ASSESSMENT THE STATUS OF SOIL ACIDITY AND ITS MANAGEMENT PRACTICES UNDER DIFFERENT LAND USE TYPES: THE CASE OF WONDO VILLAGE OF GOMBORA DISTRICT, HADIYA ZONE, SOUTHERN ETHIOPIA

M.SC. THESIS

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Assessment the Status of Soil Acidity and Its Management Practices Under Different Land Use Types: The Case of Wondo Village of Gombora District, Hadiya Zone, Southern Ethiopia

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A Thesis

Submitted to the School of Graduated Studies of Jimma University, College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirements for the Degree of Masters of Natural resource management (specialization in Soil Science)

Major Advisor: Alemayehu Regassa (PhD)

Co –Advisor: Bahilu Bezabih (PhD Scholar)

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I have incorporated the comments, suggestion and modifications given from internal defense during my thesis work and got the approval of my advisers for external defense. Hence, I hereby kindly request the Department to allow me to submit my thesis for external thesis defense.

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We, the thesis advisers have verified that the student has incorporated the suggestions and modifications given during his thesis work and the thesis is ready to be submitted.

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Decision/suggestion of Department Graduate Council (DGC) _________________________

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Chairperson, DGC Signature Date

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DEDICATION

I donate this thesis document to my wife Netsanet Fekadu and my child Kalkidan Tesfaye for their permanent gift throughout my life. Their tolerance, support, total encouragement, praying and giving of their capacity in every circumstance of my life. Without their decision allowed me to pass through M.Sc. education, in a situation not significantly encouraged, I would have never been in this present position.

STATEMENT OF THE AUTHOR

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Place: Jimma University, Jimma, Ethiopia

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BIOGRAPHICAL SKETCH

The author, Tesfaye Abure Anulo was born on 1st September 1987 in Anlemo District of Hadiya Zone, South Ethiopia. He attended his elementary and junior education at Anna-Gero-Darisha in 2000 and then, he completed his secondary education at Wachamo comprehensive secondary schools on October 2002. After completion of his secondary education, he joined Wolaita Sodo ATVET college in 2003 and graduated with Diploma in Natural resource on August 2, 2005. After his graduation, he has been employed at Gombora District Agriculture and Rural development office at natural resource development core process expert position in 2006 and served for four years. After that he joined Haramaya university in 2010 and graduated with bachelor degree in Natural resource management in September 2012. After his graduation, he has been employed at Gombora District Agriculture and Rural development office at natural resource development core process expert position in 2016 and served four years. until his joining of postgraduate study in Soil science at Jimma University Agriculture and Veterinary medicine college in September 2016.

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LIST OF ABBRIVATIONS AND ACRONYMS

ANOVA	Analysis of Variances
CAN	Calcium Ammonium Nitrate
CEC	Cation Exchange Capacity
DAP	Diammonium Phosphate
ECEC	Effective Cation Exchange Capacity
FAO	Food and Agricultural organization
FC	Field Capacity
FYM	Farm Yard Manure
GDP	Gross Domestic Product
PAS	Percentage Acid saturation
PBS	Percentage Base Saturation
SNNP	South Nation Nationality People
SOM	Soil Organic Matter
SPSS	Statistical Package for Social Science
SSA	Sub-Sahara Africa
TN	Total Nitrogen
USDA	United State Department of Agriculture
WAS	Water Stable Aggregate
WRB	World Reference Base Soil Resources

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ABSTRACT

Soil acidity is associated with infertility and mineral toxicities are major constraints affect agricultural production and productivity of the soil in humid area of Ethiopia. The problems in the study area were high rainfall followed erosion and leaching, intensive cultivation and inappropriate use of acid forming fertilizers and removal of crop residues for livestock feed and fire wood consumption might be aggravating soil acidity. The study was aimed to assessment the status of soil acidity and its management practices under different land use types in the case of the Wondo village of Gombora District, Hadiya Zone, Southern Ethiopia. Soil samples were collected by using X-design format from four different land use types: home garden, cultivated land, grazing land and eucalyptus plantation and two soil depths were considering for this study. A total of 24 composite soil samples were taken from four land use types X two soil depths by three replications in the study area and analyzed in laboratory for soil physio-chemical properties. While household survey data were collected from108 sample respondents by using both primary and secondary sources of data was analyzed by using statistical tool SAS version 9.3 and SPSS version-20 for this study. The results indicated that cultivated land and eucalyptus plantation were strongly acidic (pH 5.15 and 5.32) and highest mean value of exchangeable acidity and acid saturation percentage were (4.6, 4.59cmol $_{(+)}$ Kg^{-1}) and (47.85, 46.96%) respectively. Whereas grazing land was moderately acidic (pH 5.63) and home garden soil was slightly acidic (pH 6.67). However, the home garden soils had statistically significant ($p<0.01$) lower exchangeable acidity (0.64 cmol $_{(+)}$ kg^{-1}) and acid saturation percentage (2.61%). The soil texture of sand and clay were affected by the main effects of land use types and soil depths, similarly, soil bulk density. However, OM, TN and available phosphorus were significantly ($p<0.01$) affected by main effects and interaction of land use by soil depths. Although, soil pH (H_2O and KCl), exchangeable acidity, acid saturation, exchangeable base, CEC and base saturation significantly ($p<0.01$) affected by both main effect and interaction effects of two factors. The highest mean value of OM, TN and available phosphorus were recorded at the surface soil of home garden, whereas, the highest mean value of exchangeable bases (Ca, Mg, K), CEC and base saturation percentage were recorded at subsurface layer of the home garden land. Although, 57.4% respondents' were aware of soil acidity problem on their land whereas 32.4% % farmers' were unaware of soil acidity problem on their land, and also 10.2% of respondents didn't realize neither existence nor absence of soil acidity problems in their land use types. Thus, their action to offset the soil acidity problems by use of farmyard manure, agroforestry system, acid tolerant crops and lime application respectively. Therefore, based on the findings of current study, the difference in status of soil acidity in different land use types is more likely due to the differences in the vital management practices. Cultivated land was beyond acidity tolerance limit of locally produced crops in the study area. Therefore, it should be advisable to, ameliorate soil acidity problems immediate use of farmyard manure and lime application should be encouraged on cultivated land for crop production. Moreover, remarkable consideration should be given to land management options for sustainable productivity of soils in cultivated land.

Keywords: Aluminum toxicity, Land use types, Perception, Soil depth, Soil properties

1. INTRODUCTION

1.1. Back-Ground

Soil acidity, associated with infertility and mineral toxicities are major constraints to agricultural production in several parts of the world (Pariasca-Tanaka *et al*., 2009). And also, influences many chemical and biological reactions that control plant nutrient availability and element toxicity (Lavelle *et al*., 1995). Both natural and anthropogenic factors cause soil acidity. However, anthropogenic activities exacerbate the rate of acidification. Many tropical soils are acidic because they are millions of years old and have been exposed to continuous weathering. As rain water percolates downwards, soluble nutrients leach out of the top layers of the soil, and gradually gets replaced by aluminum (Al), manganese(Mn) and hydrogen(H), the elements most closely associated with soil acidity (Sumner and Noble, 2003). (Al) is one of the predominant elements of the earth's crust and in soils with normal pH; it is present in insoluble form and hence causes no harm to plants. The solubility of (Al) in neutral and alkaline soils is too low to be toxic to plants. In acidic soils, it becomes soluble and enters root where it inhibits root growth and development, reacts with soluble phosphorus and converts it to insoluble aluminum phosphate which is not available to plants (Wissuwa, 2005).

Soil pH is the single most important chemical property of the soil like soil texture is to the physical properties (McLaren and Cameron, 1996). pH is defined as the negative logarithm (base 10) of the molar of H-ion concentration in soil solution and generally pH less than 7 is acidic. However, from agricultural point of view soil with pH less than 5.5 are considered as acidic because, it became toxic to plant growth and production. Eswaran *et al*. (1997), stated that approximately 43% of the world's tropical land area is classified as acidic, most acid soils are found in about 68% of tropical America, 38% of tropical Asia, and 27% of tropical Africa. Moreover, the effect of (Al) toxicity of the tropics and subtropics account for 60% of the acid soils in the world (Baligar and Fageria, 2005). Soil acidity is one of the most common chemical degradation of soil that affects optimal use of land resources for higher crop production and sustained agricultural productivity worldwide (Shiferaw and Holden, 1998)

In order to get sustainable crop production, acidic soils have to be managed by different management practices such as selection of acid tolerant species, agroforestry system, organic materials such as farmyard manure, chicken manure, compost and crop residues. And also the best one is addition of agricultural lime to a pH range which is suitable for better yield from crop production and minimize soil acidification; (Achalu *et al*., 2012). According to the world reference base for soil resources WRB (2014) classification system acid soils included under Andosols, Podzols, Plinthosols, Nitisols, Ferralsols and Acrisol. Whereas, according to USDA (1999) acid soils include Alfisols, Ultisols and Oxisols. Soil acidity affects the growth of crops because acidic soil contain toxic levels of (Al), and (Mn) ions and characterized by deficiency of essential plant nutrients such as P,N, K, Ca, Mg, and Mo (Gebrekidan *et al*., 2015).

The major cause of soil acidity could be the type of parent materials from which the soil are formed that means acidic (felsic) parent materials contain high silica content such as granite and rhyolite, leaching of base forming cations, continuous use of acid forming fertilizers such as Urea and DAP (Eshetu, 2011). In the tropics soil acidity is aggravated by leaching, erosion and continuous removal of basic cations through crop harvest. At pH below 5.5, (Al) is soluble in water and becomes the dominant ion in the soil solution.

According to Mossor-Pietraszewsk (2001), excess (Al) in acid soils, primarily injures the root apex and inhibits root elongation. The poor root growth leads to reduced water and nutrient uptake, and consequently crops grown on acid soils are confronted with poor nutrients and water availability reduced growth and yield of crops (Merino-Gergichevich *et al*., 2010). In Ethiopia, currently estimated that about 40.9% of the agricultural land area is covered by strongly to weak acid soils found in western, south western, north western and in central high land of Ethiopia. From these, 27.7% moderately to slightly acids with pH 5.8-6.7 and 13.2% covered by strong to moderately acidic soils with a pH 5.5-6.1 (Taye, 2007; Eshetu, 2011; Endalew *et al*., 2014).

1.2. Statement of the Problems

Changes in land use and soil management can have a marked effect on soil fertility, mainly the conversion of natural ecosystem to crop land usually resulted in physical, chemical and biological property degradation of soils (Habtamu *et al*., 2014). Research findings from different corners of Ethiopia have revealed that prolonged intensive cultivation without adequate fertilization have resulted in the depletion of plant nutrients. And also according to Achalu

(2015), deforestation and cultivation of virgin tropical soils often lead to depletion of N, P, and S and other plant nutrients that lead to (Al), (Fe) and (Mn) toxicity which increase soil acidity.

The soil in areas such as Chencha, Sodo, Sidam, Dawuro, Kembate, and Guragie in SNNP, are affected by soil acidity seriously limiting crop production and have very strong acid reaction 4.81(Haile and Boke, 2009; Bore, 2015). However, in Gombora district above mentioned problem has not been studied. Although, in the district there is low level of yield problems may be due to, the area experiences a high annual rainfall as high as 1500mm-1896mm, that augment to soil erosion and leaching of basic cations (Zenebe, 2015). Although farmers in the district use, urea and DAP fertilizers for a long period of time without any adequate management, prolonged intensive cultivation and total removal of crops residues for fire wood, livestock feeds, for fence construction, house roof thatching lead to removal of basic cations through crop harvest. Studies on status of soil acidity and its existing management practices under different land use types in the study area is scarce. Likewise, soil physico-chemical properties and their relationships to soil acidity have not been analyzed.

In this regard a clear understanding of soil acidity is vital to introduce sustainable land management practices to maintain the soil fertility and improve the productivity of acidic soil. Moreover, better knowledge on the soil acidity can help the farmers to enhance the productivity, rural land use planners and policy makers in designing more effective land management strategy to be implemented by the local farmers and similar agro-ecological areas of the country.

1.3. Objectives

1.3.1. General objective

The general objective of the study was to assessment of the status of soil acidity and its management practices under different land use types in the study area

1.3.2. Specific objectives

- To identify the status of soil acidity under different land use types and soil depths in study district
- To investigate selected physico-chemical properties of soil under different land use types
- To assess farmers' perception on soil acidity and their management practices to offset soil acidity problems in the study area

1.3.3. Research questions

Does land use difference influence soil acidity?

Does land use types and soil depths affect the physico-chemical properties?

Does a farmers perceive the existence of soil acidity in their land use types?

What are the different land management options applied to offset soil acidity in the study area?

2. LITERATURE REVIEW

2.1 The Concept of Soil Acidity

Soil pH is probably the most important master chemical soil parameter and it reflects the overall chemical status of the soil and influences a whole range of chemical and biological processes occurring in the soils (Bloom, 2000; Robarge, 2008). On the basis of their relative degree of acidity, soils are divided into several acidity or alkalinity classes, as shown in figure1. Such a classification enables the uses of proper terms for indicating acid-base conditions in soils.

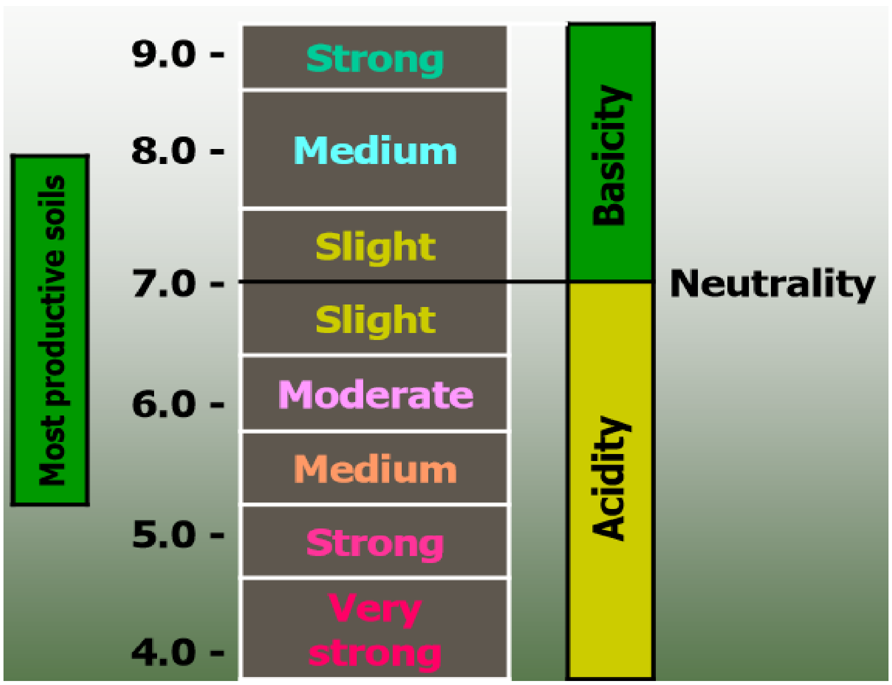


Figure 1. General Soil pH scale and reaction classes of soils

Source: (From Nutrient Manager McLaren and Cameron, 1996)

Acid soils (pH<7) are common in humid regions. In these soils, the concentration of H^+ ions exceed that of OH^- ions. Most plants grow best in soils with a slightly acidic reaction. In this pH ranges nearly all plant nutrients are available in optimal amounts (McCauley *et al*., 2009). Soils with pH<6 will more likely be deficient of some of available nutrients for optimal plant growth. Calcium, magnesium, and potassium are especially deficient in acidic soils. In strongly and very strongly acidic soils, Al, Fe, Mn may exist in toxic quantities because of their increased solubility. In addition, these elements will react with phosphates to form insoluble phosphates, of phosphate retention and fixation (Behera and Shukla, 2015). Hydrogen ion in soil solution is termed active acidity and is the acidity measured by common pH tests. Hydrogen and aluminum ions adsorbed on soil colloids are termed exchangeable acidity. Active acidity is due to the hydrogen ion concentration of soil solution whereas exchangeable acidity, refers to those hydrogens and aluminum ions adsorbed on soil colloids (Summer and Noble, 2003).

Adsorbed H^+ and Al^{+3} ions $\leftrightarrow$ soil solution (H^+ and Al^{+3}) ions
(Exchangeable acidity) (Active acidity)

The main source of soil acidity includes; Hydrolysis of aluminum, Alumino-silicate clay dissociations, Organic matter dissociations, Carbonation, Nitrification, Sulfur oxidation and soil amendments. All these processes produce H^+ ions, which causes soil acidity. For example,

- Hydrolysis of aluminum

  $Al^{+3}(soln) + H_2O \leftrightarrow Al(OH)_2^+ + H^+$

  $Al^{+3}(OH)^{2+} + H_2O \leftrightarrow Al(OH)_2^+ + H^+$

  $Al^{+3}(OH)_2^+ + H_2O \leftrightarrow Al(OH)_3^+ + H^+$

  H^+ is precipitate each hydrolysis reaction liberates H^+ and lowers soil pH

Active acidity**:** Is measured and expressed as soil pH. The active acidity is measure of the H^+ ion activity in the soil solution at any given time. However, the quantity of free H^+ ions concentration of the soils solution at any particular time is relatively very small compared to the quantity in the exchangeable and residual acidity forms. For example, only about 2Kg of calcium carbonate would be required to neutralize the active acidity in a hectare furrow slice of an average mineral soil at pH 4 and 20% moisture. Even though the concentration of hydrogen ion owing to active acidity is extremely small, it is important because this is the environment to which plants and microbes are exposed (Eshetu, 2011).

Salt replaceable (exchangeable) acidity: This type of acidity is primarily associated with the exchangeable aluminum and hydrogen ions that are present in largest quantities in very acid soils (Jena, 2008). These ions can be released in to the soil solution by un-buffered salt such as KCl. In moderately acid soils, the quantity of easily exchangeable aluminum and hydrogen is quite limited. Even in these soils, however, the limestone needed to neutralize this type of acidity is commonly more than 100 times that needed for the soil solution (active acidity). At a given pH value, exchangeable acidity is generally highest for smectites, intermediate for vermiculites, and lower for kaolinite. In any case however, it accounts for only a small portion of the total soil acidity.

Krstic *et al.* (2001) stated that, during soil acidification, protonation increases the mobilization of Al and Al forms serve as a sink for the accumulation of H^+. The concentration of the H^+ in soils to cause acidity is pronounced at pH values below 4 while excess concentration of Al^{3+} is observed at pH below 5.5 (Bolan *et al*., 2003). In strongly acidic conditions of humid regions where rainfall is sufficient to leach exchangeable basic cations, exchangeable Al occupies more than approximately 60% of the effective cation exchange capacity, resulting in a toxic level of Al in the soil solution. Generally, the presence of more than 1 parts per million of Al^{3+} in the soil solution can significantly bring toxicity to plants. Hence, the management of exchangeable Al is a primary concern in acid soils (Desta, 2015).

Residual acidity**:** Mossor-Pietraszewska (2001) reported that, a third type of soil acidity which they called residual acidity. Residual acidity is that which remains in the soil after active and exchangeable acidity has been neutralized. Residual acidity is generally associated with Al hydroxyl ions and with Al and H atoms that are bound in non-exchangeable forms by organic matter and silicate clays. If lime is added to soil, the pH increase and the Al hydroxyl ions are changed to uncharged gibbsite. In addition, as the pH increase bound H and Al can be released by calcium and magnesium in the lime material $Ca(OH)_2$ is used as an example of the reactive calcium liming material (Achalu 2015).

The residual acidity is commonly far greater than either the active or salt- replaceable acidity. Conservative estimates suggest the residual acidity may be 1000 times greater than the soil solution or active acidity in a sandy soil, 50,000 or even 100,000 times greater in a clayey soil high in organic matter. The amount of ground limestone recommended to at least partly neutralize residual acidity is commonly 4-8 metric tons per hectare furrow slice (1.8-3.6 tons/AFS). It is obvious that the pH of the soil solution is only “the tip of the iceberg” in determining how much lime is needed (Krstic and Djalovic, 2001).

2.2. Effects of Soil Acidity on Nutrient Availability to Plants

The major impact that an very low pH has on plant growth is related to the bioavailability of plant nutrients or the soil concentration of plant toxic minerals (McLaren and Cameron, 1996). In highly acidic soils,(Al) and (Mn) can become more available and more toxic to the plant where as at lower pH values calcium, phosphorous and magnesium are less available macronutrient to the plant (Moyer-Henry, 2006). Nutrients are ready for uptake by plant when they are present in their available form (Table 1). The availability of phosphorus is strongly influenced by soil pH.

Table 1. Available form of essential plant nutrients

Macro nutrients			Micro nutrients		
Element	Symbol	Forms taken up by the plants	Element	Symbol	Forms taken up by the plants
Carbon	C	CO_2, HCO_3	Iron	Fe	Fe^{2+}
Hydrogen	H	H_2O	Manganese	Mn	Mn^{2+}
Oxygen	O	O_2, H_2O	Cupper	Cu	Cu^{2+}
Nitrogen	N	NO^-_3, $NH_4{}^+$	Zinc	Zn	Zn^{2+}
Phosphorus	P	$H_2PO^-_4$, HPO^{2-}_4	Boron	B	H_3BO_3
Potassium	K	K^+	Chlorine	Cl	Cl^-
Sulphur	S	SO_2, SO^{2-}_4	Molybdenum	Mo	MoO^-_4
Calcium	Ca	Ca^{2+}			
Magnesium	Mg	Mg^{2+}			

Source: McLaren and Cameron (1996)

The impact of soil acidity on plant varies according to the tolerance of different species but can indicate stunted root growth, decreased quality and bulk of pasture and susceptibility to disease. Plants thrive best in different soil pH ranges. The pH tolerance range for various crop species can vary. Soil pH values above or below these ranges may (Table 2) result in less vigorous growth and nutrient deficiencies. Most of secondary and micronutrients deficiencies are easily corrected by keeping at the optimum pH value.

Table 2. Optimum pH requirement of some crop plant

Crop type	pH range	Crop type	pH range
Wheat	5.5-6.5	Cabbage	6.0-7.5
Barley	5.8-6.5	Carrot	5.5-7.0
Field beans	6.0-7.5	Cauliflower	6.0-7.5
Field pea	6.0-7.5	Potato	4.8-6.5
Corn/maize/	6.0-7.0	Tomato	5.5-7.5
Oats	5.0-6.5	Lettuce	6.0-7.0
Soybean	6.5-7.0	Straw berry	5.0-6.5
Red clover	5.6-7.0	Alfalfa	6.5-7.0
Asparagus	6.0-7.5	Apple	5.5-6.5

Source: McLaren and Cameron (1996)

As indicated in Table 2, Potatoes are often thought of as "acid loving" plants. They are acid tolerant and will grow reasonably well at soil pH levels down to about 4.8. A nutrient that is necessary for healthy plants need to be dissolved before uptake by plants. Dissolution of these nutrients usually takes place in neutral to slightly acidic pH values (Desta, 2015). Under acidic condition, the presence of high levels of soluble micronutrients such as iron, aluminum and manganese leads to the precipitation of insoluble phosphate compounds. Besides, phosphate can be ‘fixed’ hydrous oxides of Al and Fe and by certain silicate clays, which can also reduce availability (McCauley *et al*., 2009). The amount of available phosphorus in an environment, therefore; can drastically affect productivity. The availability of micronutrient (Fe^{2+}, Mn^{2+}, Cu^{2+}, Zn^{2+}) increases as soil pH decreases, except for molybdenum (Figure 2). Since plants need only minute quantities of micronutrients, plant toxicity in addition to other detrimental effects occurs with excess amounts.

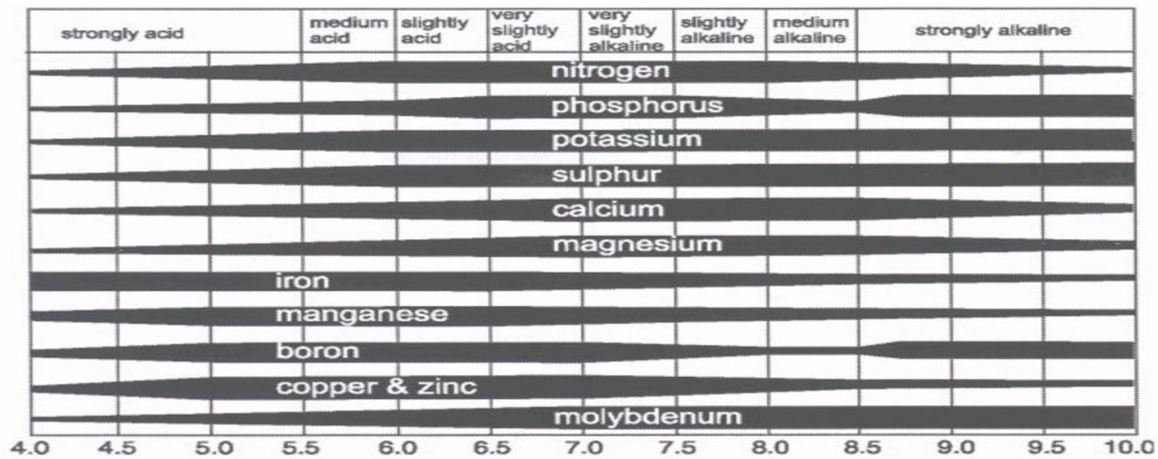


Figure 2. The relationship between soil pH and plant nutrient availability (source, ENRC, 2004)

According to Jones and Montanarella (2003), the description soils with a pH (H_2O) of less than seven are acidic. Moderately acidic soils have a pH range of 5.6 to 6.0. Strongly acidic soils have a pH range of 5.1 to 5.5. Very strongly acidic soils have a pH range of 4.5 to 5.0 and soils with a pH or 4.5 or lower are regarded as extremely acidic (McLaren and Cameron, 1996).

Table 3. Soil reaction ratings

pH range	Soil reaction rating
<4.6	Extremely acidic
4.6-5.5	Strongly acidic
5.6-6.5	Moderately acidic
6.6-6.9	Slightly acidic
7.0	Neutral
7.1-8.5	Moderately alkaline
>8.5	Strongly alkaline

Source: FAO, 2008

2.3. Effects of Soil Acidity on Aluminum Toxicity

Aluminum is not essential for plants growth. Although, metallic aluminum is non-toxic to plants, its ionic form (Al^{3+}), prevalent in acid soil conditions is toxic to all living cells. The ionic form of aluminum rapidly inhibits root elongation by targeting multiple cellular sites, including cell wall and plasma membrane, and various cellular processes such as signal transduction pathways and calcium homeostasis (Wissuwa, 2005). In response to aluminum stress, roots become stubby and brittle. The root tips and lateral roots thicken and turn brown. Such aluminum injured roots becomes inefficient in absorbing nutrients, water and the root system as a whole gets affected with many stubby lateral roots and no fine branching. Consequently, plants become susceptible to various stresses especially drought.

Thus, acid soils occupy up to 40% of the world's arable land (Pariasca-Tanaka *et al*., 2009), aluminum phyto-toxicity may be considered as one of the major limiting factors of crop productivity in the world (Hede *et al*., 2001). Crop production is drastically reduced when aluminum saturation of the active cation exchange sites is greater than 60% and tends to be optimum when aluminum saturation is zero. When a soil is more acidic than pH 6.0 to 6.5, the availability of plant nitrogen, phosphorus, Sulphur, calcium, potassium, magnesium and molybdenum, may be too low for satisfactory plant growth. In general, young seedlings are more susceptible to Al than older plants (Panda and Matsumoto, 2007).

2.4. Effects of Land Use Management Practices on Soil Acidification

Ethiopian's ancient and highly weathered soils and current systems of agricultural land use are particularly vulnerable to soil acidification process. It is emerging land degradation problem in western Ethiopia. However, information on the effect of land use and management practices on soil chemical properties in the country is very little (Negassa and Gebrekidan, 2007). In the highlands, due to intensive land use and high population pressure, the land is severely degraded, eroded and the nutrient status of most soils is decreasing. Between 70 and 75% of the agricultural soils of the highland plateau area of Ethiopia are phosphorus deficient (Gebrekidan and Mishra, 2005). Animal manure and crop residues, instead of being returned to the land, are largely used as fuel and livestock feed respectively (Lemenih, 2004).

Continuous cultivation and inorganic fertilizer application resulted in decline of soil pH and caused loss in basic cations especially under intensive cropping on inherently poor soils (Alemu and Lelago, 2016), thus, agricultural production increases the rate of acidification through the addition of acidifying fertilizers, increased nitrate leaching and the export of produce and also observed the occurrence of K deficiency on crops in the Alfisols at state farms of Wollega in Western Ethiopia that was subjected to intensive cultivation. Planting trees such as Pinus and Eucalyptus species invariably alters many soil properties. Soils under plantations typically become more acidic, the effect usually being attributed to the uptake of basic cations into the forest biomass. Pine needle litter contains acidic organic compounds that are released into the soil during decomposition (Mills and Fey, 2003). Coniferous forests can produce an acid litter because the tissues of such vegetation contain considerable concentration of soluble organic acids (Abbasi *et al*., 2007). Dilute acids together with the soluble organic acids from vegetation can readily leach fulvic acids, in soil humic material. This can produce strong acidification and weathering of soils leading to podosol formation and low base saturation. Plantation forestry has resulted in an increase in soil nitrate in many areas, possibly due to greater mineralization under forests than grasslands (Mills and Fey, 2004).

2.5. The Main Causes of Soil Acidity Problems

The causes of soil acidity are more easily understood when we consider that a soil is acid when there is an abundance of acidic cations, like hydrogen (H^+) and aluminum (Al^{3+}) present compared to the alkaline cations like calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+) (Álvaro *et al*., 2009).

Wet climates have a greater potential for acidic soils. In time, excessive rainfall leaches the soil profile's basic ions (Ca, Mg, Na, and K) that prevent soil acidity. Soils that develop from weathered granite are likely to be more acidic than those developed from shale or limestone.

Organic matter decay produces hydrogen ions (H^+), which are responsible for acidity an ion is a positively or negatively charged element (Zhang *et al*., 2002). Like that from rainfall, an acidic soil development from decaying organic matter is insignificant in the short term. Harvest of high-yielding crops plays the most significant role in increasing soil acidity.

During growth, crops absorb basic elements such as Ca, Mg, and K to satisfy their nutritional requirements. As the crop yields increase, more of these limes like nutrients are removed from the field (Zhang *et al*., 2002). Compared to the leaf and stem portions of the plant, grain contains minute amounts of these basic nutrients. Therefore, harvesting high-yielding forages such as Bermuda grass and alfalfa affects the soil acidity more than harvesting grain does. The natural rate of acidification is accelerated by agricultural practices like use of nitrogen fertilizers. The impact of nitrogen fertilizers on acidification depends on the type of fertilizer (Slattery and Hollier, 2002).

2.5.1. Rainfall and leaching

In conditions where rainfall exceeds evapotranspiration leaching during most of the year, the basic soil cations (Ca, Mg, K) are gradually depleted and replaced with cations held in colloidal soil reserves, leading to soil acidity. Soil acidity is really a high rainfall problem (Slattery and Hollier, 2002). Clay soils often contain Fe and hydroxyl Al, which affect the retention and availability of fertilizer cations and anions in acidic soils. Sandy soils are often the first to become acidic because water percolates rapidly, and sandy soils contain only a small reservoir of bases buffer capacity due to low clay and organic matter contents. Since the effect of rainfall on acid soil development is very slow, it may take hundreds of years for parent material to become acidic under high rainfall (Zhang *et al*., 2002).

2.5.2. Weathering of parent materials

The kind of parent materials from which the soil is formed influences the pH value of the soil. Soils developed from basic rocks generally have higher pH values than those formed from acidic rocks. Due to differences in chemical composition of parent materials, soils will become acidic after different lengths of time. Thus, soils that developed from granite material are likely to be more acidic than soils developed from calcareous shale or limestone. The western part of the Blue Nile basin has been more maturely eroded; nearly all volcanic rocks have been eroded, exposing mostly Precambrian metamorphic and granite rocks. The latter rocks are acidic, i.e.

trachyte and rhyolites, then the plateau basalts. Tertiary and quaternary basalt and rhyolites occurring in topographic positions from gently undulating to dissected hills is the main rock types (Gebrekidan and Mishra, 2005).

In warm, humid climate, it is likely to be thoroughly oxidized, well leached, and comparably low calcium because of leached out. Thus together with the climate, the nature and properties of parent materials are the most significant factors affecting the kind and quality of the soils. The rock compositions, which have more than 66% silica, are grouped under acidic soil and the lighter color alkali-alumino-silicates are predominant acidic rocks (Tessema, 2008)

2.5.3. Organic matter decomposition

Soil organic matter is derived from the decayed tissue of plants and from animal excreta; particularly urine (McCauley *et al*., 2009). Organic matter consists of numerous compounds that vary greatly in their ease of decomposition. Microbes rapidly decompose sugars, starches and proteins while lignin, fats and wax are resistant to this process. Fresh organic residues consist mostly of easily decomposed compounds that break down rapidly under favorable conditions. The result is a rapid reduction in the volume of SOM. Slattery and Hollier (2002) stated that, adding organic material to soil increases their capacity to tolerate a decreased pH in the short term. However, a buildup of organic material may make soil more acidic since decomposition of organic matter adds to soil acidity. Decaying organic matter produces H^+ that is responsible for acidity. The carbon dioxide (CO_2) produced by decaying organic matter reacts with water in the soil to form a weak acid called carbonic acid. The same acid develops when CO_2 in the atmosphere acts with rain to form acid rain naturally. The contribution to the acid soil development by decaying organic matter is generally very small, and it would only be the accumulated effects of many years (Slattery and Hollier, 2002).

2.5.4. Crop production and nutrient removal from soils

Large quantities of mineral nutrients are removed from soils as the result of plant growth and development and the harvesting of the crop (Mohammed *et al*., 2015). He elaborated as nutrient removals by crop as an effect on soil acidity development because crops absorb the lime-like elements, as cations, for their nutrition. When these crops are harvested and the yield is removed from the field, then some of the basic material responsible for counteracting the acidity developed by other processes is lost, the net effect is increased soil acidity.

Thus, increasing crop yields will cause greater amounts of basic material to be removed (Ketterings *et al*., 2006). The major acidification processes in intensively cultivated soils are due to removal of basic cations (Na^+, $Ca^{2+,}$ $Mg^{2+}$and K^+) and acidity developed from continuous application of inorganic fertilizer (Zhang *et al*., 2002). High yielding forages, such as Bermuda grass or alfalfa, can cause soil acidity to develop faster than other crops. Most agricultural products are slightly alkaline so their removal from the farm leaves soils slightly acidic. The alkalinity of different agricultural products, and therefore the impact of their removal vary, as indicated in (Table 4). Soil acidification is often expressed in terms of the amount of lime required to neutralize the input of acids into the soil (Upadhyay *et al*., 2013).

Table 4. Approximate amount of calcite and dolomite removed by crops

Product	Yield	$CaCO_3$ and ($Ca Mg (CO_3)_2$)
Wheat	2 t/ha	18 kg/ha
Lupines	2 t/ha	40kg/ha
Grass hay	5 t/ha	125 kg/ha
Clover hay	5 t/ha	200 kg/ha
Lucerne hay	5 t/ha	350 kg/ha

Source: Douglas et al. (2001)

Clover and Lucerne hay remove more basic cations from the soil (Table 4). Thus removing their crop residue aggravates soil acidity development.

2.5.5. Inappropriate application of acid forming fertilizer

The acidification from use of nitrogen fertilizer has the most serious effect in weakly buffered soils. This is because of the leaching of small reserve exchangeable cations and the increase aluminum concentration in the soil solution and reduction of soil buffering capacity (Samac and Tesfaye, 2003). The use of fertilizers, especially those supplying nitrogen, has often been blamed as a cause of soil acidity. Although acidity is produced when ammonium-containing materials are transformed to nitrate in the soil, this is countered by other reactions and the final crop removal of nitrogen in a form similar to that in the fertilizer. The most popular source of nitrogen is Urea and its decomposition consumes protons as follows:

$$CO(NH_2)_2 + 2H^+ + 2H_2O \rightarrow 2NH^+{}_4 + H_2CO_3$$

$$NH_4^+ + 2O_2 \rightarrow NO_3 + H_2O + 2H^+$$

(Samac and Tesfaye, 2003). The two hydrogen ions are very active to be acid in soil solution

In the soil solution, the nitrogen present in ionic form as $NH_4^{+,}$ NO^-_3 or $CO(NH_2)_2$ (Urea), all of which can be absorbed by plant roots. Being positively charged, NH_4^+ is adsorbed in soil by exchange with $Ca^{2+,}$ Mg^{2+} and other cation on the negatively charged clay and organic matter. Nitrate ion usually remains in the soil solution. Urea rapidly hydrolyzed by the enzyme to release ammonia (Bal *et al*., 2012). Acidifying effect of various N fertilizers followed this order: ammonium sulfate> ammonium nitrate>anhydrous ammonia>urea>calcium nitrate (Table 5).

Table 5. Acid forming nitrogen fertilizers and lime requirement to neutralized acidity

Fertilizer	N content (%)	Theoretically acid produced (kg-H/kg-N)	CaCO3 to neutralize acidity (kg/kg-N)
Urea	46.6	3.57	1.80
Ammonium sulfate	20.5	7.14	5.35
Ammonium nitrate	33.5	3.57	1.75
DAP	21.2	5.36	3.10
CAN	20.5	Varies	0.3-0.7

Source; Upjohn *et al*. *(2005*)

Application of such fertilizers before a plant is at a suitable stage of growth to absorb the available nitrogen is an example of inappropriate use that causes soil acidity. The amount of nitrate that leaches will depend on the amount of nitrogen in the soil and the amount of water draining below the root zone. Generally, the impact of nitrogen fertilizers on acidification depends on the type of fertilizer and what happens to the nitrogen (Tessema *et al* 2008).

2.6. Status and Distribution of Soil Acidity Problem in Ethiopia

Soil pH is the single most important chemical property of the soil like soil texture is to the physical properties (McLaren and Cameron, 1996). pH is defined as the negative logarithm (base 10) of the molar of H-ion concentration in solution and in generally pH less than 7 is acidic but, in agricultural point of view the soil acidity is the pH less than 5.5 that toxic to the plant growth and production (Hede *et al*., 1997)

Geologically, Ethiopia lies at the northern end of the continental part of the Eastern Rift. Voluminous piles of Proterozoic marbles occur in the Western (Gojjam, Wollega, Illubabor, Kaffa) and Southern (Omo, Sidamo) parts of Ethiopia (Straaten and van, 2000). Mainly tertiary volcanic rocks occupy large parts of the country along the Rift Valley. A general observation is that these resources occur in areas where strong to moderately acid soils (pH< 5.5) are dominant and marble deposits are well distributed over the area of acid soils that require liming materials to improve soil productivity (Lemma, 2011; Behera and Shukla, 2015).

Agriculture is the basis of the Ethiopian economy, accounting for 46% of its gross domestic product (GDP) and 63% of the national export earnings and about 85% of the country's population derives their livelihood directly from this sector. Smallholders' farmer operating under entirely rain-fed conditions dominates the sector and it accounts to 95% of the total area under crop cultivation (Endalew *et al*., 2014). Even though its role, the sector is characterized by low productivity and high exposure to risk due to adversely varying environmental conditions(Bore, 2015)

The total area of Ethiopia is 111.8 million hectares out of these only 79 million of hectare is suitable for agriculture. Out of these about 40.9% of the area is covered by strongly to weak acid soils. From these, 27.7% moderately to weak acids with pH 5.8-6.7 and 13.2% covered by strong to moderately acidic soils with a pH less than 5.5 (Deressa, 2013). In Ethiopia, soil acidity is a problem that has not been linked to soil production constraints. Yields of the major cereal crops, particularly barley, are as low as 0.5 Mg ha–1partly as a result of soil acidity (Gebrekidan and Wolancho, 2015). Improving the soil pH by applying lime, nitrogen, and phosphorus has increased yields by three fold Examples of some acidic soils are given in Table 6, where it is observed that most of these soils are found in the highlands receiving high rainfall (Eshetu, 2011).

Table 6. Status of soil acidity and phosphorus concentration by the soil types

Location	Soil type	Soil pH(H_2O)	Phosphorous (ppm)
Bako	Chromic vertisol	4.2	19.0 *(Olsen)
	Pellic vertisol	5.8	10.0
	Humic	4.6	4.0 "
Metehara	Mollic andosol	5.4	-
N.Easteren	Humic /Mollic	5.2	8.0 "
Escarpment	Andosol	4.7	1.0 "
Anno(east	Humic acrisol	5.35	4.39 **(Bray) "
Wellega)	Nitisol	5.49	4.87 "
Aleta Wondo	Nitisol	5.42	7.04 "
Dale (Yirgalem)	Nitisol	5.24	9.36 "
Chora (Illubabur)	Nitisol	5.07	5.82 "
Metu (Illubabur)	Nitisol	5.07	5.17 "

Gembi	Nitisol	5.36	18.42
Harru	Nitisol	5.8	1.5 “
Anfilo	Luvic phaeozem	5.4	1.25’’
Kossa (Limu)	Eutric Nitisol	5.2	2.8
	Eutric Nitisol	5.2	2.7 “
Gumer (Limu)	Nitisol	5.2	0.2 “

Source; adepted from Straaten (2000)

2.7. Management Practice of Soil Acidity Problems

Major constraints to crop production in acid soils are toxicities of Al and Mn and deficiencies of Ca/Mg (Goulding, 2016). In order to have successful agriculture in these regions, acid soil stresses need to be alleviated. The agronomic and management options to correct acid soils, improve nutrient use efficiency, and increase crop production on acidic soils include liming, application of organic materials, appropriate crop rotations and crop mixtures, and use of plant species and varieties tolerant to Al and Mn toxicity (Lockwood *et al*., 2004). And Land use change could be a long-term management strategy for soil acidity

2.7.1. Agricultural lime application

Liming of acid soils starts from the basic assumption that neutral soils are base-saturated while acid soils that contain exchangeable hydrogen and aluminum are base-unsaturated. Each soil has a region of buffering. In other words, soils behave like buffered weak acid and resist sharp changes in reaction (pH) with the addition of bases. For instance, some acid soil rich in organic matter could have similar pH values with a soil poor in organic matter. As a result, the amount of base or lime required to neutralize it to a desired level of total acidity could be diametrically different than the soil poor in organic matter. In other words, the percentage base saturation or the proportion of the cation exchange sites balanced by basic cations would be different. Conversely, if such soil is progressively neutralized with bases, the quantity of base needed to reach pH 7 is considered to be a measure of the total acidity of that soil or its lime requirement (Douglas *et al*., 2001).

$$CaO + H_2O + 2CO_2 \rightarrow 2Ca(HCO_3)_2$$

$$Ca(OH)_2 + 2CO_2 \rightarrow Ca(HCO_3)_2$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

According to Brady and Weil (2000), these materials react directly with acid soil the calcium and magnesium replacing the hydrogen and aluminum on the colloidal complex.

$$\text{Micelle}^{H^+}_{Al^{+3}} + 2Ca(OH)_2 \rightarrow \text{Micelle}^{Ca^{+2}}_{Ca^{+2}} + Al(OH)_3 + H_2O$$

$$\text{Micelle}^{H^+}_{Al^{+3}} + 2Ca(HCO_3)_2 \rightarrow \text{Micelle}^{Ca^{+2}}_{Ca^{+2}} + Al(OH)_3 + H_2O + 4CO_2$$

$$\text{Micelle}^{H^+}_{Al^{+3}} + CaCO_3 + H_2O \rightarrow \text{Micelle}^{Ca^{+2}}_{Ca^{+2}} + Al(OH)_3 + 2CO_2$$

The insolubility of $Al(OH)_3$ and the release of CO_2 to the atmosphere pulls these reactions to the right

Traditional methods of managing acidic soils: for agriculture in the humid tropics, such as slash-and-burn agriculture practiced in its various forms, also rely on the "application" of carbonates in this case in the form of ashes produced by the burning of woody and vegetative materials. Ashe contains a large proportion of the carbonates of mineral cations (K, Ca, &Mg) originally present in the vegetation.

Type of liming material: Soil acidity is corrected by the application of lime materials. The lime material has to be a calcium or magnesium salt of a weak acid such as limestone ($CaCO_3$), dolomite (Ca Mg $(CO_3)_2$), quicklime (CaO), hydrated lime or slaked lime (Ca $(OH)_2$). In correcting acidity, enough lime should be added to neutralize not only the active acidity but also the reserve or potential acidity. Acidity is normally corrected to increase pH to about 5.9 (Bolan, 2003). From the initial pH of the soil and reduction of pH of the buffer solution, the lime requirement could be calculated using standard. The liming of acid soils is regarded as the major solution to soil acidification at present in the western, southern and central highland of Ethiopia. Currently, determination of lime requirement has been done based on acid saturation. Lime Requirement (LR) may be affected by the reactivity of the liming material. Less reactive materials may require heavier application rates to compensate tables (ENRC, 2004).

The degree of fineness of liming material: is equally important in the selection of a liming material since the speed with which the various materials will react is dependent on the surface area that is in contact with the soil. If coarse, the reaction would be slight; but if fine, the reaction will be extensive. Therefore, for materials such as calcium oxide and calcium hydroxide that are by nature powdery, no problem of fineness is involved. On the other hand, limestone is entirely a different matter since its reaction is related to particle size (Taye, 2007). Crushing limestone also produces fragments of many sizes. These can range from fine dust upwards. Thus, limestone crushed to pass a 10-mesh (aperture of 2.0 mm), or a 30-mesh sieve (aperture of 0.59 mm) may contain a considerable amount of fine material that passes a 100-mesh sieve (aperture of 0.15mm)

Placement: For both direct and indirect effects on soils and plants, placement is decisive since lime particles do not move readily in soils. Consequently, it must be placed where needed and completely mixed with the soil to ensure uniform distribution. For instance, lime applied on the surface of an acid sub-soil could lead to transitory effects since it does not readily and substantially move to effectively bring about the intended soil reaction change for fertility improvement (Mohammed *et al*., 2015). This means that deeper plowing would be necessary for through blending with the soil.

2.7.2. Organic materials and crop systems to reduce soil acidity

Soil organic materials here in represents all forms of organic materials from both plants and animal origins. It has long been established that apart from improving the fertility, structure and some biological properties of the soil, organic materials have the capacity to reduce soil acidity and Al saturation. And also organic matter maintenance and management are central to the sustainability of soil fertility in the tropics (Chukwuka, 2009). In low input agricultural systems in the tropics, soil organic matter helps retain mineral nutrients in the soils and makes them available to plants in small amounts over many years as soil organic matter in mineralized. Soil organic matter increases the soil flora and fauna (associated with the soil aggregation, improved infiltration of water, and reduced soil erosion), complex toxic Al^{3+} and Mn^{2+} ions leading to better rooting, increases the buffering capacity of low activity clay soils, and increases water holding capacity (Kumwenda *et al*., 1996).

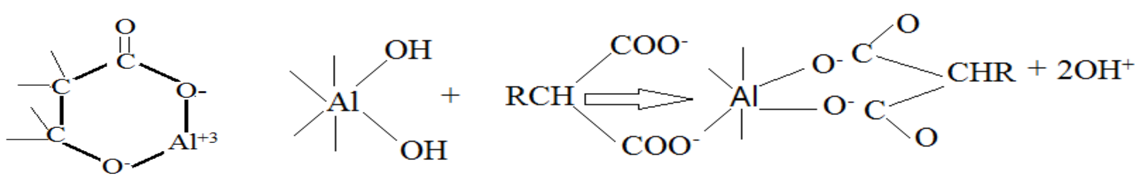
Some manure types have the liming effects and can reduce soil acidity. Therefore, the application of manures to reduce Al toxicity is a cheapest alternative approach to traditional liming. The release of cations and anions after the mineralization of manure affect nutrients balance of the soil solution and consequently its reaction. The cations can increase the potential cations and the base saturation of soil thus increasing soil pH and reducing Al toxicity (Pimentel, 2006). However, the effect of manure on soil pH is a conflicting issue. Manure has been reported to increase of soil pH (Summer and Nobel 2003). The application of animals manures to a Nigerian weathered Ultisols increased significantly the soil pH from 4.6 to 6.7 and also reduced exchangeable acidity from 3.00 cmolc kg-1 to 0.1 cmolc kg-1 while increased soil Ca from 1.6 cmolc kg-1 to 6.6 cmolc kg-1 (Ano and Ubochi, 2007)

2.7.3. Mechanism of aluminum detoxification

Manure can play the dual role of providing nutrients and mitigating the deleterious effects of soil acidity, but the precise mechanism of Al detoxification by manure has not yet well been understood like lime. The decomposition of animal and plant debris released a wide range of organic compounds which can bind strongly aluminum and render it nontoxic.

The organic compound involved in Al detoxifying can be grouped in to (i) organic acids: with Low-Molecular-Weight Organic Acids which include formic, acetic, propionic, butyric, crotonic, lactic, oxalic, succinic, fumaric, tartaric and citric (ii) humic materials: with High-Molecular-Weight-Organic-Molecules made up of a core phenolic polymers (Van Lynden, 2000). The Al neutralization potential of manure has been attributed to several chemical pathways. The mechanisms involved in the reactions of Al with organic matter are complex and probably include simultaneous chelation, complex formation, adsorption and co-precipitation (Jones and Montanarella, 2003).

The proposed mechanisms include: Complexation of Al in soil solution the products of organic decomposition particularly low-molecular-weight-organic-acids form stable complexes with aluminum (Al^{+3}) in soil solution reduce its toxic effects as suggested by (Wong *et al.*, 2003)



Although the use of liming materials is the most effective way of managing and correcting soil acidity, numerous studies reviewed by (Alhassane, and Samake, 2014) have shown that the application of organic matter such as compost ,manure ,and undecomposed plant residues can ameliorate the effect of soil acidity on crop growth. However, organic amendment in the longer term as they decompose, have an acidifying effect on soils (Obiri-nyarko, 2012). Nevertheless, for farmers who do not have access to agricultural liming materials either because of they are unavailable or too costly, these materials may be useful as a partial short term solution to soil acidity.

2.7.4. Mechanisms of plants tolerance to aluminum toxicity

Different plants had different strategies to adapt the acid soil. Plants those are more tolerant of acid ($Al^{3+)}$ stress (more adaptive to acid soils) should be developed for maintaining and increasing productivity on acid soils (Dong *et al*., 2008). The emerging era of adapting the plant to the natural environment is paramount to stabilizing crop yields and world food security for the future. The key to this effort will be breeding cultivars with high nutrient use efficiency and tolerant to abiotic stresses. Recent findings have shown the existence of inter-intra specific differences in acidity tolerance and nutrient use efficiency in many crops cultivars and genotypes (Baddeley *et al*., 2014). Genotypes that have high nutrient use efficiency genetic and physiological components of plants have profound effects on the ability of plants to acquire, transport, and utilize absorbed nutrients under various environmental and ecological conditions (Baligar and Fageria, 2005).

Plants have evolved different mechanisms to overcome Al stress, either by preventing Al^{3+} from entering the root or by being able to neutralize toxic Al^{3+} absorbed by the root system. The basis of which has been the focus of intense research (Kochian *et al*., 2004). So far the only well documented mechanism of Al resistance is the exclusion of Al from the root tip based on the release of organic acids, which chelate Al^{3+} forming stable, nontoxic complexes. Release of malate, citrate and/or oxalate from roots upon exposure to Al has been correlated with differential Al tolerance in a large number of monocot and dicot species (Maron *et al*., 2008).

In the first mechanism, Al is prevented from moving through the plasma membrane to the cytoplasm in the root cells. This is achieved by the secretion of organic acids from the radical apex to the rhizosphere, which, in turn, modifies the pH and chelates the toxic aluminum ion (Kinraide *et al*., 2005). Further, these organic anions (i) compete with phosphate groups for binding sites in the soil and thus block the sorption of P to other charged sites and (ii) form stronger complexes with $Al^{3+,}$ Fe^{3+} and Ca^{2+} than phosphate does and thus make the phosphorus available to plants. The second mechanism involves chelation of Al by specific proteins, short-chain organic acids, phenolic compounds and tannins that can bind and form complexes with aluminum ion (Al^{3+}) and subsequently compartmentalize it in the vacuole thus reducing Al-toxicity in the cell (Jones and Ryan, 2004).

Table 7. Crop tolerance for acceptable acid saturation

Crop type	Acid saturation tolerance limit(%)	Crop type	Acid saturation tolerance limit (%)
Cabbage	1	Sorghum	10
Carrot	1	Barley	10
Tomato	1	Wheat	10
Field bean	5	Sweet potato	10
Sunflower	5	Haricot Bean	20
Pepper	5	Maize	20
Cotton	5	Groundnut	20
Kale/rapeseed	5	Potato T	30
Onion	5	Teff	40

Source; MoARD (2007)

Cultivated crops vary in their tolerance to soil acidity. Therefore, selecting and growing species and variety adaptable to acidic soils is one solution (Pattanayak and Pfukrei, 2013). If the crop to be sown is teff, then, permissible acid saturation could be 40% (Ttable 7). Therefore, sufficient lime is needed to bring the acid saturation from 50% to 40%. If it is assumed that, the neutralizing value of the available lime is 75% that of the pure $CaCO_3$ and that incorporation depth is 15cm the lime requirement factor will be approximately 3000kg lime/ha/cmol of acidity to be eliminated (Kochian *et al*., 2004).

If the neutralizing value is lower or higher than 75%, the lime requirement factor is adjusted accordingly. Similarly, if incorporation depth is greater than 15cm, as it is likely, to be when tractor drawn implements are used the requirement factor is increased accordingly. Relatively, teff and potatoes are more tolerant to soil acidity and followed haricot bean, maize and finger millet whereas most vegetables like, cabbage, carrot and tomatoes are very susceptible to soil acidity (Table 7). In general, crops with low acid saturation tolerance limit need more lime to raise soil pH (Iqbal, 2012).

2.7.5. Agroforestry system

The considerable potential for agroforestry as a land management alternative for conserving soils as well as maintaining soil fertility and productivity in the tropics is becoming obvious. It involves the deliberate integration of trees with crops on the same land, several positive effects have been documented from this interaction. Nutrients such as nitrate, Ca, Mg, etc. leached from the root zones of crops to sub-horizons can be taken up by these deep rooted species and return them to the surface via litter fall. Wong *et al*. (1999) observed a reduction in nitrate loss through leaching when deep rooted species such as perennial grass, multipurpose trees or shrubs instead of annuals were strategically located within crops in the field.

Agroforestry systems such multi-story systems can also reduce erosivity of rain drops and leachability of nutrients. The ability of this system to reduce soil acidity, however, depends on the tree species and the structure of the agroforestry system. Baggie *et al*. (2000) investigated the potential of organic residues from nitrogen fixing trees such as *Albizia zygia* and *Gliricidia sepium* for ameliorating acid infertile rice soil in Ghana. Their study revealed that after 4 weeks of incubation, *Albizia zygia* and *Gliricidia sepium* had increased the pH of the soil from 4.4 to 5.1 and 5.3, respectively due to the high content of basic cations in these tree species.

Deep-rooted perennial plant species such as *Lucerne*, *alfalfa* and agroforestry tree species can be used in farming systems to redistribute alkalinity from more alkaline areas to where acid amelioration is needed. Wong *et al*. (1997), described two examples of agroforestry systems for the redistribution of alkalinity to deal with their different spatial distributions in the landscape. Firstly, a hedgerow intercropping system with shallow-rooted crops grown between alleys of trees was used to redistribute alkalinity from lower parts of the profile to the topsoil. Secondly, pure stands of trees were grown and prunings of *Leucaena leucocephala* cut, transported and applied to the acid soil to demonstrate the transfer of base from the production to the mulch plots. Both systems were effective in treating soil acidity and, the system recommended takes into account the location of source of alkalinity.

Some trees have shown potential for selectively accumulating certain nutrients. The litter and detritus from *Gmelina arborea* contained twice as much Ca as that of virgin forest or mature pine plantation while the Mg content of litter was three times as much as in *Pinus* litter. reports 117 and 161 kg Ca ha^{-1} yr^{-1} were returned in *G. arborea* litter for two plantations sites in Nigeria. Trees that produce base rich litter may have the potential for ameliorating soil acidification on the soil surface (Wong *et al*., 1999).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in Gombora District of Hadiya Zone, Southern Nations, Nationalities and Peoples Regional state (SNNPRS) of Ethiopia. Gombora District is located at about 259 km South of Addis Ababa and 27km away from Hossana, the capital of Hadiya Zone and it is one of the 11 District of Hadiya Zone. It is geographically located between 7^0 43′ 27" up to 7^0 57' 7" N latitude and 37^0 42' 35" up to 37^0 54' 47" E longitudes (Figure 3). Gombora District is bordered in the North by Gibe District, in the North East by the Misha District, and on the South Soro District, in the East by the Lemo District, and in the West by Omo River Yam Special District and Oromiya Regional States. This District has 22 rural villages and 1 urban town. The administrative center of this District is Habicho; other town in Gombora district includes Bushana (Zenebe, 2015).

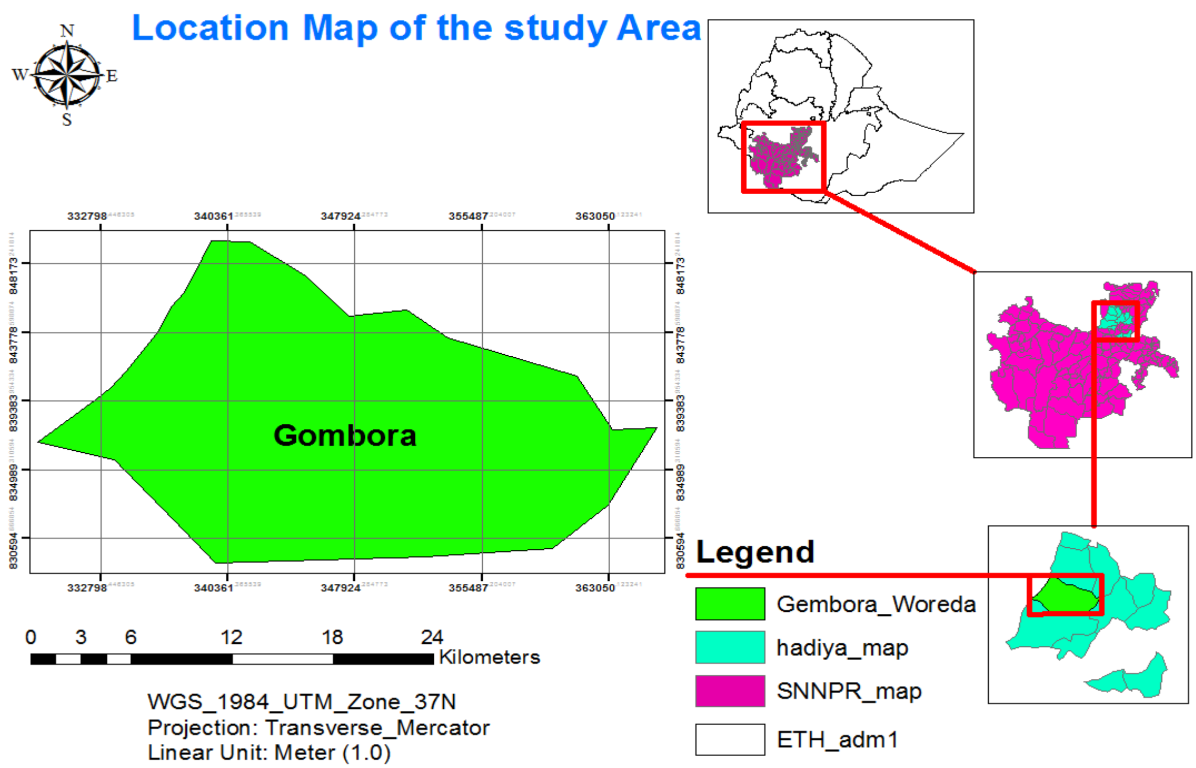


Figure 3. Location map of Study Area

3.1.1. Topography and climate

Topographic feature of a District is mostly characterized by moderately gentle and steep lands. The altitude ranges between 1972-2214 m.a.s.l. About 74% of the land mass of the district is classified as, woina-dega according to the traditional agro-ecology classification system of Ethiopia. The rainfall distribution is bimodal, which occurs in two main rainy seasons, *Belg* and *Maher*. *Belg* is short rainy season that starts from beginning of January up to April and that of *Maher* is longer rainy season that extend from May to the end of September. The annual precipitation varies between 1500mm-1896mm and also the minimum and maximum temperatures are 13.2 -26.85°C (Zenebe, 2015).

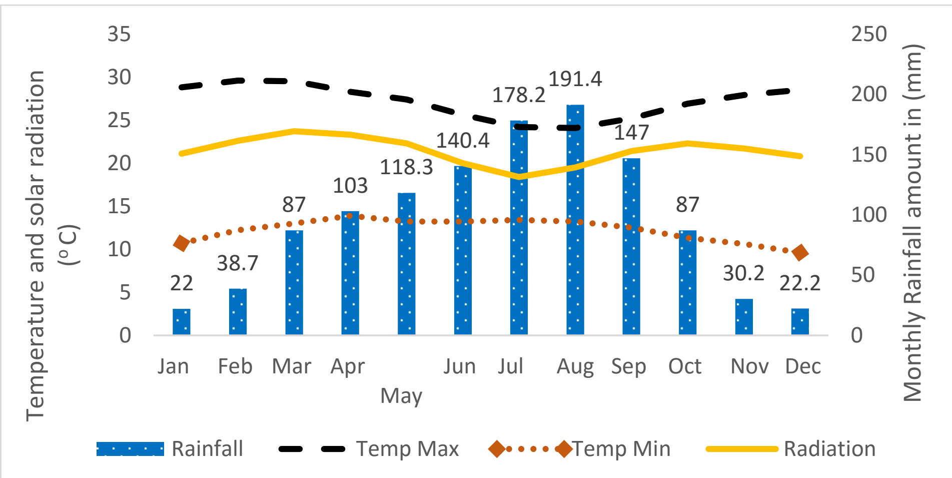


Figure 4. Mean monthly rainfall, temperature and solar radiation of the study area

(Source: MarkSim weather file generator, http://gismap.ciat.cgiar.org/MarksimGCM/ accessed date 01/08/2018)

3.1.2. Soil and vegetation

The study area is dominated by relatively soft weathered rocks that are particularly susceptible to erosion. The volcanic parts of the landscape are dominantly composed of acid to basic lava with covering of ash and tuffs. Soil of the study site is derived from highly weathered rocks, mainly granite and basalts, pyroclastic, Humic-Nitisols (60%), Eutric-Vertisol (20%), Eutric-Leptosol (10%) and Lithic-Leptosol (10%) cover extensive area. Soil covering extensive area is deep, well drained having more than 50-150 cm rooting depth. Nitisols dominate the district and they support highly intensive land uses (FAO, 2008).

The distribution of natural forest is declining from time to time, due to human interferences. The livelihood of the people in the district depends mainly on mixed agriculture (crop-livestock production). It is characterized by mixed farming of rain-fed crops and livestock production associated with tree species on farmland. The most commonly cultivated crops in the study sites include enset (*Ensetevenrtricosum*), teff (*Eagrostistef*), wheat (*Triticum vulgare*), maize (*Zea mays*), Sorgum (*Sorghum bicolor*), Faba bean (*Vicia faba*), coffee (*Coffeaarabica*), barley (*Hordeumvulgare*) and chat (*Cathaedulis*) in order of their importance. Currently forest coverage of the District is only 4.5% of the total land area (GDANRMO, 2017).

3.2. Sampling Framework

Two types of sample were employed to evaluate soil acidity problem and its management practices and farmers' perception towards soil acidity. These were soil sampling and household survey (figure 4).

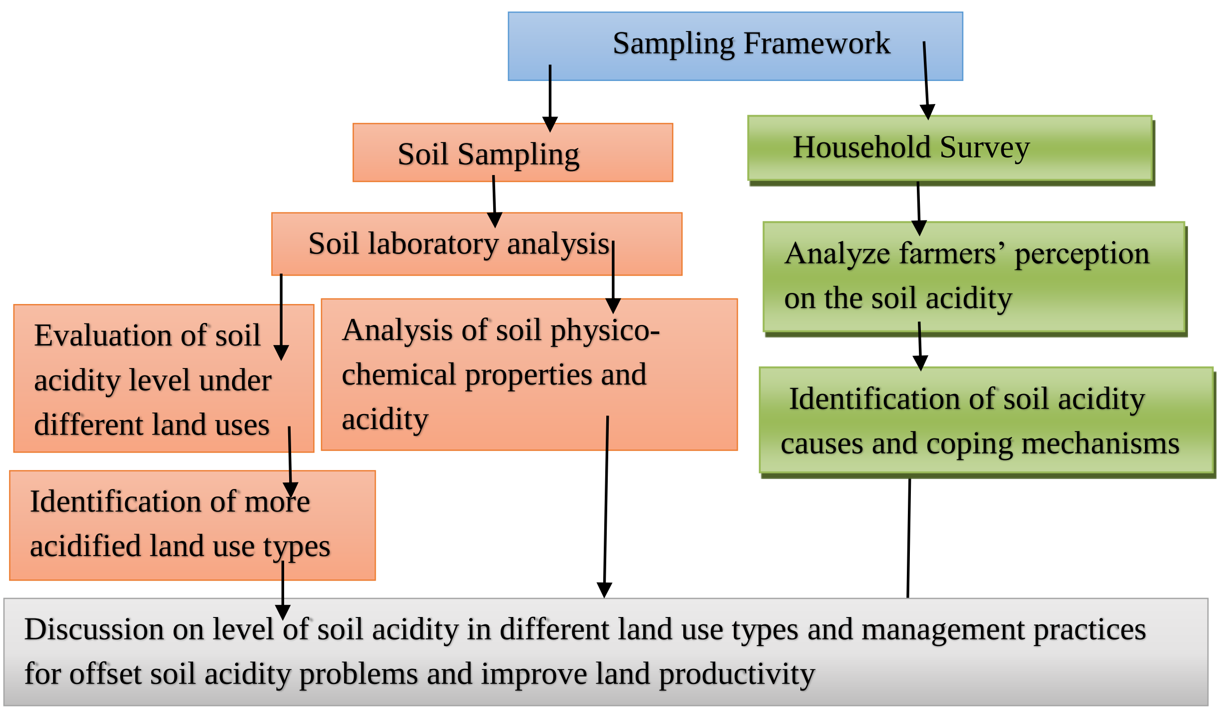


Figure 5. Sampling strategy and data collecting procedure

3.2.1. Site selection

Before soil sample collection, field observation and a reconnaissance soil survey were carried out. Apparently purposive sampling method was employed to identify village, exposed to the problems. The criteria used to select the study village was (1) Area related to acidity problem from previous report (2) Crops lack response to fertilizers or inactive information from farmer's

(3) Similar topography and soil types were considered to reduce the heterogeneity of land use types and its adverse impacts on the soil acidity and (4) Similar climatic condition in order to minimize agro-ecological influence i.e. woina-dega based on traditional agro-ecology classification system. Based on this information the reconnaissance survey of the prevailing areas, were collected from the farmers' interviews, agricultural experts and development agents. After that, one soil sampling village i.e. (Wondo village) was selected from Gombora district specifically for case study to soil physico-chemical analysis.

3.2.2. Soil sampling techniques

Soil samples were taken from four land use types with three replications of each at two depths. The land use types were (home garden, cultivated land, grazing land and eucalyptus plantation land). According to EthioSIS sampling guideline, the composite soil samples were collected from two soil depths (0-20cm) and (20-40) from each land use types (EthioSIS, 2013) in each land use types 20m by 20m = (400m^2) size plots were established. Then, the X-design format was used to collect composite soil sample from the four corners and in the center of the square plots. By following similar procedures, for four land use types, two soil depths by three replications were considered to collect totally twenty-four (24) composite soil samples.

The soil samples were well mixed, quartered and reduced to 1kg and sealed with plastic bags together with a tag, which holds proper labeling of land use types, soil depth, geographical position, altitude, name of landowner, name of village, field history, and date of collection and field code of the sample. In each step brief description of the sampling places were recorded by using GPS garmin72H. During the collection of samples; dead plants, furrow, old manures, wet spots, areas near trees and compost pits were excluded. This was done to minimize differences, which may arise because of the dilution of soil OM due to mixing through cultivation and other factors. Finally, the composite soil samples were brought to Jimma University college of Agriculture and Veterinary Medicine and Jimma research center soil laboratory for analysis of soil physico chemical property parameters.

3.2.3. Laboratory analysis

The soil samples collected from each land use types at various soil depths were air dried and passed through 2-mm sieve for the determination of most of the soil physico-chemical properties; however, the soil samples for organic carbon, analyses were ground to pass 0.5-mm size sieve. The bulk density of the soil was estimated from undisturbed soil samples which was collected by using a core sampler following the procedures of Gupta, (2000). The particle size distribution was determined according to the procedure outlined by Bouyoucos (1962) with the help of the hydrometer method. The pH of the soil was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5, soil: liquid ratio and the liquid was water and 1M KCl solution (Carter, 1993).

The Walkley and Black (1974) wet digestion method was used to determine soil organic carbon content and percent soil organic matter was obtained by multiplying percent soil organic carbon by a factor of 1.724 following the assumptions that organic matter is composed of 58% carbon. Total Nitrogen was determined using the Micro-Kjeldahl digestion, distillation and titration method as described by Bremner and Mulvaney (1982) by oxidizing the organic matter in concentrated sulfuric acid solution (0.1N H_2SO_4). Available soils P was extracted by the Bray-II (1945), method quantified using spectrophotometer (wave length of 880m) calorimetrically using vanadomolybedate acid as an indicator.

Cation exchange capacity and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Ca and Mg in the extracts were determine using atomic absorption spectrophotometer while Na and K were determined using a flame photometer (Chapman, 1965; Rowell, 1994). Cation exchange capacity was there after estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Exchangeable acidity (Al and H) were determined from a neutral 1 M KCl extracted solution through titration with standard NaOH solution based on the procedure described by McLean (1965). Percent base saturation (PBS) was calculated by dividing the sum of the charge =equivalents of the base-forming cations (Ca, Mg, Na and K) by the ECEC of the soil and multiplying by 100 and Percent acid saturation (PAS) was calculated by dividing the sum of the charge =equivalents of the acid-forming cations (Al^{+3} and H^{+}) by the ECEC of the soil and multiplying by 100.

3.2.4. Household survey

3.2.5. Sample size determination for household's survey

The total numbers of household heads living in the village are 502 household heads, from this village, representative household heads were determined based on sample size determination formula by using Cochran (1977) sample size determination techniques used to select respondents, for interview.

$$no = \frac{Z^2 * P * q}{d^2} \quad , \qquad n1 = \frac{no}{1 + \frac{no}{N}}$$

$$no = \frac{1.9^2 * 0.1 * 0.9}{0.05^2} = 138 \qquad n1 = \frac{138}{1 + \frac{138}{502}} = 108$$

$n_{o=}$ desired sample size Cochran's (1977) when population greater than 10,000

n_1= finite population correction factors (Cochran's formula, 1977) less than10, 000

Z = standard normal deviation (1.96 for 95% confidence level)

P = 0.1 (proportion of population to be included in sample i.e. 10%)

q =is 1-P i.e. (0.9)

N = is total number of population

d =is degree of accuracy desired (0.05)

Following the above Cochran's formula, 108 respondents were determined from the population using an error margin of 5%, and the probability of the sample size had confidence interval of 95 %. In this case, systematic randomly sampling techniques were employed to selecting 108 respondents for interviewed from the village data frame.

3.2.6. Sources and types of data

Concerning sources of data, both primary and secondary data sources were generated by gathering valuable data. primary data sources were collected from sample respondents, key informants and personal observation. Secondary data source was collected from published and unpublished documents, books and Governmental reports. For this study, both quantitative and qualitative data types were also used.

3.2.7. Methods of data collection

The method of data collection for this study was semi-structured questionnaires, key informant interview method and personal observation. The questionnaires were prepared in English and translated to local language in order to understand respondents the questions perfectly. One to one key informant interview was conducted from villages' representative, extension workers and soil experts were interviewed from sample village about the perception on soil acidity as well as land management options in the study area.

3.2.8. Data analysis and statistical procedures

The data was generated from soil laboratory analysis by comparing the four land use type's and two soil depths by analytically descriptive statistics and using two-way analysis of variance (ANOVA) used to detect whether variations in the soil parameters and soil depths, the studied significantly different ($p<0.05$) within and among the lands uses types and soil depth or not. The LSD mean separation method was employed to distinguish the means that were significantly different at 5% levels executed using Statistical Analysis System (SAS) version 9.3 (SAS, 2004). The household survey was analyzed by using descriptive statistics and the data was edited, coded in Microsoft Excel and analyzed percentages, frequencies and ranking by using Statistical Package for Social Sciences Released Version 20 (SPSS, 2011).

4. RESULTS AND DISCUSSION

4.1. Soil Acidity under Different Land Use Types and Soil Depths

4.1.1. Soil texture and bulk density

The sand and clay fraction were significantly affected by land use types and soil depth ($P < 0.05$, $P < 0.01$) respectively. But not affected by the interaction of land use by soil depth and similarly the silt fraction was not significantly ($P \leq 0.05$) affected by land use types, soil depth and the interaction of the two factors (Table 8 and Appendix Table 5).

The highest mean value of clay content (36%) was observed under the home garden land whereas the lowest mean value (31.50%) was observed in the cultivated land. In contrast, the highest mean value of sand content (35.33%) was observed under the cultivated land whereas the lowest mean value (31.66%) was observed under the eucalyptus plantation land. But there was no any significant variation between the home garden, grazing land and cultivated land. The lowest proportion of clay content in the cultivated land might be due to soil erosion and lack of control grazing or releasing cattle population after harvesting crop in the study area, this might have led to in the cultivated land removal of the fine particles clay eroded by sheet and rill erosion by water and suspension of fine particles by wind erosion.

This finding is in line with Brady and Weil (2002), Over a very long period of time, pedogenic processes such as erosion, deposition, eluviation and weathering can change the textures of various soil horizons. In contrast, to clay large size particles of sand and silt remain in the surface and not easily transported by water and wind. In line with Bezabih *et al., (*2014), who reported a relative variation in proportion of sand and clay content in cultivated land could be due to soil erosion because most of the cultivated land in the study area lacks any management practices contributed lowest proportion of clay in the cultivated and in opposite highest proportion of sand that could be due to it is not easily transportable relative to silt and clay.

The mean value of clay fraction of the home garden, grazing land, cultivated land and eucalyptus plantation were 36.00, 33.33, 31.50 and 34.66%, respectively (Table 8). The highest clay content observed in soils of the home garden compared to the remain three land use types, it could be less contribution of water and wind erosion and might be the contribution of organic matter. There were no textural class differences among the four land use types and two soil depths. The textural class of the surface (0-20 cm) and the subsurface (20-40 cm) soils was also clay loam, according to textural triangle of (USDA, 1999) (Table 8).

Considering the two soil depths, higher mean sand (35.17%) fractions were observed within the surface soils. Opposite to sand, higher clay fraction (35.50%) was found in the subsurface soil (Table 8). Sand and silt content decrease while clay content increases across depths from surface (0-20cm) to subsurface (20-40cm) soils. Even though, the increase in clay contents with depth under all land use types might be due to translocation of clay from surface to subsurface layers, whereas, ultimately increase the proportion of sand and silt contents on the surface soil layers. However, the fact that texture is an inherent soil property, management practices might have contributed indirectly to the changes in particle size distribution particularly in the surface layers as a result of removal of soil by sheet and rill erosions, and mixing up of the surface and the subsurface layers during continuous tillage activities and intensive grazing, can be observed in the study area.

Bulk density was significantly ($P \leq 0.01$) affected by the land use types and soil depths but, not significantly affected by interaction of land use by soil depth (Table 8 Appendix Table 5). The highest (1.21 g/cm^3) mean value of bulk density was recorded on the grazing land and the lowest (1.08 g/cm^3) mean value under the home garden (Table 8). The bulk density of grazing land and cultivated lands were not significantly differences between them, but they higher than compared to the rest land use types. This study agreed with Ahmed (2002) who, reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth.

Possible reason for the difference might be due to cattle in the study area have been freely released to the grazing land and cultivated land after harvesting the crops, this most probably caused trampling effect and responsible for an increase in soil bulk density in the grazing land. The lowest soil bulk density observed in the home garden area when compared to the remain land use types because, the home garden soil could be attributed to the high organic matter contents and no trampling effect. This study is in line with Bazebih *et al*. (2014), the lowest soil bulk density observed in the Enset *(Enset ventricosum)* farm land when compared to grazing land use. This, might be strongly linked with, the fact that free grazing in the Enset *(Enset ventricosum)* farm is strictly forbidden in the study area.

Soil bulk density increased in the 0-20 and 20-40 cm layers relative to the length of time the soils were exposed to cultivation and over grazing. This study is in line with Wakene (2001) who reported that bulk density was higher at the sub-surface than the surface horizons in the unrestricted and lands left fallow for twelve years.

Table 8. Main effects of land use and soil depth on selected physical properties of the soils in the wondo village (Mean± S.E), N=24

Land use types	Sand%	Silt %	Clay%	STC	Bd g/cm3
HG	34.00±0.39[a]	30.3±0.41	36.00±0.53[a]	Clay loam	1.08±0.03[c]
GL	34.66±0.14[a]	32.33±0.36	33.33±0.25[ba]	Clay loam	1.21±0.04[a]
CL	35.33±0.21[a]	33.73±0.16	31.50±0.37[b]	Clay loam	1.18±0.02[a]
EP	31.660±0.32[b]	33.66±0.38	34.66±0.36[a]	Clay loam	1.14±0.02[b]
LSD (0.05)	**2.13**	**NS**	**3.41**		**0.034**
Soil depth					
(0-20cm)	35.17±0.24[a]	32.75±0.46	32.25±0.41[b]	Clay loam	1.13±0.04[b]
(20-40cm)	32.66±0.29[b]	32.33±0.18	35.50±0.25[a]	Clay loam	1.18±0.05[a]
LSD(0.05)	**1.50**	**NS**	**2.12**		**0.024**
CV	**5.06**	**8.46**	**7.16**		**2.4**

Main effect means within a column followed by the same letter are not significantly different from each other at P ≤ 0.05; LSD least significant different NS=not significant CV=coefficient of vibration CL=cultivated land, HG=home garden, GL=grazing land, EP=Eucalyptus plantation, STC=soil textural class and BD= bulk density and S.E= Standard Error of mean and N= Number of samples

4.1.2. The soil pH level

In all land use types and two soil depths, soil pH values measured in water were higher by about (0.8 – 1.35) unit than their respective pH values measured using KCl solution (Table 9). The low soil pH with KCl determination indicates the releases of significant amount of exchangeable hydrogen (H^+) and aluminum ions (Al^{+3}) in to soil solution exchange through the reaction with potassium (K) in KCl solution. This is related to the presence of exchangeable Al^{+3} and H^+ in clay lattice or colloidal surface that indicated high potential acidity (Anon, 1993; Heluf and Wakene, 2006).

The mean value of pH-H_2O and pH-KCl were significantly ($p<0.01$, $P \leq 0.05$) affected by all land use types, soil depths and similarly, with the interaction effect of land use by soil depths were significantly affected respectively (Table 9,10 and Appendix Table 6).

The highest mean value (6.67) and (5.88) and the lowest mean value (5.15) (3.80) of soil pH-using H_2O and pH-KCl were recorded under the home garden land and cultivated land respectively, compared to the rest of land use types (Table 9). The home garden soil mean value number which tells the increment of pH-H_2O and pH-KCl by about (29.5%) and (54.7%) compared to its amount with in cultivated land. The highest value of soil pH- using H_2O and KCl under the home garden might be due to the contribution of organic matter through addition of manures, compost, mulching of its residue, adding of wood ashes and crops residue from outfield garbage, this shows farmer's soil management in home garden land use types should be encouraged. The effect of manure on soil pH is a conflicting issue. However, manure has been reported to increase of soil pH (Wong *et al*., 2000; summer and Nobel 2003). Similarly, the application of animals manures to a Nigerian weathered Ultisols increased the soil pH from 4.6 to 6.7 and also increased soil exchangeable Ca from 1.6 cmolc kg-1 to 6.6 cmolc kg-1 (Ano and Ubochi, 2007).

On the contrary, lowest value of pH-H_2O and pH-KCl were recorded under the cultivated land, eucalyptus plantation and grazing land might be due to continuous removal of basic cations by crops, intensive cultivation that enhanced leaching of basic cations, washed away of exchangeable bases by rill and sheet erosion, continuous use of acid forming inorganic fertilizers on acid soils and excessive precipitation might aggravate soil acidity. This finding is agreement with Heluf and Wakene (2006), who reported that land use and management practices have remarkably influenced the soil chemical properties. Whereas, Soils under Eucalyptus plantations were acidic, due to more uptakes of basic cations by the trees and poor return rate to the soil. The relative decline in soil pH under Eucalyptus plantation land could be also due to oblong shaped canopy leading the rain to form big drops consequently enhancing leaching of basic cations as well by releasing organic acids associated with mineralization of organic matter (Mohammed *et al*., 2005). Generally, the pH values both (H_2O and KCl) observed in the study area were within the ranges of extremely acidic to slightly acidic soil reactions as indicated by FAO (2008).

Considering the two soil depths, the higher mean values of pH-H_2O (5.86) and pH-KCl (4.86) were observed within the sub-surface soils (20-40cm) (Table 9). In general, Soil pH increased with increase in soil depth. Mean value of Sub- surface soil number which tells the increment of pH-H_2O and pH-KCl by about (6.2% and 9.2%) compared to its amount with in surface soil. This study is in line with the findings of Wakene (2001) soil pH increased with depth of soil profile and relatively high pH was observed at subsoil horizons in Nitisol of Bako area. And also the variability pattern in soil pH suggested the increase in bases accumulation with increase in depth that could be attributed to the downward movement of solutes by leaching within a profile

(Mohammed *et al*.,2005). Malo *et al*. (2005), also reported that the increase in pH with soil depth could be associated with enhanced carbonate levels and less weathering rates.

4.1.3. Exchangeable acidity and acid saturation percentage

The soil exchangeable acidity and acid saturation were significantly ($p<0.01$) affected by land use types, soil depth and similarly, acid saturation percentage values were significantly affected by the interaction effect of land use types by soil depth ($P < 0.01$) whereas exchangeable acidity values were significantly affected by the interaction effect of land use types by soil depth ($P < 0.05$) (Table 9,10 and Appendix Table 6).

The mean exchangeable acidity values were 0.64, 2.65, 4.60 and 4.59 cmole (+) kg^{-1}) for home garden, grazing land, cultivated land and Eucalyptus plantation land, respectively (Table 10). The highest (4.60 cmol (+) kg-^{1}) and the lowest (0.64cmol (+) kg-^{1}) exchangeable acidity was recorded under the cultivated lands and home garden soil, respectively (Table 9). The home garden land mean value show that reduction of exchangeable acidity by about (-86.1%) compared to its amount with in cultivated land. These results might be, due to the difference in management practices and application of wood ash, farm yard manure. Similarly, the application of animals manures to a Nigerian weathered Ultisols reduced exchangeable acidity from 3.00 cmolc kg-1 to 0.1 cmolc kg-1(Ano and Ubochi, 2007). Whereas, the mean value result might show intensive cultivation and application of inorganic fertilizers leads to the higher exchangeable acidity content under the cultivated land.

This variation in exchangeable acidity might be due variation in soil pH, soil organic matter, soil texture and cropping history. According to Moore (2001); Hazelton and Murphy (2007) the mean exchangeable acidity in all land use types and two soil depth in the districts except home garden are categorized or rated as very high. The results of this study were in agreement with those reported by different Authors (Baligar *et al*., 1997; Wakene, 2001), who reported that inorganic fertilizer application is the root cause of soil exchangeable acidity.

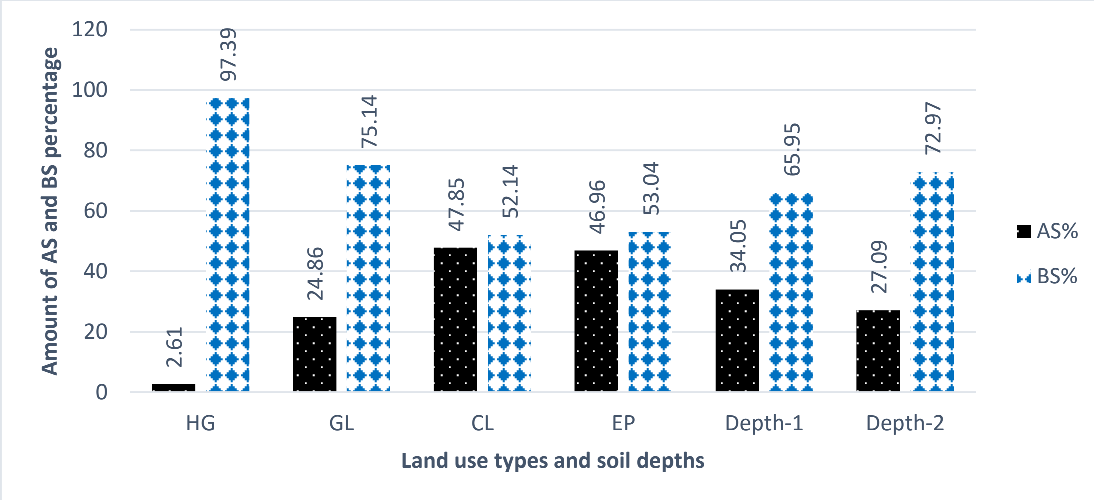


Figure 6. Comparison of acid saturation percentage with base saturation percentage under different land use types and depths

Although, the acidity saturation means values of soil were 2.61%, 24.85%, 47.85%, and 46.98% in home garden, grazing land, cultivated land and Eucalyptus plantation land, respectively (Table 9). The highest mean value of (47.85%) acid saturation was observed under the cultivated land, whereas the lowest mean value of (2.61%) was observed under the home garden soil. This home garden mean value which tells reduction of acid saturation by about (94.5%) compared to its amount with in cultivated land. Similar trends were observed in acid saturation percentage like exchangeable acidity.

Although this significant differences between the cultivated land and home garden land were probably due to the difference in management practices and application of wood ash, farm yard manure, house refuses and none application of chemical fertilizer. Hence, cultivated field, Eucalyptus plantation and grazing land had very high level of acid saturation. According to acid saturation described in soil acidity management and lime application principles guidelines prepared by the Ministry of Agricultural and Rural Development (2007), the acceptable acid saturation tolerance limit of crops listed by order as cabbage, carrot and tomatoes (1%), onion, field bean and rage seed (5%), wheat and barley (10%), maize potatoes and teff 20, 30, 40% in that order. However, the acid saturation in cultivated land was beyond a saturation tolerance limit (>40%) of locally produced crops in the study area.

Considering the two soil depths, the lower mean values of exchangeable acidity (2.91) and acid saturation percentage (27.09%) were recorded within the sub-surface soils (20-40cm), respectively (Table 9). In general, soil exchangeable acidity and acid saturation percentage decreased from the surface to the sub-surface soil depth. Sub-surface soil figure which tells the reduction of exchangeable acidity and acid saturation percentage by about (12.6% and 20.4%) compared to its amount with in surface soil. This condition of variability in exchangeable acidity and acid saturation percentage suggested the increase in bases accumulation with increase in depth that could be attributed to the downward movement of solutes by leaching within a profile (Mohammed *et al*., 2005)

Table 9.Main effects of land use and soil depth on soil pH (H_2O), pH(KCl), Ex. Acidity acid saturation percentage, SOM, TN and Aval. P of the soils in the wondo village N=24

	pH(H_2O) 1:2.5	pH(KCl) 1:2.5	ΔpH	EA $cmol_c kg^{-1}$	AS %	SOM %	TN%	Av. P $mgkg^{-1}$
		Land use types						
HG	6.67^a	5.88^a	0.80	0.64^c	2.61^c	7.07^a	0.27^a	12.73^a
GL	5.63^b	4.78^b	0.85	2.65^b	24.86^b	3.86^b	0.17^b	3.48^b
CL	5.15^d	3.80^d	1.35	4.60^a	47.85^a	2.34^c	0.12^c	2.83^c
EP	5.32^c	4.16^c	1.16	4.59^a	46.96^a	2.39^c	0.13^c	2.98^c
LSD(0.05)	0.09	0.14		0.25	1.61	0.82	0.012	0.49
		Depth Soil						
0-20cm	5.52^b	4.45^b	1.07	3.33^a	34.05^a	4.49^a	0.21^a	6.42^a
20-40cm	5.86^a	4.86^a	1.00	2.91^b	27.09^b	3.34^b	0.13^b	4.59^b
LSD	**0.07**	**0.10**		**0.18**	**1.14**	**0.58**	**0.01**	**0.35**
CV	**1.31**	**2.39**		**6.57**	**4.26**	**5.21**	**5.61**	**7.22**

Main effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; CL=cultivated land, HG=home garden, GL=grazing land, EP=Eucalyptus plantation, KCl= potassium chloride, AS= Acid saturation percentage. LSD =least significance difference, CV=coefficient of variation, EA = exchangeable acidity, SOM.=soil organic matter, TN=Total Nitrogen and Av.P= available phosphorus, S.E= Standard Error of mean and N= Number of samples

Considering interaction effect mean value of soil pH-H_2O and pH-KCl were significant ($P < 0.05$) affected by the land use types and soil depths (Table 10). The highest (6.80) pH-H_2O was recorded at the 20-40cm subsurface layers of the home garden soils while, the lowest (4.93) was recorded at the surface layer (0-20cm) of the cultivated land soils, compared to the remaining land use types. The highest pH at the subsurface layer of the home garden soil could be the result of high clay content and high accumulation of basic cation and while, lowest the pH in the surface layer of the cultivated land could be the result of leaching of basic cations.

Although, Continuous cultivation practices, excessive precipitation, and application of inorganic fertilizers could be some of the factors which are responsible for the variation in pH in the soil profiles. This in line with study conducted by Nega and Heluf (2013), they found that pH the soil was affected by the interactions of land use changes and the soil depths in Western Ethiopia similarly, this with Brady and Weil (2002), who stated as, in acid soils, Al^{3+} becomes soluble and increase soil acidity while in alkaline soils; exchangeable basic cations tend to occupy the exchange sites of the soils by replacing exchangeable H^+ and Al^{3+} ions. According to FAO (2008) the soil pH range of the study area (4.93-6.80) indicated strongly acidic to slightly acidic soil condition under all the land use types.

Results show that the highest mean (6.13) pH-KCl was recorded at the 20-40 cm soil depth of the home garden soil, whereas the lowest (3.56) was recorded at the surface layer 0-20cm of the cultivated land compared to the three land use types (Table 10). The highest pH-KCl observed at the subsurface layer of the home garden land might be attributed to the accumulation of soluble cations, translocation of clay texture and soil erosion through tillage as was also reported by (Fungo *et al.,* 2011; Kumar *et al*., 2012). Generally, the pH-KCl value ranged from very strongly acidic to moderately acidic (3.56--6.13) soil reactions as classifications indicated by (Brady and Weil 2002).

The value of the exchangeable acidity and acid saturation percentage were significantly ($p<0.05$) affected by the interaction effects of land use types by soil depth (Table 11 and Appendix Table 6). The highest mean value 4.7, 51.29% and lowest mean value 0.46, 1.72% exchangeable acidity and acid saturation percentage were recorded at the surface soil depth (0-20cm) of cultivated land and subsurface soil depth (20-40cm) of home garden soil respectively, compared to the rest land use types (Table 10). These results might be show that, intensive cultivation and application of inorganic fertilizers leads to the higher exchangeable acidity and acid saturation percentage content under the surface of cultivated land whereas, the lowest exchangeable acidity and PAS figures might be show, better soil management condition on the sub-surface of home garden soil signify the importance of manure and wood ash application that increase basic cation than the other land uses types.

Table 10. The interaction effects of land use and soil depth on soil pH (H_2O), pH(KCl), Ex. Acidity and acid saturation percentage of the soils in the wondo village N=24

Land use types	pH(H2O) 1:2.5		pH(KCl)1:2.5		EA. cmol(+)kg^{-1}		Acid saturation (%)	
	Soil depth (cm)							
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
HG	6.53^{b}	6.80^{a}	5.63^{b}	6.13^{a}	0.83^{d}	0.46^{e}	3.49^{e}	1.72^{e}
GL	5.4^{d}	5.87^{c}	4.50^{d}	5.06^{c}	3.12^{b}	2.18^{c}	30.81^{c}	18.90^{d}
CL	4.93^{f}	5.36^{d}	3.56^{g}	4.03^{f}	4.70^{a}	4.49^{a}	51.29^{a}	44.41^{b}
EP	5.2^{e}	5.43^{d}	4.10^{fe}	4.23^{e}	4.69^{a}	4.50^{a}	50.59^{a}	43.33^{b}
LSD(0.05	**0.132**		**0.18**		**0.36**		**2.34**	
CV	**1.31**		**2.39**		**6.57**		**4.26**	

The interaction effect within a column followed by the same letter are not significantly different from each other at P ≤ 0.05; CL=cultivated land, HG=home garden, GL=grazing land, EP=Eucalyptus plantation, KCl= potassium chloride, AS= Acid saturation percentage. LSD =least significance difference, CV=coefficient of variation, EA = exchangeable acidity and N= Number of samples

4.2. Soil Acidity and Plant Nutrient

4.2.1. Soil organic matter

Soil organic matter (SOM) content was significantly ($P \leq 0.01$) affected by land use, soil depth and the interaction of land use by soil depth (Tables 9, 11 and Appendix Table 6). Soil OM content was highest (7.07%) recorded under the home garden soil whereas, the lowest was (2.33%) recorded on the cultivated land. The cultivated land mean value tells a reduction of SOM by about (67.04%) compared to its amount with in home garden land. but no significant difference between in the cultivated land and eucalyptus plantation at both soil depths, (Table 9). The lowest in SOM contents in the cultivated land low amount of organic matter applied to the soils, complete removal of crop residue from the cultivated land. Besides this, leaching problem that can be attributed to the relatively high sand content. The results of this study was in agreement with the finding of Yihenew (2002), who reported that most cultivated soils of Ethiopia are poor in organic matter contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field. And also, due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion problem (Eylachew, 2001).

Considering the two soil depths, higher mean value SOM (4.49%) was observed in the surface soil (0-20 cm), whereas the lowest mean value (3.34) was observed in subsoil depth (20-40 cm), which, tells an increment of SOM by about (34.4%) compared to its amount with in sub-surface soil depth (Table 9). The relatively higher SOM in soil at surface depth in all land use types might be due to relatively better return of biomass for decomposition at the surface. According, to Wakene (2001), also reported surface soil horizons to be more biologically active in the soil systems.

According, to the rating of soil organic matter as per the ranges suggested by Landon (1991), the soils of cultivated land, and eucalyptus plantation at both soil depths are in the range of low, the grazing land medium and home garden soil under the high rating class in the study area (Table 9). Low organic matter content implies that intensive cultivation, removal of crop residues, insufficient soil management in the cultivated land significantly depletes OM in the study area. This finding was in agreement with Tesema *et al*., (2008) and Achalu *et al*. (2012), who reported that less biomass return results in less SOM and total nitrogen content in the cultivated lands.

Considering the interaction effect, Soil organic matter (SOM) content was significantly ($P \leq 0.01$) affected by the interaction of land use type with soil depth (Table 11). The interaction effect of land use types by soil depth, in the SOM was significantly higher value (8.46%) was recorded at surface soil depth of the home garden soil. This might be related to reduced erosion was expected to occur in home garden, because the canopy formed by the trees and under-story vegetation shields the soil from the erosive energy of raindrops and thereby protecting the soil from splash erosion and surface or sheet erosion, this will again further reduce soil acidity through reducing leaching of basic cations.

Whereas, the lower mean values of SOM (2.21 and 2.22%) recorded at sub-surface soil depth of cultivated land and eucalyptus plantation compared to rest land use types respectively (Table 11). The lowest value of SOM in the cultivated land the reason, might be due to intensive cultivation of the land, fast decomposition SOM and the removal of crop residues for animal feed, income generation and source of energy. This result is in agreement with Dawit *et al*. (2002), who reported that SOM content under grazing and cultivated soils were lower than those under home garden. Therefore, poor organic matter content might be due to poor nutrient management in cultivated land and over grazing in grazing land. This finding was in agreement with Tesema *et al*. (2008), and Achalu *et al*. (2012), who reported that less biomass return results in less SOM and total nitrogen content in the cultivated and grazing lands.

Table 11. The interaction effects of land use and soil depth on soil SOM %, TN %, Ava. P and CEC of the soils in the Wondo village N=24

Land use types	SOM%		TN%		Ava. P ($mgkg^{-1}$)		CEC $cmolc\ kg^{-1}$	
	Soil depth (cm)							
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
HG	8.46^{a}	5.68^{b}	0.32^{a}	0.23^{b}	14.49^{a}	10.97^{b}	26.63^{b}	28.47^{a}
GL	4.45^{c}	3.28^{dc}	0.22^{b}	0.12^{c}	4.45^{c}	2.51^{e}	12.91^{d}	13.89^{c}
CL	2.46^{d}	2.21^{d}	0.12^{c}	0.09^{d}	3.33^{d}	2.26^{ed}	12.56^{d}	12.71^{d}
EP	2.57^{d}	2.22^{d}	0.13^{c}	0.10^{d}	3.39^{d}	2.60^{e}	12.73^{d}	12.95^{d}
LSD(0.05)	**1.19**		**0.02**		**0.76**		**0.76**	
CV	**5.21**		**5.61**		**7.22**		**2.61**	

The interaction effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; HG=home garden, GL=grazing land, CL=cultivated land, and EP=Eucalyptus plantation. LSD =least significance difference, CV=coefficient of variation SOM.=soil organic matter, TN=Total Nitrogen and Av. P= available phosphorus, CEC= cation Exchange capacity and BS= base saturation percentage and N= Number of samples

4.2.2. Total nitrogen

The total nitrogen (TN) content was significantly ($P \leq 0.01$) affected by land use types, soil depth and the interaction effects of land use by soil depth (Tables 9, 11 and Appendix Table 6).

The mean value of TN was highest (0.27%) was recorded under the home garden soil whereas, the lowest (0.12% and 0.13%) were recorded under the cultivated land and eucalyptus plantation soil respectively, which tells a reduction of TN by about (55.5%) and (51.85%) compared to its amount with the home garden soil respectively. The mean TN content decreased considerably from 0.21% in the surface (0-20cm) to 0.13% in the subsurface (20-40 cm) soil depth (Table 9), which tells a reduction by about 38% compared to its amount in the surface soil depth. The study in line with McDonagh *et al*. (2001), the considerable reduction of total N in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue or root biomass whenever added following intensive cultivation.

Considering the interaction effect of land use types by soil depth highest mean value of TN (0.32%) was recorded under the home garden soil at surface soil depth (0-20cm) whereas, the lowest mean value TN (0.09%) was recorded under the cultivated land in the subsurface soil depth (20-40cm). However, there was no mean separation difference between the cultivated land

and eucalyptus plantation in the both depth of surface and subsurface soil (Table 11). The highest value of TN under the home garden soil due to the addition organic matter, compost and easily decomposable garbage from the house also dense vegetation cover reduced soil erosion. This finding in line with, the presence of dense vegetation affords the soil adequate cover thereby reducing the loss in macro and micro nutrients that are essential for plant growth and energy fluxes (Eswaran *et al*., 1997).

While, the lower TN value in the cultivated land could be continuous cropping without replacement of nutrients, higher soil disturbance as a result of tillage, absence of soil organic matter management, use of crop residues as energy source, income generation and animal feeds. This finding agreement with Yihenew and Getachew (2013), who report that due to low amount of organic matter applied to the soils and complete removal of biomass from the cultivated land. Total nitrogen decreased consistently with increasing depth of soil under all land use types corresponding to the findings of (Gong *et al*., 2005; Alemayehu, 2013). According, to the rating of soil TN as per the ranges suggested by Havlin *et al.* (2013), the soils of cultivated land and eucalyptus plantation soil were low and grazing land medium and two soil depth of surface and sub-surface were in the range of high and low respectively, whereas, home garden soil under the high rating class in the study area (Table 9).

4.2.3. Available phosphorus

The available phosphorus (Av.P) content was significantly ($P \leq 0.01$) affected by land use types, soil depth and the interaction effects of land use by soil depth (Tables 9, 11 and Appendix Table 6). The content of available P in the home garden soil of performed to be significantly higher than the rest land use types. Accordingly, the main effect land use type and soil depth of the highest (12.73) and the lowest (2.83) available P contents were recorded under the home garden and the cultivated land, respectively, which tells a reduction of available phosphorus by about (77.76%) compared to its amount with in the home garden soil (Table 9). The data also revealed that available P was higher (6.42) in the surface soil (0-20 cm) than in the (4.59) subsurface (20-40) depth which, tells a reduction by about (28.5%) compared to its amount in the surface soil depth (Table 10).

Considering the interaction effect of land use types by soil depth highest mean value of available P (14.49) content was recorded under home garden surface soil depth (0-20cm) whereas, lower mean value of available P (2.26) content was recorded under cultivated land in subsurface soil depth (20-40cm) followed by grazing land and eucalyptus plantation soils respectively, (Table 11). This clearly shows that home garden soil the major contribution of the soil organic matter content to the P pool of the soils in the study area.

In line with this, the positive effects of soil organic matter on available P, by forming organophosphate complexes that are more easily assimilated by plants and anion replacement of H_2PO from adsorption sites, were reported in different studies (Abebe and Endalkachew, 2012; Nega and Heluf, 2013; Yihenew and Getachew, 2013). Similarly, the result was also in agreement with that of Boke (2004) who found high available P under enset in soils of Kokate and Adilo and concluded that transformation of organic P to available P through mineralization, addition of manure and crop residue to enset crop may have coated the reaction surfaces of the soil particles and prevent or delayed P sorption, and thereby increased P solubility.

Whereas the lowest available P of cultivated land due to the low organic matter content and intensive cultivation and crop harvest. This finding in line with Tekalign *et al*. (2002), also reported low availability of P in most Ethiopian soils recognized to the effects of numerous crop harvest, erosion, fixation and low accumulation of soil organic matter content. Available phosphors decreased consistently with increasing depth of soil under all land use types in the study area. According to Landon (1991) to as per available P rating, the mean available P content of the soils of the study area was within the range of medium in soils of home garden soil and low in soils of cultivated land, eucalyptus plantation and grazing land respectively.

4.2.4. Exchangeable basic cation

The exchangeable calcium (Ca), magnesium (Mg) and potassium (K) were significantly ($P < 0.01$) affected by land use, soil depth and the interaction of land use by soil depth (Table 12, 13 and Appendix Table 6). Whereas, the exchangeable sodium (Na) was only showed a significantly ($p<0.01$) variation in the soil depth (Table 13 and Appendix table 4).

The mean values of exchangeable calcium (Ca cmol+Kg^{-1}) recorded under the home garden, grazing land, cultivated land and eucalyptus plantation were (10.86, 3.63, 2.23 and 2.28 $cmol_c kg^{-1}$soil) respectively (Table12). The highest mean value of calcium (10.86) was recorded under home garden land followed grazing land. Whereas the lowest mean value (2.23) was recorded under the cultivated land compare to the rest land uses types. But there was no variation between the cultivated land and eucalyptus plantation. The higher exchangeable calcium in home garden soils was probably related to application of manure, wood ashes and high clay content. The study in line with Bal *et al. (*2012), nutrients such as nitrate, Ca, Mg, etc. leached from the root zones of crops to sub-horizons can be taken up by these deep rooted species and return them to the surface via litter. In contrast to home garden the lowest exchangeable calcium in cultivated land was probable cause due to the major acidification processes in intensively cultivated soils are due to removal of basic cations (Na, Ca, Mg, and K) by crop uptake, leaching and erosion. This is in line with study of in highly acidic soils, aluminum and manganese can become more available and more toxic to the plant where as at lower pH values calcium, phosphorous and magnesium are less available to the plant (Moyer-Henry, 2006).

The mean value magnesium (Mg) recorded under the home garden, grazing land, cultivated lands and eucalyptus plantation were (10.75, 2.76, 1.75 and 1.85) respectively (Table 12). The highest mean value of magnesium (10.76) was recorded under the home garden soil whereas, the lowest mean value magnesium (1.75) was recorded under the cultivated land compared to the rest land use types. but there was no any significant variation between the cultivated land and eucalyptus plantation. In the studied soils, Ca and Mg were the dominant cations. This is in agreement with the finding of Fassil and Yamoah (2009) who indicated that in neutral Vertisols the exchangeable sites are mainly occupied by Ca and Mg and to small extent by K and Na.

The mean value of exchangeable potassium (K^+) recorded under the home garden, grazing land, cultivated lands and eucalyptus plantation were (2.49, 1.55, 0.86 and 0.87cmol+Kg^{-1}) respectively (Table 12). The highest mean value of potassium (2.49) was recorded under the home garden soil whereas, the lowest mean value magnesium (0.86) was recorded under the cultivated land compared to the rest land use types. but there was no any significant variation between the cultivated land and eucalyptus plantation. This study in line with Alemu and Lelago (2016) Continuous cultivation and inorganic fertilizer application resulted in decline of soil pH and caused loss in basic cations especially under intensive cropping on inherently poor soils of cultivated land.

Considering the two soil depth, the mean value of the exchangeable calcium, magnesium, potassium and sodium were higher (5.03 4.81, 1.63 and 0.3 $cmol_c$ Kg^{-1} soil) in the subsurface soil (20-40 cm) depth than in the surface (0-20) soil depth (Table 12). The contents of exchangeable

Ca^{+2}, Mg^{+2}, K^{+1} and Na^{+1} increase with increase soil depth in subsurface soil may be indicate that, there was higher clay content and downward leaching of basic cations to accumulated or deposited in the subsurface soil depth.

Considering the interaction effects of land use by soil depth, the highest (11.49, 11.57 and 2.75 $cmol_c kg^{-1}$) exchangeable Ca^{+2}, Mg^{+2} and K^{+1} were recorded at the subsurface (20-40 cm) soil depth of the home garden soil respectively whereas, the lowest mean value (2.12, 1.41and 0.72 $cmol_c kg^{-1}$) were recorded on the surface soil depth (0-20cm) of the cultivated land respectively compared to the rest land use types (Table 13). But exchangeable Na^{+1} showed that no any significant variation in the interaction of land use types by soil depth.

The highest mean value of exchangeable Ca^{+2}, Mg^{+2} and K^{+1} were obtained in home garden soils probably related to high amount of organic matter and clay content combined with management effect as a main factor for Ca^{+2}, Mg^{+2} and K^{+1} difference and relatively low soil erosion and application of manure and wood ashes and mulching by crop residue maintain soil Ca, Mg and K^{+1} accumulating in soil and their leaves, stems and barks with soil amendments was important because it contributes an important proportion of food requirement in the study area. This finding in line with Wakene *et al.*, (2001) observed that the chemical composition of applied farmyard manure supplied to the crop that had considerable amounts of different essential macronutrients and small amounts of micronutrients usually deficient in acid soils.

Whereas the lowest value of exchangeable Ca, Mg and K were recorded on the cultivated land at the surface soil depth may be related to the decreasing trend of exchangeable Ca, Mg and K concentration in the cultivated, eucalyptus plantation and grazing land use types on the surface soil depth might be due to the leaching effect due to intensive cultivation, crop residues removal, low clay content and organic matter degradation which finally intensify the acidification processes. The study supported by planting trees such as Pines and *Eucalyptus* species invariably alters many soil properties. Soils under *Eucalyptus* plantations typically become more acidic, the effect usually being attributed to the uptake of basic cations into the forest biomass (Mills and Fey, 2003). Moreover, soil erosion, overgrazing and crop harvest removal for the contributed for the depletion of Ca, Mg and K in the cultivated and grazing lands and also, the low exchangeable K contents observed under cultivated land could probably due to continuous cultivations and inorganic farming practices in the study area which is supported by previous findings that indicate intensity of weathering, cultivation and use of acid forming inorganic fertilizers affect the distribution of K in the soil system and enhance its depletion (Malo *et al.,* 2005). Many research results from different areas of tropics supported the findings of this study. According to Heluf and Wakene (2006); Mesifin (2007); Tesema *et al*., (2008); Achalu *et al*., (2012) who observed that continuous cultivation and use of acid forming inorganic fertilizers affected the distribution of Ca, Mg and K in the soil and enhanced acidification.

According to Landon (1991) and FAO (2008), soil fertility classification, the study area land use types and soil depths rated as, high exchangeable Ca^{+2} in the home garden but, low in grazing land, cultivated land and eucalyptus plantation soil. Similarly, exchangeable Mg^{+2} and k^{+1} high in home garden soil but, low in grazing land, cultivated land and eucalyptus plantation. And also exchangeable Na^{+1} medium in the home garden soil but, low in the grazing land, cultivated land and eucalyptus plantation. Although the exchangeable Ca^{+2}, Mg^{+2}, K^{+} and Na^{+} rated as, low, medium, medium and low in surface soil depth respectively, whereas medium, high, high and medium in subsurface soil depth respectively.

4.2.5. Effective cation exchange capacity

The mean value of effective cation exchange capacity (ECEC) was significantly ($p < 0.01$) affected by land use types and soil depth. Similarly, significant variation between the interaction effects of land use types by soil depth (Table 12 and Appendix Table 6). The mean value of (ECEC $cmol_c kg^{-1}$) recorded under the home garden, grazing land, cultivated land and eucalyptus plantation were (25.13, 10.84, 9.63 and 9.83 $cmol_c kg^{-1}$) respectively (Table 12). The highest mean value of ECEC (25.13) was recorded under home garden soil whereas, the lowest mean value (9.63 and 9.83) were recorded under the cultivated land and eucalyptus plantation soil respectively. But no any significant variation between the cultivated land and eucalyptus plantation soil. This might be attributed to low basic cations due to leaching, soil erosion and low proportion of clay content in the cultivated land resulted in lower ECEC value than the rest land use types. This finding agreement with, the natural rate of acidification is accelerated by agricultural practices like use of nitrogen fertilizers. The impact of nitrogen fertilizers on acidification depends on the type of fertilizer (Slattery and Hollier, 2002).

4.2.6. Cation exchange capacity

The mean value of cation exchange capacity (CEC) was significant ($P \leq 0.01$) affected by land use types, soil depths and as a result of the interaction effect of land uses by soil depths (Table 9, 12 and Appendix Table 6). The mean value of (CEC $cmol_c kg^{-1}$) recorded under the home garden, grazing land, cultivated land and eucalyptus plantation were (27.55, 13.40, 12.64 and 12.84$cmol_c kg^{-1}$) respectively (Table 12). The highest mean value of CEC (27.55) was recorded under home garden soil followed grazing land whereas, the lowest mean value (12.64 and 12.84) were recorded under the cultivated land and eucalyptus plantation soil respectively. But no any significant variation between the cultivated land and eucalyptus plantation soil.

The lowest mean value of CEC might be due to the depletion of exchangeable bases as the result of intensive cultivation and application of acid forming inorganic fertilizers which reduced the CEC under the cultivated land. However, the highest CEC in the of home garden land might be the result of the different management practice that improves soil organic matters and increase the proportion of clay content through addition of manures and mulching of residue. Thus, could reduce the risk of erosion, leaching of cations, improved soil structure. This study in line with Bezebih *et al*. (2014), the highest CEC was found in the Enset *(Ensetventricosum)* farm land followed by Grazing land. This may be due to a significant difference of clay content combined with management effect as a main factor for CEC difference.

Considering the interaction effect, the highest mean value CEC (28.46 $cmol_c kg^{-1}$) was recorded in the subsurface layers (20-40cm) of soils under the home garden soil, whereas the lowest mean values (12.56 $cmol_c kg^{-1}$) were observed at the surface layers (0-20cm) of soils under the cultivated land use types. In line with Boke (2004) soil with large amounts of clay or OM have higher exchange capacities than sandy soils, which are usually low in organic matter. The highest CEC in the subsurface layers of soil under all land uses types could be the result of the high clay content and accumulation basic cations. Whereas, the lowest CEC at the surface layers of cultivated land use types could be the result of leaching of basic cation and downward movement of clay particles as was also reported by (Fassil and Yamoah, 2009; Eyayu *et al.*, 2009; Deekor, 2012). As per the ratings were suggested by FAO (2008) and Landon (1991) the CEC of the studied soils qualified in the range of high in home garden and low in the cultivated land eucalyptus plantation and grazing land respectively, medium in soil depth.

4.2.7. Base saturation percentage

Percentage base saturation (BS%) was significantly ($P \leq 0.01$) affected by land use types, soil depths and similarly, the combination of land use types by soil depths (Table 12,13 and Appendix Table 6). Considering the main effects of land use, the highest mean value (97.39%)

and the lowest (52.14%) mean values of BS% were recorded under the home garden and the cultivated lands, respectively (Table 12). But no any significant difference between the cultivated and eucalyptus plantation land. This study related with Eucalyptus produce strong acidification and weathering of soils leading to podosol formation and low base saturation. (Mills and Fey, 2004). The highest base saturation percentage under the home garden soil may be due to a significant clay content combined with management effect as a main factor for exchangeable base difference. On the other hand, among the two soil depths, higher (72.91%) was recorded in the subsurface (20-40cm) layer than the surface layer. In general processes, that affect the magnitude of basic cations also affect base saturation percentage. As percent base saturation ratings was suggested by Hazelton and Murphy (2007), the percent base saturation content of the studied soils qualified in the range of high to low across the different land uses types and soil depths.

Table 12. Main effects of land use and soil depth on soil exchangeable cations and base saturation percentage of the soils in the Wondo village N=24

	Ex. Ca^{+2} $cmol_c\ kg^{-1}$	Ex. Mg^{+2} $cmol_c\ kg^{-1}$	Ex. K^{+1} $cmol_c$ kg-1	Ex. Na^{+1} $cmol_c\ kg^{-1}$	ECEC $cmol_c\ kg^{-}$	CEC $cmol_c$k	BS%
		Land use types					
HG	10.86^a	10.84^a	2.49a	0.3	25.13^a	27.55^a	97.39^a
GL	3.63^b	2.76^b	1.55^b	0.25	10.84^b	13.40^b	75.14^b
CL	2.23^c	1.75^c	0.86c	0.2	9.63^c	12.64^c	52.14^c
EP	2.28^c	1.85^c	0.87c	0.23	9.83^c	12.84^c	53.04^c
LSD(0.05	0.098	0.093	0.022	NS	0.308	0.53	1.61
		Depth Soil					
0-20cm	4.47^b	3.79^b	1.25^b	0.19^b	13.04^b	17.01^b	65.95^b
20-40cm	5.03^a	4.81^c	1.63^a	0.3^a	14.68^a	16.21^a	72.91^a
LSD(0.05)	0.69	0.065	0.015	0.07	0.22	0.38	1.14
CV	1.66	1.73	1.21	33.17	1.79	2.61	1.87

Main effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; HG=home garden, GL=grazing land, CL=cultivated land, and EP=Eucalyptus plantation. LSD =least significance difference, CV=coefficient of variation, CEC=cation exchange capacity, Ex.=exchangeable and BS%=base saturation percentage and $cmol_c$=cent mole charge, ECEC=effective cation exchange capacity and N= Number of samples

Table 13. The interaction effects of land use and soil depth on soil exchangeable cations and base saturation percentage of the soils in the wondo village N=24

Land use types	Ex. Ca^{+2}		Ex. Mg^{+2}		Ex. K^{+1}		ECEC $cmol_{c}/Kg$		BS%	
	Soil depths (cm)									
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
HG	10.2^{b}	11.4^{a}	10.12^{b}	11.57^{a}	2.24^{b}	2.75^{a}	23.60^{a}	26.66^{b}	96.50a	98.27a
GL	3.36^{d}	3.90^{b}	2.13^{d}	3.39^{c}	1.33^{d}	1.77^{c}	10.12^{b}	11.55^{c}	69.18c	81.09c
CL	2.12^{f}	2.34^{e}	1.41^{e}	2.1^{d}	0.72^{f}	0.99^{e}	9.13^{e}	10.13^{d}	48.71e	55.58d
EP	2.16^{f}	2.41^{e}	1.50^{e}	2.19^{d}	0.73^{f}	1.01^{e}	9.28^{e}	10.38^{d}	49.41e	56.67d
LSD(0.05	0.15		0.13		0.029		0.43		2.33	
CV	1.66		1.73		1.21		1.79		1.81	

The interaction effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; HG=home garden, GL=grazing land, CL=cultivated land, and EP=Eucalyptus plantation. LSD =least significance difference, CV=coefficient of variation and N= Number of samples

4.3. Relationships of Soil Acidity and Selected Soil Physico-chemical Properties

There was a strong relationship between soil acidity and soil properties from soils of different land uses types. The correlation analysis showed that soil pH (H_2O; KCl) was highly significantly ($P<0.01$) and positively correlated with total exchangeable bases (Ca^{+2}, Mg^{+2} and K^{+}) (r=0.96** 0.96** 0.97**; r=0.93** 0.92** 0.98**), CEC (r=0.93**; r=0.89**) and the same is true for base saturation and ECEC, but negatively correlated with exchangeable acidity (r=-0.94**; r=-0.96**) and acid saturation (r=-0.96**; r= -0.97**) for water and KCl respectively (Table 14).

This result is in agreement with the findings of Yihenew (2002), at Injibara area who observed that pH is highly significantly ($p<0.01$) and positively correlated with Ca (r=0.886**) and Mg (r=0.775**) whereas highly significantly and negatively correlated with exchangeable acidity (r=-0.612**). McLaren and Cameron (1996) elaborated that basic cations (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}) are usually found only in low amounts in acidic soil; because they have been displaced from cation exchange sites by H^{+} and Al^{+3} ions and subsequently leached from the soil.

Although, available phosphorous was highly significantly ($p<0.01$) and negatively correlated with level of exchangeable acidity and acid saturation (r=-0.82** and r=-0.82**) respectively (Table 14). However, they were strongly ($p<0.01$) and positively (r=0.83**, r=0.79**) correlated with soil pH (H_2O) and pH of KCl respectively (Table 14). The availability of phosphorus was strongly influenced by soil pH. The form of phosphate ion presents in the soil changes with pH.

Table 14. Pearson correlation coefficients (r) between soil acidity and other soil properties (N=24)

	H_2O	KCl	Ex. Ac	AS	OM	TN	P	ECEC	Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	BS	CEC
pH(Kcl)	**0.97****	**1.00**												
Ex. acidity	**-0.94****	**-0.96****	**1.00**											
AS%	**-0.96****	**-0.97****	**0.99****	**1.00**										
Om%	**0.80****	**0.80****	**-0.87****	**-0.87****	**1.00**									
TN	**0.67****	**0.66****	**-0.75****	**-0.74****	**0.95****	**1.00**								
Aval. P	**0.83****	**0.79****	**-0.82****	**-0.82****	**0.90****	**0.91****	**1.00**							
ECEC	**0.95****	**0.90****	**-0.89****	**-0.89****	**0.82****	**0.76****	**0.93****	**1.00**						
Ca^{+2}	**0.96****	**0.93****	**-0.93****	**-0.92****	**0.86****	**0.79****	**0.93****	**0.99****	**1.00**					
Mg^{+2}	**0.96****	**0.92****	**-0.91****	**-0.91****	**0.82****	**0.75****	**0.92****	**0.89****	**0.94****	**1.00**				
K^{+}	**0.97****	**0.98****	**-0.98****	**-0.98****	**0.81****	**0.67****	**0.80****	**0.92****	**0.94****	**0.94****	**1.00**			
BS%	**0.96****	**0.97****	**-0.99****	**-0.99****	**0.87****	**0.74****	**0.82****	**0.89****	**0.92****	**0.91****	**0.98****	**0.38ns**	**1.00**	
CEC	**0.93****	**0.89****	**-0.88****	**-0.88****	**0.82****	**0.77****	**0.94****	**1.00****	**0.99****	**0.99****	**0.90****	**0.32ns**	**0.88****	**1.00**

(**) = correlation is significant at the 0.01 level ($p<0.01$), (*) = correlation is significant at the 0.05 level ($p<0.05$), and (ns) indicate there was no significant differences at 0.05 level, n=24 Ex. acidity= Exchangeable Acidity, Aval.P= Available phosphorous, AS%=Acid Saturation Percentage, ECEC=Effective Cation Exchange capacity, CEC= Cation Exchange Capacity, OM= Organic matter, TN= Total Nitrogen and BS= Base saturation percentage

According to McLaren and Cameron (1996), under acidic condition, the presence of high levels of soluble iron, aluminum and manganese leads to the precipitation insoluble phosphate compounds. Moreover, phosphate can be fixed by hydrous oxides of Al and Fe and by certain silicate clays, which can also reduce its availability. In contrast, organic matter and total nitrogen content were highly significant ($p<0.01$) and negatively correlated with level of exchangeable acidity and acid saturation (r= -0.87**, -0.87** and r= - 0.75**, -0.74**) correlation between under different land use systems (Table 14).

4.4. General characteristics of surveyed respondents

Table 15. General characteristics of respondents

General characteristics	Categorical	Frequency (N)	Percentage
	Male	72	66.7
Sex	Female	36	33.3
	Total	108	100
	Married	77	71.3
Marital status	Single	31	28.7
	Total	108	100
	Literate	38	35.2
Education status	Illiterate	70	64.8
	Total	108	100
	Continuous variables	Mean	S. deviation
Age		49.8	8.46
Family size		5	2.5
Land size (ha)		1.35	0.66

Source own survey (2017)

4.5. Farmers awareness on soil acidity and their management practices

Most farmers were aware of the existence of soil acidity problems in their land use types. Therefore, about 57.4% of surveyed respondents said that had no soil acidity problems on their cultivated land, while less than 32.4% of surveyed respondents were unaware of the existence of soil acidity problems on their land and also about 10.2% of surveyed respondents didn't realize neither existence nor absence of soil acidity problems in their land use types (Table 16).

Table 16. Awareness of farmers on existence of soil acidity problems in their land

Categorical	Frequency (N)	Percentage (%)
Yes	62	57.4
No	35	32.4
I don't realize	11	10.2
Total	108	100.0

Source: Own survey (2017)

Those farmer's awareness due to the promotion activity of the government farmers for lime application on farm demonstration trial. In fact, they didn't know the name of acidic soil before the stated year but locally in hadiyisa, they call such land "***shakka'lli bucha";*** meaning inactive soil. They explained as, the name "*shakka'lli bucha"* was given it, due to crops lack of response for fertilizer and poor strength of the crop to be grown. These lands were not suitable for many crops except some relatively acid tolerant crops like, teff and potatoes with good agronomic management. This is in agreement with Baligar *et al*., (2005) who explained that acid soils frequently are inactive with fertilization; that is why the added fertilizers in spite of the nutrient deficiency even decrease the yields. Local farmers have experiences of changing "shakka'lli bucha" to none "shakka'lli bucha" by frequent application of farmyard manure as means of reclamation if near to the home.

4.5.1. Crop yield decline

Agricultural experts and farmers have the opinion that crop yield has been declining year after year since the last twenty years. About 40.7% and 30.6% of the surveyed respondents also perceived that soil acidity and soil erosion were the main reasons for low level yield of crops (Table 17). Some of the crops such as field pea, faba bean, wheat, linseed, barley and others become low level of production due to soil acidity problems unless special management was employed

Table 17. Farmers' response for probable cause of crop yield reduction (N=108**)**

Probable cause	Frequency (N)	Percent
Hell and pest	10	9.3
Soil acidity	44	40.7
Soil erosion	33	30.6
Deforestation	10	9.3
Over grazing	11	10.2
Total	108	100.0

Source: Own survey (2017)

The perception of farmers on the causes and indicators of soil acidity reflects if farmers have rightly understood the problem and helps to evaluate if their actions were focused in mitigating the right causes. Thus, those farmers who assured soil acidity were a key problem asked to list and rank the main causes of soil acidity. In the study area were, more than 50% of the surveyed respondents perceive that soil acidity was not due to a single factor but it was the combined effect of high rainfall followed by erosion and leaching, continuous cultivation and inappropriate use of nitrogenous fertilizers and neither farmers nor key informants directly implicated mineral fertilizers for the development of soil acidity. However, the farmers said that 'mineral fertilizer was addictive and has already damaged our soil' (Table 18). Soil acidity has increase in large areas of sub-Sahara Africa (SSA) due to a combination of high rates of erosion, leaching of basic cation, removal of crop-residues and cow- dung, continuous cultivation of the land without adequate fertilization or fallowing (Yebo, 2015).

Table 18. What are the main causes of soil acidification in your study village (N=108)?

Causes of acidification	Frequency (N)	Percentage (%)
Inherent acidic parent materials	3	2.8
High rain fall followed by erosion and leaching	8	7.4
Continuous cultivation and removal of crop residues	32	29.6
Inappropriate use of acid forming fertilizers	10	9.3
Combining effects of above listed	54	50.0
Total	108	100.0

Source: Own survey (2017)

4.5.2. Farmers' response to use of crop residues

Removing crop residue from the cultivated land can be thought of as equivalent to removing lime, leaving the soil more acidic. The way that plants take up nutrients results in a partitioning of acidity into the soil and alkalinity into the plant as dry matter. As agriculture removes plant material from as grain or pasture, less alkalinity was returned to the soil, and the soil becomes more acidic. About 34.3% and 28.7% of the surveyed respondents were reply that, the majority of crop residues were used for livestock feed and as fuel wood at study area. This condition forces farmers not only to travel very long distances to collect wood, but also to increasingly burn crop residues and organic manure for cooking and heating (Negassa and Gebrekidan, 2007).Nevertheless, there was no more experience of mulching; rather crop residues were mostly used for livestock feed (Table 19).

This has an agreement with the observation by Lemenih (2004), he noted that in the highlands, animal manure and crop residues, instead of being returned to the land, are largely used as fuel and livestock feed. farmers reported that they heavily rely on crop residue for animal feed. Thatching houses was also another use of stalks from small cereals like wheat and barley. Stalks of crops like wheat and teff straw were preferred for roofing than feed. Grain, pasture and crop residues generally have an alkaline pH due to their high content of basic minerals (Upjohn *et al*., 2005). Continuous and intensive cultivation of the same land and use of crop residue for fuel wood and livestock feed speed up nutrient removals from the field and increase soil acidity.

Table 19. Response of farmers towards the use of crop residues (N=108)

Use of crop residues	Frequency (N)	Percent
Mulching	5	4.6
Feed for livestock	37	34.3
For fuel	31	28.7
House roof shading	19	17.6
To fencing	16	14.8
Total	108	100.0

Source: Own survey (2017)

4.5.3. Farmers' response to soil acidity problems and their coping mechanisms

The basis for responsibility certain traditional practices among others was recognition of problems by the local people. Indigenous practices were aimed at arresting the local priority problems. According to Teklu and Gezahegn (2003), indigenous knowledge refers to the perception that farmers have about their natural and social environment, which they use to adapt and develop technologies to their local context. Hence, the farmers' understanding and response to soil acidity problem was based on their observations of indicators mainly related, low level of yield and similar poor tillering, poor response of barley, wheat, field pea and other similar crop species. Their responses were also focused on solving these problems. Farmer aware soil acidity problem in their farm responded by applying either one or more of the following soil management options to offset soil acidity problem described as follows (Appendix Table 7).

Table 20. Farmers' to offset soil acidity problems in their village

Management options	Frequency (N)	Percent
Farmyard manure application	45	41.7
Lime application	8	7.4
Use of acid tolerant crops/plants	17	15.7
Agroforestry system	27	25
Fallowing	11	10.2
Total	108	100

Source own survey (2017)

4.5.3.1. Farmyard manure (FYM)

Evidences clearly show that soil application of organic manures either alone or in combination with agricultural lime can directly neutralize the soil acidity. Farmyard manure was very good to improve organic matter content of soil, increase moisture retention and reduce soil acidity problems. However, the application was limited to home garden due to inadequate availability and labor requirement for transportation to cultivated land. More than 41% of farmers, on surveyed respondents were agreed that farmyard manure improve crop yields, soil fertility and reduce soil acidity, while half of them also noted that they enhance the physical structure of the soil and increase its organic matter content (Table 20).

There is evidence that addition of organic manure to acid soils can have a direct effect on soil organic matter content, can ameliorate Al toxicity and reduce soil acidity, mainly by complexation and chelation of monomeric Al, presumably forming Al– organic acid complex in the soil (Wong and Swift, 2003). It was concluded that, regardless of the rate of the lime applied, its effects on both soil acidity and crop yields could not be substantiated. On the contrary significant effects of FYM was observed on both soil pH and crop yield, while also reducing the levels of exchangeable Al in the top 20 cm of the soil. For example, addition of 2t ha-1 of lime led to an increase in pH of 0.2 - 0.6 (Buri *et al*., 2005). Whereas an application of 40-50 t ha-1 of organic matter resulted in increases of pH of 0.8 -1.9 (Hede, 2001). Farmers said that the disadvantages of using mineral fertilizers were damage the soil and need to be applied every year, while the main constraints on producing and applying organic inputs outfield were the high labor and transport requirements.

4.5.3.2. Agroforestry system and fallowing

Farmers' perceived as agroforestry system was making the farmland suitable to the crop to be grown by nutrients such as NO^-_3, Ca, Mg, etc. leached from the root zones of crops to sub-horizons can be taken up by these deep rooted species and return them to the surface via litter fall, reduce erosivity of rain drops and use as shade for agricultural crops. As indicated in (Table 20), about 25% of the surveyed respondents were in the studied area agree that, agroforestry system used on their farm to tackle soil acidity problems.

According to Baggie *et al*. (2000) investigated the potential of organic residues from nitrogen fixing trees such as *Albizia zygia* and *Gliricidia sepium* for ameliorating acid infertile rice soil in Ghana. Their study revealed that after 4 weeks of incubation, *Albizia zygia* and *Gliricidia sepium* had increased the pH of the soil from 4.4 to 5.1 and 5.3, respectively due to the high content of basic cations in these tree species.

Land was left to fallow one to maximum of three years when yields of most crops become very poor. Soil acidity could be improved by fallow vegetation, about 10.2% of the surveyed respondents were experienced of using fallow for nutrient recovery (Table 20). Nevertheless, usually unaffordable due to scarcity of land.

4.5.3.3 Use of acid tolerant species and lime application

Use of acid tolerant species and lime application was an early stage and not clearly innovated in the study area. Even though about 15.7% and 7.4% surveyed respondents were reported minimal use of lime and acid tolerant species (Table 20). they were not aware of soil acidity problems, did not clearly know their importance and also that lime was not readily available in the local agricultural input store. More than 84% and 92% of the respondents didn’t know about lime amendments and acid tolerant varieties unless the environment selects the tolerant one. These findings were similar to those from a review conducted by Kisinyo *et al.*, (2014) who indicated that very few farmers were aware of the soil acidity problem.

They further stated that most farmers did not use lime either due to lack of knowledge about its importance or lack of liming materials in the market, or the liming activity was labor intensive and expensive for resource poor farmers. However, in an acidic soil of application of different levels of lime (calcite) at 0.2 LR (lime requirement) increased the soil pH from 5.1 to 6.9 and decreased the exchangeable Al^{3+} from 0.62 to 0 cmol (+) $kg\text{-}^{1}$ within seven days of incubation (Jena, 2008). And also Nekesa (2007) described that lime improves the crop responses to fertilizers by improving nutrient availability and uptake especially phosphorus, reducing aluminum (Al) toxicity and promoting the activities of such desirable organisms as rhizobia bacteria that fix nitrogen for legumes

4.5.4. Farmers’ perception on eucalyptus plantation and soil acidity

Respondents claim that forest cover in previous days was more than one third of the in a district area. However, due to growing population numbers and heavy utilization the indigenous trees were decline an alarming rate. About 69.4% of the surveyed respondents were in wondo village perceived that natural forest has decreased drastically which existed before 20 years and exotic plantation forest has been increased (Appendix Table 7). Shrinking natural forest resources were being compensated by rapid expansion of the use of planted exotic trees.

The majority 55.6% of surveyed respondents have explained that among the exotic trees, Eucalyptus tree become the most dominant tree species around the area (Table 21). Almost all of the farmers select eucalyptus tree to other species meet with its comparative economic advantage. According to Daba and Gong (2000) observation at Chancho area, the financial return from *Eucalyptus globulus* is more than ten times higher than the financial return from agricultural crops. Among Eucalyptus species the most commonly found species in wondo area was *Eucalyptus globulus* also known as “Kashar Bahir-Zaafa” in hadiyisa, Tasmanian blue gum in English (MacLachlan, 2001). Eucalyptus was chosen over other species, because of its fast growing, environmentally compatible for acidic soil, drought resistant, has a straight form for construction, easy for propagation and it was a cash crop or source of income.

Table 21. Farmers’ response for dominant plantation tree in surveyed area (N=108)

Dominant trees	Frequency (N)	Percentage
Eucalyptus globulus	60	55.6
Acacia decurrens	5	4.6
Cupressus lusitanica	11	10.2
Gravilia robusta	17	15.7
Other indigenous trees	15	13.9
Total	108	100.0

Source own survey (2017)

The farmers themselves said that the tree was not good for the soil and negative impacts because there was an impact on stream flow decrement or dried in the surrounding deplete underground water, leaves were not decomposable, no more organic matter return to the soil, shading effect. This was verified by Lisanework and Michelson (1994), who compared *Cupressus lusitanica* and *Eucalyptus globulus* (exotics) and natural forest effects on nutrient cycling in forested areas. They reported that the annual nutrient input by litter of the two exotics generally was much lower than that of the *Juniperus procera* and, in particular, that of the natural forest.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Results from soil laboratory analysis and farmers' responses on soil acidity in the study area, it is possible to conclude that, the soil acidity was influenced by land use types, soil depth and management practices. Soil in all land use types are strongly acidic except in home garden soils. Higher soil pH and lower exchangeable acidity and acid saturation percentage in home garden soils indicate that, it's suitable for crop production and have better available nutrients due to the application of wood ash, farmyard manure and organic materials, whereas significantly lower soil pH and higher exchangeable acidity and acid saturation percentage in cultivated land, eucalyptus plantation and grazing land indicate that, the soil poor in available nutrients.

Moreover, almost all soil physicochemical parameters, namely exchangeable bases, CEC, BS, OM, TN, available phosphorous, and proportion of clay showed lowest mean values in the cultivated land, eucalyptus plantation and grazing land relatively highest mean values at home garden land. With regard to soil depths, also the mean values of soil parameters, including, sand, silt content, OM, TN and available phosphorous are decreased with increasing soil depth from 0-20cm to 20-40cm. In contrast, the mean value of Ca, Mg, K, Na, CEC, BS, and clay content increased with increasing soil depth from 0-20 cm to 20-40cm.

More than half of surveyed respondents were aware of the problems of soil acidity in their land, which explained that based on their observation indicators related with lack of response of agricultural land to inorganic fertilizer, poor performance and tillering, low water holding capacity and low level yield of their crops. Such, land locally known as *shakka'lli bucha,* meaning inactive soil. Their action to offset soil acidity problems focused on use of organic materials such as compost, chicken manure, and farmyard manure application, agroforestry system, acid tolerant crops and finally lime application. In general, it might be concluded that the difference in level of soil acidity in different land use types are more likely due to the differences in management practices.

5.2. Recommendations

- Soil acidity on cultivated land was serious problems for locally produced crops, therefore need for quick intervention to ameliorate soil acidity problems, use of compost and lime application should be encouraged on cultivated land in the study area.
- In the study area for both logistic and economic reasons, it is often not practicable for the resource-poor farmers to apply high rates of lime in the acidic soils. However, it should be better to use farmyard manure and acid tolerant crops in cultivated land.
- Moreover, remarkable consideration should be given to land management options such as farmyard manure application, agroforestry system, acid tolerant crops, lime application and integrated fertility management should be better for sustainable productivity of soils in cultivated land.
- Future line of works on the soil type based fertilizer and lime application should be better to increase production and productivity of acidic soils of cultivated land in study area.
- And although, work on micronutrient status, field experiments and detailed soil profile studies should be made to give a clear picture regarding the study area
- Liming trial on cultivated land should be encouraged

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APPENDIX

Appendix Table 1. Brief description of sampling site

Soil depth	Land use types	Sample code	Geographic position E/longitude	N/latitude	Altitude	slope	Land use history
Soil depth(0-20) and (20-40cm)	home garden	WhgSSD1	0838722	0358501	1969	3	>30yrs inset. Coffee. Vegetables and fruits
		WhgSSD1	0838790	0353553	1959	4.1	>potato, tomato. Maize carrot cabbage
		WhgSSD1	0838797	0353561	1960	2.7	>30yrs inset. Coffee. Vegetables and fruits
	Grazing land	WglSSD1	0838725	0353447	1961	3.1	Communal grazing land and private
		WglSSD1	0838713	0353387	1960	2.9	For 31 years free grazing
		WglSSD1	0838733	0353415	1962	3.4	
	Cultivated land	WclSSD1	0838797	0353341	1957	4.0	Wheat, teff, barley and sometimes sorghum for >32
		WclSSD1	0838501	0353479	1953	3.8	
		WclSSD1	0838489	0353321	1952	2.2	Using fertilizer for long period of time
	Eucalyptus land	WflSSD1	0838410	0353049	1931	3.2	Special eucalyptus plantation for 25years decrances, grevillea other scattered indigenous trees
		WflSSD1	0838425	0353031	1925	4.3	
		WflSSD1	0838443	0353072	1934	2.5	

Appendix Table 2. Mean monthly rainfall temperature and solar radiation of the study area of 2017

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fall	22	38.7	87	103	118.3	140.4	178.2	191.4	147	87	30.2	22.2
Temp Max	28.8	29.6	29.5	28.3	27.4	25.6	24.2	24.1	25.2	26.9	27.9	28.5
Temp Min	10.7	12.2	13	13.9	13.2	13.2	13.4	13.2	12.5	11.3	10.6	9.6
Radiation	21.1	22.6	23.7	23.3	22.3	20	18.4	19.5	21.4	22.3	21.7	20.8

Appendix Table 3. Soil laboratory analysis results of physico-chemical properties of wondo village

Soil Depth	Land Uses	g/cm3		Soil Texture (%)			T. class	Soil pH 1:2.5 ratio		cmol (+)/Kg							cmol (+)/Kg		Ex. base cmol+/Kg				
		Bd	**MC(%**	**Sand**	**Silt**	**Clay**		**(H2O)**	**(KCl)**	**Ex.acidity**	**Ex.Al**	AS (%)	OC(%)	OM(%)	TN(%)	av.P(ppm)	**ECEC**	**CEC**	**Ca**	**Mg**	**K**	**Na**	BS%
Surface soil (0 -20)	**HG1**	**1.09**	**29.32**	**38**	**28**	**34**	**clay loam**	**6.60**	**5.70**	**0.86**	**0.01**	**3.61**	**4.96**	**8.56**	**0.33**	**15.07**	**23.82**	**26.74**	**10.39**	**10.11**	**2.25**	**0.21**	**96.39**
	HG1	**1.00**	**27.84**	**37**	**38**	**25**	**loam**	**6.50**	**5.60**	**0.71**	**0.01**	**3.04**	**4.83**	**8.33**	**0.32**	**13.92**	**23.32**	**26.34**	**10.11**	**10.12**	**2.22**	**0.16**	**96.96**
	HG1	**1.08**	**30.31**	**35**	**32**	**35**	**clay loam**	**6.50**	**5.60**	**0.91**	**0.01**	**3.84**	**4.92**	**8.49**	**0.32**	**14.49**	**23.67**	**26.83**	**10.21**	**10.14**	**2.24**	**0.17**	**96.16**
	GL1	**1.18**	**29.32**	**37**	**31**	**32**	**clay loam**	**5.40**	**4.60**	**3.21**	**0.01**	**30.72**	**2.65**	**4.58**	**0.23**	**5.35**	**10.45**	**12.23**	**3.52**	**2.16**	**1.33**	**0.23**	**69.28**
	GL1	**1.17**	**27.84**	**34**	**34**	**32**	**clay loam**	**5.40**	**4.40**	**3.14**	**0.34**	**31.56**	**2.81**	**4.58**	**0.23**	**3.69**	**9.95**	**13.28**	**3.28**	**2.10**	**1.31**	**0.12**	**68.44**
	GL1	**1.15**	**30.31**	**37**	**28**	**35**	**clay loam**	**5.40**	**4.50**	**3.01**	**0.34**	**31.16**	**1.52**	**4.19**	**0.21**	**4.32**	**9.98**	**13.21**	**3.28**	**2.13**	**1.34**	**0.22**	**69.84**
	CL1	**1.17**	**25.04**	**36**	**36**	**28**	**loam**	**4.80**	**3.50**	**4.26**	**2.74**	**49.02**	**1.38**	**2.62**	**0.14**	**3.07**	**8.69**	**12.21**	**2.10**	**1.45**	**0.73**	**0.15**	**50.98**
	CL1	**1.16**	**27.84**	**33**	**34**	**33**	**clay loam**	**5.00**	**3.60**	**4.96**	**2.53**	**52.99**	**1.34**	**2.39**	**0.13**	**3.45**	**9.36**	**13.25**	**2.13**	**1.37**	**0.71**	**0.19**	**47.01**
	CL1	**1.13**	**25.24**	**35**	**33**	**32**	**clay loam**	**5.00**	**3.60**	**4.85**	**2.91**	**51.87**	**1.46**	**2.39**	**0.15**	**3.48**	**9.35**	**12.22**	**2.12**	**1.41**	**0.72**	**0.25**	**48.13**
	EP1	**1.12**	**35.00**	**31**	**38**	**31**	**clay loam**	**5.20**	**4.00**	**4.27**	**3.02**	**48.41**	**1.34**	**2.36**	**0.14**	**3.68**	**8.82**	**12.32**	**2.15**	**1.52**	**0.74**	**0.14**	**51.59**
	EP1	**1.10**	**35.00**	**34**	**28**	**38**	**clay loam**	**5.20**	**4.10**	**4.98**	**0.62**	**52.59**	**1.46**	**2.52**	**0.13**	**3.22**	**9.47**	**13.54**	**2.16**	**1.42**	**0.72**	**0.19**	**47.41**
	EP1	**1.16**	**35.00**	**34**	**32**	**34**	**clay loam**	**5.20**	**4.20**	**3.12**	**1.39**	**50.78**	**2.81**	**2.84**	**0.24**	**1.77**	**9.57**	**12.33**	**2.17**	**1.55**	**0.73**	**0.26**	**49.22**
Subsurface soil (20-40)	**HG2**	**1.10**	**35.19**	**31**	**32**	**37**	**clay loam**	**6.90**	**6.10**	**0.41**	**0.01**	**1.54**	**4.56**	**7.86**	**0.23**	**10.91**	**26.65**	**28.51**	**11.48**	**11.67**	**2.72**	**0.37**	**98.46**
	HG2	**1.09**	**36.55**	**31**	**33**	**36**	**clay loam**	**6.80**	**6.10**	**0.43**	**0.01**	**1.61**	**2.66**	**4.60**	**0.22**	**10.87**	**26.66**	**28.45**	**11.58**	**11.51**	**2.74**	**0.40**	**98.39**
	HG2	**1.12**	**34.45**	**31**	**33**	**36**	**clay loam**	**6.70**	**6.20**	**0.54**	**0.01**	**2.02**	**2.65**	**4.58**	**0.23**	**11.14**	**26.68**	**28.44**	**11.41**	**11.54**	**2.78**	**0.41**	**97.98**
	GL2	**1.32**	**31.24**	**33**	**34**	**33**	**clay loam**	**6.10**	**5.20**	**3.21**	**1.24**	**17.75**	**2.06**	**3.63**	**0.28**	**1.26**	**11.55**	**14.42**	**3.98**	**3.29**	**1.75**	**0.48**	**82.25**
	GL2	**1.21**	**33.58**	**35**	**33**	**32**	**clay loam**	**5.40**	**4.60**	**3.34**	**1.24**	**20.54**	**1.91**	**2.30**	**0.11**	**0.70**	**11.44**	**13.54**	**2.16**	**1.42**	**0.72**	**0.19**	**79.46**
	GL2	**1.25**	**34.21**	**35**	**29**	**36**	**clay loam**	**5.30**	**5.20**	**2.95**	**1.34**	**18.42**	**1.73**	**2.68**	**0.23**	**1.08**	**11.67**	**13.21**	**3.28**	**2.13**	**1.34**	**0.22**	**81.58**
	CL2	**1.23**	**29.09**	**34**	**34**	**32**	**clay loam**	**5.40**	**4.00**	**4.60**	**1.87**	**45.77**	**1.29**	**2.22**	**0.10**	**2.53**	**10.05**	**12.44**	**2.35**	**2.01**	**0.98**	**0.11**	**54.23**
	CL2	**1.19**	**32.25**	**31**	**32**	**37**	**clay loam**	**5.40**	**4.10**	**4.50**	**1.82**	**44.29**	**1.28**	**2.21**	**0.07**	**2.72**	**10.16**	**28.45**	**11.58**	**11.51**	**2.74**	**0.40**	**55.71**
	CL2	**1.21**	**30.15**	**34**	**33**	**33**	**clay loam**	**5.30**	**4.00**	**4.40**	**2.81**	**43.18**	**1.26**	**2.20**	**0.11**	**2.65**	**10.19**	**12.22**	**2.12**	**1.41**	**0.72**	**0.25**	**56.82**
	EP2	**1.16**	**35.02**	**28**	**33**	**39**	**clay**	**5.50**	**4.10**	**4.58**	**2.08**	**44.55**	**1.33**	**2.32**	**0.11**	**2.08**	**10.28**	**12.96**	**2.41**	**2.11**	**1.01**	**0.17**	**55.45**
	EP2	**1.17**	**31.59**	**35**	**32**	**35**	**clay loam**	**5.40**	**4.50**	**4.49**	**1.39**	**43.30**	**1.29**	**2.22**	**0.08**	**1.84**	**10.37**	**13.75**	**3.82**	**3.32**	**1.79**	**0.16**	**56.70**
	EP2	**1.15**	**36.10**	**33**	**33**	**34**	**clay**	**5.40**	**4.10**	**4.42**	**1.39**	**42.14**	**1.22**	**2.11**	**0.10**	**2.87**	**10.49**	**12.33**	**2.17**	**1.55**	**0.73**	**0.26**	**57.80**

Appendix Table 4. Mean square (MS) and results of two-way analysis of variance (ANOVA) of soil physical properties under four land use types and two soil depths in wondo village

Source of variation	Land use types			Soil depth			Land uses X soil depth			Error	R-square (R^2)
Degree of freedom	3			1			3				
Soil property	MS	F	p	MS	F	p	MS	F	P	MS	
Sand%	15.28	5.17	0.0129	37. 5	12.7	0.0031	3.28	1.11	0.378	2.95	0.695
Silt%	15.70	2.07	0.1506	1.041	0.14	00.716	3.04	0.40	0.7548	7.59	0.395
Clay%	22.15	3.77	0.035	63.37	10.78	.0054	4.48	0.76	0.533	5.88	0.639
BD cm^3Kg^{-1}	0.0197		0.0001	0.0198		0.0002	0.001		0.3174	0.001	

Appendix Table 5. Mean square (MS) and results of two-way analysis of variance (ANOVA) of soil chemical properties under four land use types and two soil depths in wondo village

Source of variation	Land use types			Soil depth			Land uses X soil depth			Error	R-square
Degree of freedom	3			1			3				
Soil properties	MS	F	p	MS	F	P	MS	F	P	MS	
pH(H2O) 1:2.5	2.77	501.49	.0001	.74	132.77	.0001	.021	3.71	.0373	.0055	.991
pH(KCl) 1:2.5	4.99	401.07	.0001	1.04	83.73	.0001	.056	4.51	.0206	.012	.989
EA $cmol_c$ kg^{-1}	21.44	508.56	.0001	1.68	25.71	.0002	.184	4.37	.0228	.042	.991
AS%	2763.57	1631.23	.0001	290.37	171.40	.0001	25.75	15.20	.0001	1.69	.997
SOM%	29.505	66.80	.0001	7.81	17.68	.0009	2.04	4.62	.0190	0.44	.944
TN%	.033	367.11	.0001	.031	338.38	.001	.002	17.87	.001	.0001	.991
Ava. P(mgkg-1)	139.73	883.17	.0001	19.91	125.84	.0001	2.32	14.66	.0001	.158	.995
ECEC cmolc Kg-1	340.57	5497.94	.0001	16.24	262.10	.0001	1.39	22.36	0.0001	.062	.999
Ex.Ca cmolcKg-1	102.12	16399.6	.0001	1.93	310.33	.0001	.35	55.41	.0001	.010	.999
Ex.Mg cmolcKg-1	115.53	20716.2	.0001	6.28	1126.68	.0001	.229	41.07	.0001	.006	.999
Ex.K cmolcKg-1	3.57	11733.7	.0001	.844	2773.97	.0001	.021	69.86	.0001	.0003	.999
Ex.Na cmolcKg-1	.008	1.19	.3488	.065	10.02	.0069	.011	1.73	.2073	.0065	.612
CECcmolcKg-1	319.99	1707.25	.0001	3.832	20.44	.0005	.92	4.92	.0155	.187	.997
BS%	2763.57	1631.23	.0001	290.37	171.40	.0001	25.75	15.20	.0001	1.69	.997

Appendix Table 6. The Soil nutrient level of the Wondo village under different land use types and soil depths based on, source: cation exchangeable capacity Landon (2014), total nitrogen

Soil properties	Home garden	Grazing land	Cultivated land	Eucalyptus plantation	Depth (0-20cm)	Depth (20-40cm)
pH(H2O) 1:2.5	Medium	low	Low	Low	Low	Medium
pH(KCl) 1:2.5	Medium	Low	Very low	Very low	Very low	Low
EA cmolc kg^{-1}	Low	Medium	High	High	Medium	Low
AS%	Low	Medium	High	High	medium	Low
SOM%	Medium	low	Low	Low	Medium	Low
TN	High	Medium	Low	Low	Medium	Low
Ava. P(mgkg-1)	Medium	Low	Low	Low	Medium	Low
ECEC cmolc Kg-1						
Ex.Ca cmolcKg-1	High	Medium	Medium	Medium	Medium	High
Ex.Mg cmolcKg-1	High	Medium	Medium	Medium	Medium	High
Ex.K cmolcKg-1	High	Low	Low	Low	Medium	Medium
Ex.Na cmolcKg-1	Low	Low	Low	Low	Low	low
CECcmolcKg-1	High	Low	Low	Low	Low	Low
BS%	high	Medium	Low	Low	Low	Medium

CEC=cation exchange capacity, Ex.=exchangeable, BS%=base saturation percentage and cmolc=cent mole charge, ECEC=effective cation exchange capacity, AS%= acid saturation percentage, SOM= Soil organic matter, Ava.P= Available phosphorus, TN= Total Nitrogen and EA= Exchangeable acidity

Appendix Table 7. Do you have test the soil physical and chemical property of your farmland

	Frequency (N)	Percent	Cumulative (%)
No	92	85.2	85.2
Yes	16	14.8	100
Total	108	100	

Appendix Table 8. What change have you observed in the forest cover since the last 20ys

Forest cover	Frequency (N)	Percent	Cumulative (%)
I don't realize it	10	9.3	9.3
Natural forest has decline and plantation forest has increased	75	69.4	78.7
Natural forest has increased	6	5.6	84.3
Natural forest has no change	12	11.1	95.4
Plantation forest has decreased	5	4.6	100
Total	108	100	

Appendix Table 9. Comparisons of crop yield decline quintal per hectare (Qt/ha) in 2004 and 2009 E.C

No	Crop type	Average yield Qt/ha in 2004 E.C	Average yield Qt/ha in 2009 E.C	Yield difference	Percentage(%)
1	Wheat	25	12.5	12.5	- 50 decline
2	Barely	23	15	8	-34.9 "
3	Teff	12.5	8.5	4	-32 "
4	Maize	51.5	42	9.5	- 18.4 "
5	Sorghum	45	37.5	8.5	- 18.8 "
6	Potato	65	42.3	22.7	- 34.9 "
7	Bean	12	*	*	*
8	Field pea	10.5	*	*	*

Appendix Table 10. Farmers' opinion to use to acidic soil (shakka'lli bucha) N=108

Farmers use to acidic soil	Frequency (N)	Percentage
Eucalyptus plantation	44	40.7*
Left for grazing land	32	29.6*
Producing crops with farmyard manure	21	19.4
Other	11	10.2
Total	108	100.0

Source; own survey (2017)

Dear respondent this research has the following objectives:

To identify the status of soil acidity under different land use types and soil depths

To investiget selected physico-chemical properties of land use types and soil depths

To assess farmer's perception and their management practices to offset the soil acidity problem in the study area

The information you provide has the sole purpose of achieving the targets mentioned above. Thus, you are respectfully requested to respond to questions responsibly. In responding to a given question, you should take into account the history of your farm land.

Part I. General Information Questionnaire No.----------

Survey Area: Region------------------Zone--------------------District-----------------------

Village----------------------------Date of interview---

Name of interviewer--------------------------Name of head of household-------------------

Part II. Personal Information

1. Sex of the respondent female----0 male----1,

2. Age of the respondent……….

3. Marital Status of the respondent, unmarried -----0 married-----1,

4. Educational status of the respondent, illiterate---0 and literate-- 2,

5. Family size Male--1…Female---2………. Total…….

Part-III land holding; soil acidification; and land management practices

I would like to ask you about soil acidity problems on your land uses and how you manage it.

1. Do you have your own land No--------0, Yes---------1?

2. If yes, how many hectares of lands do you possess?

3. How do you see your current landholding to support the household?

A. insufficient -----0, B. sufficient ---1, C. excess--------2

4. If your answer is 'insufficient' do you have any option of having additional land?

A. no-----0, B. yes-----1

5. If your answer is 'yes', what are the options? A. share cropping-------1 B, lease/contract land—2, C clearing forest and grazing land------3 and D, others(specify)------------

6. How is the trend in your landholding size? A. decreasing---0, B. increasing-----1 C. no change-----2 and D. other (specify)--------------

7. If your answer is 'increasing' what are the reasons behind the increment

A, encroachment into forest area-----1, B. land reallocation-----2, C. cultivation of marginal land----3 and D. others (specify)----

8. Do you have observed yield decline year to year? no--0, yes---1, go to question#9;

9. What is the cause of yield decline? A. soil acidity----1 B. soil erosion-------2, E. hell and pest--------3, F. Deforestation---4, G. Overgrazing in cultivated land-----5, F. I don't realize-----6

10. Do you have soil acidity problem in your villages? no---0, yes--1, I do not realize--2 go to ques#10 then 11;

11. What is the local name of soil acidity? --

12. What are the characteristics of acid soils that distinguish it from other soil types?

13. Do you have test the soil physical and chemical property of your cultivated land? No-0, yes---1

A. change in soil physical characteristics (color, depth, structure) ---1 B. low level yield ----2 C. weeds infestation------3 D. I don't realize-4 if you have others specify---

14. What are the main causes of soil acidification in your land?

A. Inherent acidic parent material---1

B. High rainfalls followed by leaching and erosion-----2

C. Continuous cultivation and removal of crops residue from the land-----3

D. Inappropriate use of acid forming fertilizer-------4 E. combining effects-------5, if you have others specify--0

15. What is the level of soil acidity by your perception in your land?

A. Neutral---0, B. Slightly acidic---1, C. Moderately acidic----2, D. Strong acidic---3 E. very strong acidic---4, F. Extreme acidic---5

16. How do you overcome acidic soils in your village? A. farm yard manure application -----1 B. Agroforestry system-----2, D. liming and proper use of fertilizers---3 Use of acid tolerant crops/ plants ---------4 E. soil conservation structure-----6

if you have others specify____

17. Do you use fallowing as management practice? no------0, yes-------1 if no why____

18. Do you mulch your farm land with crop residues? no-----0, yes----1 if no, ans#18

19. What is the use of crop residues? A. feed for livestock-------1, B. fuel---------2, C. house roof shading ----3, D. for fence construction-------4, E income generation----5 F. all ----6, if you have others specify_____________________________________

20. For what purpose do you use this acidify soil type? A. Eucalyptus plantation----1, B. for grazing--2, C. producing crop by using farmyard manure if the area is nearby the home---- -3

21. In which land use type is soil acidity problematic in your opinion A. cultivated land---0, B. plantation forest--1, C. grazing land—2, D. home garden--3 why?

Part-IV crop production

1. Which crops have poor performance in acidic soils by perception in your plot? ____

2. Is there any shift in crop grown in the area since 10yrs? no-----0, yes-----1

if yes, which crop disappeared? __________________________________

3. Which one become new introduce in the cropping system of the area? ____

4. Do you use the correct fertilizers rate according to recommendation of ministry of agriculture? no-----0, yes------1 if no, why? ________________________________

5.How do you see the productivity of the farm land overtime? A. decreasing----0, B increasing---1, C. no changed---3, D. I don't know---4

6. If your answer is 'decreasing', what are the reasons? A. decrease in rainfall---1,
B. increase soil acidity----2, C. decrease in soil fertility---3, D. others---0 (specify)------------------
----

7. If your answer 'increasing', what are the reasons? A. access to new land---1, B. better land management---2, C. benefit from agricultural extension technologies---3, D. adequate rainfall---4, E. others--5(specify)------------------------

8. Where do you get information about land management? A. traditionally---0
B. from neighbors---1, C. from Das--2, D. from NGOs---3, E. from mass media----4, F. if other (specify)---

9. Is there any effort made by District Agriculture and natural resource management office to promote Conservation practices? no---0 yes---1,

10. If your answer is 'yes', mention those efforts? ……………………….

11. In which land use type do you get better yield?

---

12. Would you tell me the productivity of cereal crops?

---

13. Which crop type show relatively better performance in acidic soil?

No	Crop type	Average yield Q/ha in 2004 E.C	Average yield ton/ha in 2009 E.C	Yield difference	Percentage(%)

E.C = Ethiopian calendar

14. Do you use manure on cultivated field far away from home? no---0, yes-----1
if no, why? --

Part-V plantation forest and grazing land

1. Is there a natural undisturbed forest currently in this village? no----0, yes----1 if no, was there a forest 15yrs ago? no----0, yes---1

2. What change have you observed in the forest cover since the last 15ys?

A. natural forest has decline and plantation forest has increased -----1, go to ques#3

B. natural forest has increased----2, C. natural forest has no change----3

D. plantation forest has decreased---4, E. I don't realize it-----0.

3. If your answer is A, which plantation forest is become dominant by now in your village? A. *Eucalyptus globules*---1, B. *Acacia decurrens*---2 C. *Cupressus lusitanica*---3, D. other indigenous trees---04.

If your answer is A, why is it widely spread? Reason: -------------------------------

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5. What are the main problems to eucalyptus globules in your farmland? ----------------------------

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6. Do you have eucalyptus globules trees in your farmland? no-----0, yes------1

6. Is there a natural indigenous forest plantation currently in this village? no----0, yes----1 if no, was there a forest 15ys ago? no------0, yes-----1 if yes which type disappeared and which one becomes new introduced in the area?

7. Do you have your own grazing land no-----0, yes-----1 if yes how many hectares? and how do you manage it?

8. What type of communal grazing lands in your village?

9. Do you use control-grazing system in communal grazing lands? no---0, yes---1 if no, why? ---

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10. How do you feed your livestock? A. free grazing on communal grazing land---1, B. own grazing land---2, C. cut and carry from communal pasture land—3,

D. crop residue---4, E. others (specify)--

11. How do you see the size of grazing land overtime? A, decreasing—0, B. increasing—1, C. remain the same---2

12. If your answer is 'decreasing', what are the reasons? A, expansion of farm land—1, B. grazing land distribution among people—2, C. area closure---3, D. other(specify)-------------------

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