2021-07-23

EFFECT OF LAND USE TYPES, SLOPE GRADIENT AND LAND MANAGEMENT PRACTICES ON SELECTED SOIL PHYSICO-CHEMICAL PROPERTIES IN BURAT WATERSHED, NORTH WESTERN ETHIOPIA

Awoke Abebaw

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MSc Thesis

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE (MSC.), IN "SOIL SCIENCE"

Major Advisor: Walle Jembere (PhD)

Co-advisor: Mekonnen Getahun (MSc.)

June, 2021

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (MSc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. **Awoke Abebaw** entitled: "**Effect of Land Use types, Slope gradient and Land Management Practices on Selected Soil Physicochemical Properties in Burat Watershed North Western Ethiopia**." We here by certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc.) in **Soil Science.**

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DECLARATION

This is to certify that this thesis entitled "**Effect of Land Use types, Slope gradient And Land Management Practices on Selected Soil Physico-Chemical Properties in Burat Watershed, North Western Ethiopia**." is submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in "**Soil Science**" to the Graduate Program of College Agriculture and Environmental Sciences, Bahir Dar University by Mr. **Awoke Abebaw** (ID. No BDU 1100796) is an authentic work carried out by him under our guidance. To the best of our knowledge and belief, the matter embodied in this research work has not been submitted earlier for the award of any degree or diploma.

Name of the Student

Awoke Abebaw Jegnie

Signature ________________ date ________________

Name of the Supervisors

1) Walle Jembere (PhD) (Major Supervisor)

Signature ________________ date ________________

2) Mekonnen Getahun (MSc.) (Co-Supervisor)

Signature ________________ date ________________

ACKNOWLEDGEMENTS

This thesis would not have been completed without valuable support from many individuals. Above all, I thank the LORD GOD for giving me the strength to start and go through with my studies and his mercy and grace upon me during all these days here in Bahir Dar and in all my life.

I would like to express my deepest gratitude to my advisors, Dr.Walle Jembere and Mr. Mekonnen Getahun, for their constructive comments, unreserved advice, and invaluable guidance from the preparation of the thesis proposal to the completion of this work,

I would like to thank Dera district agricultural office and Dera district administrative office for their permission and providing me with some of secondary data I needed.

My special thanks go to my best friend Mr. Awoke Endalew, Sisay Moges and Marye Shiferaw for their unlimited support, conversation, suggestion and for making everything clear and conceivable during my university stay and sharing experience and for being such a friendly companion. This is also a special opportunity to express my respect, love and gratitude to my beloved family, Yeshi Tilaw, Dagm Awoke, Bisrat awoke and Wosen Awoke for their help in terms of good will, finance, encouragement and share their time with me to complete my research.

I would like my heartfelt gratitude and deepest appreciations goes to my mother Amaled Assefa, my father, Kes Abebaw Jegnie, my brother Abera Abebaw and my all other families for their incredible moral supports and initiation to continue my study.

Last but not list I would like to acknowledge Bahir Dar University College of Agriculture Environmental Science for all material support and educating me leading to my MSc. Degree and all authors cited in this work.

LIST OF ABBREVIATIONS/ACRONYMS

ANOVA	Analysis Of Variance
Bd	Bulk density
ANRS	Amhara National Regional State
Av. P	Available Phosphorous
Ca	Calcium
CEC	Cation Exchange Capacity
Ns	Not significant
C: N	Carbon to Nitrogen Ratio
DDAO	Dera District Agricultural Office
ECEC	Effective Cation Exchange Capacity
FAO	Food and Agriculture Organization
K+	Potassium
N	Nitrogen
NMA	National Meteorological Agency
OC	Organic Carbon
OM	Organic Matter
P	Phosphorus
P^H	Power of Hydrogen
SAS	Statistical Analysis System
SEM	Standard Error of Mean
TN	Total Nitrogen

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ABSTRACT

The problem of natural phenomena and interference of human activities were aggravating soil fertility degradation (erosion and overgrazing). The objective of the study was to investigate effects of land use types and land management practices on selected soil physicochemical properties along slope gradient. Treatments were arranged in a factorial randomized complete block design (RCBD) with three factors (three land use type (GL, CL, FL) two slope gradient (2-5% and 5-10%) and two land management practices with (area closure and soil bund) or not. A total of 36 disturbed and un disturbed soil samples were collected from 0-20 cm depth within three land use types, two slope gradient and two land management practices. Composite soil samples were analyzed for particle size distribution, pH, soil organic matter (SOM), total nitrogen (TN), available P (Av. P), cation exchange capacity (CEC) and exchangeable cations ($Ca^{2+,}$ $Mg^{2+,}$ K^{+} *and* Na^{+}*) using standard procedures while undisturbed soil samples were analyzed for bulk density (BD). The statistical differences in soil properties among land use types, slope gradient and land management practice were tested using a two way ANOVA following the General Linear Model (GLM). The results indicated that, land use types, slope classes and land management practices significantly (*$P<0.01$*) influenced most soil physicochemical properties. General, comparisons between the crops land that have been cultivated forever on the one hand and the forest and grazing lands on the other revealed highly significant difference on major soil physico-chemical properties. The highest mean CEC (31.6 cmol (+)* kg^{-1}*), TN (0.16%), and SOM (5.03%) were observed under the forest land as compared with other land use types. Considering the land management practices the higher mean values of TN (0.15%), CEC (29.25 cmol (+)* kg^{-1}*) SOM (4.35%) were recorded in the managed area than in the unmanaged one. Considering the slope* gradient *the higher mean SOM (4.12%), TN (0.15%), CEC (28.46 cmol (+)* kg^{-1}*) were recorded under the lower slope than the upper slope. Generally, land use type, land management practices and slope gradient cause variation of soil physico-chemical properties. Therefore, we recommended that appropriate and integrated land management options for different land use types and slope* gradient *to improve physico-chemical properties of soil in the study area.*

Keywords: Soil erosion, leaching, soil properties.

Chapter 1: INTRODUCTION

1.1 Background and Justification

Ethiopia is considered as one of the least developing countries where agriculture had always played a central role in the country's economy, Although agriculture has always been the mainstay of Ethiopian economy, it is characterized by very low growth rate with the rapidly increasing population this led to a declining availability of cultivable land and a very high rate of soil erosion (Abera Berhane, 2003). In Ethiopia, rapid population growth and environmental factors lead to the conversion of natural forest land and grassland into cultivated farmland (Tesfahunegn Gebreyesus, 2016). Soil is the foundation resource for nearly all land uses, and the most important component of sustainable agriculture (Mulugeta Demelash, and Karl 2010).

The rate of soil quality degradation depends on land use types, slope gradient, land management practices and climatic conditions. Several works showed that inappropriate land use aggravates the degradation of soil physico-chemical and biological properties (Saikh *et al.,* 1998; He *et al.,* 1999).The loss of soil nutrients in Ethiopia is related to cultural practices like management and cultivation. The removal of vegetative cover, burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands are major contributors to the loss of nutrients (Mesfin Abebe, 1998).

Therefore, assessment of soil quality indicators with respect to land use types and management practices along slope gradient were the primary indicator for sustainable agricultural land management and development. Understanding the effect of the above factors on soil properties was useful for devising land management strategies. The information can also be used to forecast the likely effects of any potential changes in land use types slope gradient and management practices on soil properties. It is apparent that the destruction of vegetative cover can promote soil erosion, which eventually increases the load of soil related constraints to crop production. Generally, a sound understanding of land use and management effects on soil properties provides an opportunity to evaluate sustainability of land use systems (Woldeamlak Bewuket, 2003).

There was awareness that soil nutrient depletion from the agro ecosystem is a very widespread problem and an immediate crop production constraint in Ethiopia (Stoorvogel and Smaling 1990; Stoorvogel *et al.* 1993). A change in land use, unwise soil management, topography of the area and socioeconomic activities can negatively affect the potential use of an area and may ultimately lead to land degradation and loss of productivity. Loss of arable land due to soil degradation was a wide spread phenomenon in the highlands of Ethiopia, which accounts for 45% of Ethiopian total land area and 66% of the total land area of Amhara Region (Lakew *et al.,* 2006). Low soil fertility was reported as one of the major factors affecting soil fertility crop production in west part of Amhara region (Yihenew Gebreselassie, 2002 and Yihenew Gebreselassie, 2007). But, the rate and real extent of land uses, slope, land management practices and there effect on selected soil physico-chemical properties are little or no numerically studied at Burat watershed, Dera District Northwest Ethiopia. Thus, considering the seriousness of the constraints the present study was initiated to evaluate the effect of different land use types, management practices along slope gradient on soil physiochemical properties. Finally, the result of this study expected to add its own value to the up-to-date scientific documentation of the status of soil properties of different land use types, slope and land management practices of the study area and for other similar agro-ecological areas of the country.

1.2. Statement of the problem

The survival of present and future generations depends on the fertility status of soil in agriculture countries like Ethiopia. The natural phenomena and interference of human activities are aggravating soil degradation that needs immediate remedies to improve soil fertility for; livestock production, crop production and productivity. It is obvious that Soil is the only media, which supports the germination, growth and maturity of crops in association with other life supporting systems for better yield (Ministry of Agriculture, 2001).

The study area is suitable for different crop production, (such as Finger milt, maize, noug, teff, bread wheat and potato) homestead, tree plantation, and livestock grazing. However due to increase in human population in the study area has reduced land holding per capital and created pressure on limited land for agriculture production. Most of the study area covered by forest is changed to cultivated land; grazing land and grazing land is dominated by over grazing; land management practice is highly cultural. That brought disturbance to the ecosystem particularly soil that are the determinant factors of agricultural production and productivity. Beside these, soil degradation, particularly soil erosion was assumed to be known by the community and District agriculture office, but the extent and the rate of this problem in terms of physical and chemical degradation of soils are not properly identified and quantified. Also the area is exposed to soil erosion, formation of excess rill and some gullies were observed these leading to the decline in crop and forage productivity. The study area of the watershed grazing lands is degraded due to continuous use of animal feeding (over grazing) is another problem. Assessment of soil quality with respect to each land use type and management practice is therefore crucial for sustainable agriculture. Thus, this study was to investigate the impacts of different land uses, slope gradient and management practices of (forest, grazing and cultivated) lands on selected soil physico-chemical properties of the study area.

1.3. Objectives

1.3.1. General objective

To assess the effects of land use types, slope gradient and land management practices on selected soil physico-chemical properties.

1.3.2. Specific objectives

The specific objectives of this study were to:

- To assess the effects of land use types on selected soil physico-chemical properties
- To point out the effects of land management practices on selected soil physico-chemical properties
- To assess the effect of slope gradient on selected soil physicochemical properties.

1.4 Research Questions

- What is the effect of land use types on selected soil physico-chemical properties?
- What is the effect of land management practices on selected soil physico-chemical properties?
- What is the effect of slope gradient on selected soil physico-chemical properties?

Chapter 2: LITRATURE REVIEW

2.1 Effects of Land Use types on Selected Soil Physico-Chemical Properties

Land is a known area of the earth's terrestrial surface having all attributes of the biosphere immediately above or below this surface, including those near surface climate, the soil and terrain forms, the plant, animal populations, the human settlement pattern of past and present activity (IDWG/LUP, 1994). It is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth (Richards, 1990). As a result, control over land and its use are often subjected to intense human interaction. Human activities that make use of, and hence change or maintain, attributes of land cover are considered the proximate source of change. According to FAO (1997) land use is characterized by the arrangement, activities, and inputs, people undertaken in certain land to produce for survival. This includes rural land use and also urban and industrial land use (FAO, 1993).

Land use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing transformations in the rooting zone. It can either help or hinder soil erosion, and thus land use is the main factor that impact physical, chemical and biological processes of the soil. The possible major land use types are agriculture, grazing, forestry and settlement each of them has subdivisions (FAO, 1976). A crop or cultivated land use type refers to a land used for the production of adapted crops. These include arable lands under protective cover and land under permanent in open air both naturally grown and cultivated (FAO, 1995). Grassland is a land use type with plant communities in which naturally grown grasses are dominant, shrubs were rare and trees absent (Skerman and Riveros, 1990). Natural forestland is land use type with forest which has spontaneously generated itself on the location and which consists of naturally immigrant tree species. In Ethiopia, massive deforestation of natural forests and extensive use of agricultural lands have resulted in soil degradation and loss of environmental quality. The major causes for the disappearance of forests are rapid population growth leading to the extensive forest clearing for cultivation and grazing, exploitation of forests for fuel wood and construction material (EFAP, 1994).

In mountain areas and on hilly lands, the management of land and its uses of the production of crops demand large efforts, because rates of runoff and amounts of soil erosion are so sever, which could bring depletion of nutrients along with rapid soil loses. As a consequence, a soil physico-chemical property shows various properties with lands under cultivation and grazing. Various research results (Belayneh Adugna, 2009) indicated that deforested and intensively over-grazed/cultivated lands bring about disturbances of soil aggregation; encourage quick losses of organic matter advance leaching processes; and rapid erosion losses of essential plant nutrients such as exchangeable cations, total nitrogen, organic carbon and phosphorus. The results obtained from their studies indicated that the direction and magnitude of changes in soil attributes under different land uses reflect the long term impact of human being on the land scape as a consequence of increasing human as well as livestock population.

2.1.1 Effects of land use types on selected Soil Physical Properties

Physical properties of soils determine their adoptability to cultivation and the level of biological activity that can be supported by a soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants (Kolay, 1993; Miller and Donahue, 1995). Numerous physical properties of soils do also change with land use system and its management such as cultivation, intensity of cultivation, the instrument used and the nature of the land under cultivation, reproduction the soil less permeable and more susceptible to runoff and erosion losses (Belayneh Adugna, 2009).

2.1.1.1 Soil Texture

Soil texture is the proportion of sand, silt and clay particles with a varying range of their size in diameter. Sand particles range in size from 0.05-2.00, mm silt ranges from 0.002-0.05, mm and the clay fraction is particles size smaller than 0.002, mm in diameter, particles larger than 2.0, mm are referred to as rock fragments and are not considered in determining soil texture, although they can influence both soil structure and soil water relationships (Brady and Weil, 2008). Soil texture determines a number of physical and chemical properties of soils. It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Foth, 1990; Gupta, 2004). It is also indicative for some other related soil features such as type of parent materials, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil (Miller and Grardiner, 2001). The fine and medium textured (clay loam, silt clay loam, silt loam) soils are favorable from an agricultural viewpoint because of their higher tension of available water, OM and exchangeable nutrient contents (Ladd et al., 1990; Jaiswal, 2003).The same authors reported that soils relatively higher in clay content tend to be stabilized and retain more OM than those low in clay content. Soil texture forms the inherent property of soils and textural classes are not subject to easy modification in the field (Wakene, 2001). Whereas, this property is subject to change under conditions of land use change which leads to varied soil management practices that may contribute indirectly for changes in particle size distribution. Under land use changes, which usually involve conversion from forest to cultivated lands, the soil protective cover loosen sand erosion prevails. Whilst soil erosion takes place, fine particles are preferentially moved, resulting in a greater concentration of clay and silt in the sediments than in the original soil (Woldeamlak Bewket and Stroosnijder, 2003).

According to the study of Woldeamlak Bewket (2003) in the Chemoga Watershed Northwestern Highland of Ethiopia, the sand fraction was lowest in the forest (29%) and highest in the cultivated fields (41%). The clay fraction, on the other hand, was highest in the forest plots (21%) and lowest in both the cultivated and grazing fields with proportion of 15% and 18% respectively, whereas the values under eucalyptus plantation were just in between the highest and the lowest. But, the silt content did not differ among the land use types (natural forest, grazing, cultivated and eucalyptus plantation). In the same study it was indicated that the general trend in soil texture after natural forest has been converted in to the other types of land uses have therefore been an increase in the sand and a decrease in the clay content. Mulugeta Lemenih (2004) concluded that the difference in particle size distribution can be attributed to the impact of deforestation and farming practices such as continuous tillage or cultivation and intensive grazing which aggravates soil erosion. This ultimately caused to change the particle size fraction composition of the original soil. This phenomenon is observed in the Ethiopian highlands where severe soil erosion prevails. Over a very long period of time, pedogenic processes such as erosion, deposition, eluviation and weathering can alter the textures of various soil horizons (Foth, 1990; Ahmed Hussen, 2002).

2.1.1.2. Bulk Density

Bulk density is the weight of oven dry soil solids per unit volume of total soil including the pore space. Bulk density is a soil property required for calculating soil pore space, as an indicator of aeration status and water content. White (1997) stated that values of bulk density range from 1 g cm^{-3} for soils high in OM, 1.0 to 1.4 g cm^{-3} for well- aggregated loamy soils and 1.2 to1.8 gcm^{-3} for sand compacted horizons in clay soils. Bulk density normally decreased as mineral soils become finer and in texture.

Soils that have low and high bulk density show favorable and poor physical conditions, respectively. Bulk densities of soil horizons are inversely related to the amount of pore space and soil OM which is highly influenced by land use and management practice (Brady and Weil, 2002; Gupta, 2004). Any factors that affect soil pore space will also affect the bulk density and vice versa. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity of soil.

The study results of Woldeamlak Bewket and Stroosnijder (2003) and Mulugeta Lemenih (2004) explained that the bulk density of cultivated soils was higher than the bulk density of forest soils. Soil bulk density increased in the 0-10 and 10-20 cm layers relative to the length of time the soils were subjected to cultivation (Mulugeta Lemenih, 2004). Similarly, Ahmed Hussien, (2002) reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth. This was due to the lower level of OM, cultivation, less aggregation, fewer roots and other soil dwelling organisms and compaction caused by the weight of the overlying layers (Landon, 1991).

According to Woldeamlak Bewket (2003) low bulk density values in forest, cultivated, eucalyptus plantation and grazing lands considered in the study. It was lowest (0.6 g cm^3) in areas under forest, and the highest (1.0 g cm^{-3}) was registered in the areas of eucalyptus. Compaction resulting from intensive grazing was assumed to have caused the relatively higher bulk density values in both soil depths in the grazing land than that of the respective soil depths in the forest land. Further, Tisdale *et al.* (1995) pointed out that continuous ploughing of lands to horizon depth leads to the development of a plough pan, which increases soil bulk density.

2.1.2 Effects of land use types on selected Soil Chemical Properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plant and microbes. Chemical properties of soils change with changes in management and land use. Good management enhances soil fertility while improper management may irreversibly damage the soil environment (Aemro Terefe, 2011).

Changes in land use alter the conditions of soil organic matter, nitrogen and other essential nutrients. Application of fertilizers, manure and lime correct the nutrient deficiencies of the soil. Deforestation and subsequent cultivation facilitate oxidation and increases the reduction in organic matter content (Brady and Weil, 2002; Woldeamlak Bewket, 2003; Mulugeta Lemenih, 2004). 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. Animal manure and crop residues, instead of being returned to the land, are largely used as fuel and livestock feed respectively (Aemro Terefe, 2011).

2.1.2.1. Soil Reaction pH

Soil reaction has a direct influence on chemical and biological soil properties and parameters. Low productive soils and sites were associated with low pH and corresponding low levels of exchangeable bases and organic matter. Soil pH in a soil can be attributed to the type of parent material, extent of soil erosion or the leaching of bases as a result of climatic factors. Soil pH is an indispensable means for characterizing soil from the standpoints of nutrient availability and soil physical conditions like structure, permeability, workability etc. (Aemro Terefe, 2011). It is also indicative of the status on microbial environment/ community and its net effect on the mineralization of organic residues like humus and/or immobilization of available nutrients and also provides the most rational basis for managing soils for selective agricultural land uses such as crop production, pasture cultivation, forestry, etc. Soil pH is also associated with soil fertility status. Soils with high organic matter content have a higher soil pH which favors better exchange of bases and increase availability of nutrients that are needed for the growth of plants in a given soil and ecology. The concentration and characteristic nature of soil reaction (pH) can be influenced by different anthropogenic and natural activities (Tisdale *et al*., 1995; Brady and Weil, 2002). According to Gebeyaw Tilahun (2007) land use changes, for example from forest to cultivated land resulted in reduction of soil pH. For instance, the highest and the lowest soil pH-H_2O values were recorded under the forest and cultivated lands, respectively.

The lowest value of pH under the cultivated land was attributed to two reasons: the depletion of basic cations in crop harvest and drainage to streams in runoff generated from accelerated erosion and due to its highest microbial oxidation that produces organic acids which provide H ions to the soil solution thereby lowers soil pH.

2.1.2.2. Soil Organic Matter

Soil OM arises from the green plants, animal residues and excreta that are deposited on the surface and mixed to a variable extent with the mineral component (White, 1997) Soil OM is defined as any living or dead plant and animal residues in the soil and it comprises a wide range of organic species such as humic substances, carbohydrates, proteins, and plant residues (Foth and Ellis, 1997).

Humus is the residue substance left after soil organisms have modified original organic materials to a rather stable group of decay products as is the colloidal remains of OM (Sopher and Baird, 1982; Miller and Grardiner, 2001). Foth (1990) has indicated that the distribution of OM, showed as organic carbon, is 38% in trees and ground cover, 9% in the forest floor and 53% is in the soil including the roots plus the OM associated with soil particles.

Most cultivated soils of Ethiopia are poor in OM contents because of low amount of organic materials applied to the soil and complete removal of the biomass from the field (Yihenew Gebreselassie, 2002), and due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion hazards (Eylachew Zewdie 1999). Biological degradation is frequently equated with the depletion of vegetation cover and OM in the soil, but also announces the reduction of beneficial soil organisms that is important indicator of soil fertility (Oldman, 1993).

Uncultivated soils are higher in soil OM (both on surface and in soil) than those soils cultivated for years (Miller and Gardiner, 2001). In the forest land use, there is a continuous growth of plants and additions to the three pools of OM: standing crop, forest floor and soil. In the grassland areas, much more of the OM is in the soil and much less occurs in the standing plants and grassland floor. Although approximately 50% of the total OM in the forest ecosystems may be in the soil, over 95% may be in the soil where grasses are the dominant vegetation (Foth, 1990).

Soluble and exchangeable aluminum in acid soils are substantially reduced by organic amendments (Hoyt and Turner, 1975; Hue and Amien, 1989) showed that most conspicuous soil property, which is influenced by land use and was strongly correlated with a wide range of other soil properties, is OM. It was significant to note especially the high correlation between OM and physical properties that define soil structural characteristics such as aggregate stability, bulk density and water retention. This implies that OM may have been involved directly or indirectly in the process, which generate or modify soil structure. This contribution reflects the importance of OM on soil productivity.

The soil, which had higher OM, also had higher nutrient element concentrations. Furthermore, humus from OM decomposition combined with clay minerals to form organo-mineral complex that increase the soils CEC from where plant roots can take up nutrients. The content of OM in a given soil results from a balance between OM input and soil carbon loss. Evrendilek *et al*. (2004) reported that conversion of grassland into cultivated land during the 12-years period decreased soil OM by 48.8%, for the 0-20 cm soil depth. According to Briggs and Courtney (1989), the growth, death and decay of plant materials and the activities of the grazing animals in the grassland have an important influence on the underlying soil. This influence operates through varieties of processes and affects the soil in many different ways. It has been recognized for many years that cultivated land, sown to grass experience a relatively rapid and marked increase in soil OM content, particularly in the upper 2-3 cm of soil horizon. These differences reflect the ability of the grass to improve the structural stability of the soil. This is because the fine roots of some grasses grow through the soil aggregate and help bind them together.

The highest values for soil OM content were found in soils from forestland. This result indicates that soil organic matter level would decrease after land use shifts from the forest land and grassland to cultivated land. Relative to soil OM of the forest land and soil organic matter of cultivated land soils decreased by 44 % for 0 -10 cm layer and by 48 % for the 10 - 20 cm layer over 12 years (Celik, 2005). Gebeyaw Tilahun (2007) also showed highest SOM content (1.8%) under the grazing land and lowest (0.99%) on the cultivated land and confirmed that organic matter content was significantly ($P \leq 0.01$) affected by land use.

2.1.2.3 Total Nitrogen and C: N Ratio

Nitrogen (N) is one of the essential nutrient elements that are taken up by plants in greatest quantity after carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production (Mesfin Abebe, 1998). Mohammed *et al*. (2005) also revealed that surface soil total N contents vary from very low in the cultivated soils too high in uncultivated soils. The highest (0.56%) content of total N corresponded to the profile having high value of OM content (5.59%) whereas the lowest amount of total N (0.04%) was recorded in the profile, which had the lowest OM content (1.70 %).

The N content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub humid tropics due to leaching and in highly saline and sodic soils of semi-arid and arid regions due to low OM content (Havlin *et al.*, 1999). Average total N increased from cultivated to grazing and from Graizing to forest land soils, which again declined with increasing depth from surface to subsurface soils (Nega, 2006). The considerable reduction of total N in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic materials derived from crop residue (root biomass) whenever added following intensive cultivation (McDonagh *et al.,* 2001). Moreover, the decline in soil OC and total N, although commonly created following deforestation and conversion to farm fields, might have been exacerbated by the insufficient inputs of organic substrates from the farming land (Mulugeta Demelash 2004). The same author also stated that the levels of soil OC and total N in the surface soil (0-10 cm) were significantly lower, and decreased increasingly with cultivation time in the farm fields, compared to the soil under the natural forest. Total and available N content of soil under cultivated land were significantly lower compared to levels in the forestland (Islam and Weil, 2000). This may be due to more litters, porosity and high soil moisture to improve microbial activity and decomposition of OM. Poorer macro aggregates due to periodical tillage and less biomass return on harvested land probably account for the lower total and available N level in the cultivated land.

The contents of carbon (C) and N in particle size separates from the different land use system increased in the order: coarse sand < fine sand < silt < clay (Solomon *et al*., 2002). In A horizon of these soils, on the average, 47% of C and 57% of N were associated with clay, while only 6% of C and 4% of N were found in coarse sand (Solomon *et al.,* 2002).

The C: N ratio was highest in the coarse sand and decreased with decreasing particle size fraction. The sand-bound organic C is made of plant debris with high C: N ratio while those found in finer fractions consist of recalcitrant materials with low C: N ratio (Solomon *et al.*, 2002). The decreasing C: N ratio with decreasing particle size fraction indicates that the intensity of microbial mediated decomposition processes decreases from sand to clay (Tchienkoua and Zech, 2003). This suggested that OM of fine aggregates has a stronger humification (Urioste *et al.,* 2006). Narrower C: N ratios within a soil type are found under cultivated land than under grassland, indicating slightly greater decline in N than C upon cultivation (Saggar *et al.,* 2001).

In general, C: N ratios of soils of cropland were lower than of uncultivated land soils (Wang et al., 2005). According to Saikh *et al*. (1998), the cultivated land soil has C: N ratio less than 10, an indication of low level of OM incorporated into the soil system. The low C: N ratio could probably be the result of a combination of increased mineralization rates of organic C in comparison with organic N because introduction of more oxygen during tillage increased soil temperature (Fantaw *et al.,* 2007). Higher C: N ratio in cultivated soils could be caused by the input of relatively recent materials such as plants or microbes (Islam and Weil, 2000). The high C: N ratio could be an indication of immobilization of N or low N content of the soil in the area even if the OC content of the soil may be high (Yihenew Gebreselassie, 2002).

2.1.2.4 Available Phosphorus

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils renders the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). Following N, P has more wide spread influence on both natural and agricultural land uses than any other essential elements. In most natural lands such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by the very low solubility of the scarce quantity that is present (Marschner, 1993; Brady and Weil, 2002).

Tropical and subtropical soils are predominantly acidic with high P sorption (fixation) capacities and often are extremely P deficient. Therefore, substantial P inputs are required for optimum growth and adequate food and fiber production (Sanchez, 1976). Generally, P availability in soils is often limiting factor for plant growth, although the total amount of soil P may be great. Ethiopian soils, particularly Nitisols and other acidic soils, are reported to have low P contents. This is due to, not only the inherent low available content, but also due to the high P fixation capacity of the soils (Yihenew Gebreselassie, 2002).

The highest concentrations of available P were recorded in the surface soil of the intensively cultivated (research field) soil compared to the soil of the farmer's field and the virgin land in Bako area (Wakene and Heluf, 2003). This could be attributed to the continuous application of inorganic P fertilizer for the past three decades. The low concentration of available P on the virgin land and the farmers' field could be due to the inherent P deficiency of the soil since little or no P fertilizers had been applied. Phosphorus fixation tends to be more pronounced and ease of P release tends to be lowest in soils with higher clay content (Havlin *et al*., 1999). Tekalign *et al*. (1988) reported that topsoil P is usually greater than that of the sub soils due to sorption of the added P and greater biological activities and accumulation of organic materials in the former. The same author observed that sorption of P was significantly correlated with the exchangeable and extractable forms of iron (Fe) and aluminum (Al) as well as pH and OM. The lower concentration of available P in the sub soils is due to fixation by clay and calcium (Ca), which were found to increase with profile depth. However, soil P content varies with parent material, extent of pedogenesis, soil texture and management factors such as rate and type of P applied and land use pattern. Birru Yitaferu (1999) reported that the concentration of available P was lower in grazing lands than in crop lands. This might be due to the effect of applied mineral P fertilizers and some crop residues on the crop lands.

2.1.2.5 Cation Exchange Capacity

Cation exchange capacity (CEC) is a very important parameter of soil because it gives a sign of the kinds of clay minerals present within the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior, the number of lime to be applied to acid soils; besides it's used for soil classification (Baissa Teklu, 1992). in keeping with Landon (1991), a general interpretation and rating of CEC values in cmol $_{(+)}$ kg-1 for the highest soils is as follows: < 5 is incredibly low, 5 - 15 is low, 15 - 25 is medium, 25 - 40 is high, and > 40 is incredibly high. Soils with great deal of clay and OM have higher CEC than sandy soil slow in OM (Saikhetal., 1998).In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while within the subsoil particularly where Bt horizon exist, more CEC is contributed by the clay fractions than by OM thanks to the decline of OM with profile depth (Foth, 1990; Brady and Weil, 2002). Wakene (2001) reported highest CEC values on the surface layers of the soil profiles that were characterized on different land use and management practices at Bako area compared to the respective subsoil layers. in keeping with GAO and Chang (1996), CEC is extremely correlated with OM content of the soil, which is successively stricken by soil management practices like intensive cultivation, fertilization and alter in land use. Soils with low effective cation exchange capacity (ECEC), but 4 cmol (+) kg-1soil wouldn't support agricultural productivity without substantial fertilization (Juo, 1979). Generally, processes that affect texture (such as clay) and OM because of land use changes also affect CEC of soils. Woldeamlak Bewket and Stroosnijder (2003) also reported a major difference in CEC of soils because of land uses types with highest values being found in soils under forest and lowest under cultivation.

2.2. Effect of Slope Gradient on Selected Soil Physicochemical Properties

Slope is part of topography which affects soil properties and controlling soil erosion processes through the redistribution of soil particles and soil organic matter (Ziadat and Tiameh, 2013). Soil loss would normally be expected to increase with increase in slope gradient because of respective increase in velocity of surface run off and decrease in infiltration rate. Amuyou and Kotingo (2015) reported that slope gradients have marked influence in soil properties as expressed in the distribution in soils along slope position. Nejad (1997) reported the effect of topography on soil genesis and development of soils shows that slope gradient had direct and indirect effect on soil physicochemical properties. Bezuayehu *et al.* (2002) revealed that soils on steep slope are generally shallow; their nutrient and water storage capacities are limited. He suggested that when soils in areas having steep slopes are exposed to soil eroding agents, they face greater consequence of degradation compared to soils in flat area.

Slope affects physical properties of soil. Particle size distribution, clay content increases as slope gradient lowers while sand content decreases down the slope gradient. This is most probably due to removal of the clay particles by erosion is enhanced on the upper slope gradient while deposition of these particles occurs on the lower slope gradient. Mostafa *et al.* (2005) reported that finer soil materials are deposit at the lower slope position, where they are coming from the upper position. Bulk density is low from gently sloping and high as slope gradient increase. The variation of bulk density among the slope gradients might be attributed to the variation of soil particle size distribution and disturbance of soil particles with erosion. Slope gradient affects soil chemical properties.

The lowest pH value was found in steep slope gradient and highest pH found in gently sloping gradient loss (Nega Emiru and Heluf Gebrekidan, 2013). The lowest pH in soils of moderately steep slope gradient could be attributed to the loss of basic cations through runoff and erosion. This increases the activity of H^+ ion in the soil solution and reduces soil pH and there by increases soil acidity. They argued that highest basic cations concentration and pH were found at bottom slope position. Minimum organic matters were found in soils of gently sloping areas. The lowest exchangeable bases found in steep slopes whereas highest value of exchangeable bases found in gently sloping areas due to increasing trend of exchangeable basic cations concentration from moderately steep to gently sloping gradient, which might be due to their loss through runoff and erosion in the highest sloping areas and accumulation in areas having lower slope (Aytenew Mulugeta, 2015). CEC also affected by slope gradient. Lowest CEC is found in strongly slopping and highest CEC is found in gentle sloping area. The lowest CEC in the strongly slopping area is in line with the relatively low organic matter and clay content (Teshome Yitbarek *et al.*, 2013).

2.3. Effect of Management Practices on Selected Soil Physico-Chemical Properties

Land and fertility management practices provide the basis for evaluating sustainability and monitoring environmental impacts. Sustainable land management within the Ethiopian context is defined because the use of renewable natural resource for agricultural and other purposes to fulfill individual and community needs, while simultaneously ensuring the long-term productive potential of those resources and therefore the maintenance of their environmental functions through systematic use of indigenous and scientific knowledge/technologies(AemroTerefe,2011).Sustainable land management involves more than the use of physical conservation measures. It also includes the utilization of appropriate soil fertility management practices, agricultural water management, forestry and agro forestry practices forage and land management, and therefore the application of those measures in a very more integrated way to satisfy community needs while solving ecological problems (MoARD, 2007).The aim of sound soil management is to keep up the fertility and structure of the soil. Better management of the chemical and physical characteristics of the soil is critical to sustainability. . Management schemes that maintain the soil quality include conservation tillage practices, crop rotation, crop residue management, fertilizers, organic amendments, water conservation techniques, terracing, contour farming, improved drainage, and better management systems that match with the respective cultivar to the soil and atmospheric condition (Pagiola, 1992).

Physical soil conservation measures include all mechanical /structural/-engineering measures used to control the velocity of surface runoff and there by minimize soil erosion. Physical soil conservation measures normally involve the moving of earth/soil to form an embankment, which forms a barrier for running water. Soil bund can be designed slightly graded sideways, with a gradient of 0.4% up to a maximum of 1% towards a water way or river. Such a gradient is for surplus runoff to be drained if the retention of the bund is not sufficient (Daniel Danano *et al*., 2001).Tadele Amdemariam *et al.* (2011) in their study on the effect of different soil and water conservation measures on physico-chemical properties of soil at Absela Kebele reported that the non-conserved treatment was found to exhibit significantly higher mean bulk density than the remaining treatments. Mulugeta Demelash and Karl (2010) also stated that non-conserved micro-watershed was found to exhibit significantly the highest mean value of bulk density than the micro-watershed treated with SWC measures which could be attributed to the presence of significantly higher organic matter as a result of conservation measures. According to Tadele Amare *et al.* (2013) the long-term impacts of soil and water conservation structures at Anjeni watershed, significantly improved the soil quality and crop yield. Soil nutrients transported from the upper parts of the terrace are trapped by the conservation structures at the lower sides of the terraces.

Chapter 3. MATERIALS AND METODS

3.1 Description of the Study Area

3.1.1. Location

The study was conducted in Burat watershed which is located in Dera District, South Gondar Zone of the Amhara National Regional State (ANRS), northwestern Ethiopia. It has a total area of 670 ha is situated 602 km northwest of Addis Ababa and 33 km northeast of Bahir Dar. Geographically, the study site lies between 11^{0}45'50″to11^{0}46'1″ N latitude and 37^{0}32′41″ to 37^{0}34'52″ E longitude and altitude ranging from1882 to 1995 meters above sea level (m.a.s.l). The study area is 15 km far from the center of Dera district.

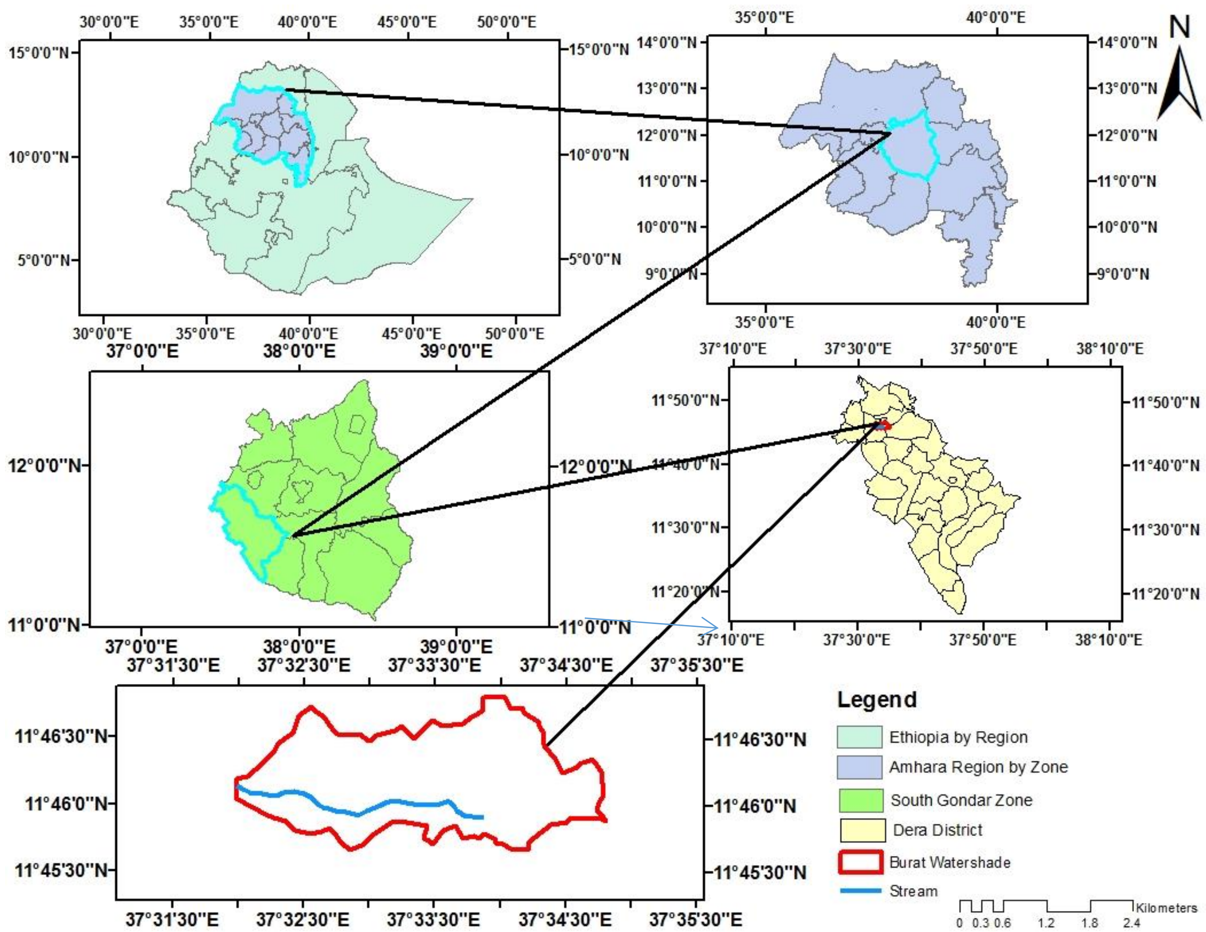

Figure 3.1 Location map of the study area

3.1.2 Population

Dera district has a total population of 294040 an increase of 15.49% over 2007 census, of whom 146030 are men and 148010 women; 28634 or 10 % are urban inhabitants. Total of 69665-households was counted in this woreda, resulting in an average of 4 persons to a household (DDAO, 2018).

3.1.3. Topography and climate

Burat watershed is characterized by gentle to slightly steep slope topography. It is found between 1982 to 1995 m.a.s.l. Most of Burat watershed is characterized gentle slope to slightly undulating plain with the slope from 0 to 44% (DDAO, 2018).

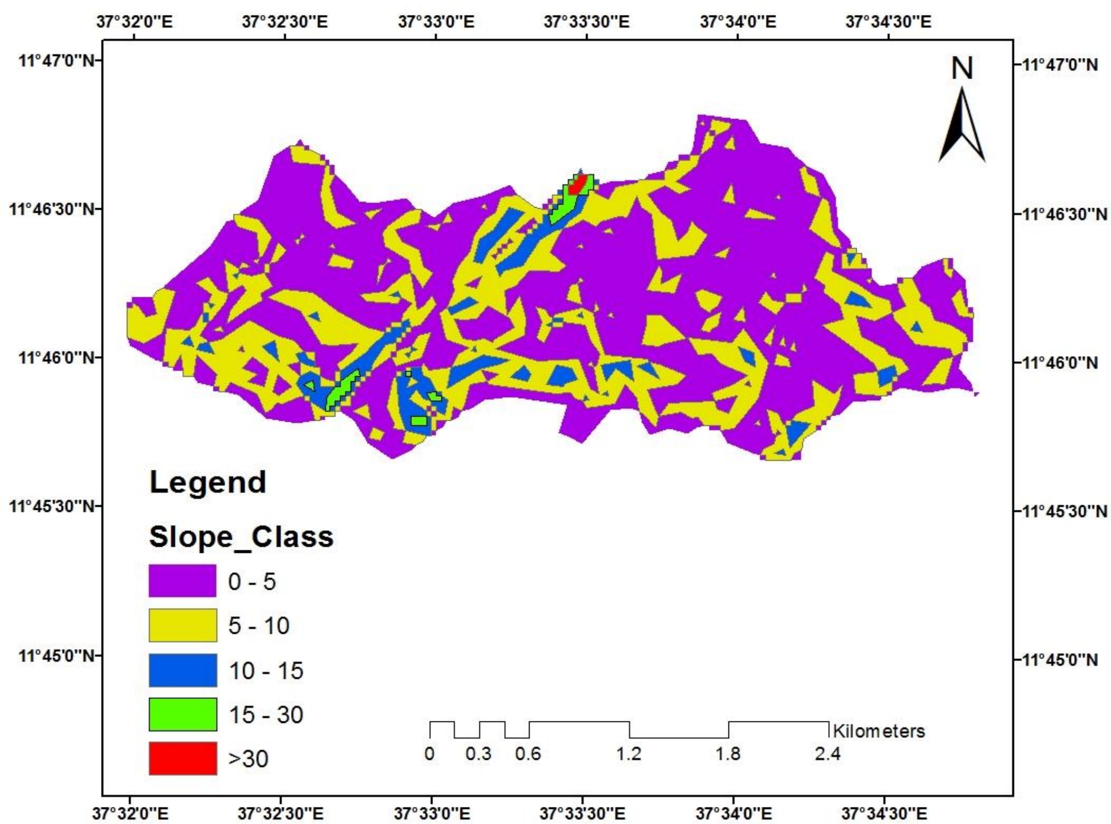

Figure 3.2 slope map of the study area

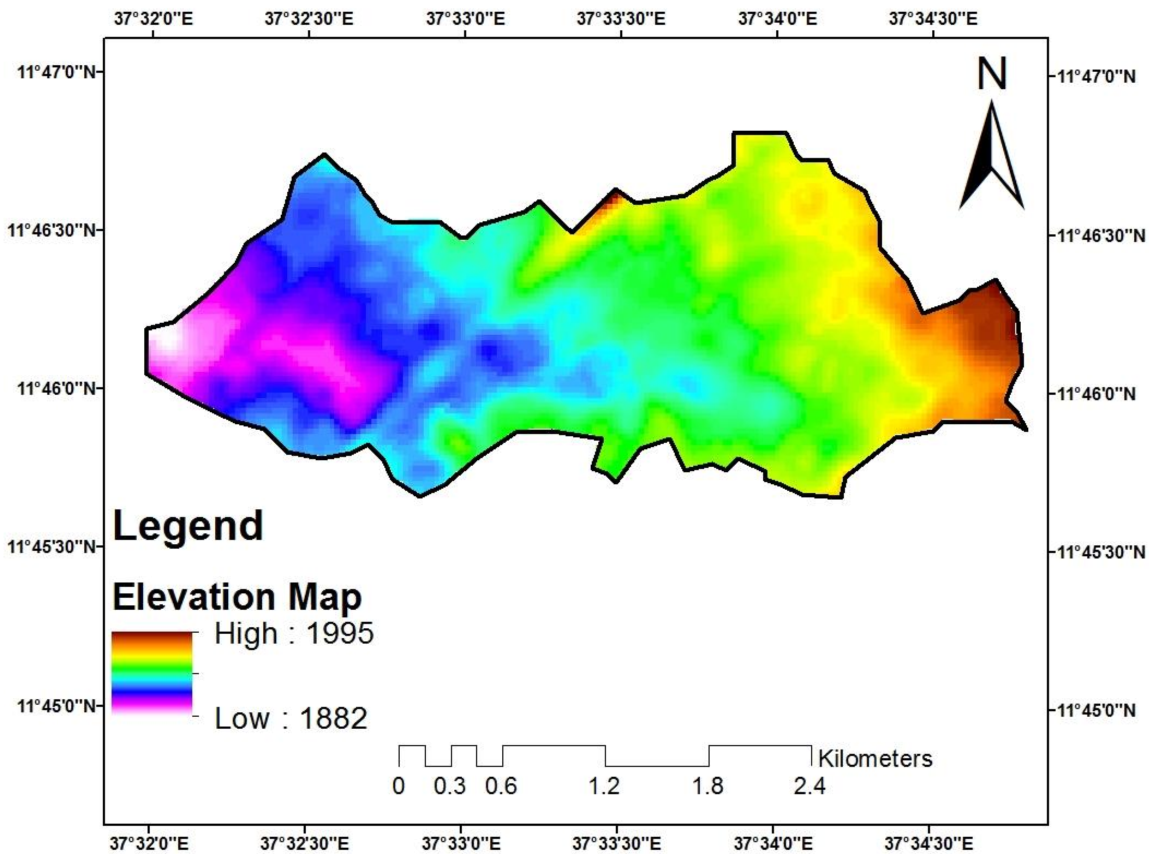

Figure 3.3 Elevation map of the study area

Meteorological data were taken from one station (Bahir Dar station) assuming both experimental sites and the meteorological stations are found under similar rainfall and temperature regimes. The area receives an annual average rainfall of 1845.83 mm. The rain season is from May to October. The month of July and August receives the highest amount of rainfall. Average means of minimum and maximum temperature from 10.7-25°C. The main rainy season of the study areas extend from which 90% occurs in the months of June to September represent the climate condition of the area. The long term mean annual rainfall of the study areas for the past 10 years **(**2010 – 2019**)** was recorded on July and the mean annual minimum rainfall was recorded on December (NMA, 2019).

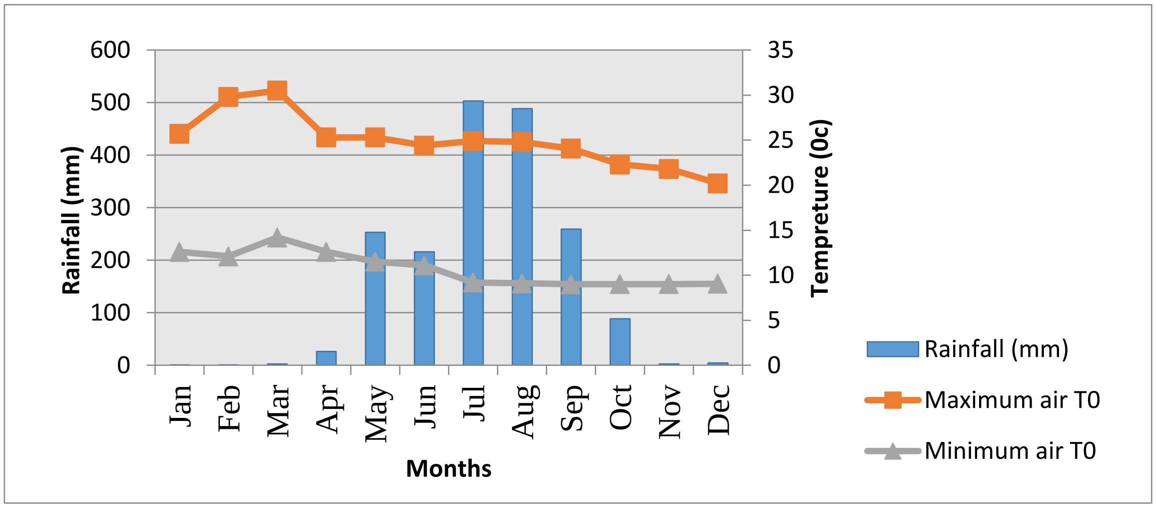

Figure 3.4 Mean monthly total rainfall (mm) and average maximum and minimum temperature of the study area from the year 2010 – 2019: NMA, (2019)

3.1.4. Soils

The common type of soil in the study area is Nitisols (locally, dewel) It is deep, well-drained, red, tropical soils with diffuse horizon boundaries and a subsurface horizon with more than 30 percent clay and moderate to strong angular blocky structure elements that easily fall apart into characteristic shiny, polyhedric (*nutty*) elements. Weathering is relatively advanced but Nitisols are far more productive than most other red, tropical soils (FAO 2006).

3.1.5. Land Use and Farming System

The farming system in the study watershed is typically a mixed farming system. Under mixed farming systems, farmers integrate both crop production and animal husbandry. Ploughing of the farm fields was carried out by traditional farm implement by oxen.

Subsistence farming of mixed crop-livestock with maize *(Zea mays)*, finger millet, *teff Eragrostis teff (Zucc.Trotter)*, wheat (*Triticum aestivum* and *Triticum durum)*, barley (*Hordeumvulgare*), tomato (*Lycopersicumesculentu*), and potato (*Solanum tubersoum*) crops grown under rain fed conditions are the means of livelihood of the farming community.

Table 3.1 General Description of the land use type in the watershed

Land use type	Description
Cultivated land	Land allocated for annual crop production Continuously cultivated land and cultivated land mixed with sparse/scattered trees. The major crops grow include maize, teff, finger millet and noug.
Natural forest	Lands covered by indigenous natural forest, where trees and shrub species are dominant.
Grazing land	Land allocated for domestic animals grazing which dominated with naturally grown grasses is dominant.

Cattle and small ruminants comprise the major livestock classes raised by the ‘’community in the watershed according to DWAO (2018).Cattle easily accessible inputs required for crop production such as plowing and threshing power in the agricultural production system, while crop production supports the livestock by providing crop residues that supplement the feed required by livestock. The farming system is traditional agro forestry system with scattered trees on farm lands.

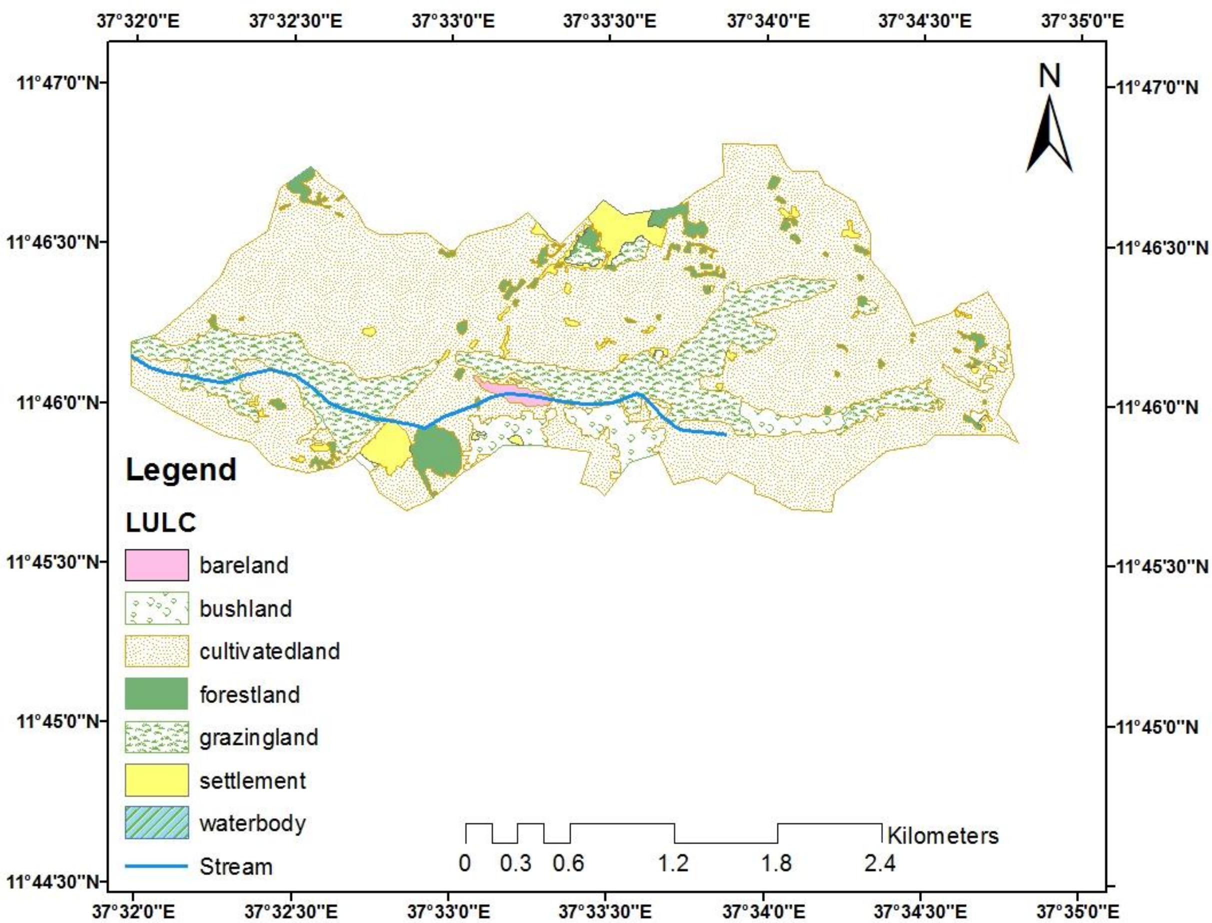

Figure 3.5 Land use map of the study area

3.2 Experimental design and soil sampling

Through transverse walk was done to check the presence of each land use type, slope gradient and land management practices. Field observation was made to determine the representative sites of the study area. Representative soil sampling sites were selected based on three land uses that were forest land, cultivated land and grazing lands with two management practices managed means the land managed by area closure and soil bund un managed means without area closure and soil bund, for each slope gradients (Table 3.1). Following the general site selection, twelve representative sites were selected from each land uses (2 managements practices * 2 slope gradient*3 replication). Accordingly, a total of 36 sampling plots (3 land uses*2 management practices * 2 slope gradient*3 replication) were maintained (Table 3.2). To avoid variations due to environmental aspects, the experiment was laid out in randomized complete block design (RCBD), whereby each slope position represented blocks (replications) comprising three different land use types. The experimental treatments were combinations of three land use types (GL, CL and F), two slope gradient and two management practices; the management were area closure and soil bund.

Table 3.2. Number of composite samples in the study area

Land uses	Slope (2-5%)		Slope (5-10%)		Composite sample
	Managed	Non managed	Managed	Non managed	
Grazing land	3	3	3	3	12
Cultivated land	3	3	3	3	12
Forest land	3	3	3	3	12
Total	9	9	9	9	36

Regarding to soil sampling, sampling intensity per unit area, and the sampling design were usually considered when developing soil-sampling protocols to monitor change in major soil fertility parameters. For the determination of soil physicochemical properties, representative soil samples were collected from 10 m*10 m plot area from each land use with three replications based on slope similarity and management practices. Representative samples were collected from five points per plot to prepare one composite sample for each land use using sampling auger in an ‘X’ pattern and replicated three times to make a total of 36 composite samples for all the three land use types with two management practices and two slope gradients were considered. The samples were collected from the top 0-20 cm depth of the soil. T other hand, from each land use types, with two management practice and two slope classes a total of 36 undisturbed soil samples were collected sharp-edged steel cylinder core-sampler for bulk density determination Rowell, D.L. (1994).

3.3. Soils Sample Preparation and Laboratory Analysis

Each sample was taken from each sampling points were thoroughly mixed divide by quartering method, labeled and tie with plastic bag. The soil samples were air-dried, grounded and sieved through a 2 mm sieve for the analysis of selected soil physicochemical properties except TN and OC that were pass through 0.5 mm diameter sieves. The selected soil physicochemical properties analysis which considered in the study area were carried out at the Amhara Design and Supervision Work soil laboratory following the standard laboratory procedures.

Particle size distribution was analyzed by the hydrometer method (Day, 1965) after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexa metaphosphate ($NaPO_3$). Soil bulk density was determined for the undisturbed core sampling method (Blake, 1965) after drying the soil samples in an oven at $105^{O}C$ to constant weights. Then, bulk density was computed by dividing the oven dry mass of the soil sample to the volume of the corresponding core sampler (Equation 1). Total porosity was computed from the value of bulk density and particle density as presented in Equation 2.

$$\text{BD (g cm}^{-3}) = \frac{Oven\ dry\ weight\ of\ soil\ (g)}{Volume\ of\ the\ cylynder\ (\text{cm}^3)} \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

$$\text{TP (\%)} = \left(1 - \frac{\text{Bulk density}}{Particle\ density}\right) 100 \ \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2}$$

Soil pH was measured using a pH meter in a suspension of 1:2.5 soils: water ratio, (Van Reeuwijk, 1993). The soil OC content was determined following the wet digestion method as outlined by Walkley and Black (1934) with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid solution and titrated with 0.5N ferrous sulfate solution, and percent OM was obtained by multiplying percent OC by 1.724 (Equation 3), assuming that soil OM contains 58% organic carbon. Total N content in the soil samples were determined following the Kjeldahl method as described by Jackson (1958). The method involves oxidation of OM in concentrated sulfuric acid solution (0.1M H_2SO_4) and converting the nitrogen in the organic compound into ammonium sulfate during the oxidation. The ammonium ions were back trapped by boric acid that liberated by distilling with sodium hydroxide (NaOH), and determined by back titration with standard sulfuric acid (H_2SO_4) solution. Available P was determined using the standard Olsen extraction method (Olsen *et al*., 1954).

SOM (organic matter) (%) = 1.724 x SOC (%) ………………………………….… Equation 3

Exchangeable bases were extracted with 1N ammonium acetate at pH 7. The atomic absorption spectrophotometer (AAS) was used to measure the exchangeable Ca and Mg contents of the soil (Bon *et al*, 2001). Flame photometer was used for exchangeable Na and K. (Rowell, 1994). Cation exchange capacity (CEC) was determined after extracting the soil samples by 1N ammonium acetate solution and washed with ethanol (97%) to remove excess salt followed by leaching with sodium chloride to displace the adsorbed (NH^{4+}). The quantity of ammonia was then measured by distillation and taken as CEC of the soil (Chapman, 1965). The percent base saturation of the soils was calculated as the percentage of the sum of the basic exchangeable cations (Ca, Mg, K and Na) to the CEC (Bohn *et al.*, 2001).

3.4. Statistical Analysis

Statistical differences between the values of different soil parameter under different land use types was tested using a two way analysis of variance (ANOVA) following the general linear model (GLM) procedure of statistical analysis software version 9.0 (SAS, 2002). Tukey's Studentized Range (HSD) Test was employed for mean separation of the same parameters among the land use types, and their interaction that were found to be significantly different ($P \leq 0.05$). In addition, correlation analysis was carried out to reveal the magnitudes and directions of relationship between the selected soil parameters. T-tests were used to compare the mean differences for all the tested parameters between slope gradient and management practices.

Chapter 4. RESULT AND DISCUSSION

4.1. Effect of Land Use Types, Slope Gradient and Land Management Practices on Selected soil Physical Properties

4.1.1. Particle size distribution

The result of analysis revealed that sand fraction highly significantly ($P \leq 0.01$) varied among the land use type, management practice and slope gradient, while it was not significantly affected by the interaction effect between the main effects (Appendix Table 4.1). Accordingly, the mean value of sand fractions was the highest (33.42%) in cultivated land followed by the lowest was (26.92%) under forest land (Table4.1). This is probably attributed that clay particle was easily exposed to erosion than sand particles in the free grazing and cultivated land rather than forest land. Yihenew Gebreselassie *et al.* (2015) reported that progressive increase sand fractions could be due to the selective removal of clay particles by erosion leaving the sand particles in the crop land and freely grazed land. Similarly, Fikru Assefa *et al.* (2020) also reported higher sand fraction under cultivated land in Kabe watershed, Ethiopia. By contrary, Nahusenay Abate and Kibebew Kibret (2016) reported higher sand fractions under forest land and low under cultivated land could be due to the mixing of soil during tillage activities.

Considering the effect of management practice; unmanaged area (31.67%) showed higher mean sand content than managed area (Table 4.1). Soil with no management practice is subject to soil erosion and removal of finer soil fraction with runoff water. The finding of Muktar Mohammed *et al.,* (2020) is in lined with this finding, in which higher sand fraction was observed under un-conserved area in west Oromiya, Ethiopia. Mengie Belayneh *et al.,* (2019) and Damte Balcha *et al.* (2020) also agreed with this result. On the other hand, the higher mean sand content was recorded in higher slope (31.72%) soils of the study area (Table 4.1). The reason for higher sand fraction in higher slope might be due to the removal of finer particles from upper slope to lower slope and coarser textured classes dominated on the upper slopes. This result is in agreement with Mulugeta Aytenew (2015); Kehali Jenberie *et* *al.* (2017) and Muktar Mohammed *et al.,* (2020) who reported lower sand fraction under lower slope (3-15%).Silt content was highly significantly ($P \leq 0.01$) affected by management practice, while land use, slope and the interaction of the main effects were not significantly ($P > 0.05$) affected the silt fraction (Appendix Table 4). Accordingly, the higher mean silt fraction was recorded under soils of un-managed (31.16 %.) area against the managed area in Burat watershed (Table 4.1). In line with Mengie Belayneh *et al.* (2019) who reported higher mean silt fraction under non-conserved plot, which was statistically not significant ($P > 0.05$) in Gumara watershed, Upper Blue Nile Basin, Ethiopia. Considering the main land use, the relatively highest (31.67 %) and the lowest (28.83 %) mean silt content was recorded under grazing land and forest land, respectively (Table 4.1). This might be the removal of the finer particles (mainly clay) by erosion is enhanced in bare lands. In agreement with this finding, Eyayu Molla and Mamo Yalew (2018) reported that lower silt content under forest land in Agdit watershed, north western Ethiopia. However, this result disagrees with the result of Achalu Chimdi *et al.* (2012) who reported highest silt fraction for soils of FL in Bedele area in Ilubabor Zone, South western Ethiopia. Similarly, Nahusenay Abate and Kibebew Kibret (2016) was reported the highest mean silt fraction in forest land and the lowest mean silt fraction in cultivated land at Wadla Delanta Massif, North central Highlands of Ethiopia. Regarding slope, mean silt fraction was numerically higher (30.94) under upper slope (Table 4.1). This result in line with the work of Damte Balcha *et al*. (2020) who reported higher mean silt value under upper slope in Mawula Watershed, Loma District, Southern Ethiopia.

Clay content was highly significantly affected by land use, management practice and slope ($P \leq 0.01$) while it was not significantly ($P > 0.05$) differ among the interaction effect (Appendix Table 4). Considering the clay fractions, the highest (44.25%) and the lowest (35.67%) mean clay content were observed in forest land and cultivated land followed by grazing land (Table 4.1). The reason for lowest clay in cultivated land might be due to selective removal of clay from the surface by erosion, tillage activities in cultivated land. This result is in line with the finding of Eyayu Molla and Mamo Yalew (2018) who reported higher clay fraction under forest land in Agdit watershed, north western Ethiopia. Similarly, Fikru Assefa *et al.* (2020) also agreed with this result.

Considering the management practice; soils of managed area (43.11%) showed higher mean clay fractions than soils of unmanaged area one (35.17%) in the study area (Table 4.1). This might be attributed to the relative effect of soil management on soil erosion, which reduces the removal of top fine soil particles. This result is in agreement with the work of different authors (Mengie Belayneh *et al.,* 2019; Damte Balcha *et al.,* 2020) who reported lower clay fraction under non-conserved soils. Regarding with slope, lower slope (40.94%) had higher clay content than higher slope (37.33%) in the study area (Table 4.1). This could be attributed to due to transportation of clay fractions from the upper slope and deposition in the lower slope. Similar result was reported previously (Mulugeta Aytenew, 2015). Similarly, Kehali Jenberie *et al.* (2017) and Muktar Mohammed *et al.* (2020) also reported the same scenario. In contrast to this finding, Fanuel Laekemariam *et al.* (2016) reported the lowest clay content recorded from almost flat slope, while the highest value was recorded from strongly sloping.

4.1.2. Bulk density

Bulk density showed a highly significant difference on land use type and management practice ($P < 0.01$) slope gradient ($P < 0.05$) but it was not significantly ($P > 0.05$) affected by their interaction (Appendix Table 4). Consequently, the highest BD (1.25 g cm^{-3}) was recorded under cultivated land and the lowest (1.09 g cm^{-3}) was on forest (Table 4.1). The lower bulk density recorded under forest land could be attributed to the relatively high organic matter content, whereas the highest bulk density in the cultivated land soils may be the result of compaction from repeated cultivation and low organic matter content. This result was in line with the finding of Nahusenay Abate and Kibebew Kibret (2016) who reported the highest and the lowest bulk density under the cultivated and forest land, respectively at Wadla Delanta Massif, north central highland of Ethiopia. Similarly, Teshome Yitbarek *et al*. (2013); (and Mulugeta Tufa *et al.* (2019) also reported the higher bulk density value under cultivated land as compare to adjacent grazing land and forest land of the surface soil. By contrary, Yihenew Gebreselassie *et al.* (2015) and Eyayu Molla and Mamo Yalew (2018) found higher bulk density under grazing land compared to the adjacent forest land and cultivated land.

Regarding the main effect of management practice, bulk density was higher (1.23 g cm^{-3}) under the soils of an unmanaged area than the managed one in the study area (1.13 g cm^{-3})

(Table 4.1). The higher bulk density in un-managed area could be due to the higher compaction effect of the grazing and erosion of the top soil because of absence of vegetation cover. Different authors (Mengie Belayneh *et al*., 2019; Damte Balcha *et al*., 2020; Muktar Mohammed *et al*., 2020) were observed higher bulk density in soils of un-managed area.

On the other hand, the higher mean bulk density was recorded under the higher slope gradient (Table 4.1). The lower bulk density in the lower slope gradient could be due to relatively higher accumulation of organic matter in the lower slope gradient. This result is in agreement with the finding of Mulugeta Ayitenew (2015); Damte Balcha *et al*. (2020) and Muktar Mohammed *et al*. (2020) who recorded higher mean value of bulk density in upper slope. Bulk density was negatively correlated with, clay ($r= -0.78$; $p < 0.01$, pH, $r= -0.82$; $P < 0.01$, TN, $r= -0.82$; $P < 0.01$, and SOM content $r= -0.67$; $P < 0.01$), while positively correlated with sand ($r= 0.61$, $P < 0.01$ and silt fraction $r= 0.58$, $P < 0.01$) (Appendix Table 5).

4.1.3. Total Porosity

Like bulk density, total porosity was significantly affected by land use type, management practice ($P \leq 0.01$) and slope gradient ($P \leq 0.05$), while it was not significantly ($P > 0.05$) affected by their interaction effects (Appendix Table 4). Accordingly, the forest land was showed the highest (59.03%) mean value of total porosity and the cultivated land was showed the lowest (52.89%) mean value of total porosity in the study area (Table 4.1). The lower total porosity recorded in cultivated land could be attributed to the lowest organic matter and clay in soils of cultivated land (Table4.1). This result is supported by Eyayu Molla and Mamo Yalew (2018) who showed the lowest and highest mean value of total porosity in cultivated land and forest land, respectively at Agdit watershed, northwest Ethiopia. Similarly, Fikru Assefa *et al.* (2020) also showed the lower total porosity under the cultivated land and the higher mean value under forest land in Kaba watershed, Ethiopia.

Considering the main effect of management, the managed area had significantly ($P \leq 0.01$) higher (57.57%) mean value of total porosity than unmanaged area (53.52%) in soils of the study area (Table 4.1). The reason higher total porosity could be the advantage of management practice in maintaining physical and biological soil environment. A similarly higher in the total porosity of managed soil compared to no management has been reported by Damte Balcha *et al*. (2020) in Mawula Watershed Loma District Southern Ethiopia.

The higher (56.39%) mean value of total porosity was recorded under the lower slope gradient (Table 4.1). This could be attributed due to finer particles get suspended in the runoff water and are transported down the slope get and accumulated at the bottom slope positions, leaving coarser material at the top slope positions that raise bulk density and lower pore spaces. Thus, lowering bulk density and raising total porosity of lower slopes. Similarly, Damte Balcha *et al*. (2020) reported a significant reduction in total porosity from the lower slope (59.68%) to the upper slope (57.64%). Likewise, Mulugeta Aytenew (2015) found total porosity to be decreased with increase in the slope.

This trend followed clay fraction and OM (Table 4. 2) and the fact that as BD decreased TP of the soil increased and vice versa. This was due to the fact that as BD increases the pore space of the soil might decrease and the soil particle compact together hindering the air and water circulation between soil pore spaces which intern decrease TP of the soil. Porosity was positively and significantly correlated (r = 0.82, (P < 0.01) and r = 0.78, (p < 0.01) with SOM and clay, respectively, whereas, it was negatively affected by sand (r = -0.61, p < 0.01) and silt (r = -0.58, p < 0.01) (Appendix table 5).

Table 4.1. Main effects of land use, slope and land management practice on s soil physical properties

Land use, management and slope	Particle size distribution (%)			Textural class	BD (g cm-3)	TP (%)
	Sand	Silt	Clay			
Land uses						
Grazing land	30.83[b]	31.67	37.50[b]	Clay loam	1.20[a]	54.72[b]
Cultivated land	33.42[a]	30.92	35.66[b]	Clay loam	1.25[a]	52.89[b]
Forest land	26.92[c]	28.83	44.25[a]	Clay	1.09[b]	59.03[a]
MSD(0.05)	2.51	NS	2.25		0.05	1.95
SEM(±)	0.89	1.20	1.44		0.02	0.84
CV %	9.50	12.79	10.83		5.48	4.39
Management						

Unmanaged	31.67[a]	33.16[a]	35.17[b]	Clay loam	1.23[a]	53.52[b]
Managed	29.11[b]	27.77[b]	43.11[a]	Clay	1.12[b]	57.57[a]
P-value	**	**	**		**	**
SEM(±)	0.87	0.85	0.90		0.02	0.62
Cv %	9.50	12.79	10.83		5.48	4.39
			Slope			
Lower (2-5%)	29.06[b]	30.00	40.94[a]	Clay	1.15[b]	56.39[a]
Higher (5-10%)	31.72[a]	30.94	37.33[b]	Clay loam	1.20[a]	54.70[b]
P-value	**	NS	**		*	*
SEM(±)	0.92	1.01	1.41		0.02	0.89
CV %	9.50	12.79	10.83		5.48	4.39

**Main effect means within a column followed by the same letter are not significantly different from each other at P ≤ 0.05; NS = Not significant at P > 0.05; BD = Bulk density; SEM - Standard Error of Mean; TP = Total porosity*

4.2. Effect of Land Use Types, Slope and Land Management Practices on Selected Soil Chemical Properties

4.2.1. Soil reaction (pH)

The mean soil pH (H_2O) value was significantly ($P \leq 0.01$) affected by land use, management practice and slope, while it was not significantly affected by their interaction (Appendix Table 4). Accordingly, the highest (5.73) pH was recorded of under forest and the lowest (5.20) were recorded under cultivated land (Table 4.2). The lowest result recorded under cultivated land could be due to depletion of basic cations in crop harvest, leaching of basic cations down a slope through erosion, and continuous use of ammonium based fertilizers. This is comparable with the results of Yihenew Gebreselassie *et al.* (2015) who reported lower mean value of pH in cultivated land than grazing land and forest land in Zikre watershed, northwestern Ethiopia. Likewise, Gebeyaw Tilahun (2015) found a significant difference in pH value among land uses and indicated that, the lower value of pH under the cultivated land. Different authors (Nahusenay Abate and Kibebew Kibre, 2016; Fikru Assefa *et al*., 2020; Gebretsadik Melak *et al.*, 2020) also reported that the higher and lower mean pH value was observed in forest land and cultivated land, respectively. Similar to these authors, Daniel Jaleta (2020) showed lower pH value under cultivated land in central highland of Ethiopia.

Regarding the main effect of management practice; relatively higher mean value of pH was recorded under managed area (5.65) than unmanaged (5. 62) (Table 4.2). This may be due to leaching of basic cations through erosion in un-managed area to decrease pH values. The higher amount of soil loss due to erosion might have removed the top soil and exposed the sub-soil to the surface resulting in lower soil pH values. Mengie Belayneh *et al.* (2019) and Muktar Mohammed *et al*. (2020) who explained that the mean pH value was higher under conserved plots. Similar to the above authors, Yihenew Gebreselassie *et al.* (2015) and Damte Balcha *et al.* (2020) also showed the same scenario.

According to EthioSIS (2016), soil pH level < 5.5 is rated as strongly acidic, 5.6- 6.5 moderately acidic. Based on the above ratings, the surface soils of the forest land qualify moderate acidic while the grazing and cultivated lands qualify for strong acidic status of soil pH. Like forest land, the mean pH value of managed areas and the lower slope areas were rated as moderately acidic, while the mean pH value of un-managed areas and the upper slope areas were rated as strongly acidic. (Table 4.2).

On the other hand, the mean pH value of the lower slope was significantly higher (5.57) than in higher slope (5.33) in the study area (table 4.2). Besides this, there was a decreasing trend with increasing slope gradients. This result is supported by Muktar Mohammed *et al*. (2020) reported slope gradient change soil pH; the increase in soil pH at the lower slope gradient could be because of the accumulation of basic cations that were presumed to have been eroded from the upper to lower slope gradient. In the same way, Mulugeta Aytenew (2015), Nahusenay Abate and Kibebew Kibre (2016) and Kehali Jenberie *et al.* (2017) depicted that soil pH was significantly influenced by slope gradients. It was positively and significantly correlated with OM (r = 0. 82**), clay (r = 0.85**), total porosity (r = 0.83**), exchangeable Ca (r = 0.83**), Mg (r=76**), Na (r = 0.86**), K (r = 0.89 **, CEC (r=88**), PBS (r =0.51**) of the soil ,where as it was negatively and significantly correlated with sand (r=0.77**) silt (-0.54**) (Appendix Table 5).

4.2.2. Soil organic matter (SOM)

The ANOVA revealed that SOM was highly significantly ($P \leq 0.01$) affected by land use types, management practice and slope gradient, while it was not significantly ($P > 0.05$) affected by the interaction effect of the main effects (Appendix Table 4). The highest (5.03%) and the lowest (3.27%) mean value of SOM were recorded under forest land and agricultural land followed by grazing land, respectively (Table 4.2). This is due to the fact that in forest land, fall of plant materials could increase SOM. In contrary, the lower SOM content of the cultivated land might be resulted from the removal of SOM through oxidation as a result of intensive cultivation and erosion which deplete SOM. This is attributed to the fact that cultivation increases soil aeration which enhances decompositions of SOM by soil microorganisms and most of the percent SOM produced in soils of CL is removed with harvested plant biomass causing reduction in SOM contents. On the other hand, less soil disturbance in the forest land might have apparently led to the observed increase in SOM content as compared to the soils under cultivated land. This result is also in consent with the result reported by Achalu Chundi *et al.* (2012); Yihenew Gebreselassie *et al.* (2015); Eyayu Molla and Mamo Yalew (2018) who revealed higher SOM content was observed in natural forest, while the lower in cultivated land due to the effect of continuous cultivation that aggravates organic matter oxidation and insufficient inputs of organic substance from the farming system due to removal of crop residue and absence of crop rotation. Nahusenay Abate, Kibebew Kibret (2016) and Fikru Assefa *et al*. (2020) also obtained the highest mean SOM content in the forest land and the lowest in the cultivated land.

Considering the main effect of management practice, soils of managed area (4.35%) had higher mean SOM content than soils of unmanaged area (3.46%) (Table 4.2). The variations in mean value of OM could have attributed to the effect of management practices implemented and biomass accumulated. The result in line with the finding of Tadele Amdemariam *et al*. (2011) and Yihenew Gebreselassie *et al.* (2015) who observed higher mean contents of organic matter under conserved land as compare to un-conserved and. Likewise, Mengie Belayneh *et al.* (2019); Damte Balcha *et al.* (2020) and Muktar Mohammed *et al*. (2020) also agreed with this result.

Lower slope had numerically higher (4.12%) mean SOM content than higher slope (3.69%) but not statistical significant (P > 0.05) (Table 4.2). Soil organic matter accumulation might be higher at the lower slope of the study area for the fact that it would be transported to the lowest slope in the landscape through run off and erosion. Khan *et al.* (2013) reported excess amount of OM in lower slope could be explained by the soil materials, which are downward movement with runoff water from upper slope and accumulation at the bottom slope position. Mulugeta Ayitenew (2015) and Muktar Mohammed *et al*. (2020) reported that the content of organic matter was higher on lower slope gradients in comparison to the upper slope gradient. Similarly, Amuyou and Kotingo (2015) revealed high OM in bottom slope is probably associated to the effect of cultivation and geomorphologic processes that result in the transportation and deposition of soil materials. Soil OM was positively and significantly correlated with clay (r = 0. 84**), TN (r = 0.66**), Av.P (r = 0.76**), exchangeable Ca and (r = 0.75**), Mg (r=76**), Na (r = 0.87**), K (r = 0.73 **), CEC (r=74**), PBS (r =0.55 **) of the soil, while it was negatively and significantly correlated with sand (r = -0.77 **), BD(r = -0.82 **) and silt (r = -0.51**) (Appendix Table 5). As per the rating of SOM content suggested by EthioSIS (2016), the SOM content of the study area is categorized as optimum for the soils of all land uses and slope gradients, while low for soils of un-managed area.

4.2.3. Total nitrogen and C: N ratio

Land use, management practice and slope had highly significant effect on total nitrogen in soils of the study area; however, it was not significantly influenced by the interaction e (Appendix Table 4). Mean value of total nitrogen was highest (0.16%) and the lowest (0.11%) recorded in forest land and cultivated land, respectively (Table 4.2). Large losses of total N in the continuously cropped fields compared to the forest land could be attributed to rapid mineralization of soil OM following cultivation, which disrupts soil aggregates, and thereby increases aeration and microbial accessibility to OM (Solomon *et al.,* 2002); Mining of soil N by cultivated plants coupled with the absence and /or reduced input of plant. This result in agreement with Yihenew Gebreselassie et al. (2015) and Eyayu Molla and Mamo Yalew (2018) reported the lowest mean total N on the cultivated land. Soil organic matter physical protection (stabilization) in conventionally tilled land is lower since the soil is more frequently disturbed than forest and grazing lands (Moncada *et al*., 2014). Gebretsadik Melak *et al*. (2020) have also reported the factors contributing to the net decline of SOC during cultivation: erosion on sloping lands, lower litter inputs, and increased SOM oxidation caused by tillage as cited by Nandwa (2001).

Following the rating of total N suggested by EthioSIS (2016), the soils of the cultivated , grazing lands managed and unmanaged land, higher and lower slope of the study area rated as low (0.10 to 0.15%) whereas forest land rated for optimum (0.15 to 0.3%) status of TN (Table 4.2).

The mean value of total nitrogen was higher under the soils of managed area (0.15%) than the soils of unmanaged area (0.12%) in the study area (Table 4.2). The increases in total nitrogen content under soil managed area were due to less loss of fertility bearing soil fractions such as clay and silt and addition of organic matter. The soil management practices reducing runoff, soil loss and enhancing water storage, would enhance crop growth and contribute to OM and nitrogen input in the soil. The result is in line with Mulugeta and Karl (2010) and Wolka *et al.* (2011) who reported the highest mean total nitrogen content under conserved soils than un-conserved soils. The higher mean content of total nitrogen also reported by Mengie Belayneh *et al.* (2019) and Damte Balcha et al. (2020). Muktar Mohammed *et al*. (2020) also reported the higher mean total nitrogen content under conserved soils of in west Oromia, Ethiopia.

Considering the main effect of slope gradient, lower slope soils (0.15) had higher mean value of total nitrogen than higher slope soils (0.12%), (Table 4.2). This may be due to the movement of nitrogen from the higher slope to the lower slope due to erosion. This result agreed with the finding of Mulugeta Ayitenew (2015) who showed higher total nitrogen content in soils of gentle slope, which might be due to their downward movement with runoff water from higher slope gradient and accumulation there at the lower slope gradient Dawja Watershed in Enebse Sar Midir District, Amhara National Regional State. Different authors (Fanuel Laekemariam *et al.*, 2016, Damte Balcha *et al*. 2020 and Muktar Mohammed *et al*., 2020) also support this result, which showed higher content of total nitrogen in lower slope than the higher slope. The distribution of total nitrogen was similar to that of organic matter as they were strongly and positively correlated OM (r =66, clay (r = 77**), porosity (r = 67**), Av.P (r = 73**), Ca (r = 84**), Mg (r = 77**), K (r = 83**), Na (r = 75**) **), CEC (81**) and PBS (r = 0.53**) was positively and significantly correlated with total nitrogen content of the soils. On the other hand, total nitrogen was negatively and significantly correlated with BD (r = -0.67**), sand (r = -76**), and silt (r = -0.41*) (Appendix Table 5).

The ANOVA show that the C: N ratio was highly significantly ($P \leq 0.01$) affected by land use and slope was significant at ($P \leq 0.05$) however it was not significantly ($P > 0.05$) affected by management practices and the interaction (Appendix Table 4). Accordingly, the higher (18.98) and lower (14.75) mean C: N ratio was recorded under forest land and grazing land, respectively (Table 4.2). Considering the main effect of land use, numerically the highest mean C: N value was recorded under managed area (17.27) soils as compared to soils of unmanaged area (16.33) (Table 4.2). The relatively higher C: N ratio was showed in higher slope (17.99) than lower slope (15.64) in the study area this shows that there is high rate of N erosion on the upper slope (Table 4.2).

4.2.4. Available Phosphorus (Av.P)

Available phosphorus was highly significantly ($P \leq 0.01$) affected by land use types, management practice and slope gradient, while it was not significant for their interaction (Appendix Table 4). Consequently, the mean value of available P was higher (12.19 ppm) in soils of forest land and lower (8.16 ppm) in soils of cultivated land followed by grazing land in the study area (Table 4.2). An increase in Av.P content in the natural forest could be ascribed to the relative higher organic matter content in forest soils. A lower content of available phosphorus in cultivated land might be due to intensive cultivation, low application of external inputs (Diammonium phosphate (DAP) fertilizer and compost) and removal of phosphate anion by erosion and fixation by aluminum. This result is supported by Abera Donis and Kefyalew Assefa (2017) and Fikru Assefa *et al*. (2020) who reported lower available phosphorus content in cultivated land followed by grazing land. By contrary, Yihenew Gebreselassie *et al*. (2015) and Gebretsadik Melak *et al.* (2020) showed highest mean available phosphorus under the cultivated land than the other land use types, which could be due to the application of Diammonium phosphate (DAP) fertilizer on the cultivated land.

The mean value of available phosphorous content in soils under soil of managed area (11.14 ppm) was higher than the value recorded in unmanaged area (8.50 ppm) (Table 4. 2). This could be the soil organic matter difference. According to Yihenew Gebreselassie *et al*. (2015), the mean available phosphorus value was significantly higher under the managed fields than the un-managed fields. In the same way, Mulugeta and Karl (2010) also reported the highest mean available phosphorus value was recorded under conserved field than un-conserved field.

Considering the main effect of slope, the higher mean value of available P was obtained in lower slope (11.02 ppm) than higher slope (8.60 ppm) in the study area (Table 4.2). This may be because of its removal from the higher slope and deposition in the lower slope. This shows that soil organic matter could contribute for the presence of more available P in the soil system. In consent with this, Fisseha Hadgu *et al*. (2014) found low available P with in soils having low content of OM. This result was in agreement with the finding of Damte Balcha *et al* (2020) who reported the higher mean available phosphorus content in the lower slope than in the upper slope in Mawula Watershed Loma District Southern Ethiopia. According to the rating of Av. P suggested by Av.P (London, 1991) the content of Av.P of the study area was rated as medium (15 ppm) (Appendix Table 1). Av. P was positively (r= 0.82, 86, 0.76, 0.80, 0.74, 85, 87 and, 0.80) and significantly ($P<0.01$) correlated with clay, pH, OM, exchangeable Ca, Mg, K, Na, and CEC, respectively whereas negatively correlated with BD (r= -0.80**), sand (r= -0.68**), silt (r= -0.54**) (Appendix Table 5).

Table 4.2. Main effects of land use types and slope gradient and management practice on some soil chemical properties.

Land use, management and slope	pH (H_2O)	OM	TN	C:N	Av.P
			Land uses		
Grazing land	5.43^b	3.41^b	0.14^b	14.75^b	9.10^b
Cultivated land	5.20^c	3.27^b	0.11^c	16.70a^b	8.16^b
Forest land	5.73^a	5.03^a	0.16^a	18.98^a	12.19^a
MSD(0.05)	0.12	0.47	0.013	3.08	1.66
SEM (±)	0.08	0.19	0.01	0.93	0.67
Cv%	3.55	15.69	11.84	17.66	19.94
			Management		
Unmanaged	5.26^b	3.46^b	0.12^b	16.33	8.50^b
Managed	5.65^a	4.35^a	0.15^a	17.27	11.14^a
P*value	**	**	**	NS	*
SEM (±)	0.05	0.17	0.01	0.89	0.51
CV%	3.55	15.69	11.84	17.66	19.84
			Slope gradients		
2-5%	5.57^a	4.12^a	0.15^a	15.64	11.02^a
5-10%	5.33^b	3.69^b	0.12^b	17.99	8.60^b
P-value	**	**	**	NS	*
SEM (±)	0.08	0.24	0.79		0.63
CV	3.55	15.69	11.84	17.66	19.94

Main effect means within a column followed by the same letter are not significantly different from each other *at P ≤ 0.05; NS = Not significant at P > 0.05; OM = organic matter; TN= Total nitrogen; C: N = carbon to nitrogen ratio; Av.P= available phosphorus MSD=mean significant difference, SEM =significant error of mean, CV=coefficient of variation.*

4.2.5. Exchangeable Calcium

Exchangeable Ca was highly significantly influenced by land use types, management practice and slope gradient ($P \leq 0.01$), while it was not significantly affected by their interaction effect

(Appendix Table 4). Accordingly, the highest (8.94 $cmol_ckg^{-1}$) recorded in forest land and the lowest (6.25 $cmol_ckg^{-1}$) mean exchangeable Ca content were obtained in agricultural land soils (Table 4.3). The highest exchangeable calcium observed in the forest land could be due to the relatively higher soil organic matter content of the soil. Whereas, the lowest exchangeable calcium in the soils of the cultivated land could be due to lower soil organic matter. Lowest exchangeable Ca could be due to the influence of intensity of cultivation, its continuous removal with crop harvest with no or little organic matter input into the soil (He *et al*., 1999). This result is in agreement with the findings of Wakene (2001) and Wakene and Heluf (2003) who indicated that cultivation enhances leaching of Ca^{2+} especially in acidic tropical soils.

Regarding the management practice, a managed area (8.37$cmol_c$kg-1) soil was showed higher exchangeable Ca content than unmanaged (6.55 $cmol_ckg^{-1}$) (Table 4.3). The lower mean exchangeable Ca content on un-conserved plot could be due to leaching and higher rate of soil erosion compared to conserved field. In agreement with this different author reported higher mean value of exchangeable Ca in conserved areas than un-conserved areas (Damte Balcha *et al.,* 2020; Muktar Mohammed *et al*., 2020). This may be attributed to soil organic matter content and clay content due to accumulation among the conserved area. In the same way, Fikru Assefa *et al*. (2020) reported significantly higher exchangeable Ca content in treated area than that of untreated area.

Regarding to the main effect of slope, there was a decreasing trend with an increase of slope gradient classes. Similarly, lower slope (8.32 $Cmol_ckg^{-1}$) had higher mean exchangeable Ca content than higher slope (6.55$cmol_ckg^{-1}$) (Table 4.3). This result is supported by the work of Fantaw Yimer (2017) and Damte Balcha *et al*. (2020) who reported that exchangeable calcium significantly affected by slope gradient classes; the higher mean value of exchangeable calcium was observed in lower slope than the upper slope gradient. Similarly, the higher mean exchangeable calcium content was observed in gentle slopes and the lowest was observed in the steep slope gradients as revealed by Mesfn Anteneh and Mohammed Assen (2020) in the Gumara watershed, Lake Tana basin of North–West Ethiopia. This showed an increasing trend of exchangeable basic cations concentration from higher slope to lower slope gradient, which might be due to their loss through run off and erosion in the high sloping areas and accumulation in areas having lower slope gradient. The correlation results revealed that, exchangeable Ca was showed significantly positive relationships with clay, (r= 0.90**), PH (r = 0.83**) and SOM (r=0.75**). However, it was negatively correlated with sand (r=-0.71**), silt (r = -0.65**), and BD (r= -0.77**) (Appendix Table 5).

According to the ratings of exchangeable Ca by FAO (2006), the observed mean exchangeable Ca was medium in the soils of all land uses, slope gradients and management practices in the study area (Appendix Table 2).

4.2.6. Exchangeable magnesium

Statistical analysis revealed that exchangeable Mg was highly significantly affected by land use, management practice and slope ($P < 0.01$) (Appendix Table 4). The highest (3.10 $Cmol_ckg^{-1}$) and lowest (1.47 $Cmol_ckg^{-1}$) mean exchangeable Mg were observed under forest land and cultivated land, respectively. However, cultivated land didn't show a significant difference ($P>0.05$) with grazing land (Table 4.3). The exchangeable Mg decreased from the forest land to cultivated land could be attributed to the higher soil organic matter content observed in the forest land. The relatively low exchangeable Mg observed in the soils of the cultivated land might be due to its continuous removal with crop harvest. This is in agreement with the finding of Nega Emiru (2006) who reported that forest land soils are richer in Mg contents than other land uses. In the same way, Mesfn Anteneh and Mohammed Assen (2020) also observed the higher and the lower mean exchangeable Mg content was observed under forest and cultivated land, respectively.

Considering the main effect of management practice, higher (2.48 $Cmol_ckg^{-1}$) exchangeable Mg was obtained under managed area. The lower (1.78 $Cmol_ckg^{-1}$) mean exchangeable Mg was showed in unmanaged area (Table 4.3). The higher mean exchangeable Mg observed under managed land could be due to higher organic matter content. This result is in line with the finding of Damte Balcha *et al.* (2020) who revealed higher exchangeable Mg concentration in the managed area than unmanaged area in all slope gradients in Mawula Watershed, Loma District, and Southern Ethiopia. Similarly, Mengie Belayneh *et al.* (2019)

and Muktar Mohammed *et al*. (2020) also showed the lower mean exchangeable Mg concentration in un-conserved plots than the mean value recorded in conserved plots might be due to leaching and higher rate soil erosion compared to conserved field.

Regarding the main effect of slope gradient, lower slope (2.51 $Cmol_ckg^{-1}$) contained relatively higher mean exchangeable Mg than the upper slope (1.75 $Cmol_ckg^{-1}$) (Table 4.3). This result is agreement with Damte Balcha *et al.* (2020), who revealed that the highest mean value of exchangeable Mg in lower slope than higher slope in Mawula Watershed, Loma District, and Southern Ethiopia. Similarly, Mesfn Anteneh and Mohammed Assen (2020) also reported the higher mean value of exchangeable Mg in gentle slope than steeper slope in the Gumara watershed, Lake Tana basin of North–West Ethiopia. The finding, Muktar Mohammed *et al*. (2020) was also in line with this result. The increment of mean content of exchangeable magnesium from the higher slope to the lower slope indicated that there is a downward leaching of basic cations from the upper slope area and accumulated in the lower slopes. Exchangeable Mg was positively and significantly correlated with SOM (r = 0.76**), clay (r = 0.80**), pH. (r = 0.76**) and total N (r = 0.77**), while it was negatively and significantly correlated with sand (r = -0.75**), BD (r= -0.71**) and silt (r= -0. 47**) (Appendix Table 5).

As per exchangeable Mg ratings by FAO (2006), the observed mean exchangeable Mg was medium (1-3 $Cmol_ckg^{-1}$) in the soils of all slope gradients, management practices and the rest land use types, while high (3-8 $Cmol_ckg^{-1}$) in the soils of forest land (Appendix Table 2).

4.2.7. Exchangeable potassium

Exchangeable K showed highly significant ($P \leq 0.01$) difference by the main types of land use, management practices and slope gradient, while it was not significant ($P > 0.05$) with their interaction effect (Appendix Table 4). Accordingly, the higher exchangeable K content was recorded under forest land (0.62 $Cmol_ckg^{-1}$) and the lowest recorded in cultivated land (0.36 $Cmol_ckg^{-1}$) (Table 4.3). The higher content in the forest land could be related with its high pH value, addition of OM. In agreement with this study Mesfin Abebe (1996) that indicated the relationship between exchangeable K and tropical soils with higher pH. This finding is in lined with Eyayu Molla and Mamo Yalew (2015) and Mesfn Anteneh and

Mohammed Assen (2020), who reported the higher mean exchangeable K value in forest land and lower value in agricultural land. As reported by Saikh *et al*. (1998) high intensity of weathering, intensive cultivation and use of acid forming inorganic fertilizers (diammonium phosphate and urea) has an impact on distribution of K in soils and enhance its depletion. This might be the possible reason for the relatively low exchangeable K in soils of the cultivated land.

Regarding the main effect of management practice, the mean exchangeable K was higher in managed area (0.59 $Cmol_ckg^{-1}$) than unmanaged area (0.38 $Cmol_ckg^{-1}$), (Table 4.3). The higher mean exchangeable K observed under managed land could be due to higher organic matter content. Damte Balcha *et al.* (2020) is in line with this result. On the other hand, lower slope (0.59 $Cmol_ckg^{-1}$) had higher mean exchangeable content than higher slope (0.38 $Cmol_ckg^{-1}$), (Table 4.3). In agreement with this result Mulugeta Aytenew (2015) showed an increasing trend of exchangeable K concentration from upper slope gradient to lower slope, which might be due to its loss through run off and erosion in the high sloping areas and deposition in areas having lower slope gradient. Similarly, the higher mean exchangeable K was recorded in the lower slope than the middle and the upper slope gradients of the watershed in west Oromia, Ethiopia could be attributed to erosion, deposition and leaching processes as presented by Muktar Mohammed *et al*. (2020). This result also in agreement with the finding of Damte Balcha *et al.* (2020) who reported higher mean exchangeable K content under lower slope gradient than the upper slope gradient could be due to erosion in the upper slope and deposition in the lower slope. Exchangeable k was positively and significantly correlated with SOM (r = 0.73**), clay (r = 0.86**), pH. (r = 0.89**) and total N (r = 0.83**), while it was negatively and significantly correlated with sand (r = -0.76**), BD (r= -0.73**) and silt (r= -0.54**) (Appendix Table 5).

However, according to the exchangeable K rating by FAO (2006), the observed mean values of the exchangeable K of soil of the study area fall in the range of high in forest land, medium in rest land uses, and in all management practices and slope gradients (Appendix Table 2).

4.2.8. Exchangeable Sodium

The ANOVA showed that, Exchangeable Na was highly significantly affected by land use types, management practice and slope gradient ($P \leq 0.01$), while it was not significantly affected by their interaction effect (Appendix Table 4). Consequently, the highest (0.61 $cmol_c kg^{-1}$) obtained in forest land and the lowest (0.35 $cmol_c kg^{-1}$) mean exchangeable Na content was recorded in agricultural land soils (Table 4.3) in the study area. The higher exchangeable Na in forest land might be due to the availability and accumulation of plant residues and biological functions there by enhance exchangeable Na in the forest land. On the other hand the lower exchangeable Na in agricultural land was due to low OM, removal of surface vegetation, surface erosion and leaching. In consent with this finding, Heluf Gebrekidan and Wakene Negessa (2006) revealed that variations in the distribution of exchangeable bases depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, intensity of cultivation and the parent material from which the soil is formed.

Considering the management practice, managed area (0.52 $Cmol_c kg^{-1}$) soils was showed higher exchangeable Na content than unmanaged (0.37 $Cmol_c kg^{-1}$) in the study area (Table 4.3). The lower mean exchangeable Na content recorded in the unmanaged might be due to leaching and higher rate of soil erosion compared to conserved field. The finding of Mengie Belayneh *et al. (2019*) and Damte Balcha *et al.* (2020) is in lined with this result. Similarly, Muktar Mohammed *et al*. (2020) also revealed higher mean content of exchangeable Na under conserved area than un-conserved one.

On the other hand, lower slope (0.52 $Cmol_c kg^{-1}$) had higher mean exchangeable Na content than higher slope (0.38 $Cmol_c kg^{-1}$) in study area (Table 4.3). The higher exchangeable Na observed in the lower slope could be due to its removal though erosion in the upper slope and accumulation in the lower slope gradient (Mulugeta Aytenew, 2015). Similarly, Gebeyaw Tilahun (2015) and Behailu Bezabih *et al.* (2016) also revealed the highest exchangeable Na concentration at the lower slope could be also related to the influence of intensity of cultivation and abundant crop harvest with little or no use of input. Exchangeable Na was positively and significantly correlated with SOM (r = 0.87**), clay (r = 0.88**), pH. (r =

0.86**) and total N (r = 0.75**), while it was negatively and significantly correlated with sand (r = -0.76**), BD (r= -0.82**) and silt (r= -0.57**) (Appendix Table 5).

According to the ratings of FAO (2006), the mean exchangeable Na values were medium in the soils of all land uses types, management practices and slope gradients (Appendix Table 2). Generally, study by Heluf Gebrekidan and Wakene Negessa (2006) revealed that variations in the distribution of exchangeable bases depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, intensity of cultivation and the parent material from which the soil is formed.

4.2.9. Cation exchange capacity (CEC) and Percentage base saturation (PBS)

Land use, management practice and slope had the highly significant ($P \leq 0.01$) effect on CEC in soils of the study area; however, it was not significantly influenced by the interaction effect of land use, management practice and slope (Appendix Table 4). Accordingly, the higher (31.60 $Cmol_c kg^{-1}$) mean CEC was recorded under forest land and the lower (23.44 $Cmol_c kg^{-1}$) mean content of CEC was obtained under cultivated land followed by grazing land (25.98 $Cmol_c kg^{-1}$). (Table 4.3). However, the mean value of cultivated land (23.44 $Cmol_c kg^{-1}$) was not significantly lower with grazing land (25.98 $Cmol_c kg^{-1}$) (Table 4.3). The mean CEC values in the agricultural land use were lower mainly due to the depletion of OM because of continuous cultivation and removal of biomass. In lined with this result of Eyayu Molla and Mamo Yalew (2018) also revealed the lowest mean value of CEC under cultivated land and the highest mean value of CEC under forest land followed by grazing land in Agedit watershed, Northwest Ethiopia. Similarly, (GAO, 1996) reported that continuous cultivation decreases soil OM and resulted in CEC reduction in the cultivated land than that of uncultivated land. Moreover (Nega Emiru and Heluf Gebrekidan, 2009) reported that soil CEC recorded values in cultivated land uses decreased mainly due to the reduction in organic matter content. Basically, CEC of a soil depends on the relative amounts and type of colloidal substances (organic matter and clay) as both provide negatively charged surfaces that play important role in exchange process. Particularly, organic matter plays an important role in exchange process, because it provides more negatively charged surfaces than clay particles do (Gao, 1996).

Considering management practice, the higher mean CEC value was recorded under managed area (29.25Cmol$_c$kg^{-1}) than unmanaged area (24.77 Cmol$_c$kg^{-1}) (Table 4.3). This result is in lined with Yihenew G/Selassie *et al* (2015) who reported higher mean value of CEC under managed (manure and soil bund, bund and manure) areas as compare to un-managed area. This could be due to higher organic matter and clay fraction in managed area than un-managed area. This idea was supported by the finding of Mulugeta and Karl (2010) and Yihenew Gebreselassie and Getachew (2013) who revealed high clay soils can hold more exchangeable cations than a low clay containing soils. In the same way, Abay Challa *et al*. (2016) and Muktar Mohammed *et al*. (2020) also reported the higher mean exchangeable CEC content in managed areas.

Considering slope gradient, the higher mean CEC content was recorded under lower slope (28.46 Cmol$_c$kg^{-1}) than higher slope gradients (25.55 Cmol$_c$kg^{-1}) (Table 4.3). This could be due to the removal of clay particles and organic matter from the higher slope by run off and accumulation under the lower slope. As a result, the distribution of CEC in different slope gradients followed the distribution trend of clay and organic matter. This investigation suggested that soil organic matter and clay percentage can be governed the CEC of the soil. This result in lined with the findings of Rezaei *et al*. (2015), Mulugeta Ayitenew (2015) and Kehali Jenberie *et al*. (2017), who revealed that the accumulation of CEC was found to be greater on lower slope gradients than on the medium and upper slope gradient classes. As a result, the CEC records of soils of the study area were positively correlated with OM and clay. CEC was positively and significantly correlated with pH. (r = 0.88**), Mg (r = 0.73**), K (r = 0.76**), Ca (r = 0.82 **) and Na (r = 0.77**), while it was negatively and significantly affected by sand content (r = -0.66**), BD (r = -0.79**), and silt (r = -0.58**) (Appendix Table 5).

Based on the ratings of Hazelton and Murphy (2007), the mean values of CEC was qualified as medium (1-25 cmol$_{(+)}$ kg^{-1}) in soils of cultivated land and upper slope area, while high (25-

40 $cmol_{(+)}\ kg^{-1}$) in the soils of the rest land uses, in both managed and un managed areas and lower slope soils in the study area.

With regarding PBS, statistically highly significant differences ($P \leq 0.01$) were observed by the slope gradient, while it was not significantly affected under land use types, management practice and their interaction effect (Appendix Table 4). The average amount of PBS in the soils of the study area was numerically higher (41.48%) under forest land and lower (35.74%) in the cultivated land (Table 4.3). The reason for the high PBS content of the forest land may be due to the high soil organic matter content of this soil. The lowest PBS recorded in the surface layer of the cultivated land could be attributed to the low exchangeable bases, pH and low soil organic matter content. In line with this result, Kedir Abate (2015) stated that variation in PBS could also be because of variation in pH, SOC content, soil texture, parent materials, and intensity of cultivation, leaching, slope and soil management practices. Similarly, Eyayu Molla and Mamo Yalew (2018) also showed that the higher mean PBS content under forest land and the lower mean PBS content under cultivated land in soils of Agedit watershed, Northwest Ethiopia. Considering management practice slope gradient PBS were numerically higher under managed area (40.64%) than unmanaged area (36.34%) (Table 4.3).

Higher PBS was recorded under lower slope gradient (41.67%) than the upper slope (35.34%) (Table 4.3). The factors that cause low in PBS could probably be because of low pH, removal of basic cation from top soil and accumulation of sand particles in the sites. This study is in agreement with the finding of Mulugeta Ayitenew (2015) who reported PBS was significantly influenced by slope gradient variations. In general, the trends on the distribution of PBS showed similarity with the distribution of CEC and exchangeable bases since factors that affect these soil attributes also affect the PBS. Based on the rating set by Hazelton and Murphy (2007), the mean values of PBS were low in soil of grazing and cultivated land, in the soils of un-managed area and under higher slope gradients, while medium in forest land, managed land and lower slope gradients in the study area (Appendix Table 2). PBS was significant and positive correlation with soil pH (r= 0.51**), TN (r= 0.53**), Ca (r= 0.77**), Mg (r= 0.77**), K (r= 0.67**), Na (r= 0.67**) and CEC (0.32), whereas significant and negative correlation with sand, silt and BD (r= -054**,-0.42** and -0.46**, (Appendix Table 5).

Table 4.3 Main effects of land use and slope gradient and management practice on selected soil chemical properties.

Land use, management and slope	Exchangeable bases ($Cmol_c kg^{-1}$)				CEC	PBS
	Ex. Ca	Ex.Mg	Ex.K	Ex.Na		
	Land uses					
Grazing land	7.12^{b}	1.83^{b}	0.47^{b}	0.38^{b}	25.98^{b}	37.95^{ab}
Cultivated land	6.25^{c}	1.47^{b}	0.36^{b}	0.35^{b}	23.44^{c}	35.74
Forest land	8.94^{a}	3.10^{a}	0.62^{a}	0.61^{a}	31.60^{a}	41.84
MSD(0.05)	0.71	0.45	0.07	0.05	2.48	NS
SEM (±)	0.44	0.19	0.05	0.04	1.04	1.83
Cv%	13.52	25.55	25.68	21.11	9.36	15.12
			Management			
Unmanaged	6.51^{b}	1.78^{b}	0.38^{b}	0.37^{b}	24.77^{b}	36.34
Managed	8.37^{a}	2.48^{a}	0.59^{a}	0.52^{a}	29.25^{a}	40.64
P-value	**	**	**	**	**	NS
SEM (±)	0.33	0.16	0.03	0.03	0.80	1.84
Cv%	13.52	25.55	25.68	21.11	9.36	15.12
			Slope gradients			
2-5%	8.32^{a}	2.51^{a}	0.59^{a}	0.52^{a}	28.46^{a}	41.67^{a}
5-10%	6.55^{b}	1.75^{b}	0.38^{b}	0.38^{b}	25.55^{b}	35.34^{b}
P-value	**	**	**	**	**	**
SEM (±)	0.39	0.21	0.04	0.04	1.13	2.10
CV%	13.52	25.55	25.68	21.11	9.36	15.12

Main effect means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; NS = Not significant at $P > 0.05$; CEC = cation exchange capacity; PBS =percent base saturation.

Chapter 5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

- From the study, it is possible to conclude that natural phenomena and interference of human activities are aggravating soil fertility degradation (erosion and overgrazing).
- Soil physico-chemical properties significantly vary among land use types, slope gradient and land management practices.
- The overall fertility status of the soils under the cultivated land decreases compared to the soil properties of the adjacent forest and grazing land use types.
- Cultivated land soils have lowest mean value of clay, pH, total nitrogen, available phosphorus (Av. P), and organic matter, exchangeable $Ca^{2+,}$ K^+, Na^+, CEC and PBS than other land use types.
- Forest soils have highest clay fraction, total porosity, organic matter, total nitrogen, available phosphorus, exchangeable bases, CEC, and PBS; but lower in sand fraction and bulk density.
- Soil management practices had a significant positive effect on improvement of soil fertility as expressed by different soil physical-chemical properties, such as clay fraction, total porosity, pH, organic matter, total nitrogen, available phosphorus, exchangeable cations (K^+, Ca^{2+}, Mg^{2+}, and Na^+), and cation exchange capacity were higher in managed areas compared with unmanaged areas in all land use types, while sand and silt fractions as well as bulk density were higher in unmanaged areas.
- Regarding to slope the mean value of clay fraction, total porosity, pH, available phosphorus, exchangeable cations (K^+, Ca^{2+}, $Mg^{2+,}$ and Na^+), and cation exchange capacity were higher in the lower slope classes compared with higher slope classes, Whereas, sand fraction and bulk density were higher in the higher slope gradient in *Burat* watershed.
- Integrated land management practices for different land use types and slope gradient are the most effective way in reducing soil erosion and increasing soil fertility.

5.2. Recommendations

According to the findings of this study the following recommendations are forwarded;

- ✓ Different integrated land management practices should be conducted to cultivated and grazing lands and slope gradient to improve soil fertility and achieve sustainable agricultural production of the study area.
- ✓ Take a care for free grazing and livestock intervention; apply cut and carry system of animal feeding to minimize soil disturbance.
- ✓ There is a need to apply proper land use policy, sustainable soil management and cropping practices to alleviate the ongoing soil degradation and improve soil fertility in the study area.
- ✓ Appropriate soil and water conservation measures should be considered on cultivated and grazing lands (soil bund and biological measures).
- ✓ Further studies should be carried out on other soil physico-chemical properties (micro nutrients) to get more information about the effect of those factors on slope gradient of the different land use types and land management practices.

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APPENDIXS

Appendix Table 1. Rating of some soil physicochemical properties

Ratings	BD (g/cm^3)	TP (%)	OM (%)	TN (%)	Av.P (ppm)	pH	Ratings
Very low	<1	<2	<2	<0.1		<5.5	Strongly acidic
Low	1-1.3	2-5	2-3	0.1-0.15	< 5	5.6-6.5	Moderately acidic
Optimum	*1.3-1.6*	*5-15*	*3-7*	*0.15-0.3*	*5-15*	*6.6-7.3*	*Neutral*
High	1.6-1.9	15-40	7-8	0.3-0.5	>15	7.3-8.4	Moderatl yalkaline
Very high	>1.9	>40	>8	>0.5	>150	>8.4	Strongly alkaline

Source: BD FAO (2006); TP Hazelton and Murphy (2007) and pH, OM and TN EthioSIS (2016). Av.P a (London, 1991)

Appendix Table 2. Rating of exchangeable bases, CEC and PBS

Ratings	Ca (cmol$_{(+)}$ kg^{-1})	Mg (cmol$_{(+)}$ kg^{-1})	K (cmol$_{(+)}$ kg^{-1})	Na (cmol$_{(+)}$ kg^{-1})	CEC (cmol$_{(+)}$ kg^{-1})	PBS (%)
Very low	<2	<0.3	<0.2	<0.1	<6	<20
Low	2-5	0.3-1	0.2-0.3	0.1-0.3	6-12	20-40
Medium	5-10	1-3	0.3-0.6	0.3-0.7	1-25	40-60
High	10-20	3-8	0.6-1.2	0.7-2	25-40	60-80
Very high	>20	>8	>1.2	>2	>40	>80

Source: Exchangeable (Ca, Mg, K, and Na) FAO (2006); CEC and PBS Hazelton and Murphy (2007).

(Cmol (+) kg^{-1})=Centi mole charge per kilogram

Appendix Table 3: Mean monthly rainfall (mm) and air temperature (^{o}C) for the years from 2010 – 2019 of the study area

Month	Rainfall (mm)	Maximum air T^0	Minimum air T^0
Jan	0.12	25.7	12.6
Feb	0.19	29.8	12.1
Mar	2.61	30.5	14.2
Apr	26.26	25.3	12.6
May	253.02	25.3	11.5
Jun	216.27	24.4	11.1
Jul	503.01	24.9	9.2
Aug	488.47	24.8	9.1
Sep	259.54	24.05	9
Oct	88.82	22.3	9.02
Nov	2.97	21.8	9.01
Dec	4.55	20.2	9.05
Mean		25	10.7
Total	1845.83		

Appendix Table 4. Mean square estimates for a three-way analysis of variance of soil physico-chemical properties.

	Mean squares for source of variation								
Soil parameters	Land use (df=2)	Management (df=1)	Slope (df=1)	Land use* management (df=1)	Slope x landuse (df=3)	Slope * management (df=1)	Land use* slope* management (df=1)	Error (df=16)	CV (%)
Sand	128.5**	58.77**	64.00**	9.03^{ns}	9.75^{ns}	16.00^{ns}	1.58^{ns}	6.08	8.12
Silt	25.86^{ns}	261.36**	8.02^{ns}	2.53^{ns}	0.02^{ns}	0.02^{ns}	1.36^{ns}	11.33	11.05
Clay	245.2**	568.03**	117.36**	15.03^{ns}	9^{ns}	14.7^{ns}	3.7^{ns}	4.89	5.64
Bulk density	0.08**	0.1**	0.01*	0.001^{ns}	0.01^{ns}	0.0.0002^{ns}	0.001^{ns}	0.003	4.31
Total porosity	119**	117.42**	25.95*	0.85^{ns}	9.2^{ns}	0.31^{ns}	0.14^{ns}	3.68	3.45
pH (H_2O)	0.88**	1.31**	0.5**	0.01^{ns}	0.04^{ns}	0.01^{ns}	0.02^{ns}	0.02	2.63
OM	11.52**	7.03**	1.62**	0.32^{ns}	0.2^{ns}	0.05^{ns}	0.13^{sn}	0.21	11.93
Total Nitrogen	0.006**	0.005**	0.011**	0.005^{ns}	0.001^{ns}	0.0001^{ns}	0.00005^{ns}	0.0002	9.64
C:N ratio	53.7**	8.12^{ns}	49.7*	2.51^{ns}	26.37^{ns}	0.0005^{ns}	4.15^{ns}	9.13	17.97
Available P	53.36**	63.02**	52.68**	1.47^{ns}	0.28^{ns}	0.42^{ns}	1.53^{ns}	2.66	16.64
Exchangeable Ca	22.66**	31.23**	28.17**	0.22^{ns}	3.63^{ns}	0.97^{ns}	0.66^{ns}	0.48	9.4
Exchangeable Mg	8.79**	4.42**	5.04**	0.021^{ns}	0.04^{ns}	0.81^{ns}	0.61^{ns}	0.19	20.73
Exchangeable K	0.02**	0.035**	0.04**	0.024^{ns}	0.016^{ns}	0.002^{ns}	0.01^{ns}	0.0057	15.52
Exchangeable Na	0.25**	0.21**	0.168**	0.026^{ns}	0.026^{ns}	0.003^{ns}	0.0027^{ns}	0.0025	11.36
CEC	209.1**	180.9**	75.9**	10.85^{ns}	3.45^{ns}	8.7^{ns}	0.25^{ns}	5.91	9.00
PBS	114.58^{ns}	163.58^{ns}	36.49**	54.91^{ns}	38.02^{ns}	11.6^{ns}	21.26^{ns}	26.26	13.3

Appendix Table 5. Pearson's correlation matrix for soil physico-chemical properties.

	Sand	silt	clay	B.D	TP	PH	OM	TN	C:N	Av.P	Ex.Ca	Ex.Mg	EX.K	Ex.Na	CEC	PBS
Sand																
Silt	0.16															
Clay	-0.76**	-0.76**														
B.D	0.61**	0.58**	-0.78**													
TP	-0.61**	-0.58**	0.78**	-1**												
PH	-0.77**	-0.54**	0.85**	-0.82**	0.83**											
OM	-0.77**	-0.51**	0.84**	-0.82**	0.82**	0.82**										
TN	-0.76**	-0.41	0.77**	-0.67**	0.67**	0.79**	0.66**									
C:N	-0.17	-0.20	0.23	-0.3	0.3	0.17	0.56**	-0.24								
Av.P	-0.68**	-0.54**	0.82**	-0.80**	0.80**	0.86**	0.76**	0.73**	0.15							
Ex.Ca	-0.71**	-0.65**	0.90**	-0.71**	0.71**	0.83**	0.75**	0.84**	0.10	0.80**						
Ex.Mg	-0.75**	-0.47**	0.80**	-0.71**	0.71**	0.76**	0.76**	0.77**	0.12	0.74**	0.86**					
Ex.K	-0.76**	-0.54**	0.86**	-0.73**	0.73**	0.89**	0.73**	0.83**	0.03	0.85**	0.87**	0.81**				
Ex.Na	-0.76**	-0.57**	0.88**	-0.82**	0.82**	0.86**	0.87**	0.75**	0.28	0.87**	0.85**	0.83**	0.86**			
CEC	-0.66**	-0.58**	0.81**	-0.79**	0.79**	0.88**	0.74**	0.81**	0.06	0.80**	0.82**	0.73**	0.76**	0.77**		
PBS	-0.54**	-0.42**	0.63**	-0.46**	0.45**	0.51**	0.55**	0.53**	0.15	0.54**	0.77**	0.77**	0.67**	0.67**	0.32	

BIOGRAPHYICAL SKETCH

The author was born on the 25th of January 1980 in Farta District of South Gondar Zone, Amhara National Regional State. He attended his primary and secondary educations at the Gafat Elementary school and Tewodros II secondary Schools, respectively, between 1987 and 1996.After he has successfully passed the ESLCE, joined Combolcha ATVET College and studied Natural Resource Management between 1997 and 1999 and obtained diploma in Natural Resource in July 1999.And up grading BSC Degree in Debrtabor University in Natural Resource Management between 2004-2008.

Right after graduation, he joined the Ministry of Agriculture stationed at Estie District, South Gondar Zone, Amhara National Regional State, and served as Natural Resource Expert from 04/02/2000- 28/10/2010 in Estie District Agricultural office He then moved to Dera District Agriculture office and served as soil &water conservation expert from 29/10/2009-21/03/2011. He joined Bahir Dar University in September 2011 for his Master of Science degree in Soil Science.