management and optimum crop productivity. (Tisdale, 1993) suggested that in aqueous (liquid) solutions, an acid is a substance that donates hydrogen ions (H^+) to some other substance. Soil pH is an excellent chemical indicator of soil quality. Ideally, (Al^{3+}) aluminium and hydrogen (H^+) concentrations of soils quantifies soil acidity (Fageria, 2008).In natural processes soil acidity is caused by; type of parent materials, leaching, rainfall, and organic matter decay (Havlin, 2005). Thus in high rainfall areas most of soil types are inherently acidic (Maheshwari, 2006).

2.6. Aluminum toxicity and Soil acidification

Even though cause of soil acidity has several reasons of which the most common source of hydrogen is the reaction of Al ions with water and aluminum toxicity in combination with low pH .Therefore this one of the major reason that acidic soils become unsuitable for the growth of many plants in the humid tropic countries (Budianta and Vanderdeelen 1995). The increased soil acidity causes solubilisation of Al, which is the primary source of toxicity to plants at pH below 5.5 (Kariuki *et al.,* 2007). Under very acidic conditions of pH less than 4.5, the major form of aluminum is Al^{3+} and when pH is between 4.5- 6.5, aluminium-hydroxyl dominates (Carson and Dixon1979).As the pH increases, exchangeable Al^{3+} precipitates as insoluble Al hydroxyl forms at a rate of 1000 fold decrease for each unit increase in pH. As observed by (Haynes, 1984) $Al^{3+} + H_2O \leftrightarrow Al(OH)^{-}_{2} + H^+$ this shows that the reaction of aluminum-hydroxyl in very acid soils. High rainfall area can also contribute to the soil acidification by natural causing parent materials to be acidic due to leaching of cations (Sparks, 2003).

2.7. Major causes contribute to soil acidity problems

Ideally, soil acidity is largely related with the presence of hydrogen and aluminum ions in exchangeable forms (Brady, 2001; Fageria and Baligar, 2003). Inefficient use of nitrogen is one of the causes of soil acidification, followed by the export of alkalinity in produce (Guo *et al*., 2010).Ammonium nitrogen is readily converted to nitrate and hydrogen ions in the soil. It has been well known that there are several causes for soils to become acidic. Productivity of crops on such soils is very low, especially in areas where improper management measures have been taken place (He *et al*., 2003). Thus, three major causes for soils to become acid are as follows: Climate, Parent material, Harvest of high yielding crops and Nitrification of ammonium. Researchers states that in dry region availability of base cations in the soil is very high, because water passes through soil is very little. Within high rainfall, a point is reached at which the rate of removal of bases exceeds the rate of their liberation from non-exchangeable forms. Wet climates have a greater potential for acidic soils (Sanchez, 1977; Tadesse, 2001).Soil profile is leached by excessive rain fall that prevent soil acidity. High rainfall leaches soluble nutrients such as Ca and Mg which are particularly replaced by Al from the exchange sites (Brady and Weil, 2016).

2.7.1. Parent material

Rocks considered being acidic when they are containing an excess of and quartz and silica than to their content of basic materials; for example, rhyolite and granite. When rocks that are deficient in bases are disintegrated or decomposed in the process of the accumulation of soil. Material is acidic, despite no loss of base during the process of soil formation. Soils that develop from weathered granite are associated with more acidic than those developed from shale or limestone. There are large areas of siliceous and sandy soils produced from acid parent rocks, which have always been in need of lime. However, most acid soils have been developed as a result of leaching losses and crop removal of bases (Brady and Weil, 2016)

.The inherent fertility of Ethiopian soils developed under varied parent materials and climate varies depending on the origin and composition of the materials. For instance, soils developed from sandstones are poor sandy soils, whereas the inherent soil fertility developed over basic parent materials is relatively high (Woldeab and Mamo, 1991).

2.7.2. Crop production and nutrient removal

Soil acidity is increased by when high yielding crops are harvested. Basic elements; K, Ca and Mg are removed from soil when crops absorb nutrient during their growth. When crop yield increase most of the lime like nutrients removed from field. Compared to the leaf and stem portions of the plant, grain contains small amounts of these basic nutrients. Thus, harvesting high yield forages (Bermuda grass and alfalfa) more affected by soil acidity than grains (Fageria and Baligar, 2008; Rengel, 2011).

Removal of basic elements, particularly from soils with small storage of bases due to the harvest of high yielding crops is responsible for soil acidity. When soils are worked mechanically and crops are grown the balance is disturbed and the soils become more acid. This is the result of base cations being removed with crops and the simultaneous increase of leaching which takes place when soils are disturbed and worked (Brady and Weil, 2016; Fageria, 2009).

Choosing land use type and good management practices often correct most soil; physical, chemical and biological properties and result is seen in an agricultural productivity (Gebrekidan and Negassa, 2006). Previous studies shows that soil properties seriously changed due to the conversion of native forest and range land into cultivated land (Bore and Bedadi, 2015; Lemenih *et al*., 2005). As a consequence, an increase in bulk density and decline in soil organic matter content (SOM) (Conant *et al*., 2003), which in turn reduce the fertility status of a certain soil type. In addition, change in land use related with intensive cultivation, overgrazing, deforestation and inorganic fertilization can cause great variations in soil properties and decrease in productivity (Kang and Juo, 1986).

2.7.3. Use of nitrogen fertilizers

Actually, N fertilizer increases soil acidity by increasing crop yields as a result, increasing the amount of basic elements being removed. Because application of fertilizers containing $NH^+{}_4$ or even adding large quantities of organic matter to a soil can ultimately increase soil acidity and lower PH (Guo *et al*., 2010; Hue, 1992). As explained by (Fageria and Nascente, 2014; Guo *et al*., 2010) the continuous use of N fertilizers in ammonia form is one of the causes of soil acidification. Soil has found to be acidic when excessive amount of ammonium fertilizer applied to the soil

2.8. Slope Gradient

Slope gradient is one of the important topographic factors which influence the process drainage, erosion run erosion thereby affects physiochemical properties (Farmanullah, 2013The suitability of soil for crop production depends on its fertility level, which is evaluated based on the quality of the soil physiochemical ad biological properties. One of the naturally occurring soils forming factor that affecting soil properties and controlling soil erosion process through the redistribution of soil particles and soil OM is topography (Ziadat and Taimeh, 2013).Soil loss could be increase in slope gradient because of respective increase in velocity of surface run off and decrease in infiltration rate. According to Bezuayehu *et al*. (2002) states that soils on steep slope are generally shallower their nutrient and water storage capacities are limited. They suggested that when soils in areas having steep slopes are exposed to soil eroding agents, they face greater degradation consequence to soil flat areas.

2.8.1 Effect of slope gradient on soil properties

Slope gradient affects physical properties of soil which are: Particle size distribution, sand content decreases down the slope gradient while clay content increases as slope gradient lowers. This is because of removal of the clay particles by erosion is enhanced on the upper slope gradient while deposition of these particles occurs on the lower slope gradients. As stated by Mohammed *et al*. (2005) finer soil materials which are coming from the upper position deposits at the lower slope gradient. Slope gradient also affects soil chemical properties. The lowest pH value was found in steep slope gradient and highest pH found in gently sloping gradient (Nega and Heluf, 2013). The lowest pH in soils of moderately steep slope gradient could be attributed to the loss of basic cations through runoff and erosion. This increases the activity of H^+ ion in the soil solution and reduces soil pH and there by increases soil acidity. They argued that highest basic cations concentration and pH were found at bottom slope position. The variation could be contributed by the effect of slope gradient on the soil moisture storage capacity and biomass production. In the gently sloping area, the soil moisture storage is better and resulting in better biomass production. In the strongly slopping moderately steep areas, there could be high drainage, low moisture storage and less biomass production there by decrease soil organic matter content (Mulugeta and Kibebew, 2016). The lowest exchangeable bases found in steep slopes whereas highest value of exchangeable bases found in gently sloping areas due to increasing trend of exchangeable basic cations concentration from moderately steep to gently sloping gradient, which might be due to their loss through runoff and erosion in the highest sloping areas and accumulation in areas having lower slope (Mulugeta and Kibebew, 2016).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

The study was conducted in West Azernet Berbere Woreda which is located southern nation nationalities and people’s regional state, western part of silte zone that is bounded to Southwest by Hadya zone (Mish woreda) and on the Northwest Gurage zone (Endegagn and Geto woreda), on the East ,East Azernet Berbere Woreda, The Woreda capital town is Lera, Which is located at distance of 85km and 258km from zonal capital town Worabe and Addis Abeba respectively(Woreda transport office document).The total land area of woreda is estimated 18994 hectare, and total study area is 743 hectare. The geographical location of study area extends from 8^{0}56´69" to 8^{0}34´52"N latitude and from 3^{0}85´19" to 3^{0}74´14" E longitude Woreda Agriculture Sector (MABW, 2021)

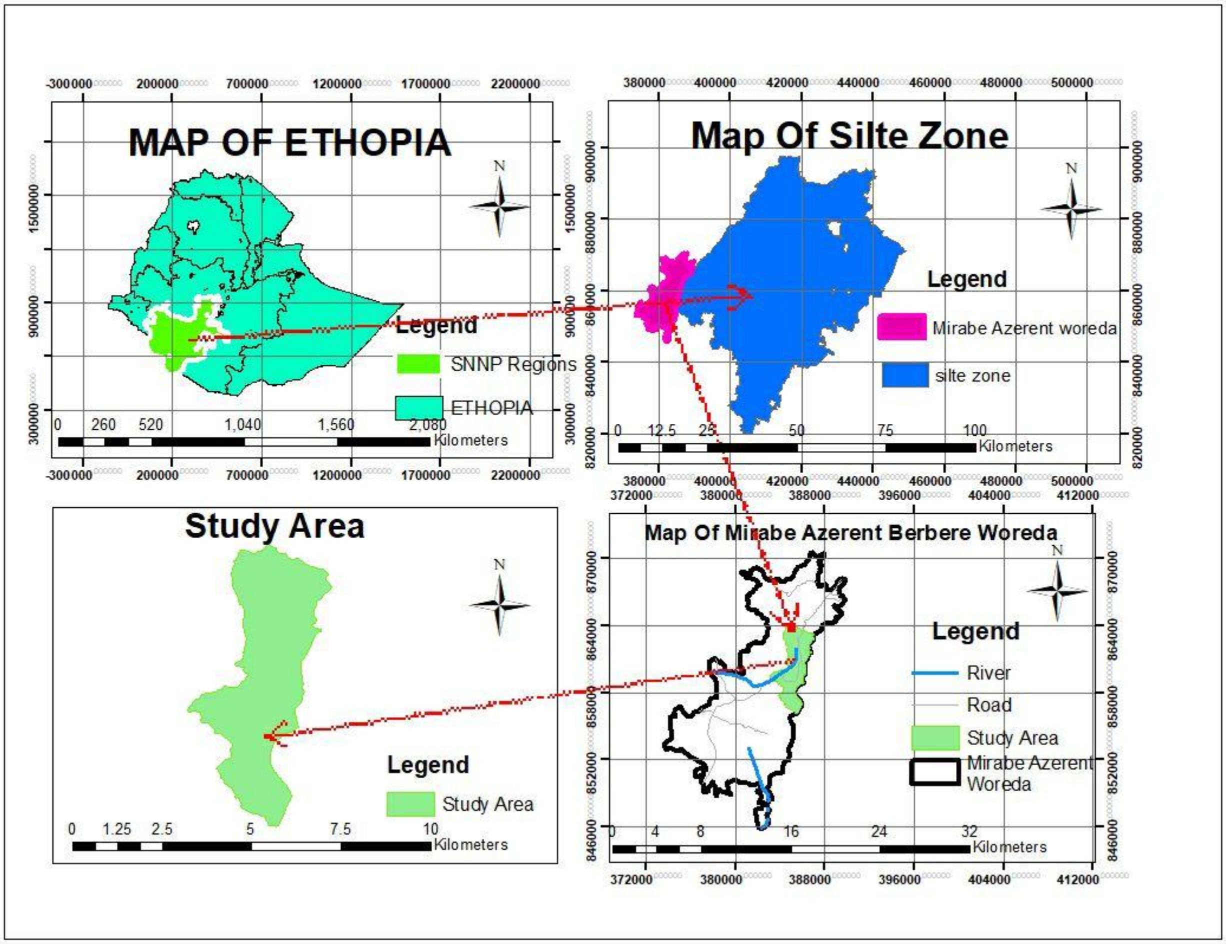

Figure1: Geographical Map of Study Area

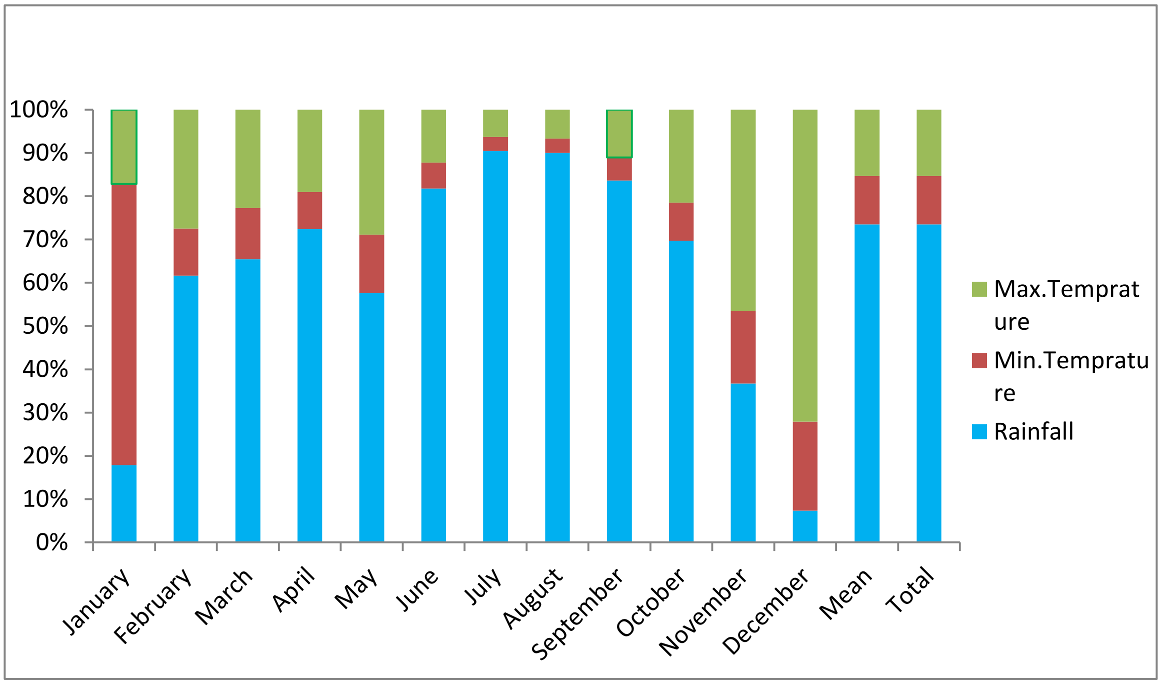

Figure 2: mean monthly rain fall (mm), minimum and maximum temperature (^{o}C) of study area

3.1.2. Topography, Soil Type and Climate

The topography of the woreda is generally characterized by flat plain 11%, steep slope 37% and moderately sloping 17% and rugged mountains 18% and 17% are others. The relief of the study Area varies from 2500-3277 m from above sea level. The agro ecology is Moist Dega (69.72%) Moist Weina is Dega (30.28 %.The major soil types include Nitosols and cambisols.According to soil color 75% is brown,7.5%black and 17.5%red(*MAWAO*). The agro ecology is 100% Dega. The mean annual rainfall distribution ranges between 900mm up to 1400mm and mean annual temperature ranges between16-19^{o}c. (Mirab Azernet berbere woreda office document 2011). The study area experiences rainfall from March to April (small rainy season) and from June to July (main rainy season) and those indicates that in the area rainfall condition shows bimodal distribution pattern, and the mean annual rainfall was range from 900mm-1400mm. Temperature varies between the mean annual maximum of 19^{o}c and mean annual minimum of 16^{o}c across the slope gradient (NMA, 2017).

3.1.3. Population and Economic activity

According to information obtained from Woreda Finance and Economic development office, the total population for the year 2012 is estimated to be 95158. Among total number of population 43581 males and 51577 females. In the woreda Crop productions are the first main economic activity. The major development challenges of the area include poor productivity. Due to Soil degradation, dependency on rain fed agriculture, and Poor socio- economic services. (Mirab azernet Berbere woreda FED office document 2012).

3.1.4. Vegetation and Major Crops

The regional and local geology of study area is generally characterized by geological formation of Quaternary (resent sediments) and Tertiary basaltic flows consisting of ignimbrite (found inter bedded with the plateau basalt, basalt occupy the lower elevation and trachyte of study area (woreda agriculture office). The major food crops produced in the study area are: Enset, Wheat, barley, Bean, pea, fruit crops and the major vegetables are Potato, Cabbage, Garlic, Onion, etc. The main land use systems are cultivated lands (potato, barley, wheat, pea, bean and enset), grazing lands (GL), natural forest and man-made forests.

3.2. Site Selection

Before the start of the study reconnaissance survey was conducted during off season. During surveying, the general geography of the area was identified. The sub area was selected using the following criteria: district which has different land use types, Its representativeness on the basis of sever yield reduction problems in the district Then, three land use types (cultivated, grazing land and natural forest) was selected within the sub watershed according to similarity in soil type, climate condition, slope gradient and altitude. Land use types that bordering each other with in the respective land use types selected for soil sampling.

3.3. Soil sample collection and Analysis

Composite soil samples were collected randomly at equal interval in adjacent land use types (cultivated, grazing, and natural forest) lands by blocking each slope gradients which were: upper, middle and lower level of slope gradients . Along the plot with three replications was used for soil sampling under each land use, soil samples was obtained from a plot with dimension of 10mx 10m at constant depth 0-20 cm, following lay out design. The 20 subsamples from each plot were mixed to form one composite sample. (Three replications*three land use types*3 slope gradients) by using randomized completely block *design (RCBD) method.

Total of 27 composite samples was collected from the sub watershed which was carried out to Wolkite soil laboratory research center. Standard laboratory procedure was followed in Wolkite soil laboratory research center for the analysis of the selected physiochemical properties which were considered in the study.

3.3.1. Analysis of soil physical properties

Soil particle size distribution (texture) was analyzed by the Bouyoucus hydrometer method (Bouyoucus, 1962) after the soil samples were dispersed with sodium hexametaphosphate $Na_6 [(PO_3)_6]$ using H_2O_2 as an oxidant (Omueti, 1980). Soil bulk density was measured from the core sampling method after drying the soil samples in an oven at $105C^0$ to constant weights (Black, 1965), while particle density (PD) was measured using the pycnometer method (Barauah and Barthakulh, 1997) at Wolkite Soil Research Center. Total porosity (TP) was calculated from the values of bulk density (Pb) in g $cm^{-3}$and particle density (DP) in g cm^{-3}(Brady and Weil, 1996).

3.3.2. Analysis of soil chemical properties

Soil pH was measured potentiometrically in 1:2.5 soils: H_2O using a combined glass electrode pH meter (VanReeuwijk, 2002). The cation exchange capacity (CEC) of the soil was determined at pH 7 from the NH^{+4} saturated samples that was subsequently replaced by K from a percolated KCl solution (Chapman, 1965). Organic carbon content of the soil was determined by the wet combustion procedure of Walkley and Black (1934). Organic matter was determined by multiplying OC by 1.724. Exchangeable Ca and Mg was determined by using atomic absorption spectrophotometry (AAS), while exchangeable Na and K was measured by flame photometer from the same extract (Chapman, 1965). Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution as described by Rowell (1994). From the same extract, exchangeable Al in the soil samples was determined.

Available P was extracted by the Bray II method (Bray and Kurtz, 1945) using 0.03 M NH_4F and 0.1 M HCl solution. The total N content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982).

3.4. Method of data analysis

Land uses and slope gradients were taken as main factors. The data were collected and summarized according to land use types and slope gradients. The data obtained from laboratory analysis it was subjected to two -way analysis of variance (ANOVA)following the General Linear model (GLM) procedure using SAS software version9.4(SAS, 2013) For statistical and data interpretation of acidity related physical and chemical properties of soil on land use types and slope gradients. Least significant difference (LSD) at probability 5% ($P \leq 0.05$) test was used to separate statistically significant means of soil parameters, In addition simple correlation analysis was carried out by calculating the Pearson's coloration coefficient to determine relationship between soil acidity parameters and acidity related physical and chemical properties.

4. RESULTS AND DISCUSSION

4.1. Effects of Land Use and Slope Gradient on Soil Physical Properties

4.1.1. Soil particle size distribution

The analysis of variance (ANOVA) results indicate that except silt, sand and clay particle size distributions were significantly ($P \leq 0.05$) affected by under different land use types and slope gradients (Table1). Accordingly the highest clay content (37.22%) and silt (35.11%) were found in soils of the cultivated land and forest land respectively while the highest sand (40.88 %) content was recorded in soils of grazing. There were no significant different between among natural forest and grazing lands. (Table1) .The lower content of clay fractions in forest land may be due to the process of relatively low weathering rate and continual illuviation of clay content from the top soil. These soils might be prone to acidity and leaching of some nutrients due to the high sand contents, high rain fall and very high susceptibility to soil erosion of the area. The intensive cultivation which might cause compaction on the surface soil that reduces translocation of clay particles by tillage activities in line with the findings of Waken (2001) and Jaiyeoba (2001).proportion of clay, silt and sand were ranged from to(24.74 to 37.22%,30.90 to35.11%,29.66 to40.88%) respectively.

Table 4.1.The main effect of land use Type sand slope gradients on particle size distribution

Treatments	Particle size distribution (%)			
Land uses Types	Sand	Silt	Clay	Textural Class
Cultivated land	29.66^{b}	33.11^{a}	37.22^{c}	Clay loam
Grazing	40.88^{a}	30.9^{a}	28.22^{ab}	Clay loam
Forest	40.15^{a}	35.11^{a}	24.74^{a}	Loam
LSD	9.22	11.109	11.6	
Slope gradient				
10-15%	37.66^{ab}	33.68^{a}	28.67^{a}	Clay loam
5-10%	36.55^{a}	34.05^{b}	30.00^{a}	Clay loam
2-5%	32.86^{c}	33.66^{b}	33.55^{b}	Sandy Clay loam
LSD (0.05)	0.015	0.03	0.75	
CV (%)	24.95	29	28.5	

Means within a columns followed by the same letter(s) are significantly different from each other at $P < 0.05$, LSD = Least significant difference and CV = Coefficient of variation

There was significant difference in percentage of sand and clay content ($p \leq 0.05$) as a result of the main effect of slope gradients except silt .The mean value of sand fraction was higher (37.66%) in upper10-15% slope classes and lower (32.86%) value was recorded in 2-5%r slope classes areas. Whereas the higher silt (33.68%) content was recorded in 10-15% slope classes and lower silt (33.66%) content were recorded in 2-5% slope classes. Whereas, higher clay (33.55%) content was recorded in 2-5% and lower clay (28.67%) content were recorded in 10-15%classes slope (Table1). It was revealed that the clay fraction indicated an increasing order as slope gradient lowers while the sand fraction showed a decreasing order down the slope gradient. This is due to the removal clay particles by erosion on the upper slope gradient while deposition of these particles occurs on the lower slope gradient. This agreement is lined with Mohammed *et al*. (2005) found that finer soil materials are deposited at the lowers slope position, which are coming from the upper position.

4.1.2. Bulk density and Total porosity

Soil bulk density and total porosity were significantly different $P \leq 0.001$) due to the interaction effect of land use and slope gradients.

Total porosity of the soils of the study area varied significantly ($P \leq 0.001$) among slopes (Table2). Accordingly, higher value (74.39%) of total porosity content was recorded on l2-5% slope classes, whereas lower (68.3%) value of total porosity content was recorded on 2-5% slope classes (Table 2). Low clay content and low OM content was recorded in soils of 10-15% slope classes as compared with lower sloping areas. This agreement is lined with (Samuel, 2006) total porosity increases as the bulk density decreases while it decreases as bulk density increases. Total porosity was significantly ($p \leq 0.001$) affected by land use types (Table2). The highest and lowest total porosity were found under plantation forest (79.8%) and cultivated land (63.9%) respectively. This agreement lined with Wakene and Heluf (2004) the lowest and the highest total porosities were observed in the land cultivated for many years and the non-cultivated lands, respectively. This result revealed that the conversion of forest land to crop land followed by intensive cultivation without integrated soil fertility management reduces total porosity of the soil. According to critical value of FAO (2006b) the total porosity f soils (<2%) were rating as very low, (5-10%) low, (10-15%) medium, (15-40%) high and (>40%) very high. On the basis of these rating the study area had very high total porosity and this implies that soils has good aggregation and physically indicates it is suited to crop productivity. Total porosity had negatively correlated with bulk density at r=-1.0 and sand at r=-0.41*, besides to this positive and significant correlation with OM at(r=0.05) and clay at(r=0.33) (Table2).

Table 4.3 Interaction Effect Land Use and Slope gradient on Bulk density and Total porosity

Treatments	Land Use Types		
Slope Gradients	Cultivated	Grazing	Forest
BD(g cm^{-3})			
10-15%	1.2^{a}	0.8^{a}	0.65^{c}
5-10 %	0.93^{cb}	0.76^{ab}	0.53^{ab}
2-5%	0.83^{b}	0.6^{c}	0.51^{a}

LSD (0.05) 0.06			
Cv (%) 2.86			
Total porosity (%)			
10-15%	58^{d}	66.3^{a}	79.33^{a}
5-10%	68.5^{c}	74.0^{b}	75.5^{b}
2-5%	64.7^{b}	72.5^{bc}	74.87^{b}
LSD (0.05) 2.9			
CV (%) 2.7			

Means within a column followed by the same letter are not significantly different at $P<0.05$; BD= Bulk density; PD = Particle density; TP = Total porosity; CV = Coefficient of variation; LSD = Least significant difference

Soil bulk density was also significantly different ($p \leq 0.001$) affected by land use types and slope gradients (Table 2). Accordingly highest and lowest bulk densities were recorded under cultivated land and forest lands respectively. The highest mean value (1.35) of bulk density was recorded on the cultivated land lowest bulk density (1.15) was recorded under forest land.

The higher bulk density found under the cultivated land might be related to the intensive cultivation practices which temporarily loosen the tilled soil layer and in the long-term leads to compaction and this is reason for increment of bulk density. Similarly, availability of smallest organic matter content in the cultivated land soils also prone to the highest bulk density. Increment of bulk density value under both cultivated and grazing was might be compaction of surface soil due to intensive trampling of livestock. This result is in agreement with that of Islam and Weil (2000) and Evren dilk *et al.* (2004).In addition, this result is agreed with the findings of Abad *et al.* (2014) in who indicated that the bulk density of cultivated land was higher than that of grazing lands and forest lands. The result also revealed that highest bulk density value (1.32 g/cm^3) was recorded on 10-15% slope classes and lower value (1.07 g/cm^3) was recorded under 2-5% slope classes. The variation of soil bulk density among slope gradients might be attributed to the difference of soil particle size distribution and movement of top soil fine particles from the upper slope and deposited at lower slope. This result is agreed with findings of Mulugeta and Kibebew (2016) said that the bulk density of the soils in upper slope was highest (1.32 g/cm^3) as compared with lower slope (1.07 g/cm^3).

According critical value sated by Hazelton and Murphy (2007) bulk density of the soil is as very low (< 1 gcm^{-3}), low (1-1.3 gcm^{-3}), medium (1.3-1.6gcm^{-3}), high (1.6 -1.9 gcm^{-3}) and very high (> 1.9 gcm^{-3}).Therefore, on this rating the result of the study area could be categorized as medium for grazing and cultivated lands and low for natural forest land (Table2). Significant and negative correlation of bulk density with clay at r=-0.33 fraction and significant and positive correlation of bulk density with sand at r=0.41* In addition bulk density had significant and negative correlation with organic -matter at r=-0.44*).

4.2. Effects of Land Uses and Slope Gradient on Soil Chemical Properties

4.2.1. Soil reaction (pH)

Soil pH was significantly ($p \leq 0.001$) affected by the interaction effect of land use and slope gradients

PH value was significantly ($p \leq 0.001$) affected by slope gradients. Highest PH value (5.9) was recorded under 2-5% slope gradients and lowest PH (5.3) value was recorded in 10-15% slope classes. The lowest PH in soils of upper slope gradient might be attributed the loss of basic cations through run off and erosion. These in turn increases the activity of H^+ in the soil solution and reduce soil PH. This result revealed that findings of Nega and Heluf (2013) stated that loss of base forming cations due to leaching and run off generated from accelerated erosion reduces soil PH by increasing soil acidity. PH was significantly ($p \leq 0.001$) affected by land use types (Table 2). The highest soil PH (6.0) value was recorded under forest land whereas the lowest value of soil pH (5.2) content was recorded under cultivated land as compared to grazing lands .This might be due to the removal of basic cations from crop harvesting, through surface runoff, which created from accelerated water erosions because of depletion of protective vegetation On the other hand, low PH values of these land use types could be application of inorganic fertilizer application and severe base leaching by the high rainfall (Ndukwu et al.,2009). Additionally, over grazing might be responsible for leaching of basic cations that can lead to acidity of the area in grazing land use types. These results were in agreement with the reports of many research findings (Wakene and Heluf, 2006; Tesema et al., 2008; Achalu, 2012). The range of soil-water PH interpretation was according to Jones (2003), soil pH level (< 4.5) is rated as extremely acidic, (4.5-5.0) very strong acidic, (5.1-5.5) strong acidic, (5.6-6.0) moderate acidic, (6.1-6.5) slightly acidic, (6.6-7.3) neutral, (7.4-7.8) slightly alkaline, (7.9-8.4) moderately alkaline, (8.5-9.0) strongly alkaline and > 9.1 is rated as very strongly alkaline, the PH of the studied soils found between strongly acidic to moderately acidic. Soil PH was significantly and positively correlated with CEC, OM, Clay fraction and PBS at r=0.49*, r=0.44*, r=0.22, r=0.41* and negatively correlated with bulk density, sand exchangeable acidity at(r=-0.6*), at(r =-0.18), at(r=-0.74**) (Table 3)

4.2.3. Exchangeable acidity and Exchangeable aluminum

Exchangeable acidity and Exchangeable aluminium were significantly ≤affected by the interaction effect of land use and slopes.

Exchangeable acidity (EA) was significantly ($P \leq 0.01$) affected by under the different land use types. The highest and lowest exchangeable acidity value (1.305cmole (+)/kg) and (0.14cmole (+)/kg obtained from cultivated land and forest land respectively. These results show that intensive cultivation and application of inappropriate inorganic fertilizers leads to the exchangeable acidity content under the crop field. This finding was agreed with (Wakene Negassa, 2001). In general the highest exchangeable acidity in cultivated land indicates mainly caused by of continuous cultivation and removal of basic cations by crop uptake. In addition the development of soil acidity might be due to over grazing lands which bring exposure of sheet and rill erosion. Similarly root cause of acidification of grazing land is NO^{3-} leaching and buildup of soil organic matter this reported by Beecher and Lake (2004).The rate of soil acidification is determined by on the rate acid added to the soil and mainly related to the soil types, land use types and rainfall Helyer (1991). Exchangeable acidity was highly significantly ($p \leq 0.01$) affected among slope gradients (Table3). The higher and lower values of Exchangeable acidity content were recorded for areas from10-15% slope (0.73cmolc kg^{-1}) and 2-5% slope classes (0.51cmolc kg^{-1}) of the study area, respectively this result revealed that variation soil PH on slope gradients was due to different factors like, movement of clay particles and shifting of basic cations due to erosion from upper to down slope. Soil acidity was positively correlated with exchangeable Al and Exchangeable Al was not significantly ($P \geq 0.05$) affected by forest land. It was significantly ($p \leq 0.05$) affected by cultivate lands and grazing lands. Numerically Highest (1.305 cmolc kg^{-1}) and lowest (0.15 cmolc kg^{-1}) mean value was recorded under cultivated lands and grazing lands respectively (Table 4).Exchangeable Aluminum was also significantly different ($P \leq 0.05$) among slope gradients (Table4). The lower and higher values of Exchangeable Aluminium were recorded for areas from upper slope gradient (1.25cmolc kg^{-1}) and lower slope gradient (0.15cmolc kg^{-1}) of the study area, respectively. The significant variation of exchangeable Al between cultivated land forest lands associated with different between value of soil pH and exchangeable acidity. This is agreed with (Abdissa, 2018).

Exchangeable Al was negatively correlated ($r = -0.09$) pH, PBS($r=-0.11$) and positively correlated ($r=0.026^*$) with exchangeable acidity (Table 4). On the other hand, exchangeable Al was observed significantly in the soil in two land use types of the study area since the pH of the two land use types is less than in 5.5(cultivated and grazing lands) at which free Al^{3+} is available in the soil solution. This is supported by Parfitt et al. (1995) who considered that Al^{3+} increases in concentration in soil solution below5.5.

Table 4.4 The main effect of land use Types and slope gradients on Exchangeable acidity exchangeable, exchangeable aluminum and Ph (H_2O)

Treatments	Ex.acidity	EX.AL	Ph
Land uses Types			
Cultivated	1.3^{a}	1.2^{a}	5.2^{a}
Grazing	0.49^{c}	0.49^{b}	5.4^{b}
Forest	0.14^{b}	0.06^{c}	6.0^{c}
LSD (0.05)	0.20	0.42	0.03
Slope Gradient			
10-15%	0.73^{a}	1.25^{a}	5.3^{a}
5-10%	0.71^{a}	0.44^{b}	5.5^{b}
2-5%	0.51^{b}	0.15^{b}	5.6^{c}
LSD (0.05)	0.20	0.42	0.03
CV (%)	22.75	25.05	4.2

CL= Cultivated land G= grazing land, F= forest land, EA= exchangeable acidity, Ex. Al= exchangeable aluminum, CV= Coefficient of variation, LSD=least significant difference. Means within column followed by the same letter are not significantly different each other at $P < 0.05$

4.2. 4. Soil organic matter

Soil OM was significantlyP≤0.001 affected by the interaction on land use type and slope gradients

The mean soil OM was significantly different (p ≤ 0.001) among slope gradients (Table 6). The higher OM content (4.4 %) was found in soils of 2-5% slope classes whereas; the lower OM content (3.41%) was recorded in soils of 10-15% slope classes (Table 6).This result is in agreement with the work of Mulugeta and Kibebew (2016) reported that the variation could be related to the effect of slope gradient on soil moisture storage capacity and biomass production. Organic matter content was also significantly (P≤0.001) affected by in land use types. Highest (4.4) and lowest (3.31) mean value was recorded under forest land and cultivated land respectively. Soil organic matter content has directly related to soil acidity. This due to intensive cultivation and total removal of basic cations had significantly depleted soil OM that led to soil acidity problem.

Due to this Minimizing continuous cultivation hastens microbial break down of soil organic matter through respiration and improves aeration. This shows that in the study area intensive tillage and removal of crop residues had highly depleted soil OM that led to soil acidity problem. As stated by (Roose and Barthes, 2001) it also increases susceptibility of the soil particles to detachment and removal by water during the erosion process.

The high concentration of organic matter under the natural forest land could be due to accumulation of organic matter because of soil disturbance little as compared to the cultivated and grazing lands. Both preferential flow along trees roots and accumulation of absorbent humus on the soil surface increases Water infiltration, this highly reducing the velocity, volume, erosive and leaching capacity of surface runoff (Jiang et al., 1996). In contrast, distribution of livestock practices in grazing land use types and continuous cultivation without fallow in cultivated land use types was responsible for soil acidity problem. In general, poor integrated soil nutrient management in cultivated land and livestock in grazing land prone to poor organic matter content. This result was in agreement with Tesema et al. (2008) and Achalu et al. (2012) who stated that when amount of biomass return less in the same way content of OM is less in the cultivated and grazing lands. The organic matter content was below optimum value in all land use types based on McWilliams (2003) who said optimum organic matter ranges 11-20.

The other land use types had low organic matter (3.31-4.4%) as compared to organic matter content requirement of most crops. According to Williams (2003), the lower category of organic matter is 0-10%. High decomposition rate of organic matter aggravates acidification of the soil in cultivated land use types. Soil organic matter was positively and significantly correlated with PH(r=0.44*), clay(r= 0.09), CEC(r=0.42*) and exchangeable cations (Table 7).However, OM correlated with negatively and significantly BD (r=-0.44*), sand (r=-0.008) clay is poor in aeration slow in drainage properties resulting in slow oxidation process in the soil system since sand particles allows further decomposition of organic matter. This result is in line with the investigation of (Teshome *et al*., 2013).

4.2.5. C: N Ratio

The C: N ratio was significantly ($P \leq 0.05$) affected by all land use types. Higher C: N (11.1) value was recorded in forest land and lowest C: N (9.1) value was recorded in cultivated land. The narrow C: N ratio in cultivated land might be due to low fresh organic materials incorporated into the soil. This result is in agreement with the finding of Achalu et al. (2014) who reported that the narrow C: N ratio in soil of cultivated land was attributed to higher microbial activity and more CO_2 evolution. It was also agreed with findings of Yihenew and Getachew (2013) found that the higher C: N in natural forest than the adjacent, grazing and cultivated lands.

C: N ratio was also significantly ($P \leq 0.05$) affected by all slope gradients. Highest value of C: N (12.1) recorded under 2-5% and lowest value (10.42) was recorded under 10-15%slope classes. The finding revealed that low value of C: N content was due to down movement of carbon to nitrogen ratio to lower slope.

4.2.6. Total nitrogen

Total nitrogen was significantly ($p \leq 0.01$) affected by the interaction effect of land use and Slope gradients

The mean value of total N was significantly ($p \leq 0.05$) affected by slope gradient (Table 6).The higher total N content was recorded under 2-5% slope classes (0.24%) while, lower was recorded 10-15% slope classes (1.98%) (Table).Finding is agreement lined with Mulugeta and Kibebew(2016) revealed that total N an increasing trend from high to lower slope gradients, which might be due to their downward movement with runoff water from higher slope gradient and accumulation there at the lower slope gradients. The total nitrogen content was significantly ($P \leq 0.05$) affected by all use types. Highest (0.23) and lowest (0.15) content of mean value were recorded under forest and cultivated land respectively. This might be reason that due to low amount of organic matter applied to the soils and complete removal of biomass from the cultivated field the findings indicated that agreement with that of(Yihenew Gebreselassie, 2002).According to Barber

(1984) rates that percent of TN greater than 0.4 percent to be very high, 0.3-0.4percent high, 0.2-0.3 medium 0.1-0.2 percent low and less than 0.10 very low; result was indicated that the total nitrogen content of forest and grazing land use types were medium and content of nitrogen in cultivated land is low. This result is agreed with, several researchers indicated that Ethiopian cultivated lands have insufficient total nitrogen due to high leaching lose, crop removal, loss of organic materials and inadequate application of N fertilizers (Yifru and Taye, 2011; Abebe and Endalkachew, 2012 and Nega and Heluf, 2013).Decline in organic matter content is direct relation total nitrogen. The low N value in the grazing land could be over grazing of livestock trampling. The other reason could be continuous cropping without replacement of nutrients. The low carbon input from the agriculture subsistence agricultural system could not compensate for the large mineralization of organic matter on the farm fields and N-losses. Total N had positive and significant correlation with organic matter (r = 0.49*), silt (r =0.07), CEC (r = 0.02) while negatively correlated with sand (r = -0.03) and bulk

Density (r = -0.57*).

4.2. 6. Available phosphorus

Available phosphorus was significantly ($p \leq 0.01$) affected by the interaction effect of land use and Slope gradients

The available phosphorus contents of the soils were also significantly ($p \leq 0.001$) affected by land use types (Table4). The highest available phosphorus was recorded (5.64 ppm) under forest land and lower available phosphorus was recorded (3.2ppm) under grazing lands. The results obtained from this study are in agreement with that of

Ahmed (2002) who observed that the lowest concentration of was found under the grazing land and higher Av. P found under cultivated lands. Higher available phosphorus in the cultivated land is due to the continuous application of Phosphorus containing fertilizers. Wakene (2001) reported similar results with this study, the high concentration of available phosphorus was found under cultivated lands as compared with grazing lands

The result of analysis of variance revealed that available phosphorus was highly significantly ($p \leq 0.01$) affected by slope gradients (Table4).Although; upper and middle sloping areas were non-significant. The current study indicates that available phosphorus increased with the decreased slope gradient classes. The highest value of available phosphorus content was recorded (4.61 ppm) under 2-5% slope classes and the lowest value of available phosphorus content was recorded (3.93ppm) under 10-15% slope classes. The variation of available P content among the slope gradients is paralleled with that of OM content. This agreement is lined with Fisseha *et al.* (2014) found that low available P with in soils having low content of OM. However, Nega and Heluf (2013) conclude that available P content of tropical soils did not necessarily decrease with decrease OM. Av. P was positively correlated with OM(r=0.54*) , CEC(r=0.57**), Ca^{+2} (r= =0.76**), Mg^{+2} (r = 0.77**), K^{+} (r = 0.82**), and Na^{+} (r = 0.69*), respectively, but negatively correlated with BD(r=-0.8**) sand(-0.09). Available phosphorus as rated by Barber (1984), < 5 mg kg^{-1} rating as very low, (5- 10 mg kg^{-1}) low, (10-25 mg kg^{-1}) medium, (25-50 mg kg^{-1}) high and rating > 50 mg kg^{-1} is very high. According to this the result of study area showed that in forest land value of available phosphorus was low and value of cultivated and grazing lands were very low, all slope gradients also low very contents of available P.

Table 4.6. The main effect of land uses types and Slope gradient on Soil organic matter, carbon to nitrogen ratio, total nitrogen and available phosphors

Treatments	SOM(%)	C:N	TN (%)	Av.P
Land uses Types				
Cultivated	3.31^{b}	9.1^{ba}	0.15^{ab}	4.2^{b}
Grazing	3.6^{b}	10.1^{b}	0.21^{a}	3.2^{a}
Forest	4.4^{a}	11^{c}	0.28^{c}	5.6^{c}
LSD(0.05)	0.35	0.20	0.06	0.50
Slope gradient				
10-15%	3.48^{ab}	10.42^{b}	0.19^{b}	3.93^{ab}
5-10%	3.41^{a}	11.2^{ab}	0.18^{ab}	4.5^{ab}
2-5%	4.4^{c}	12.1^{c}	0.22^{a}	4.61^{b}
LSD (0.05)	0.35	0.2	0.06	0.508
CV (0.05%)	9.5	9.2	14.32	11.66

* = Significant at $P \leq 0.05$; ** = Significant at $P \leq 0.01$; *** = Significant at $P \leq 0.001$; Av.P= Available phosphorus; TN = Total nitrogen; Om = Organic matterppm = Parts per million; cmolc/kg = Centimol charge per kilogram; OM=organic matter.

4.2.7. Soil acidity and soil properties relationship in different land uses

There is a strong Relationship between soil acidity and other soil properties from soils of different land uses. The correlation analysis indicates that soil pH (H_2O) is strongly significant ($p<0.001$) and positively correlated with total CEC(r=0.49*) and percent base saturation(r=0.42*) but negatively correlated with exchangeable acidity (r=-0.61*).

This result was in agreement with the finding of Yihenew Gebreselassie (2002) at who observed that PH is highly significant ($p<0.001$) and positively correlated with exchangeable bases whereas high significant and negatively correlated with exchangeable acidity. Correspondingly, available phosphorous was highly significant ($p<0.001$) and negatively correlated with level of exchangeable acidity(r=-0.83**) and it is strongly ($p<0.01$) and positively (r=0.78**) correlated with soil pH (H_2O). The Availability of phosphorous is strongly influenced by soil pH. The form of phosphates ions present in the soil changes with pH. This finding is in agreement with (Mclarenn and Cameron, 1996).In general the result of the correlation analysis showed that exchangeable acidity have strong correlation with pH, CEC, and Av.P but, there was weak correlation with Nitrogen and organic matter contents of the soils in the study areas. Mg was significantly ($p<0.001$) affected by all land use types. Highest (7.7cmol$_{c/}$kg) and lowest (5.2) mean value were observed in forest and cultivated respectively. It was strongly and positively correlated PH (0.61*) and negatively (-0.66*) correlated with exchangeable acidity.

The Ca value was significantly affected by ($p \leq 0.001$) due to interaction effect of land use and slope gradients

Ca was significantly ($P \leq 0.001$) affected by all land use types. Highest (14.95cmol$_c$/kg) and lowest (12.29cmol$_c$/kg) were recorded in forest and cultivated land respectively. It was also significantly ($p \leq 0.001$) affected by among slope gradients. Highest (14.64cmol$_c$/kg) and lowest value Ca content (12.37cmol$_c$/kg) was recorded on lower and upper slope gradients. As described by Mulugeta A, etal. (2015) Exchangeable calcium was strongly correlated with soil acidity. Result revealed that highest value Ca content at lower slope was due to removal of soil materials from upper slope areas through runoff, erosion and areas in lower slope.

Na was significantly ($P \leq 0.05$) affected by due to interaction effect of by the land use type and slope gradients

The result revealed that exchangeable Na was ($P \leq 0.01$) affected by all land use tyes.highest (2.61cmol/gm) and lowest (1.5cmol$_c$/kg) value was recorded in forest and cultivated land respectively. It also significantly ($P \leq 0.01$) affected by among slope gradients Highest (1.96cmol$_c$/kg) and lowest (1.6cmol/kg) Na content was recorded in 2-5% and 10-15% slope classes. Na was not significantly ($P \leq 0.05$) affected by due to interaction effect of by the land use type and slope gradients

Exchangeable K was significantly ($P \leq 0.01$) affected by all land use types. Highest (4.06 cmol$_c$/kg) and lowest (2.3cmolc/kg) value was recorded in forest land and cultivated land respectively. The highest exchangeable K was recorded from the surface top soil of the forest land as compared to the cultivated and the grazing lands in Exchangeable potassium was high as compared to adjacent land use types. This finding is in agreement with the reports of Yihenew et al. (2008). On the other hand, many research results showed that presence of low exchangeable potassium, due to intensive cultivation weathering, and use of acid forming inorganic fertilizers on acid soils affect the distribution of K in the soil systems and increase its depletion in cultivated lands (Mesifin, 2007; Tesema et al., 2008; Achalu et al., 2012).

The decreasing trend of exchangeable K, Ca and Mg concentration in the cultivated and grazing land use types could be the leaching effect due to intensive cultivation, removal of crop residues. Moreover, soil erosion, overgrazing and crop harvest removal for the past decades contributed for the depletion of K, Ca and Mg in the cultivated and grazing lands. This is in agreement with the findings of different reasrechers who shows that continuous cultivation and use of acid forming inorganic fertilizers depleted exchangeable Ca and Mg. (Mesifin, 2007, Tesema et al., 2008; Achalu et al., 2012). Exchangeable k was ($P \leq 0.01$) significantly affected by slope gradients. Highest value (3.5cmol$_c$/kg) and lowest value (2.94cmol$_c$/kg) was recorded on 2-5% and 10-15% slope classes. According to Siraj B, et al. (2015) Mulugeta A, et al. (2015) and Fanuel L, et al. (2016) who revealed that exchangeable potassium was significantly influenced by the slope gradient classes. In general to decrease soil acidity problem and increase exchangeable base it is recommended to apply compost, lime, organic wastes, and farmyard manure and practicing plantation of forests, involve water and soil conservation practice and avoid livestock trampling on the boarder of cultivated as well as grazing lands.

Table.4.8. the main effect of land uses types and slope gradients on Soil exchangeable base and present of base saturation

	Exchangeable bases (cmol$_c$/kg)					
Treatments	Ca	Mg	K	Na	CEC	PBS (%)
Land uses Types						
Cultivated	12.29^c	5.24^c	2.3^c	1.22^b	28^c	75.07^a
Grazing	13.52^b	6.41^b	3.05^b	1.5^b	32.2^b	78.74^b
Forest	14.95^a	7.77^a	4.06^a	2.61^a	34.8^a	83.4^c
LSD(0.05)	0.77	0.66	0.40	0.52	2.05	2.11
slope gradient						
10-15%	12.37^a	6.03^b	2.94^a	1.6^a	30.9^a	71.68^a
5-10	12.74^a	6.53^b	2.97^a	1.76^a	32.35^a	80.03^b
2-5	14.64^c	6.7^a	3.5^a	1.96^a	32.8^a	85.6^c
LSD (0.05)	0.77	0.66	0.401	0.52	2.05	2.11
CV (%)	5.7	10.37	12.77	18.5	6.41	10.41

* = Significant at $P \leq 0.05$; ** = Significant at $P \leq 0.01$; *** = Significant at $P \leq 0.001$;CEC= cation exchange capacity;PBS=Percent Base saturation.

Cation exchange capacity was significantly ($P \leq 0.001$) affected by all land use types. Highest (33.63%) and lowest (30.46%) value of CEC were recorded under forest land and cultivated land respectively. And it was also ($P \leq 0.001$) significantly affected among slope gradients. Highest (32.85cmolc/kg) and lowest (30.9) contents of CEC were recorded on 2-5% and 10-15% slope classes respectively. The lower CEC in the upper sloping areas was in line with the relatively low organic matter and clay content. This is in agreement with the finding of Teshome *et al*. (2013) reported that CEC was positively correlated with soil OM and clay content. This indicates that CEC was affected by the contribution of soil OM and clay content. The lower soil CEC values in the cultivated land due to the low clay and OM contents, CEC showed strong positive correlation (r = 0.49*, 0.42*),(r= with PH and OM , respectively (Table 1.6). This result in agreement with Achalu et al. (2012a) who reported the highest CEC value in forest land and lowest under cultivated land. Reports also indicated that high CEC in forest land direct relation to OC content (Pal et al., 2013). Based on CEC ratings developed by Hazelton and Murphy (2007), the CEC of the soils was rated as moderate under all land use types.

PBS was significantly higher ($P \leq 0.01$) by the interaction effect of land use type and slope gradients

The PBS was significantly higher3 ($P \leq 0.05$) under forest land among the land use types. Highest (83.07) content of PBS and lowest (75.07) content of PBS were recorded in forest land and cultivated land respectively. This might be due to the relatively high OM content and less leaching losses of basic cations of the forest land compared to cultivated and grazing lands. The highest amount of PBS in the natural forest could also be because of the amount and nature of the clay particles and lower acidity status. The cultivated land of the study area was lowest in PBS due to intensive cultivation and high crop residue removal. This is reported by Achalu et al. (2012a) and Fassil and Charles (2009) who states that cultivated land has lower values of PBS. And it was significantly ($P \leq 0.05$) among slope gradiets.Highest (85.6) value of PBS and lowest value of PBS were recorded on lower and upper slopes respectively. This result lined with findings of Mulugeta A, et al. (2015) and Siraj B, et al. (2015) states that PBS was affected by slope classes. According to Hazelton and Murphy (2007), PBS is rated as very high, high, medium, low and very low when its values are >80%, 60-80%, 40-60%, 20-40% and 0-20%, respectively. Therefore, result of study area revealed that PBS of cultivated and grazing lands were high and areas of forest land were very high.in similar way areas of slope gradient middle and upper slopes were high and lower slope was very high. This is due to higher accumulation of base saturations in the lower slope.

	BD	Av.P	TP	PH	OC	TN	OM	PBS	CEC	Ca	Mg	K	Na	Ex.acci	Ex.AL	Sand	Silt	Clay
BD	1	-0.8**	-1.0	-0.6*	-0.44*	-0.57*	-0.44*	-0.44*	-0.52*	-0.77**	-0.7**	-0.7**	-0.55*	0.74**	0.109	0.41*	-0.15	-0.33
Av.P		1	.86**	.78**	.53*	0.20	0.54*	0.40*	0.57*	.76**	0.77**	0.82**	0.69*	-0.83**	-0.006	-0.37	0.09	0.22
TP			1	0.65*	0.44*		0.05	0.44*	0.02	.77**	0.7**	.55*	0.41*	-0.74**	-.0.005	-0.41*	0.01	0.33
PH				1	.81**	0.48*	0.44*	0.41*	0.49*	0.56*	0.61*	0.84*	.67*	-0.59*	-0.09	-0.18	0.09	0.2
OC					1	0.49*	0.99***	0.38	0.42*	0.36	0.48*	0.7**	0.41*	-0.33	-0.22	-.005	0.12	0.09
TN						1	0.49*	0.12	0.02	0.001	0.098	0.35	0.19	-0.028	-0.02	-0.03	0.07	-0.79**
OM							1	0.37	0.42*	0.36	0.47*	0.7**	0.4*	-0.32	-0.22	-0.008	0.12	0.09*
PBS								1	0.26	0.45*	0.54*	0.41*	0.38	-0.29	-0.11	-0.24	0.11	-0.26
CEC									1	0.41*	0.49*	0.51*	0.37	-0.61*	-0.202	-0.25	0.02	-0.21
Ca										1	0.78**	0.61*	0.66*	-0.66*	-0.2	-0.28	0.09	0.15
Mg											1	0.65*	.69*	-0.70**	-0.09	-0.32	0.04	-0.28
K												1	.63*	0.70**	-0.01	-0.35	0.11	0.19
Na													1	-0.61*	0.052	0.13	0.041	-0.13
Ex.acci														1	0.026	0.39	-0.05	-0.27
Ex_Al															1	0.11	-0.35	-0.34
Sand																1	-0.11	-0.7**
Silt																	1	0.6*
Clay																		1

Table 6. Simple linear correlation coefficient on soil acidity assessment under different land use and soil nutrient properties measured m

* = Significant at P ≤ 0.05; ** = Significant at P ≤ 0.01; *** = Significant at P ≤ 0.001; BD = Bulk density; OM = Organic matter; TN

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary and Conclusions

Soil acidity is one of the major land degradation problems worldwide. About 50% of the worlds' arable soils are acidic. Soil acidity mostly affects Tropical and sub-tropical regions as well as areas with moderate climatic conditions and the tropics and subtropics account for 60% of the acid soils in the world. It is also expected that about 43% of the total Arable land of Ethiopia is affected by soil acidity. The intensive need to increase agricultural production causes great pressure on easily damaged soils and natural resources. Such soils contain toxic levels of Al and Mn, are prone to compaction and erode easily. Intensive cultivation and acid forming fertilizer applications, characterized decline of the soil pH and cause loss in basic cations, especially under intensive cropping on inherently poor soils.

Even though soil acidity is major limitations for crop production in the study area, there are no previous studies taken under soil acidity problem under different land use types and slope gradients. Therefore, this research was conducted with the objective to assessment of soil acidity under different land use types and slope gradients. Before starting the study soil survey was taken to get general information about the land use types and slope gradients, climate condition and vegetation cover. Adjacent land use types (natural forest, cultivated and grazing lands) and three slope gradients (10-15%, 5-10%and 2-5%) were identified. Generally 27 composite soil samples were taken place for laboratory analysis.

- The result reveals that except silt, sand and clay particle size distributions were

- significantly ($P \leq 0.05$) affected by under different land use types and slope gradients

. Clay content was highest in cultivated land and lowest in forest land and highest in lower slope gradients. Sand content was highest in grazing land , lower in cultivated land and highest on 10-15% slope classes .Exchangable bases were significantly ($P \leq 0.05$)affected by all land use types and slope gradients. Exchangable bases were highest in forest land when compared with cultivated land and grazing lands and highest on 2-5% slope classes.(Table 5). The higher CEC values in the forest land might be due to the high OM. CEC was strong positive correlation (r = 0.42*, 0.49**) with OM and pH, respectively (Table 1.6). Reports also indicated that high CEC in forest land was Associated with OC content (Pal et al., 2013).This might be due to the relatively high OM content and less leaching losses of basic cations of the forest land compared to cultivated and grazing lands. Available phosphorous was highly significant ($p<0.001$) and negatively correlated with level of exchangeable acidity (r=-0.83***) and it is strongly ($p<0.01$) and positively (r=0.78***) correlated with soil pH (H_2O). The Availability of phosphorous is strongly influenced by soil pH. The form of phosphates ions present in the soil changes with PH.

In general acidity related physical and chemical properties of soil was decreased in cultivated land and increases with decreasing slope gradients. In study area there is series soil acidity problem in cultivated land and grazing as compared with forest land. These is due to intensive cultivation, continuous use of inorganic fertilizers, leaching of basic cations by crop harvesting, high rain fall, over grazing and the sloppy area which was not protected by different watershed management practice. Therefore, the study focused that soil acidity is critical problem in study are and wants all responsible bodies intervention in order to overcome decline of crop productivity.

5.2. Recommendations

The findings of this study showed that there is good implication of properties of soil nutrients for future investigations in order to analyze problematic acidic soils and to increase crop productivity in west azernet district. Therefore,

- Special attention should be given to land use change and policy based sustainable land management practice in ordered to increase yield of crope productivity
- It is better to use shifting cultivation, minimize over grazing and using cut and carry system.
- It is important to leave harvesting crop residues which contains base forming cations
- It is important to add acid ameliorating fertilizers like: lime and OM in the form of farmyard manure/compost on farm land.
- It is important to use appropriate inorganic fertilizer
- In general further research work is need to use analyze status of acidity related soil micronutrient status

Under different land use types, effect of lime application on crope variety, effect on vermiompost on crope yields and status of soil acidity under conserved and non-conserved land use types in order to overcome soil acidity problem in the study area

6. REFERNCE

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7. APPENDIX

Mean monthly rain fall (mm) and mean and mean monthly minimum and maximum temperatures (ºc) of study area for ten years (2009-2018) in the West Azernet Berbere

Month	Min.Temprature	Max.Temprature	Rainfall
January	89.4	23.6	24.6
February	9.8	24.6	55.3
March	11.2	21.5	62.0
April	10.4	23.2	88.2
May	11.6	24.8	49.5
June	10.8	21.8	146.4
July	11.7	22.6	324.6
August	10.9	21.9	296.0
September	11.8	24.5	185.4
October	9.2	22.4	72.8
November	8.5	23.5	18.6
December	6.4	22.5	2.3
Mean	16.8	23.07	116.575
Total	201.69	276.9	1398.9

district

Source: West Azernet Berbere Woreda AGP (Agricultural Growth Production) national metrological agency southern zone Hawassa 2009 E.C

Appendix Table 1.ANOVA table for particle size distribution

Source of variation	Degree of freedom	Mean squares		
		Sand	Clay	Silt
			(%)	
LU	2	363.4*	371.5*	34.25
SG	2	10.11*	41.81*	11.48
Rep	2	171.4*	7241.03*	44
Error	16	85.27	185.2	74.37
CV (%)		24.95	29.00	28.5

Appendix Table 2.ANOVA table for BD and Total porosity

Source of variation	Degree Of freedom	Mean square	
		BD	TP
LU	2	0.402***	572***
SP	2	0.402**	92.26***
Rep	2	0.033*	47*
LU*SP	5	0.0016	8.87**
Error	16	0.0062	13.11
CV (%)		2.86	2.7

Source of variation	Degree Of freedom	Mean square		
		pH-H_2O	Ex.acidity	EX.AL
LU	2	3.37***	3.18***	3.86*
SP	2	2.16***	0.13**	3.3*
Rep	2	0.25**	0.036***	4.5**
LU*SP	5	0.195**	0.09**	0.054**
Error	16	0.077	0.088	3.56
CV (%)		4.2	2.86	2.7

Appendix Table 4.ANOVA table for soil organic matter and percent base saturation

Source of variation	Degree of Freedom	Mean Square	
		SOM	PBS
		%	(mgkg-1soil)
Land types	2		
SG	2	2.8***	141.17*
Replication	2	0.37**	43*
LU*SP	5	1.12***	61.04**
Error	16	0.128	67.7
CV (%)		9.5	10.41

Appendix Table4 ANOVA table for organic matter, total nitrogen and available phosphorus.

Source of variation	Degree of freedom	Mean square		
		OC	TN	Av.P
Land use types	2			
SP	2	0.97*	0.014*	13.5**
Replication	2	0.3**	0.0038*	0.033**
LU*SP	5	0.38**	0.01**	0.137**
Error	16	0.0402	0.0033	0.259
CV (%)		9.2	14.32	11.66

Appendix Table 5.ANOVA table for exchangeable bases and CEC.

Source of variation	Degree of freedom	Mean Squares				
		Ca	Mg	K	Na	CEC
		(mgkg^{-1})				
LU	2					
SG	2	16***	13.3***	7.04 ***	4.8**	97.5**
Rep	2	1.1	0.404***	0.37**	1.4**	22.57**
LU*SG	5	0.98***	0.71**	0.31*	0.21*	6.1***
Error	16	0.600	0.44	0.16	0.27	6.41
CV (%)		5.704	10.37	12.77	18.5	10.41

Appendix Table 6. General rating of some chemical and physical properties

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

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

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

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

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

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

Soil reaction (pH)

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

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