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LAND USE / LAND COVER CHANGE AND THE EFFECTS OF LAND USE TYPE AND SOIL DEPTH ON SOIL PROPERTIES IN MERE WATERSHED, NORTH WEST ETHIOPIA

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MSc. Thesis

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (MSC.), IN "WATERSHED MANAGEMENT AND SOIL AND WATER CONSERVATION"

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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. Gasha Alene** entitled: "**Land Use / Land Cover Change and the Effect of Land Use Type and Soil Depth on Soil Properties in *Mere* watershed, North West Ethiopia**.**"** We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc.) in **Watershed Management and Soil and Water Conservation**.

Board of Examiners

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Chairman of the department Signature Date

DECLARATION

This is to certify that this thesis entitled"**Land Use / Land Cover Change and Effect of Land Use Type and Soil Depth on Soil Properties in *Mere* Watershed, Northwest Ethiopia**" submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in "**Watershed Management and Soil and Water Conservation**" to the Graduate Program of College Agriculture and Environmental Sciences, Bahir Dar Universityby Mr**. Gasha Alene** (ID. NO BDU 1018379PR) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for the award of any degree or diploma to the best of our knowledge and belief.

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LIST OF ACRONYMS AND ABBREVATIONS

AVP	Available Phosphorus
BD	Bulk Density
CEC	Cation Exchange Capacity
$Cmol_c/kg$	Centimol of Charge per kilogram
C:N	Carbon nitrogen ratio
CV	Cofficient of variance
ENVI	Environment for Visualizing Images
Ethiosis	Ethiopia soil information system
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
GIS	Geographic Information System
LSD	Least Significant Difference
NMA	National Meteorological Agency
OC	Organic Carbon
OM	Organic Matter
PPM	Parts Per Million
SAS	Statistical Analysis Software
SE	Standard Error
SEM	Standard Error Of Mean
TN	Total Nitrogen
UNDP	United Nations Development Program
UTM	Universal Travers Mercator
WGS	World Geodetic system

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Land Use / Land Cover Change and the Effect of Land Use Type and Soil Depth on Soil Properties in *Mere* watershed, North West Ethiopia.

By Gasha Alene Advisor Dr. Eyayu Molla and Dr. Mulatie Mekonen

ABSTRACT

In most developing countries, including Ethiopia, the amount, rate and intensity of land use changes are very high. This study was conducted in Mere watershed; northwest Ethiopia with the objective of analysing land use land *cover change and investigate the effect of different land use types and soil depth on soil properties. Land cover maps of 1990 and 2018 were interprated and analyzed within GIS to quantify the land cover change in the study area. Four major land use types: natural forest, grazing land, cultivated land and plantation forest lands were selected. While undisturbed core and disturbed composite soil sample were collected with three replications for each land use types at two depths (0-20 cm and 20-40 cm). Standard soil analytical procedures were followed in carrying out soil analysis. The soil physicochemical properties were analyzed at Amhara Design and Supervision Works Enterprise, Bahir Dar. The statistical results revealed that variations due to land use types and soil depth. sand, clay, bulk density, pH, organic matter, total nitrogen, available phosphorus, cation exchange capacity and exchangeable Ca, K, and Na were significantly ($p < 0.05$ and/or $p < 0.01$) different. In contrast, silt, carbon to nitrogen ratio and exchangeable Mg were not significantly ($p > 0.05$) affected. The highest value of all soil chemical properties except exchangeable Na and C: N ratio were recorded under natural forest and the lowest value except CEC, Na and C: N ratio was found under plantation forest. With soil depth, the higher mean value of organic matter, total Nitrogen and cation exchange capacity were recorded in the 0-20 cm than 20-40 cm depth and the higher mean value of pH and exchangeable Na was recorded in the 20-40 cm than 0-20 cm depth. Texture, bulk density, available Phosphorus, C: N, exchangeable bases (Ca, Mg and K) were not significantly ($p > 0.05$) affected by soil depth. The changes of natural forest to other land use types were one of the impacts of soil fertility that contributed to low agricultural productivity. Therefore, the study is suggesting the need for intervention to sustain and optimize the soil quality*.

Key Words: cultivated land, natural forest, grazing land, Soil depth, Soil physico-chemical properties

Chapter 1. INTRODUCTION

1.1. Background and Justification

In most developing countries, including Ethiopia, the amount, rate and intensity of land use changes are very high. The out come of these changes are deterioration of soil physico chemical properties (Rao and Pant, 2001). Ethiopia is gifted with potential rich natural resources, of which land is the prinicipal one and the economy is primarily based on agriculture production. The agriculture sector plays a central role in the life and livelihood of most Ethiopians, where about 12 million smallholder farming households account for an estimated 95% of agricultural production (UNDP, 2014). However land productivity is continuously declined because of deforestation, continuous cultivation and inadquate land management practices (Eyayu Molla and Mamo Yalew, 2018).

Land use changes, mainly the conversion of natural forests to agricultural land and settlement, are the most widely practiced activities in Ethiopia (Eyayu Molla *et al*., 2010). Land use changes without approprate management practices result depletion of soil nutrients and intensive soil erosion problem is more severe in Ethiopian highlands (Betru Nedassa, 2003; Eyayu Molla *et al*., 2010). This problem is manifested in changes soil properties such as on contents and availablity of macro and micro nutrients, organic matter, CEC and it also affects the soil structure (Aluko and Fagbenro, 2000). The reduction of vegetative cover (such as straw or stubble) or burning plant remains as practiced under the traditional crop production system or the annual burning of vegetation on grazing lands are major causes to the decline of nutrients (Mesfin Abebe, 1998).

In Ethiopia, although the adverse impact of land use changes on soil physicochemical properties and agricultural productivity is high, few studies have been conducted to quantify the amount, rate and process of soil fertility reduction under different land use practices (Eyasu Elias, 2002). Among the very few, the study of Teshome Yitbarek *et al*. (2013) reported a significant decline in soil organic matter after conversion of natural forest to cultivated land in the *Abobo* area, Western Ethiopia. Getahun Bore and Bobe Bedadi (2015) also indicated a decline in soil organic matter, total nitrogen and available phosphorus in cultivated soils compared to natural forest in *Loma* District, Southern Ethiopia and (Eyayu

Molla and Mamo Yalew, 2018; Mesert Muche *et al*., 2015) also reported similar result in the Northwest Ethiopia.

Assessing soil physicochemical properties are used to understand the potential status of nutrients in soils of different land uses (Wondowosen Tena and Sheleme Beyene, 2011). This knowledge can ascertains whether the particular land use types are useful for a specified production system and used to satisfied plants requirement for fast growth and better crops production (Shishir and Sah, 2003).

Knowledge about an up-to-dated status of soil physicochemical properties of different land use type plays a fundamental role in enhancing production and productivity of the agricultural sectors on sustainable basis. However, adequate information on the status and management of soil physicochemical properties as well as their effect on soil quality to give recommendations for best possible and sustainable utilizations of land resources remains poorly understood (Lechisa Takele *et al*., 2014).

Most parts of the *Dera* District particularly *Mere* watershed natural forest has been gradually changed in to agricultural and settlement lands. In addition continuous cultivation and over grazing coupled with poor land management practices caused an increase in runoff and erosion in the watershed. However, the imapct of this land use changes on soil propertis was not studied and documented in the watershed. Therefore, this study was conducted with the objective to analysis land use land cover change and investigate the effect of different land use types and soil depth on soil properties of the *Mere* watershed, Northwest Ethiopia. The result of this study expected to add value to the up-to-date scientific documents of the status of soil fertility and soil quality of different land use types and soil depth of the study area and other comparable agro-ecological environments in the country.

1.2. Statement of the Problem

Continuous cultivation and intensive grazing of land without proper management resulted in decline in soil physical, chemical and biological properties that aggravate crop yield reduction and food shortage (Wasihun Mengiste *et al*., 2015). Evaluating land use induced changes and soil depth on soil properties in different parts of the region is essential for understanding the impacts of agro-ecosystem transformation on soil productivity and to come up with appropriate and sustainable soil and land management options (Eyayu Molla and Mamo Yalew, 2018). However, the effect of land use type and soil depth on soil properties have not been scientifically studied and documented in the Dera district northwest highlands of Ethiopia.

The study area is suitable for the production of different crops, such as barely wheat, finger milt, potato, teff, and maize; homestead, tree plantation and livestock grazing. However, due to high population growth in the study area has been reducing land holding per capital and pressure on limited land for agriculture production. Forced the farmers to shift forest lands to cultivated lands. Land use and cover changes in the study area has become a serious problem degradation of natural resources particularly soil lowering agricultural productivity.

Moreover, land uses identified as grazing lands were degraded due to continuous overgrazing incidences. This might inevitably brought the disturbances of ecosystem and depletion of soil fertility and erosion. Consequently, in different land uses of the study area, there was a belief that the above-mentioned problems have brought a direct negative effect on soil fertility in general and crop production and productivity in cultivated lands in particular. However, the extent and rate of the problem in terms of physical and chemical soil degradations were not quantified properly. Therefore, this study was designed to analysis land use land cover change and investigate the effect of different land use types and soil depth on soil properties of *Mere* watershed, Northwest Ethiopia.

1.3. Objectives

1.3.1. General objective

To analysis land use land cover change and investigate the effect of different land use types and soil depth on soil properties of *Mere* watershed, Northwest Ethiopia.

1.3.2. Specific objectives

- To analyze the land use land cover changes in the watershed over a period of 28 years (1990 to 2018).

- To investigate the effect of different land use types on selected soil physicochemical properties.
- To investigate the effect of soil depth on selected soil physicochemical properties under different land use types.

1.4. Research Questions

- ❖ Is there any land use/cover change at *Mere* watershed?
- ❖ What is the effect of different land use types on soil physicochemical properties?
- ❖ What is the effect of soil depth on soil physicochemical properties under different land use types?

Chapter 2. LITERATURE REVIEW

2.1. Overview of Land Use Change

Land use / cover change is a dynamic process driven mainly by anthropogenic activities and natural phenomena (Lambin *et al*., 2003). One of the most significant worldwide challenges in this century relates to the management of the transformation of the earth's surface occurring through changes in land use and land cover (Mustard *et al*., 2004). In sub-Saharan Africa, a mixture of the population's growth and land degradation increases the vulnerability of people to both economic and environmental change (Millennium Ecosystem Assessment, 2005). One of a serious problem in Africa is land degradation; however, it is extreme in the densely populated highlands of East Africa (Pender *et al*., 2006). The Ethiopian highlands are amongst the most densely populated agricultural areas in Africa (McGinley, 2008).

2.2. Impacts of Land Use Change on Physical Properties of Soil

The physical characteristics of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. The soil physical properties such as structure, bulk density, total porosity, and soil water characteristics showed remarkable variations due to different land use types, particularly in A-horizon (Wakene Negassa, 2001).

2.2.1. Soil texture

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 (Gupta, 2004). It is also a display of some other related soil features such as types of parent material, homogeneity, and heterogeniety within the profile, migration of clay and intensity of weathering of soil material or age of soil (Liliefein *et al*., 2000).

Soil texture is one of the intrinsic soil physical properties that is less affected by management and which determines nutrient status, organic matter content and decomposition. The rate of increase in stickiness or ability to mound as the moisture content increases depend on the content of silt and clay fraction, the degree to which the clay particles are bound together into stable granules and the OM content of the soil (Hillel, 2004). Over a very long period, pedogenic processes such as erosion, deposition, eluviations and weathering can alter the textures of various soil horizons (Brady and Weil, 2002).

The soil texture usually varied with land use types. Some studies such as Lechisa Takele *et al*. (2014) reported that the contents of clay significantly varied among the land use types in the G*indeberet* area,Western Oromia, Ethiopia. Its content was significantly lower in forestland as compared to the cultivated and grazing lands. On the other hand the same study showed significantly higher silt content in forestland than both cultivated and grazing lands, higher sand content in grazing land and low sand content in cultivated lands. The reason for the change in clay content was due to the impact of deforestation and farming practices. Similarly, the studies of Achalu Chimdi *et al*. (2012) indicated higher clay content in cultivated land than the adjacent soils under grazing land and natural forest. These changes in soil texture is attributed to land use changes mainly the conversion of natural forest into other land use types (Eyayu molla and Mamo Yalew, 2018).

2.2.2. Bulk density

Soil bulk density is defined as the ratio of a mass of dry soil (oven-dried at105^{0}C) to its field volume and usually expressed in terms of grams per cubic centimeter (g/cm^3). Bulk density is determined by the texture of the soil and by soil structure and the amount of soil pore space, which can be altered by management. Compaction increases bulk density by decreasing soil pore space. It is an increase in bulk density and soil strength and a decrease in soil porosity by the application of mechanical forces to the soil (Assefa Derebe, 2009). Bulk density also provides information on the environment accessible to soil microorganisms. (White, 1997) confirmed 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 to 1.8 g/cm^3 for sands and compacted horizons in clay soils. Bulk density normally decreases as mineral soils become finer in texture. Soils having low and high bulk density show favorable and poor physical conditions, respectively. Bulk densities of soils are inversely related to the amount of pore space and soil OM (Brady and Weil, 2002; Gupta, 2004). Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in a decrease of total porosity (Brady and Weil, 2002).

The study results of Woldeamlak Bewket and Stroosnijder (2003) and Mulugeta Lemenih (2004) revealed that the bulk density of cultivated soils was higher than the bulk density of forest soils. In addition, Getahun Bore and Bode Bedadi (2015) stated that lower bulk density value observed in forestland soils due to its relatively highest organic matter content and as it holds a high proportion of pore space to solids.The higher bulk density value observed in grazing land soils could also be due to compaction. According to (Mulugeta Lemenih, 2004), Soil bulk density increased in the 0-10 cm and 10-20 cm layers relative to the length of time the soils were subjected to cultivation. Similarly, Ahmed Hussein (2002) reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth. On the other hand, Wakene Negassa (2001) reported that bulk density was higher at the surface than the subsurface horizons in the abandoned and lands not fallow for twelve years. The changes in the physical soil attributes on the cultivated fields can be attributed to the impacts of frequent tillage and the decline in OM content of the soils.

The bulk density of the soil was varied with land use types. Some studies such as Ceyhun (2009) suggested that the change of the grassland into cultivated land might be caused a higher bulk density in the cultivated soils. Similarly change from the natural forest to other land uses, caused a decline in soil aggregation resulted in the increased bulk density. In addition, Eyayu Molla and Mamo Yalew (2018) reported that relative to the natural forest, BD in cultivated and grazing lands increased by 27.50 and 40.20%, respectively. Other studies by Achalu Chimdi *et al*. (2012) reported that bulk density in cultivated land was higher than the adjacent soils of the natural forest and grazing lands, respectively by 24.68 % and 18.35%. Kakaire *et al*. (2015) stated that a higher soil bulk density means that less amount of water is held in the soil at field capacity, while a lower soil bulk density means soils are less compacted and are able to retain more water.

2.2.3. Soil porosity

Porosity, defined as the ratio of the total volume of pore spaces to the total volume of soil, is an indicator of the relative pore space in the soil. For soils with the same particle density, the lower the bulk density, the higher is total porosity Landon (1991). The total porosity of soil usually lies between 30% to 70% in compacted subsoil and in well aggregated, high OM surface soils respectively **(**Brady and Weil, 2002) and may be used as a universal indication of the degree of compaction of soil in the same way as bulk density is used. As is the case with bulk density, management pushes a conclusive influence on the pore space of soils (Brady and Weil, 2002). The arrangement of soil particles determines the amount, shape and direction of pore space. As soil particles vary in size and shape, pore spaces also differ in size, shape and direction (Foth, 1990). Coarsetextured soils tend to be less porous than fine textured soils, though the mean size of individual pores is greater in the previous than in the latter. According to Landon (1991), pores can be classified into macro, meso and micro-pores, depending on their size.

Generally, intensive cultivation causes soil compaction and degradation of soil properties including porosity. Macropores can happen as the spaces between individual sand grains in coarse textural soils. The decreasing OM and increasing in clay that occur with depth in many soil profiles are related to a change from macro-pores to micro-pores (Brady and Weil, 2002). The total porosity of the soils, in general, varied with bulk density. Accordingly, total porosity increases as the bulk density decreases while it decreases as bulk density increases (Wasihun Mengiste *et al*., 2015).

Highest soil mean total porosity under the soils of forestland use type may be ascribed to the comparatively lower animal trampling whereas lowest porosity is the result of higher animal tracking in the soils of grazing land use. A decline in total porosity in the soils of grazing and cultivated land as compared to soils of forest land were recognized to a decline in pore size distribution and it is also closely related to the magnitude of SOM loss which depending on the intensity of soil management practices (Achalu Chimdi *et al.*, 2012). On the other hand, the higher values of total porosity corresponded to the higher amount of organic matter contents and lower bulk density (Wasihun Mengiste *et al*., 2015).

Considering the surface soils, Wakene Negassa (2001) reported that the lowest total porosity (36.2%) was observed on the abandoned research field, followed by (41.6%) under the land left fallow for twelve years and the highest (56.7%) was recorded on the farmer’s field. Along with the increase in soil bulk density, soil total porosity showed marked declines in both soil layers (0-10 and 10-20 cm) with the increasing period under cultivation (Mulugeta Lemenih, 2004).

2.2.4. Soil water holding capacity

soil water holding capacity is the amount of water that a given soil can hold for crop use. Soil texture and organic matter are the key components that determine soil water holding capacity (Christina, 2011). The water holding capacity of any soil is determined by its texture, structure, and the amount of organic matter it contains (FAO, 2005). Olorunfemi and Fasinmirin (2017) reported that soils having a high proportion of sands are associated with low water holding capacity. Water holding capacity depends upon the capillary pore spaces in the soil. Soil with a very high amount of sand have very low water holding capacity due to large pore spaces between the particles that enable the water to infiltrate freely into deeper layers leaving upper layers practically dry. The result similar to FAO (2005) reported that if clay and organic matter contents increase, the water-holding capacity of the soil also increases and vise versal.

On the other hand (Idowu *et al.*, 2018) reported that the highest water holding capacity was recorded in natural forest soil that too has the highest organic matter content, while the lowest occurred in cropland with organic matter content that was among the least observed. Correlation between water holding capacity and organic matter content showed a significant positive relationship. This was mostly possible due to the capacity of SOM to act as a sponge in the soil, thus retaining soil moisture (Brady and Weil, 2002).

2.3. Impacts of Land Use Change on Chemical Properties of Soil

Soil chemical properties are the most essential among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil influence processes leading to soil development and soil fertility build up. Minerals innate from the soil parent materials over time-release chemical elements that undergo various changes and transformations within the soil (Lilienfein *et al*., 2000).

2.3.1. Soil reaction (pH)

Soil reaction is the degree of soil acidity or alkalinity, which is caused by the exactly chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Even though there are plants that flourish in acid or alkaline media, most crops perform best in a slightly acidic soil to neutral (pH 6.0-7.0). The values of pH less than 5.5 may lead to aluminum toxicity, therefore unavailability of phosphorus and some of the soil micronutrients such as molybdenum and reduced biological activity (Gachene, 2003). The pH level of the soil directly affects soil life and the availability of important soil nutrients for plant growth. Factors such as parent material, rainfall, and type of vegetation are dominant in determining the pH of soils. Under cultivation, however, organic acids from plant roots, frequent use of acid-forming fertilizers, plant removal, and replacement of calcium and magnesium by hydrogen ultimately lowers the pH of topsoil (Idowu *et al*., 2018).

Descriptive conditions commonly associated with certain ranges in pH are extremely acidic (pH < 4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0), and very strongly alkaline (PH > 9.1) (Foth and Ellis, 1997). The soil pH could be categorized as strongly acidic under cultivated land and grazing land whereas that of forest land was moderately acidic following the classification described by Brady and Weil (2002). In strongly acidic soils, Al^{3+} becomes soluble and increases soil acidity while in alkaline soils; exchangeable basic cations tend to occupy the exchange sites of the soils by replacing exchangeable H and Al ions. Soil acidity is universal in an area where precipitation is high enough to leach appreciable quantities of cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) from the surface layers of soils (Brady and Weil, 2002).

According to (LechisaTakele *et al*., 2014) stated that the lower value of soil pH under the cultivated land may be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution lowers its soil pH value. Excessive disturbance of the soil due to cultivation caused a high rate of OM turn over, decomposition releases both organic (H_2CO_3), and inorganic acids (H_2SO_4, HNO_2) result in the reduction of soil pH (Brady and Weil, 2002). In addition to (Getahun Bore and Bode Bedadi, 2015), reported that attributed to the removal of basic cations by harvested crops, more removal of basic cations by surface runoff and deep percolation in cultivated land because of less plant cover in cultivated land as compared to other land use types. Relatively higher pH in forestland soils could be associated with higher OM content as it can bind tightly Al ions and reduce their activity in the soil solution and thereby increase pH and reduce acidity. Inline with Abreha Kidanemariam *et al*. (2012) reported that the significantly high pH of soils from the forestland might be recognized to the ameliorating effect of the high accumulation of OM at surface soil.

According to Mengistu Chemeda *et al*. (2017), stated that the pH (H_2O) value of the soil content was significantly affected by all land use types and their interaction effects. The highest (6.47) and the lowest (5.29) soil pH (H_2O) values were recorded under the grass and the cultivated lands at 20-40 cm and 0-20 cm soil depths, respectively. Continuous cultivation practices, excessive precipitation, and application of inorganic fertilizers could be some of the factors that are responsible for the variation in pH in the soil profiles. On the other hand, the pH value of the soil varied with the change of land use types. Some studies like that of Nega Emiru and Heluf Gebrekidan (2013) reported that the mean pH value decreased the change of forestland to other land use types. It was found to be largest (6.6) in soils under forestland use whereas generally become small in agricultural fields: 3.7 for cultivated and 3.6 for grazing land soils. This variation can be ascribed by the loss of base-forming cations down the soil profiles, even beyond sampling depths, through leaching and drainage into streams in runoff generated from accelerated erosion. This in turn enhances the activity of Al^{3+} and H^+ in the soil solutions that reduces soil pH and thereby increases soil acidity. The depletion of basic cations in crop harvest, as indicated in their significant reduction is the other cause for the fall in soil pH. In addition, continuous use of ammonium-based fertilizers such as diammonium phosphate, $(NH_4)_2HPO_4$, in such cereal based cultivated fields. Similar studies by Gebeyhaw Tilahun (2015) reported that land use changes for example from forest to cropland, resulted in a decrease in soil pH of the study area. For instance, the highest (6.82) and the lowest (5.83) soil pH-H_2O values were observed under the forest and the cultivated lands, respectively.

2.3.2. Soil Organic matter

Soil OM arises from the remains of 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 organic matter (OM) is a dynamic and large pool of carbon which is subject to change to changes in management practices as a result of varying land uses (Post and Kwon, 2000). Organic matter plays vital role in regulating the flow and supply of plant nutrients and water flow, and determining the physical attributes of soil (Cotrufo *et al*., 2011).

Organic matter has an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition and biological activity in the soil (Brady and Weil, 2002). Extensive deforestation and conversion of natural forests into cultivated lands in Ethiopian ecosystems led to a significant decline in forest-derived OM levels of these tropical soils (Dawit Solomon *et al*., 2002). Woldeamlak Bewket and Stroosnijder (2003) reported the conversion of forest land into cultivation and grazing led to a decline of OM to 87% and 85%, respectively at Chemoga Watershed, the sub-humid tropical agroecosystem.

Soil organic matter contents under grazing and cultivated land were lower than the OM content of corresponding soils under forest land due to under the cultivated land use types, losses of forest-derived soil organic matter was not fully compensated by organic matter input from the cereal crop residues. A relatively lower level of disturbance in grazing land soils has apparently led to an increase in organic matter content as compared to those cultivated soils (Lechisa Takele *et al*., 2014). Though the absence of such soil disturbance minimizes rapid loss of soil OM, the export of nutrients and low biomass return after grazing have contributed much to its decline compared to observations made in the forest land (Weldeamlak Bewket and Stroosnijder, 2003; Genxu *et al*., 2004).

Getahun Bore and Bode Bedadi (2015) stated that a higher amount of OM in forestland soil is mainly due to the addition of more plant residues on its surfaces and their reduced rate of disturbance as compared to the other land use types. Considering the soil depth, a higher amount of SOM was recorded on the top surface of all land use types. This is apparent because it is attributed partly to the continuous accumulation of non-decayed and partially decomposed plant and animal residues on the surface soils. In general, forest clearing followed by conversion into agricultural fields in tropical ecosystems is known to bring about remarkable depletion of the SOM stock (Eyayu Molla and Mamo Yalew, 2018). Soil organic matter significantly influenced by land use types. Some findings such as that of Alemayehu Adugna and Assefa Abegaz (2016) reported that SOM decreases as forestland changes into cultivated and grazing land. The percentage change is higher in cultivated land than in grazing lands. Similar studies by Khresat *et al*. (2008) reported that the change of forest into the cultivated land has led to a decline in soil organic matter contents. The effect of such change is two reasons; first, it decreases the amount of fallout from vegetation and changes the quality of this fallout to a less resistant type to soil microbial mineralization. Second, it accelerates soil organic matter decomposition by providing better aeration to the cultivated soil surface. On the other hand, Achalu Chimdi *et al. (* 2012) reported the change of forestland to cultivated land has been associated with reduction in percent SOM content of the topsoil.

In general, one can corroborate that losses of forest-derived OM were not completely compensated by OM input from the cereal crops due to its low OM inputs and removal of residues from cultivated fields. This indicates that land use practices that have adverse effects on OM level and composition have far-reaching implications because of the multiple roles that OM plays in soil quality and link with soil fertility (Dawit Solomon *et al*., 2002).

2.3.3. Total nitrogen

Soil total nitrogen is naturally used as an important index for soil quality evaluation and reflects the soil Nitrogen status (Sui *et al*., 2005). In view of high nitrogen requirements of plants and low level of available N in virtually all type of soils, it considered most important and dynamic nutrient element in managed ecosystems. Soil total N composed of inorganic (NH_4^+, NO_3^- and NO_2^-) and organic forms (OM) are subject to change due to various factors. Management (cropping, fertilization, erosion and leaching) and climate (temperature and moisture) determine its level and dynamics (ICARDA, 2001). Climate condition, particularly temperature and rainfall generate a dominant influence on the amount of nitrogen and organic matter found in the soils. In a tropical environment where forest ecosystems are usually changed to agricultural systems, the total nitrogen content of soils tend to turn down quickly. Intensive cultivation of soil that led to a high rate of OM turn over accelerates its decomposition, makes the soil more susceptible to erosion, and decreases its water holding capacity at saturation (Waken Negassa, 2001: Dawit Solomon *et al*., 2002). This governs low total nitrogen content to be a characteristic feature of highly disturbed weathered soils in the humid and sub-humid tropics.

According to (Waken Negassa, 2001) reported that there was a 30% and 76% depletion of total N from agricultural lands cultivated for 40 years and abandoned the land, respectively, compared to the virgin land in *Bako* area, Ethiopia. Average total N increased from cultivated to grazing and forestland soils, which again decline with increasing depth from the surface to subsurface soils (Nega Emiru, 2006). Similarly Fantaw Yimer *et al*. (2007) and Eyayu Molla *et al*. (2009) who found a decreasing trend of TN with increasing soil depth and land use type in Eastern and Northwestern highlands of Ethiopia, respectively. In addition the study of Eyayu Molla and Mamo Yalew (2018) reported that total nitrogen increase surface soil due to large amount of root biomass, external inputs like animal wastes and other plant remains that occur in the topsoil surface as compared to lower soil depths.

According to (Yifru Abera and Taye Bekele, 2011) total N content of soils under cultivation were lower compared to contents in the natural forest soils. The increase in soil total nitrogen contents of forestland might be due to the vegetation cover that enhanced the soil organic matter contents. Land use type can affect the distribution of total nitrogen in the soil. Different studies have been conducted such as of Wasihun Mengiste *et al*. (2015) reported that total N declined with a shift of land uses from grazing land into cultivated lands, and average total N increased from cultivated 0.597% to grazing 0.681% soils. In addition, the study of Dawit Solomon *et al.* (2002) reported that the decline in TN by 46.77% in cultivated and by 17.42% in grazing lands from natural forest could be ascribed to rapid mineralization of SOM following cultivation and grazing which disrupts soil aggregates and thereby increases aeration and microbial accessibility to SOM. Other studies by Nega Emiru and Heluf Gebrekidan (2013) suggested total nitrogen content declined with a shift of land uses from the natural forest into agricultural lands, and with increasing soil depth from 0-20 cm to 20-40 cm.

2.3.4. Carbon to Nitrogen ratio

Carbon to nitrogen ratio (C:N) of soil is gained by dividing the organic carbon to total nitrogen. The concentration of either of two is expressed in the same unit (Lechisa Takele *et al*., 2014). Carbon (C) to nitrogen (N) ratio (C:N) is a sign of net N mineralization and accumulation in soils. Organic matter rich in carbon provides a large source of energy to soil microorganisms. Consequently, it brings population expansion of microorganism and higher consumption of mineralized N. Crowded populations of microorganisms inhibit the upper soil surface and have access to the soil N sources. If the ratio of the substrate is high, there will be no net mineralization and accumulation of N (Attiwill and Leeper, 1987).

Plant residues with Carbon to Nitrogen ratios of 20:1 or narrower have sufficient N to provide the decomposing microorganisms and to release N for plant use. Residues with Carbon to Nitrogen ratios of 20:1 to 30:1 provide sufficient N for decomposition but not sufficient to result in many releses of N for plant use the first few weeks after incorporation. Residues with Carbon to Nitrogen ratios wider than 30:1 decompose slowly because they lack adequate N for the microorganisms to use for increasing their number, which causes microbes to use N already available in the soil (Miller and Gardiner, 2001). They have further stated that the wider the Carbon to Nitrogen ratio of organic materials applied, the more is the need for applying N as a fertilizer to convert biomass into humus.

Land use change did not show significant differences in C:N ratio. Some studies that of Eyayu Molla and Mamo Yalew (2018) reported that C:N ratio did not show significant differences between land use types. However numerically the overall mean C:N ratio among land use types was higher in cultivated land and lower in grazing land. Other studies by Nega Emiru and Heluf Gebrekidan (2013) reported that the C:N ratio did not show significant differences but the numerical value for land uses are highest for cultivated land soils and lowest for forest soils which can be due to the rapid losses of N in the former.Thus, one can understand the impact of land use and associated management was more pronounced in soil nitrogen than organic carbon. In general, a Carbon to Nitrogen ratio less than10 may show the incorporation of low levels of organic matter in the soils of these land use types (Sakih *et al.,* 1998).

2.3.5. Available phosphorus

Phosphorus is known as the master key to agriculture because the luck of available P in the soil restrictions the growth of both cultivated and non-cultivated plants (Foth and Ellis, 1997). Following N, P as a more widespread influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forest and grasslands P uptake by plants are constrained by both the low total amount of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002).

Mohammed Assen *et al*. (2005) reported that variability of the level of available phosphorus was related to land use scenario, altitude, slope, and other characteristics such as content of clay particles and calcium carbonates. Similarly the contents of avilable phosphrus varies with depth. According to the reports of Mulugeta Seyum (2000) available phosphorus was higher in the upper horizon of the soil profile and decreasing further with depth. The lower concentration of available P at depth is due to fixation by clay and Ca, which were found to increase with profile depth. With regard to the level of extractable phosphorus in the soil, (Olsen *et al*., 1954) have indicated that extract phosphorus below 5 ppm was considered as low; between 5 to 10 ppm as medium; and greater than 10 ppm as high. The lowest value of available phosphorus extracted by both Olsen and Brady II extraction methods were obtained at the extreme lower subsoil depths both in cultivated and grazing lands (Ahmed Hussien, 2002). According to Carrow *et al.* (2004), P-Olsen between 12 to 18 mg/kg is considered as adequate and hence the available P in all land use was in sufficient range. It was also reported that soil P is more available in warm soil than in cool soil (Hartz, 2007).

Lechisa Takele *et al*. (2014) reported that the cultivated land showed 9% variation in overall mean available P content from the forest land which obviously could be due to crop mining, crop residue removal and erosion. In addition, Getahun Bore and Bode Bedadi (2015) reported that very low available P status in the cultivated and grazing land soils could be related with the low pH and high exchangeable acidity. For this reason, these soils with comparatively high exchangeable acidity can have the acidic cations such as exchangeable Al, H, and oxides of Al and Fe that could fix the soluble P in the soil solution. According to Eyayu Molla and Mamo Yalew (2018) reported that available phosphorus decreased by

3.75% with increasing soil depth. This ascribed to the increase in clay content with depth that might have caused phosphorus fixation and a decline in soil organic matter with depth in *Agedit* watershed, Northwest Ethiopia. In addition to Nega Emiru and Heluf Gebrekidan (2013) reported that available phosphorus decreased with increasing soil depth in *Senbat* watershed, Western Ethiopia. Similarly studies by Yihenew Gebreselassie and Getachew Ayanna (2013) reported that available P in all land use types decreased with increased soil depth due to increased clay and dcreased organic matter content with increased soil depth in *Achefer* District, Northwestern Ethiopia. Land use type can influence available P in the soil. The study of (Chikamnele *et al*., 2017) reported that change of forest and oil palm plantation to other land use types decreased available P. High concentration of available P under forestland and oil palm plantation compared to cultivated land and one-year grass fallow land was perhaps due to the reduced level of acidity. Generally, the availability of phosphorus under most soils decline by the impacts of fixation, abundant crop harvest and erosion (Gebeyaw Tilahun, 2015).

2.3.6. Cation exchange capacity

The Cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). Cation exchange capacity is an essential parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to keep nutrients against leaching and assessing their fertility and environmental behavior (Brady and Weil, 2002). Soils with higher amounts of clay and OM have higher CEC than sandy soils low in OM. In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while in the sub surface soil particularly where Bt horizon exist, more CEC is contributed by the clay fractions than by OM due to the decline of OM with profile depth (Brady and Weil, 2002). The CEC under the grazing and cultivated lands increased from the overlying to the underlying soil layer, which might be attributed to the increase in clay and OM contents with depth, respectively. Cation exchange capacity was significantly and positively correlated with clay and OM (Gebeyaw Tilahun, 2015). Similarly, CEC values were affected by increasing soil depth where it declined by 5.28%. Such drop down in CEC value in the subsoil with the parallel decline of SOM content is expected under normal circumstances (Eyayu Molla and Mamo Yalew, 2018).

Lechisa Takele *et al*. (2014) reported that the relatively high CEC values was recorded in forest land may attributed to the fact that soil in forest land accumulate high percent OC and has greater capacity to hold cations thereby resulted greater potential fertility in the soil. Therefore, soil CEC is expected to increase through improvement of the soil OM content. However, deforestation, overgrazing and changing of land from forest to cropland without proper management aggravates soil fertility reduction in the cultivated land. Similarly Getahun Bore and Bode Bedadi (2015), and Woldeamlak Bewket and Stroosnijder (2003) who reported highest CEC value in soils of forest land and lowest under cultivated land. According to Eyayu Molla and Mamo Yalew (2018), CEC of soil is determined by the relative amounts and/or type of the two main colloidal substances; humus and clay. Organic matter particularly plays important role in exchange process because it provides more negatively charged surfaces than clay particles do. On the other hand, the decrease in CEC with pH can be ascribed to a decline in CEC values as pH-dependent charge. Also Teshome Yitbarek *et al*. (2013) who suggested that low CEC in cultivated land was due to low clay and organic matter contents of the soils under this cultivated land. Similarly Wasihun Mengsite *et al*. (2015) reported that the cultivated land showed lower value of CEC than grazing land could be intensive cultivation, higher soil disturbance applied in cultivated land use types than the grazing land use types. On the other hand, Mengistu Chemeda *et al*. (2017) reported that CEC values decreased from surface to subsurface layers under different land use types.

Generally, the higher concentration of CEC was observed under natural forest compared to other land use types. This means the change of natural forest to other land use types decreased the CEC value of different land use types (Eyayu Molla and Mamo Yalew, 2018; Lechisa Takele *et al*., 2014; Mengistu Chemeda *et al*., 2017; Mesert Muche *et al*., 2015).

2.3.7. Exchangeable bases (Ca^{2+},Mg^{2+}, K^{+}, and Na^{+})

Exchangeable magnesium and calcium

Soils in the area of moisture deficiency (such as in arid and semi arid regions) have less potential to be affected by leaching of cations than do soils of humid and sub humid regions. Soil under continuous cultivation, use of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH are characterized by low contents of calcium (Ca) and magnesium (Mg) nutrients resulting in Ca and Mg deficiencies due to excessive leaching (Dudal and Deckers, 1993). According to Tisdale *et al*. (2002) reported that exchangeable cations generally are available to both higher plant and microorganisms. By cation exchange, H^+ ion from the root hair and microorganisms return nutrient cations from the exchange complex. According to Jones (2003) stated that, the exchangeable Mg content of the study area is rated as medium. The result confirmed that the exchangeable magnesium contents were well maintained in the forest ecosystem due to nutrient recycling when compared to grazing and cultivated lands, where basic nutrients loss upon grazing and harvesting prevailed.

The study of Lechisa Takele *et al*. (2014), stated that similar to exchangeable Mg, the exchangeable Ca was high in forestland and low in cultivated land. The low content of exchangeable Ca in cultivated land attributed to soil erosion and abundant crop harvest for the past three decades, which contributed for the reduction of Ca in the cultivated lands. With regard to Teshome Yitebarek *et al*.(2013) who observed highest and lowest exchangeable Ca in forest and cultivated lands, respectively in western Ethiopia of *Ababo* area. On the other hand, the study of Eyayu Molla and Mamo Yalew (2018) reported that the content of both Ca and Ma increased with soil depth. The increasing trend of exchangeable Ca and Ma with soil depth could be associated with an increase of clay particles in subsurface than surface soil. However, Gebeyaw Tilahun (2015) suggests that the content of exchangeable Ca and Ma decreased with soil depth except the cultivated land. These indicated there was higher down ward leaching of basic cations in the crop field than other land use types. Generally land use types affect the concentration of exchangeable Ca and Mg. some studies that of Achalu Chimdi *et al*. (2012) reported that changes in land use types from forest land to cultivated land have resulted in a decline of exchangeable Ca and Mg contents by 60.43 and 65.65% respectively. Compared to forest land the relatively lower concentrations of exchangeable Ca, Mg, K and Na contents recorded in soils of cultivated could be attributed to continuous losses in the harvested parts of plants and leaching of basic cations from top soils of cultivated land. Similarly, the studies of Gebeyaw Tilahun (2015) reported that land use types significantly affected exchangeable calcium and magnesium contents.

Exchangeable sodium and potassium

Exchangeable sodium alters soil physicochemical properties mainly by inducing swelling and distribution of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (Sposito, 1989). In general, high exchangeable Na in soil causes soil sodicity, which affects soil fertility and productivity (Sposito, 1989). Land use change influences the exchangeable sodium in the soil. The study of FantawYimer *et al*. (2008) who reported lower concentration of soil exchangeable Na in cultivated than in grazing lands and native forest.

Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, and the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution (Foth and Ellis, 1997). Potassium is the third most important essential element next to N and P that restrict plant productivity. Its behavior in the soil is influenced primarily by soils of cation exchange capacity and mineral weathering rather than by microbiological processes (Brady and Weil, 2002). Wakene Negassa (2001) reported that the difference in the allocation of K depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. The better the proportion of clay mineral high in K, the better will be the potential K availability in soils (Tisdale *et al*., 2002). The low exchangeable K contents observed under cultivated land could probably due to continuous cultivations and inorganic farming practices in the study area which is supported by previous findings that indicate intensity of weathering, cultivation and use of acid forming inorganic fertilizers affect the distribution of K in the soil system and increase its depletion (Mengistu Chemeda *et al*., 2017). In addition, Eyayu Molla and Mamo Yalew (2018) reported that the higher content in the forestland could be related with its high pH value.

Chapter 3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

The study was conducted in *Mere* watershed located in *Dera* District, South Gondar Zone, Amhara National Regional State (ANRS), northwestern Ethiopia. It is situated 614 km northwest of Addis Ababa and 42 km northeast of Bahirdar city. Geographically, the watershed lies between 11^0 41′ 26″ to 11^0 43′ 07″ N latitude and 37^0 35′ 30″ to 37^0 38′ 30″ E longitude. The study area covers about 336.36 ha (Fig 3.1).

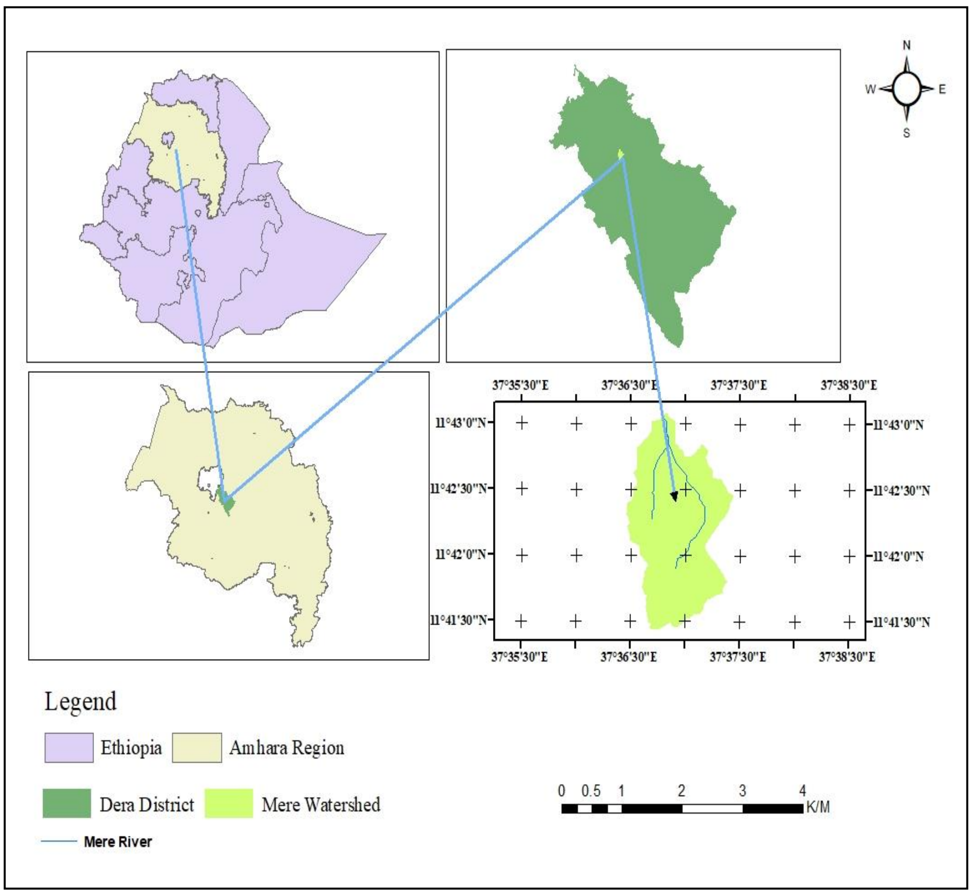

Figure 3.1: Location map of the study area

3.1.2. Topography and climate

Mere watershed is characterized by gentle to steep slope topography. Its altitudinal range from1915 to 2146 m.a.s.l. Most of *Mere* watershed is characterized gentle slope to undulating plain with the slope range 3-25% (*Dera* District Agriculture Office, 2016). The rainfall of *Mere* watershed area is variable in nature with unimodal pattern and has average annual rainfall is 1845.83 mm. The rain season is from May to October. The month of July and August receives the highest amount of rainfall. The mean temperature range minimum10.7^{0}c and maximum 25^{0}c for the period from 2008 to 2017 (Fig 3.2 and Appendix Table 1). The study area is characterized by woina dega agro climatic zone (NMA, 2018).

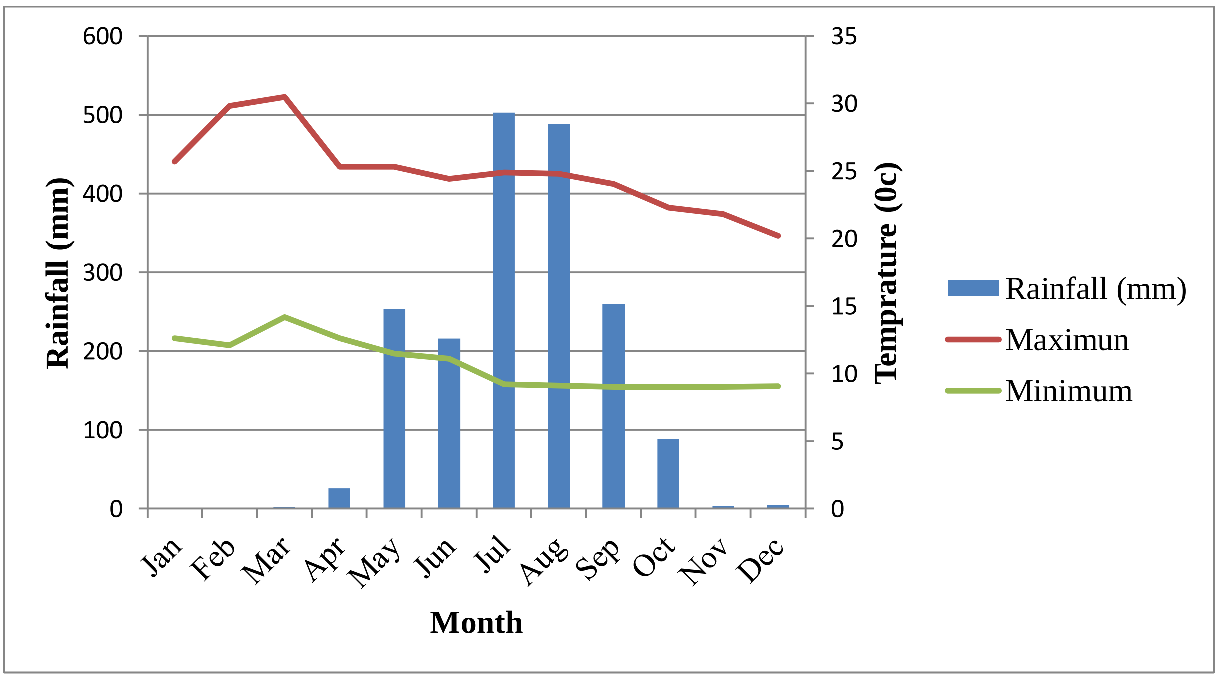

Figure 3.2: Mean monthly rainfall (mm) and air temperature (0c) for a decade (2008 – 2017) in the *Mere* watershed. Source: - NMA, 2018

3.1.3. Geology and soils

According to Mohar (1971), the geology of the study area is covered with thick trap series volcanic rocks. The trap volcanic series consists mainly of weathered and jointed basalt. According to *Dera* District Agriculture Office (2016), the common types of soil in the study area are Nilosols, Cambisols, Vertisols, Luvisols and Alisols.

3.1.4. Population

Dera District has a total population of 294040 an increase of 15.49% over 2007 census, of whom 146030 are male and 148010 female; 28634 or 9.74% are urbandwellers.Total of 69665-households was counted in this *woreda*, resulting in an average of 4.22 persons to a household (*Dera* District Administration Office, 2018).

3.1.5. Land use and farming system

The major land use types in the study watershed are cultivated land that accounts 72.88%, grazing land 7.63%, plantation forest10.1% and remenant natural forest 0.39%, and settlement 9%.The study area is suitable for different crop production. The main crops grown are maize (*Zea mays)*, tef *(Eragrostis tef)*, finger milt (*Eleusine coracana*), bread wheat (*Triticum aestivum)*, potatoes *(Solanum tubersoum)* and different oil crops (*Dera* District Agricultural Office, 2016).

The watershed farming system is dominated by traditional rain feed subsistence farming and grazing on communal lands. They used to subsistence mixed crop-livestock farming. Cattle and small ruminants comprise the major livestock classes raised by the community in the watershed. 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 agroforestry system with scattered trees on farmlands

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

Land use type	Description
Cultivation land	Continuous cultivated land and cultivated land mixed with sparse/scattered trees. the major crops grown include maize (*Zea mays)*, teff *(Eragrostis tef)*, oil crops and finger milt *(Eleusine coracana)*
Natural forest	It consisted of tall natural trees and shrubs such as *Juniperus procera*, *Podocarpus falcatus, Olea eroupaea, Cordia africana, Croton macrostachyus, Albizia gummifera, Ficus sur,* and *Acacia albida*
Grazing land	Areas are degraded with continuous grazing system and overgrazing a prevailing situation
Plantation forest	Mainly consisted of and dominated by Eucalyptus species such as *Eucalyptus globules* and *Eucalyptus grandis*
Settlement	Mainly consisted of and dominated by scattered settlement and some densely home some part of the watershed boundary.

3.2. Data Source and Land Cover Change Analysis

In this study land use/land cover changes were monitored at two-period intervals (1990-2018). Data required for the study were generated from a multispectral Land-sat satellite image (Land sat-ETM, resolution 30m x 30m, path = 170 and 169 and row = 52). The boundary of the study area was delineated on automatic delineation methods by using outlet points taken on the field. The land sat image was downloaded in zip format and has to be extracted in to TIFF format by using WINRAR software. ERDAS IMAGINE 2013 was used to perform different pre-processing activities before actual processing of the image. Before the interpretation of the satellite images, a reconnaissance survey was carried out to obtain a general understanding of land use/cover patterns of the study area. Then, identification and classification of land use/cover on the satellite images were monitored for visual perfection. Four land use/cover categories (forest land, cultivated land, grazing land and settlement) were identified. Due to the fact the scale of analysis made it difficult to separate plantation forest from natural forest, these were grouped together as one forest land. Similarly grassland was grouped into grazing lands because it was difficult to distinguish one from the other as they had the same tone on the image. To mantain uniformity among spatial data, the geo-reference data made in to similar map projection of World Geodetic system (WGS 1984); Universal Travers Mercator (UTM) Zone 37 N. The land use/cover classes from the 2018 land sat image (Land sat-ETM) were produced by supervised digital image classification method in ENVI (Environment for Visualizing Images) 4.3 software using training area taken on the basis of false colour composite (reflectance characteristics) of each land use/cover classes. The use of arc GIS 10.1 software was made it possible to link the polygon lines to label the specific land use/cover classification and calculate the statistics of each polygon. Finally, two land use/cover maps were produced corresponding to the two years (1990 and 2018) and subsequently comparing the results.

3.3. Soil Sampling

Four major land use types namely natural forest, grazing land, plantation forest, and cultivated lands were selected in the watershed. Soil samples were collected from representative sites of each of the four land use types in three replicates. Precautions were taken during the selection of sampling sites to locate them within similar physiographic conditions such as slope and aspect. Three representative plots (10 m x 10 m) for each land use types were located adjacent to and to a maximum distance of 50 to 100 m from the natural forest. Before sampling, plant and grass litter including any other material on the soil surface were removed. Then, in each plot soil samples were collected in four corners and at the center in two different soil depths i.e. 0-20 cm and 20-40 cm. Each of the soil samples from the two depths consisted of five sub-samples that were bulked to make a single composite soil sample for the respective soil depths. Consequently, a total of 24 composite samples were collected from the four land use types (4 land uses x 2 depths x 3 replications). Additional undisturbed soil samples of known volume were collected in all plots of each land use type and sample depths in three replications for bulk density determination.

3.4. Laboratory analysis

The disturbed composite soil samples collected from the representative plots of each land use type was air-dried, mixed well and passed through a 2 mm sieve for all parameters to be studied except for total nitrogen and organic carbon which passed through 0.5 mm sieve to remove the coarser materials for the analysis of selected soil physical and chemical properties. The soil physical and chemical analysis was carried out in the soil testing laboratory of Amhara Design and Supervision Works Enterprise, Bahir Dar.

3.4.1. Analysis of soil physical properties

The major soil physical properties including soil texture and bulk density were analyzed. A Soil texture was analyzed by the Bouyoucos hydrometer method. Hydrogen peroxide (H_2O_2) was used to destroy the organic matter and sodium hexametaphosphate ($NaPO_3$) was used as a dispersing agent. Finally, soil textural names were determined following the textural triangle of USDA system as described by Rowell (1994). The bulk density (BD) of the soil was estimated from undisturbed soil samples collected using a core sampler from each land uses type and weighed at field moisture by Blake (1965).

3.4.2. Analysis of soil chemical properties

The selected chemical properties of soil such as pH, CEC, exchangeable bases (Ca, Mg, Na, and K), total nitrogen content, available P, and organic carbon were analyzed. The organic carbon content of the soil was analyzed by following the wet digestion method while soil OM equated by multiplying percentage of soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon as described by (Van Reeuwijk, 1992). The pH of the soils was measured in water suspension in a 1:2.5 (soil: liquid ratio) by pH meter (Van Reeuwijk, 1992). While total nitrogen (N) was determined using the micro-Kjeldahl digestion, distillation and titration procedure as described by (Jackson, 1958). Available phosphorus of soil measured by following the Olsen method (Olsen *et al*., 1954). Exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Then extracted exchangeable Ca and Mg analyzed using atomic absorption spectrophotometer, while extracted Na and K measured by flame photometer (Rowell, 1994). The cation exchange capacity (CEC) of soil samples were first leached with 1 M ammonium acetate, then washed with ethanol and Na, replaced the adsorbed ammonium. Finally, the CEC measured titrimetrically by distillation of the ammonia that was displaced by sodium (Chapman, 1965).

3.5. Statistical Analysis

Prior to statistical analysis, treatments were arranged in a factorial randomized complete block design format of land use and soil depth factors. Then statistical differences in soil characteristics among land use types and soil depths were tested using a two-way analysis of variance (ANOVA) following the General Linear Model (GLM) procedure of the statistical Analysis System (SAS 9.0) version. When significant differences were observed comparisons of means were performed using Tukey's honest least Significant Difference (LSD) at 5% probability level. Correlation anayses were carried out to determine the relationships between soil parameters.

Chapter 4. RESULTS AND DISCUSSIONS

4.1. Land Use Land Cover Change Analysis (1990-2018)

4.1.1. Forestland

Forestland (natural +plantation forest) covers during the study period (1990-2018) increased from12.17 to 13.49% (Table 4.1 and Figure 4.1 and 4.2). In 1990, 12.17% (40.92 ha) of the study area was covered by forestland but it increase to 13.49% (45.37 ha) in 2018 (Table 4.1). Within 28 years, the overall pattern was expanded by 1.32% (4.45 ha: Table 4.1). The result in line with Biru Yitaferu (2007), report in the Lake Tana basin forestland increments from 1985 to 2003. The increment of forestland was due to most of farmers of the study area planting eucalyptus trees on their farmlands and the homestead. According to Birhan Asmame and Assefa Abegaz (2017), report forestland from 1986-2014 years due to tree plantation of local communities in *Gelana* sub-watershed. However, the local elder communities said that the natural forest was decline from 1990 to 2018 due to rapid population growth, shortage of land, the need for more production and use of forest for charcoal and fuel wood. The field survey indicated that the natural forests are mainly found around church. Generally, the natural forest significantly decreased since it shift to other land uses through deforestation is a continuous trend in different parts of Ethiopia reported by (Kebrom Takle and Hodlund, 2000; Gete Zeleke and Hurni, 2001 and Eyayu Molla *et al.*, 2010).

4.1.2. Cultivated land

Cultivated land was found the highest coverage in the study area, it covered abought 80.17% (269.67 ha) in 1990 but in 2018 it covered 69.84% (234.9ha) (Table 4.1, Figure 4.1 and 4.2). The land use/ cover change detection analysis showed that the cultivated land declined by 10.34% (34.77 ha) while grazing land, forestland and settlement increased by 2.24%, 1.32% and 6.78%, respectively. Some elders in the study said that the change of natural forest to cultivated land might be due fertility problems on cultivated lands. The trend shows that cultivated land declined by 10.34% (34.77 ha) in the study period (Table 4.1). On the average the cultivated land has decreased by 0.4% annualy in1990 to 2018 years. The result was similar to Hussien Ali (2009) reported cultivated land has decreased by 0.2% averagely in the period from 1972 to 2005 in *Lenche dima* area.

Table 4. 1: The land use/cover type coverage of *Mere* watershed in 1990 and 2018

Land use/cover types	Area covered by respective land/cover types				Change in land use area (% &ha) coverage gain (+) loss (-)	
	1990		2018		1990-2018	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Cultivated Land	269.67	80.17	234.90	69.84	-34.77	-10.34
Settlements	7.63	2.27	30.42	9.04	+22.79	+6.78
Forest Land	40.92	12.17	45.37	13.49	+4.45	+1.32
Grazing Land	18.14	5.39	25.67	7.63	+7.53	+2.24
TOTAL	336.36	100.00	336.36	100.00	0.00	0.00

4.1.3. Grazing land

Results from this study showed that the grazing land increased from 5.39% to 7.63% in 28 years interval period (Table 4.1). In 1990, grazing land coverage 5.39% (18.14 ha) of the study but it increased to 7.63% (25.67 ha) in 2018. Thus it increased by 2.24% (7.53 ha) in the study period (Table 4.1) at the expense of cultivated land (Figure 4.1 and 4.2). The result inline with Birhan Asmame and Assefa Abegaz (2017), report grass land coverage increased in the study period of (1964-1986) in *Gelana* sub-watershed, North of highlands of Ethiopia.

The increase grazing land in the study period (1990 to 2018) might be attributed to the 1996 and1997 land redistribution programme of Amhara regional state in the study area. Hence, additional lands were left for grazing purpose in the study area during this period of land redistribution.

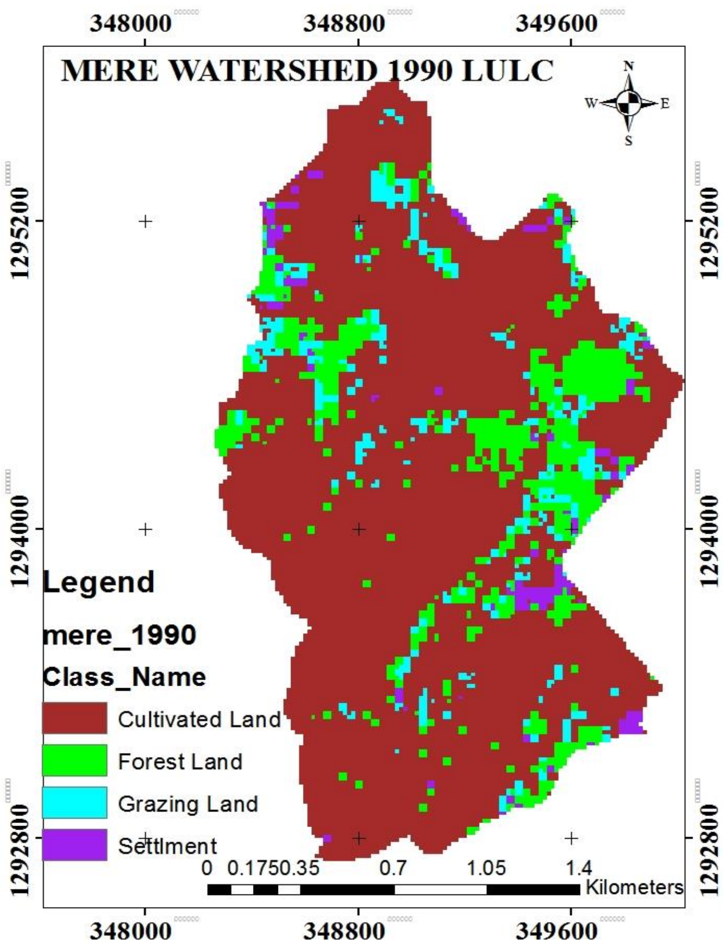

Figure 4.1: *Mere* watershed land use / cover map in 1990

4.1.4. Settlement

Settlement is the major land use next to cultivated land and forestland in 2018. It was expanded from 2.27% (7.63 ha) in 1990 to 9.04% (30.42ha) in 2018 (Table 4.1) due to population increment in the watershed. The settlement coverage was increased by 6.78% (22.79 ha) in the watershed in a given periods (Table 4.1). The land use /cover change detection analysis revealed that the increase of settlement covers observed in the study area took place under cultivated lands (Figure 4.1 and 4.2). The result was similar to Birhan Asmame and Assefa Abegaz (2017), reported that increased rural settlement land due to increasing population pressure in *Gelana* sub-watershed of North of highlands of Ethiopia. In this study also cultivated land changed to settlement.

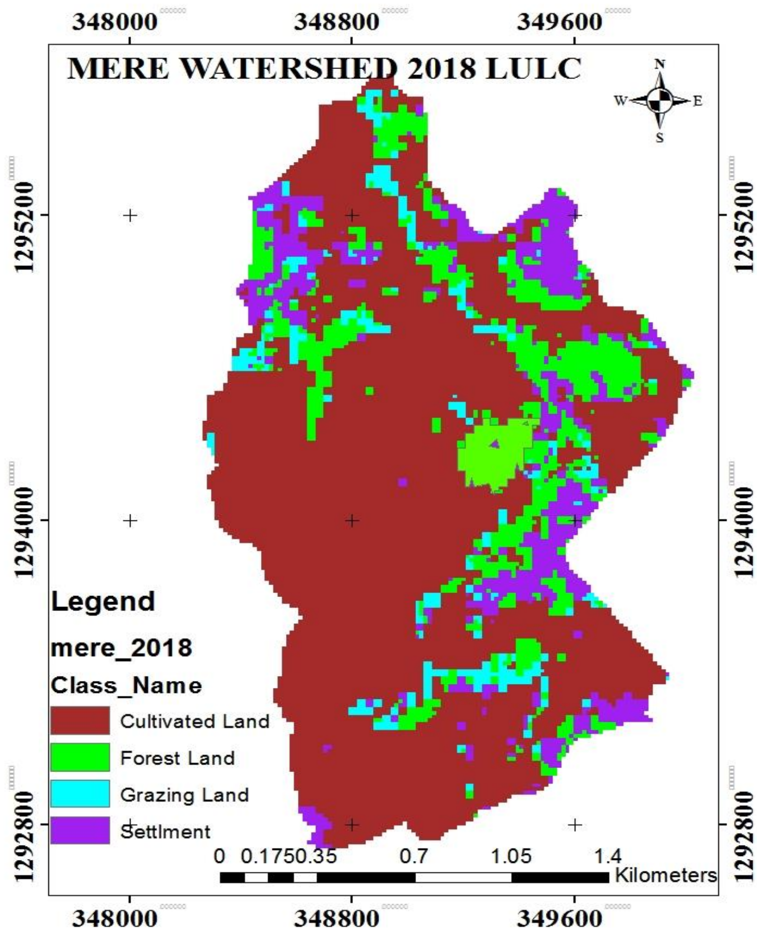

Figure 4.2: *Mere* watershed land use / cover map in 2018

4.2. The Effect of Land Use Type and Soil Depth on Soil Physical Properties

4.2.1. Soil texture

The analysis showed that the textural classes of all land use types except natural forestland were clay (Table 4.2). This indicated that soils of all land use types drived from similar parent material. The sand and clay proportion of soils significantly ($p < 0.05$) varied among land use types (Table 4.2).Whereas, both soil depth and the interaction effect of land use and soil depth didn`t show significant ($p > 0.05$) difference (Table 4.3 and Appendix Table 2). The higher (32.67%) sand proportion was recorded in plantation forest soil and the highest (57.33%) clay was observed under grazing land (Table 4.4). Nevertheless, the silt content was not significantly ($p > 0.05$) affected by land use, soil depth and interaction effect (Table 4.2 and Appendix Table 2). This result was similar to Eyayu Molla and Mamo Yalew (2018) who reported significant difference with sand and clay fraction between land use types in *Agedit* watershed, Northwestern Ethiopia. The clay fraction of grazing land, cultivated land and plantation forest was higher as compared to natural forest (Table 4.2).

However, silt contents of natural forestland was numerically higher than other land use types. This result was inline with the report of Lechisa Takele e*t al*. (2014), who showed that silt particles were higher in the forestland than both cultivated and grazing lands at *Gindebert* area, Western Oromia, Ethiopia. This might be associated with similarity in land use and management practices. Generally, in this study soil textural class was not significantly different with soil depth. However, numerically, the contents of sand fraction decreased and the clay fraction increased with an increased soil depth. This result was inline with Eyayu Molla and Mamo Yalew (2018) that reported the an increase in clay content and a decrease in sand and silt fractions in the lower soil depths. This could be attributed to the downward movement of clay particles in the soil profile and the removal of finer soil particles from surface soils by erosion leaving behind the coarser (sand and silt) fractions. Mengistu Chemeda *et al*. (2017) also reported that an increase in clay contents with depth in different land use types in *Warandhab* area, Oromia, Western Ethiopia.

4.2.2. Bulk density (BD)

Soil BD was significantly ($P < 0.01$) affected by land use types (Table 4.2), but not with soil depth and the interaction effect ($P > 0.05$; Table 4.2). The higher value (1.34 g/cm^3) of bulk density was recorded under cultivated land while the lower value (1.13 g/cm^3) in the natural forest (Table 4.2). The lower bulk density under natural forest might be related to higher organic matter content in the soil. The result was inline with Getahun Bore and Bode Bedadi (2015) report the lower bulk density observed in forest land soils of *Loma* Woreda, Southern Ethiopia. Since it has higher soil organic matter content and consequently large number of pore spaces caused lower bulk density. The cultivated land's bulk density value followed by plantation forest and grazing land had the higher BD than the adjacent soils of natural forest

(Table 4.2).Thus it concurs to the report of Eyayu Molla *et al*. (2009) and Achalu Chimdi *et al*. (2012).

Table 4. 2: Effects of land use and soil depth on selected soil physical properties (Mean±SE)

Land use or soil depth	Particle size (%)			Textural Class	BD (g/cm^3)
	Sand	Silt	Clay		
Land use type					
Natural forest	31.33±3.32[a]	32.5±3.59	36.17±5.36[c]	CL	1.13±0.02[c]
Cultivated land	24.33±3.2[ab]	22±3.08	53.67±5.15[ab]	C	1.34±0.02[a]
Grazing land	17.67±2.67[b]	25±2.36	57.33±4.97[a]	C	1.2±0.05[bc]
Plantation forest	32.67±3.84[a]	27.33±2.27	40±5.75[bc]	C	1.28±0.04[ab]
LSD (0.05)	9.35	9.72	16.38		0.11
P	*	NS	*		**
SEM (±)	3.25	2.83	5.31		0.033
Soil depth (cm)					
0-20	27.5±2.84	26.25±2.29	46.25±4.52	C	1.22±0.04
20-40	25.5±2.84	27.17±2.22	47.33±4.43	C	1.25±0.03
LSD (0.05)	6.61	6.88	11.58		0.07
P	NS	NS	NS		NS
SEM (±)	2.84	2.26	4.47		0.035
CV (%)	29.67	30.5	29.38		6.9

Mean values within a column followed by the different letters are significantly different from each other at $^{**}p < 0.01$, $^{*} P < 0.05$. (NS = Not significant; BD = Bulk density; C = clay; CL= clay loam)

The higher bulk density in cultivated lands could be attributed to compaction of surface soil by intensive cultivation. The finding agrees with Achalu Chimdi *et al*. (2012) that reported higher bulk density value in cultivated land due to compaction of soil in *Guto Gida* District, Western Ethiopia. However, this finding contradict with Wasihun Mengiste *et al. (*2015) result lower bulk density value obtained in cultivated lands due to traditional tillage practices by the local people in *Itan-kir* area of Gambella region, Ethiopia.

On the other hand soil BD was not significantly affected by soil depth (Table 4.2), but its value numerically increased by soil depth due to low soil organic matter. The result was similar to Eyayu Molla *et al.* (2009) that reported numerically increased BD with an increase in soil depth due to a decline in soil organic matter (SOM).

4.3. The Effect of Land Use Type and Soil Depth on Soil Chemical Properties

4.3.1. Soil reaction (pH)

The soil pH (H_2O) value was significantly ($p < 0.01$) affected by individual effects of land use type and soil depth (Table 4.3), but insignificant ($p > 0.05$) by the interaction effect of land use type and soil depth (Appendix Table 2). The highest pH (6.16) and the lowest (5.11) soil pH values were observed in the natural forest and plantation forest, respectively (Table 4.3). This result was inline with Nega Emiru and Heluf Gebrekidan (2013) who disclosed that varation of soil pH with land use type in *Senbat* watershed, Western Ethiopia.

The highest pH value under forestland could be due to higher organic matter content and higher total exchangeable bases. This finding was inline with Getahun Bore and Bode Bedadi (2015) who investigated higher pH in forestland soils that had higher soil organic matter contents. Organic matter can bind tightly Al ions and reduce their activity in the soil solution thereby increase as pH while reduce acidity. The main reason for the lowest value of soil pH in the Eucalyptus plantation forest could be due to prolonged uptake of basic cations by tree roots. Similarly, the decrease in soil pH of grazing and cultivated lands could be due to the depletion and removal of basic cations resulted from continuous soil disturbance and accelerated soil erosion that caused the deterioration of soil quality. This result agrees with the work of Yihenew Gebreselassie and Getachew Ayanna (2013), that reported higher acidity in Eucalyptus plantation due to the higher uptakes of basic cations by the trees and poor return rate to the soil in *Achefer* District, Amhara Region, Northwestern Ethiopia. An increase in acidity in cultivated land may also be due to loss of base forming cations down the soil profiles through leaching, to continuous cultivation and addition of nitrogenous fertilizer such as diammonium phosphate $(NH_4)_2HPO_4$) in the cereal based cultivated fields could contribute to increased acidity level (Eyayu Molla and MamoYalew, 2018).

On the other hand, the higher pH value (5.74) was recorded in the 20-40 cm soil depth (Table 4.3). The main reason for the highest pH value in subsurface soil could be higher in basic cations along with increase soil depth. Moreover, soil pH and basic cations usually show positive relationship with each other (Table 4.5). The result similar with study of Kumar *et al*. (2012) that disclosed soil pH increased with the soil depth. Generally, the soil pH of the study area in ranges between 5.11 and 6.16 as per Tekalign Mamo (1991) rated as “strongly acidic” to “slightly acidic” (Appendix Table 6).

4.3.2. Soil organic matter (SOM)

Soil organic matter has an important influence on soil physical and chemical characteristics, soil fertility status, plant nutrition and biological activity in the soil (Brady and Weil, 2002). Organic matter content was highly significantly ($p < 0.01$) affected by land use type and significantly ($p < 0.05$) affected by soil depth (Table 4.3), but insignificantly ($p > 0.05$) affected by interaction effect of land use type and soil depth (Appendix Table 2). The higher (3.65%) soil organic matter content was obtained in the natural forestland while lower (2.05%) value in the plantation forest (Table 4.3).

The highest soil organic matter under forestland could be resulted from the accumulation of residues such as litter cover, organic inputs, root growth and decay and abundance of burrowing fauna in the upper few centimeter soil depth and their lower rate of decomposition and disturbances (Saikeh *et al*., 1998, Khresat *et al*., 2008 and Price *et al*., 2010). The organic matter content of grazing land was also higher than cultivated lands but lower than the natural forest because of its higher biomass than the cultivated lands where the crop residues are removed completely for animal feed and fuelwood. This result was similar to Nega Emiru and Heluf Gebrekidan (2013) that reported lower level of disturbance of grazing land has led to more organic matter content in grazing land than cultivated land. However, the organic matter content of gazing land at both depths was found lower than those under forest lands. This situation can be ascribed to the fact that continuously degraded and abandoned lands are left for grazing purposes. Besides this, overstocking of livestock causes the removal of grass and forage biomass, ultimately discourage the accumulation of organic matter (Nega Emiru and Heluf Gebrekidan, 2013).

The lowest soil organic matter value under plantation forest could be associated to more uptake of nutrient, low accumulation soil organic matter and poor biomass return rate on to the soil as farmers of the study area used to planting eucalyptus trees on degraded lands of the watershed. On the other hand , the low organic matter content of cultivated land and grazing land might be attributed by low biomass return and livestock consumption, respectively. In a similar study, Assefa Abegaz *et al.* (2016) also reported that low soil organic matter content of cultivated land due to accelerated rate of erosion and fast decomposition of organic matter in cultivated than in forest and grazing lands.

The highest organic matter (2.83%) was recorded from the surface soil (0-20 cm) than subsurface soil (20-40 cm; Table 4.3). This is attributed partly to the continuous accumulation of non-decayed and partially decomposed plant and animal residues in the surface soils. The result inline with Nega Emiru and Heluf Gebrekidan (2013) finding also higher OM content obtained in the 0-20 cm soil layer than the corresponding subsurface soils. Generally, forest land conversion into cultivated land in tropical ecosystems known to bring about remarkable depletion of the SOM stock (Eyayu Molla and Mamo Yalew, 2018). Soil organic matter content of *Mere* watershed as per Ethiosis (2014) report indicated that it ranged from low in grazing land, cultivated land, and plantation forests to medium for natural forest (Appenix Table 6).

4.3.3. Total Nitrogen

Total N content of the soil was highly significantly ($p < 0.01$) affected by land use type and significantly ($p < 0.05$) by soil depth (Table 4.3) but insignificantly ($p > 0.05$) affected by the interaction effect (Appendix Table 2). The higher total N (0.20%) value was recorded in natural forest while low value (0.10%) under plantation forest. However, no statistically difference among cultivated land, grazing land and plantation forest (Table 4.3).

The highest total N value of forestland might be due to resulted from higher plant residue and minimal rate of decomposition as compared to other land use types. This finding also supported by Getahun Bore and Bode Bedadi (2015) study who reported higher amount of total N in forest land soils due to addition of higher plant residues and minimal rate of decomposition in *Loma* District, Southern Ethiopia. Moreover, Lechisa Takele *et al*. (2014) showed the highest soil total nitrogen obtained in forest land due to its more vegetation cover which improved the soil organic matter content in *Gindebert* area, Western Oromia, Ethiopia. However, Alemayehu Kiflu and Sheleme Beyene (2013), stated that higher total N obtained in grassland which association with higher organic matter content in *Delbo Atwaro* watershed, Southern Ethiopia. On the other hand, the high value of total nitrogen observed under forestland as compared with the grazing and cultivated lands since forest land adequate vegetation cover helps to moderate soil temperature, air and moisture against total nitrogen loss by volatilization (Chikamnele *et al*., 2017). Nega Emiru and Heluf Gebrekidan (2013) stated that remarkable losses of total N in the continuous cropping fields by rapid mineralization of soil organic matter following cultivation, that disrupts soil aggregates and thereby increases aeration and microbial accessibility to organic matter.

On the other hand, the higher total N (0.15%) was recorded in the surface (0-20 cm) but lower (0.12%) in subsurface soils (Table 4.3). The higher total N of topsoil was directly related to more organic matter on the surface soil. This result agrees with the study of Eyayu Molla and Mamo Yalew (2018), who detected a total N increase in the surface soils due to large amount of root biomass, external debris that remains in the top surface soil as compared to the lower soil depth.

The total nitrogen level of soil in the study area as per Ethiosis (2014) report indicated that it ranged from optimum in natural forest land to low in cultivated land, grazing land, and plantation forest (Appendix Table 8). The correlation analysis showed that strong and positve correlation (r = 0.95) between total nitrogen and soil organic matter (Table 4.5). Taye Kufa *et al*. (2003) reported that the incorporating high organic matter containing substances as it decomposed increased its organic carbon and total N content.

Table 4. 3: Effect of land use and soil depth on selected soil chemical properties (Mean±SE)

Treatment	pH (H_2O)	SOM (%)	TN (%)	C:N	AV.P (ppm)
Land use type					
Natural Forest	6.16±0.13[a]	3.65±0.56[a]	0.20±0.03[a]	11.02±0.7	12.54±1.95[a]
Cultivated land	5.62±0.18[b]	2.24±0.14[b]	0.11±0.01[b]	11.86±0.5	8.36±0.71[b]
Grazing land	5.53±0.05[b]	2.3±0.14[b]	0.12±0.01[b]	10.88±0.4	5.55±0.31[b]
Plantation forest	5.11±0.13[c]	2.05±0.19[b]	0.10±0.01[b]	11.48±0.2	5.44±0.50[b]
LSD (0.05)	0.25	0.73	0.04	1.18	2.91
P	**	**	**	NS	**
SEM (±)	0.123	0.257	0.015	0.45	0.87
soil depth (cm)					
0-20	5.47±0.15[b]	2.83±0.35[a]	0.15±0.02[a]	11.08±0.5	9.05±1.32
20-40	5.74±0.13[a]	2.29±0.16[b]	0.12±0.01[b]	11.54±0.2	6.90±0.79
LSD (0.05)	0.18	0.52	0.028	0.83	2.2
P	*	*	*	NS	NS
SEM (±)	0.138	0.256	0.014	0.35	1.06
CV (%)	3.59	23.1	24.48	8.3	29.45

Mean values within a column followed by the different letters are significantly different from each other at **$p < 0.01$ * $P < 0.05$. (NS = Not significant; SOM = Soil Organic matter; TN = Total Nitrogen; C : N = Carbon Nitrogen ratio; AVP = Available Phosphorus).

4.3.4. Carbon to Nitrogen ratio (C : N)

The C: N ratio did not show a significant difference between land use type and soil depth (Table 4.3). However, numerically the higher C: N ratio was recorded in cultivated land but the lower value in grazing land (Table 4.3). This finding also supported by Eyayu Molla and Mamo Yalew (2018) study that showed insignificant differences in the C: N between land use types and depth, however, numerically the overall mean C: N ratios among land use types were higher in cultivated land but lower in grazing land. Tillage enhance aeration and increased temperature as a result it increase mineralization rates of OC could probably be decreasing of C: N ratio in cultivated land (Dawit Solomon *et al*., 2002). In another study However, Achalu Chimdi *et al*. (2012) that reported, a relatively narrow C:N ratio in cultivated land than in the forest lands.

On the other hand, the C: N ratio was significantly ($p < 0.05$) affected by their interaction effect of land use and soil depth (AppendixTable 2). The highest (12.7) C: N ratio was recorded from cultivated surface soil and the lowest (9.94) C: N values recorded at surface (0-20 cm) forest land (AppendixTable 3).

Generally, according to Foth and Ellis (1997) reports soils with a C: N ratios between 10 and 12 provide nitrogen above microbial needs. Therefore, the result obtained in forest, cultivated, grazing, and plantation forest land use types showed optimum range for active microbial activities of humification and mineralization of organic residues (Table 4.3).

4.3.5. Available phosphorus (AVP)

The available phosphorus was significantly ($p < 0.01$) affected by land use type (Table 4.3), but insignificantly ($p > 0.05$) affected by soil depth and the interaction effect (Table 4.3 and Appendix Table 2). The highest (12.54-ppm) and the lowest (5.44-ppm) available phosphorus values were recorded in the natural forestland and plantation forest, respectively (Table 4.3). However, no statistical parity results ($p > 0.05$) were obtained between the three land use types. An increase in AVP content in natural forest could be the result of higher soil organic matter content as AVP has a positive and strong correlation with SOM ($r = 0.67$). This result was inline with Eyayu Molla *et al*. (2009), that reported variations in AVP among soils of different land uses in *Tara Gedam* catchment due to SOM dynamics.

Among the land use type, the natural forestland contained a relatively higher concentration of AVP. This result is in agreement with the work of Yihenew Gebreselassie and Getachew Ayanna (2013) in *Achefer* District, Northwestern Ethiopia that associated the higher concentration of available phosphorus to high organic matter content that released phosphorus during mineralization. However, this result disagrees with the reports of Mengistu Chemeda *et al*. (2017) stated that higher available P content of soils in cultivated land in *Warandhab* area, Oromia, Ethiopia. They justified their result to the application of mineral P fertilizers indicated by different farmers in the area.Very low available P in the cultivated, grazing land and plantation forest could be associated with the low pH and low organic matter content. Hence, these soils with lower pH have the acidic cations such as Al and Fe that could fix the soluble phosphorus in the soil solution. In connection with this correlation analysis showed a strong and positive correlation (r = 0.59) of available P with soil pH (Table 4.5). Besides, the lowest AVP content was observed under plantation forest due to low pH value. The result was similar to Mesert Muche *et al*. (2015) reported the lowest available P under the plantation forest of *Alaket Wonzi* watershed, Northwestern Ethiopia.

On the other hand, the content of AVP in cultivated land was higher than the grazing land due to frequent application of inorganic P fertilizers under cultivated lands. This result was similar to Alemayehu Adugna and Assefa Abegaz (2016) reports that showed higher contents of available phosphorus in cultivated land than grazing land. Besides, more P release as a result of rapid weathering process on cultivated land than on grazing land may provide greater amount of available P to the cultivated land (Alemayehu Adugna and Assefa Abegaz, 2016). However, Getahun Bore and Bode Bedadi (2015), found that very low available P concentration in the cultivated and grazing land soils and associated their findings to the lower pH and high exchangeable acidity their study area. For this reason, these soils with relatively high exchangeable acidity can have acidic cations such as exchangeable Al, H, and oxides of Al and Fe that could fix the soluble P in the soil solution.

However, the amount of AVP didn`t show significant difference (P > 0.05) with soil depth (Table 4.3) but it was numerically higher (9.05-ppm) AVP on surface soil and low (6.90-ppm) in the subsurface soils (Table 4.5). The result was similar to Nega Emiru and Heluf Gebrekidan (2013) disclosed that a declining trend of AVP from surface to subsurface layers in *senbat* sub watershed, western Ethiopia. Similarly, AVP decreased from 9.05 ppm in surface soil to 6.90 ppm in the subsurface soils. An increase in clay content with increasing soil depth might have caused phosphorus fixation and its decline with depth. This result is, therefore in agreement with Ahamed Hussein (2002) that detected the lower value of AVP with increasing soil depth at *Mount Chilalo*, Southeastern Ethiopia. Mulugeta Seyum (2000) reported that lower concentration of available phosphorus with depth due to fixation by higher clay and Ca content in soil depth. Generally, the decline in available P contents can be ascribed to the remarkable high degree of phosphorus fixation that occurs at low pH and losses through crop harvest and erosion, which are characteristic features of agricultural soils in the tropics (Nega Emiru and Heluf Gebrekidan, 2013).

4.3.6. Cation exchange capacity (CEC)

Cation exchange capacity of the soil was highly significantly ($p < 0.01$) affected by land use type and significantly ($p < 0.05$) by soil depth (Table 4.4), but insignificantly ($p > 0.05$) affected by interaction effect (Appendix Table 2). The highest (31.3 $cmol_c$/kg) and the lowest (21.44 $cmol_c$/kg) CEC values were observed under natural forest and cultivated lands, respectively (Table 4.4). However, cultivated land, grazing land and plantation forest showed statistical parity results. The result was similar to Alemayhu Adugna and Assefa Abegaz (2016) report higher CEC values in the forest than in the cultivated lands.

The highest amount of CEC in the natural forest could be due to the higher amount organic matter contents in the soil. This findings inline with Lechisa Takele *et al*. (2014) report higher CEC values obtained in forest land in *Gindebert* area,Western Oromia, Ethiopia due to higher OC content of soil. Besides, Mesert Muche *et al*. (2015) disclosed that higher CEC values in the natural forest of *Alaket Wonzi* watershed, Northwestern Ethiopia due to the amount and nature of the clay particles and organic matter content. The CEC values of plantation forest, cultivated and grazing lands were decreased mainly due to declining soil organic matter content. This result inline with Nega Emiru and Heluf Gebrekidan (2009) finding a decreased CEC values obtained in cultivated land due to low organic matter content. Besides, Berhanu Seyoum (2016) showed the depletion of organic matter in cultivated land due to continuous cultivation thus lowering the CECvalue of the soil of *Girar Jarso* District of North Shoa Zone. The correlation analysis showed that a strong and positive relationship ($r = 0.58$) between CEC and SOM (Table 4.5). Therefore, soil CEC is expected to increase through the improvement of soil OM content. The relative amount and/or types of two colloidal substances such as humus and clay determine soil cation exchange capacity. Soil organic matter particularly plays an important role in the soil exchangeable processes because it provides a more negative charge surface than clay particles do (Eyayu Molla and Mamo Yalew, 2018).

The highest (26.72 $cmol_c$/kg) CECvalue was recorded from the surface soils (Table 4.4). But it decreased with increased soil depth due to declining soil OM. Thus, from this result, it understand that SOM has a strong association and affects the distribution of CEC. The result is in agreement with the findings by Woldeamlak Bewket and Stroosnijder (2003) who found that higher CEC value recorded in forestland but low value obtained in cultivated land of the *Chemoga* watershed, Blue Nile basin, Northwestern Ethiopia.

Table 4. 4: Effect of land use and soil depth on exchangeable bases and CEC (Mean±SE)

Land use or soil depth	Exchangeable base ($coml_c$/kg)				CEC ($coml_c$/kg)
	Ca	Mg	K	Na	
Land use type					
Natural Forest	7.01±0.34^{a}	2.49±0.27	1.3±0.09^{a}	0.78±0.11^{a}	31.3±1.14^{a}
Cultivated land	4.94±0.25^{bc}	2.33±0.19	1.26±0.21^{a}	0.46±0.14^{b}	21.44±1.26^{b}
Grazing land	5.79±0.31^{b}	2.01±0.14	1.18±0.13^{a}	0.98±0.09^{a}	22.03±2.13^{b}
Plantationforest	4.53±0.24^{c}	1.60±0.22	0.60±0.05^{b}	0.52±0.07^{b}	24.6±1.36^{b}
LSD (0.05)	0.72	0.9	0.40	0.23	4.02
P	**	NS	**	**	**
SEM (±)	0.28	0.202	0.122	0.103	1.47
Soil depth (cm)					
0-20	5.46±0.35	2.11±0.19	1.02±0.09	0.51±0.07^{b}	26.72±1.45^{a}
20-40	5.68±0.34	2.12±0.14	1.15±0.15	0.86±0.1^{a}	22.99±1.47^{b}
LSD (0.05)	0.64	0.46	0.28	0.16	2.84
P	NS	NS	NS	**	*
SEM (±)	0.34	0.17	0.12	0.085	1.46
CV (%)	10.39	26.03	29.94	27.28	13.06

Mean values within a column followed by the different letters are significantly different from each other at ** $p<0.01$ * $P < 0.05$. NS = not significant.

According to Landon (1991), the soil having CEC > 40$cmol_c$/kg, 25-40 $cmol_c$/kg,15-25 $cmol_c$/kg, 5-15 $cmol_c$/kg, and < 5 $cmol_c$/kg are classified as very high, high, medium, low and very low, respectively. Based on the above ratings the soils of natural forest catagorized under high CEC status while soils of the grazing land, cultivated land and plantation forest catagorized under medium status (Table 4.4). This result agrees with Achalu Chimdi *et al*. (2012), that showed a higher and moderate CEC values were recorded, in forest land mainly due to high percentage of OC of the soil. Generally, deforestation, overgrazing, intensive cultivation and changing of land from forest to other land use types without proper management aggravates soil fertility reduction (Lechisa Takele *et al*., 2014). Therefore, the result of this study indicated that the CEC of a soil is significantly affected by land use type and managment.

4.3.7. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+})

Exchangeable (Ca) was significantly ($p < 0.01$) affected by land use type (Table 4.4), whereas soil depth and their interaction effects were not significantly ($p > 0.05$) influenced exchangeable Ca (Table 4.4 and Appendix Table 2). The highest Ca (7.01 $cmol_c$/kg) and the lowest Ca (4.53 $cmol_c$/kg) values were observed under the natural forest and plantation forest, respectively (Table 4.4). This result was inline with Mesert Muche *et al*. (2015) who stated that variations in exchangeable bases (Ca^{2+}, $Mg^{2+}$and K^{+}) between land use types and attributed the difference to the leaching losses of basic cations, their low content in the parent rock and to the migration of clay minerals resulted from the conversion of forest land to other land use types.

Exchangeable Mg was not significantly ($p > 0.05$) affected by land use type, soil depth and the interaction effects (Table 4.4 and Appendix Table 2). However, the contents of exchangeable Ca and Mg increased with soil depth increased due to an increase and clay content in subsurface soil depth (Table 4.4). The result was similar to Eyayu Molla and Mamo Yalew (2018) detected that increasing trend of exchangeable Ca and Mg with soil depth in *Agedit* watershed, Northwestern Ethiopia. As per ratings of FAO (2006) the soil of natural forest and grazing lands catagorized under medium while cultivated and plantation forests catagorized low Ca content. However, exchangeable Mg of all land use types catagorized under medium level (Appendix Table 7).

Exchangeable K content was significantly ($P < 0.01$) affected by land use type (Table 4.4). Whereas insignificantly ($p > 0.05$) affected by soil soil depth and their interaction effects

(Table 4.4 and Appendix Table 2). The highest exchangeable K (1.3 $cmol_c$/kg) value was observed in the natural forest while the lowest value (0.6 $cmol_c$/kg) in the plantation forest (Table 4.4). The highest exchangeable K of natural forest related with its higher CEC value. The result inline with (Mesert Muche *et al*., 2015) finding the higher accessible K recorded in the natural forest which attributed by highest CEC value. The lowest content K in the plantation forest might be related to its low CEC and pH values compared to other land use types.

The highest exchangeable K value was recorded in the subsurface soil depth that is exchangeable K follout with soil depth could be associated with its pH. The result was similar to Eyayu Molla and Mamo Yalew (2018) that detected the increasing trend of exchangeable K with soil depth in *Agedi*t watershed, Northwestern Ethiopia. However, according to FAO (2006) the contents of soil K under all land use types are not in deficient (Table 4.6 and Appendix Table 7).

The content of exchangeable Na highly significantly ($p < 0.01$) affected by land use type and soil depth (Table 4.4). But insignificantly ($p > 0.05$) affected by the interaction of land use type and soil depth (Appendix Table 2). The higher exchangeable Na (0.98 $cmol_c$/kg) found in the grazing land and lower exchangeable Na (0.46 $cmol_c$/kg) recorded in the cultivated land (Table 4.4). The highest value of exchangeable Na was observed in the grazing land might be due to the presence of more urine in the grazing land through free grazing. Thus it concurs to the report of (Lalisa Alemayehu *et al*., 2010) in *Welmera* District, Oromia Region, Ethiopia. The lowest exchangeable Na found under cultivated land might be due to intensive cultivation and more application of inorganic fertilizer. This result corroborates the findings of FantawYimer *et al*. (2008) who reported lower concentration of soil exchangeable Na in cultivated than in grazing lands and native forest.

On the other hand, the higher exchangeable Na (0.86 $cmol_c$ /kg) was recorded in the 20-40 cm soil depth (Table 4.4). The increase Na concentration with increase soil depth due to down ward movement within soil profile. The result was similar to Alemayehu Kiflu and Sheleme Beyene (2013), in *Delbo Atwaro* watershed, Southern Ethiopia. According to FAO (2006) the ratings soil of natural forest and grazing lands catagorized under high, while soils of cultivated land and plantation forests catagorized under medium Na level (Appendix Table 7).

Deforestation, leaching, limited recycling of organic residues in the soil, very low use of chemical fertilizers, declining fallow periods or continuous cropping and soil erosion have contributed to depletion of basic cations and CEC on the cultivated land as compared to the adjacent natural forest soils (Gebeyaw Tilahun, 2015).

Table 4. 5: Pearson's correlation matrix for soil physicochemical parameters.

	pH	BD	OM	TN	AVP	Ca	Mg	K	Na
BD	-0.27								
OM	0.61^{**}	-0.38^{*}							
TN	0.60^{**}	-0.46^{*}	0.95^{**}						
AVP	0.59^{**}	-0.34	0.67^{**}	0.73^{**}					
Ca	0.67^{**}	-0.69^{**}	0.47^{*}	0.52^{**}	0.61^{**}				
Mg	0.53^{**}	-0.18	0.52^{**}	0.53^{**}	0.58^{**}	0.45^{*}			
K	0.49^{*}	0.04	0.17	0.20	0.27	0.35	0.37		
Na	0.42^{*}	-0.29	0.13	0.15	0.003	0.55^{**}	0.23	0.16	
CEC	0.42^{*}	-0.34	0.58^{**}	0.57^{**}	0.56^{**}	0.44^{*}	0.05	0.07	-0.08

**significant at $p < 0.01$ level,*significant at $p < 0.05$ level, pH = pH (H_2O)

Chapter 5. CONCLUSIONS AND RECOMMANDATIONS

5.1. Conclusion

The quantitative evidence obtained through interpretation of satellite image indicated that the occurance of significant land cover change in the *Mere* watershed between 1990 and 2018. During the study period (1990-2018) cultivated land constituted the largest coverage in the study area. The temporal trend over the 28 years period indicated that the coverages of forestland, grazing land, and settlement were increased while cultivated land decreased. Also the result of this finding suggests that differences in land use type and soil depth to the measured parameters indicated changes in soil physicochemical properties.The change of natural forest to cultivated, grazing and/or plantation forest lands caused the reduction of soil physicochemical properties. Similar to land use type, most of soil chemical properties showed significant difference with soil depth while soil physical properties not a significance different in soil depth. In this study most of soil properties were maintained relatively under the natural forest. Besides, In most cases, plantation forest, grazing, and cultivated land had the poorest soil physicochemical properties. The variation in soil physicochemical properties between land use type and soil depth are the sign of the risk to different crop production activities in the study area. This is to the result of inappropriate cultivation practices, overgrazing, use of acid forming fertilizers, and crop residue harvest for different purpose and eucalyptus plantation that caused limited nutrient availability and poor crop productivity. Therefore, the study is suggesting the need for intervention to sustain and optimize the soil quality.

5.2. Recommendation

Based on the above conclusion drawn the following recommendation are forwarded

- ❖ Developing sustainable land management strategies for the study area.
- ❖ Improvement the management of the soil resources for sustainable agriculture use.
- ❖ Regulating land use planning for this watershed in particular for sustainable natural resources management.
- ❖ Enhance farmers' capacity to invest in affordable integrated soil fertility management techniques practiced into different land use types.
- ❖ In the future further studies need be conducted by including slope difference.

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APPENDIX

Appendix Table 1 : Mean monthly rainfall (mm) and air temperature (0c) for the years from 2008 to 2017 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		

Source: NMA (2018)

Appendix Table 2: Mean square estimate of two-way analysis of variance of soil properties under four land use types and two soil depths

Soil parameter	Mean square of sources of variation †				
	Land use (3)	Soil depth (1)	Land use x Soil depth (3)	Error (14)	CV (%)
Sand (%)	288.2*	24^{ns}	52.89^{ns}	61.83	29.67
Silt (%)	118.04^{ns}	5.04^{ns}	12.15^{ns}	66.52	30.5
Clay (%)	634.8*	7.04^{ns}	111.7^{ns}	189.02	29.38
BD (g/cm^3)	0.05**	0.0042^{ns}	0.0005^{ns}	0.007	6.9
pH (H_2O)	1.14**	0.43*	0.076^{ns}	0.04	3.59
OM (%)	3.24**	1.78*	0.375^{ns}	0.35	23.1
Total N (%)	0.011**	0.008*	0.003^{ns}	0.001	24.48
C:N	1.21^{ns}	1.23^{ns}	4.04*	0.88	8.3
AVP (ppm)	66.57**	27.71^{ns}	5.48^{ns}	5.52	29.45
Ca ($coml_c/kg$)	7.22**	0.303^{ns}	0.32^{ns}	0.33	10.39
Mg ($coml_c/kg$)	0.92^{ns}	0.0006^{ns}	0.03^{ns}	0.30	26.03
K ($coml_c/kg$)	0.65**	0.11^{ns}	0.1^{ns}	0.11	29.94
Na($coml_c/kg$)	0.35**	0.76**	0.01^{ns}	0.04	27.28
CEC($coml_c/kg$)	122.76**	83.18*	5.67^{ns}	10.54	13.06

Figures in parenthesis = Degrees of freedom; * = Significant at p = 0.05; ** = Significant at p = 0.01;ns = Non-significant; C:N = carbon nitrogen ratio; CEC = Cation Exchange Capacity ;

Appendix Table 3: Means values of soil properties affected by land use and soil depth.

Soil properties	Surface (0-20 cm)					Sub surface (20-40 cm)				
	FRL	CUL	GRL	EPL	Mean	FRL	CUL	GRL	EPL	Mean
Soil physical properties										
Sand (%)	35	27.67	17	30.33	27.5	27.67	21	18.33	35	25.5
Silt (%)	32.67	23	24.33	25	26.25	32.33	21	25.67	29.67	27.2
Clay (%)	32.33	49.33	58.67	44.67	46.25	40	58	56	35.33	47.3
BD (g/cm^3)	1.1	1.33	1.18	1.27	1.22	1.15	1.35	1.21	1.28	1.25
Soil Chemical properties										
pH (H_2O)	6.13	5.33	5.47	4.96	5.47	6.21	5.9	5.59	5.26	5.74
OM (%)	4.27	2.26	2.56	2.24	2.83	3.04	2.22	2.04	1.86	2.29
TN (%)	0.25	0.10	0.15	0.11	0.15	0.15	0.11	0.10	0.09	0.11
C:N ratio	9.94	12.7	10.3	11.4	11.1	12.1	10	11.5	11.6	11.3
AVP(ppm)	14.98	9.34	5.8	6.08	9.05	10.1	7.38	5.31	4.8	6.9
CEC($coml_c$/kg	32.73	23	25	25	26.4	30.57	20.2	19.1	24.1	23.5
Ca($coml_c$/kg)	7.05	4.51	5.67	4.6	5.46	6.97	5.37	5.91	4.46	5.67
Mg($comi_c$/kg)	2.78	2.17	1.81	1.66	2.1	2.21	2.49	2.22	1.55	2.12
K($coml_c$/kg)	1.29	1	1.19	0.59	1.02	1.31	1.53	1.17	0.6	1.15
Na($coml_c$/kg)	0.62	0.23	0.79	0.39	0.51	0.95	0.69	1.16	0.65	0.86

FRL= forest land; CUL= cultivated land; GRL= grazing land; EPL= eucalyptus plantation land; BD = bulk density; OM = organic matter; TN = total nitrogen; AVP = available phosphorus

Appendix Table 4: Means square (Ms) and result of two-way ANOVA of soil physical properties under four-land use type and two-soil depths in the *Mere* watershed.

Physical properties	Land use			Soil depth			Interaction		
	MS	F	P	MS	F	P	MS	F	P
Sand (%)	288.2	4.66	*0.02	24	0.39	0.54^{ns}	52.89	0.86	0.49^{ns}
Silt (%)	118.04	1.77	0.17^{ns}	5.04	0.08	0.79^{ns}	12.15	0.18	0.91^{ns}
Clay (%)	634.8	3.36	*0.04	7.04	0.04	0.85^{ns}	111.7	0.59	0.63^{ns}
BD (g/cm^3)	0.05	7.03	**0.004	0.0042	0.58	0.46^{ns}	0.0005	0.07	0.98^{ns}

*significant at $p < 0.05$;**significant at $p < 0.01$; ns = non-significant; p = probability; BD = bulk density.

Appendix Table 5 : Means square (Ms) and result of two-way ANOVA of soil chemical properties under four-land use type and two-soil depths in the mere watershed.

Chemical properties	Land use			Soil depth			Interaction		
	MS	F	P	MS	F	P	MS	F	P
pH (H_2O)	1.14	28.01	**0.0001	0.43	10.5	**0.006	0.075	1.87	0.18^{ns}
OM (%)	3.24	9.25	**0.0013	1.78	5.09	*0.04	0.38	1.07	0.39^{ns}
Total N (%)	0.011	10.31	**0.0008	0.008	7.87	*0.01	0.003	3.19	0.06^{ns}
C:N	1.21	1.37	0.29^{ns}	1.23	1.4	0.26^{ns}	4.04	4.59	0.02*
AVP (ppm)	66.57	12.07	**0.0004	27.71	5.02	0.055^{ns}	5.49	0.99	0.42^{ns}
Ca ($coml_c/kg$)	7.22	21.58	**0.0001	0.30	0.91	0.36^{ns}	0.32	0.95	0.44^{ns}
Mg ($coml_c/kg$)	0.92	3.06	0.06^{ns}	0.0006	0.00	0.96^{ns}	0.03	1.01	0.42^{ns}
K ($coml_c/kg$)	0.65	6.2	**0.007	0.11	1.05	0.32^{ns}	0.1	0.97	0.44^{ns}
Na($coml_c/kg$)	0.35	9.9	**0.0009	0.76	21.6	**0.0004	0.01	0.3	0.82^{ns}
CEC($coml_c/kg$)	122.76	11.65	**0.0004	83.18	7.89	*0.01	5.67	0.54	0.66^{ns}

*significant at $p < 0.05$;**significant at $p < 0.01$; ns = non-significant; p = probability; OM = organic matter; AVP = available phosphorus

Appendix Table 6 : Rating of soil pH (Tekalign, 1991), organic matter (Ethiosis, 2014), and CEC (London, 1991)

pH rating	OM (%) rating	CEC ($coml_c$/kg) rating
< 4.5 very strong acid	> 8 very high	> 40 very high
4.5-5.2 strong acid	7-8 high	25-40 high
5.3-5.9 moderately acid	3-7 optimum	15-25 medium
6.0-6.6 slightly acid	0.2-3 low	5-15 low
6.7-7.3 neutral	<0.2 very low	< 5 very low
7.4-8 moderately alkaline		
> 8 strongly alkaline		

Appendix Table 7 : Rating of exchangeable cations in the soil (F A O, 2006)

Rating ($coml_c$/kg)	Ca	Mg	K	Na
very high	> 20	> 8	> 1.2	> 2
High	10-20	3-8	0.6-1.2	0.7-2
Medium	5-10	1-3	0.3-0.6	0.3-0.7
Low	2-5	0.3-1	0.2-0.3	0.1-0.3
very low	< 2	< 0.3	< 0.2	< 0.1

Appendix Table 8 : Rating of total nitrogen in the soil (Ethiosis, 2014)

Description	Rating (%)
Very high	> 0.5
High	0.3-0.5
Optimum	0.15-0.3
Low	0.1-0.15
Very low	< 0.1

Key informant discussion in *Mere* watershed

1. What are the major land use types in your watershed in the last 28 years (provide qualitative description?
2. In the past years, which land use type is more covered the watershed? Explain the major causes
3. In the past years, what are the natural forest looks like and now a day? Explain the major causes
4. What are the dominant tree species in the study area?
5. What are the major cause's changes of one land use to other land use type? Explain brief the major causes
6. What are the major effects the conversion of one land use type to other land use type?
7. What are the major changes in land use (area+ quality) and management you noted in communal properties over the last 28 years and institutional changes that go along with those changes?

Amhara Design & Supervision Works Enterprise
Laboratory Servise
Soil Chemistry & Water Quality Section

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soil Analysis of Laboratory Report
Client: Gasha Alene (BDU)

Sr. No.	Lab. No.	Client Code	pH (H_2O)	Texture % Sand	% Silt	% Clay	Classes	OC %	OM %	TN %	Av.P ppm	Ex.Ca Cmol (+) / Kg	Ex.Mg	Ex.Na	Ex.K	CEC
1	1637 /18	GC1D1	5.65	19	27	54	Clay	1.57	2.71	0.12	7.54	4.25	1.73	0.18	1.08	27.41
2	1638 /18	GC1D2	6.31	15	17	68	Heavy clay	1.51	2.61	0.13	6.27	5.26	1.92	0.47	1.06	20.15
3	1639 /18	GC2D1	5.15	29	11	60	Clay	1.21	2.09	0.09	10.62	5.08	2.67	0.32	1.01	21.82
4	1640 /18	GC2D2	5.52	19	19	62	Heavy clay	1.24	2.13	0.11	6.80	5.14	2.79	0.52	2.27	18.9
5	1641 /18	GC3D1	5.19	35	31	34	Clay loam	1.15	1.99	0.10	9.85	4.19	2.12	0.19	0.91	19.8
6	1642 /18	GC3D2	5.88	29	27	44	Clay	1.12	1.93	0.11	9.08	5.72	2.76	1.08	1.25	20.6
7	1643 /18	GF1D1	6.55	47	37	16	Loam	3.60	6.20	0.35	19.08	7.18	3.68	0.88	1.02	34.5
8	1644 /18	GF1D2	6.21	31	41	28	Clay loam	2.08	3.58	0.18	13.69	7.52	1.78	1.13	1.44	28.5
9	1645 /18	GF2D1	5.62	29	37	34	Clay loam	2.35	4.05	0.20	9.08	6.53	2.23	0.54	1.25	30.8
10	1646 /18	GF2D2	5.99	23	37	40	Clay	1.64	2.82	0.14	6.77	5.56	2.14	0.67	1.47	27.7
11	1647 /18	GF3D1	6.22	19	29	52	Clay	1.48	2.55	0.19	16.77	7.45	2.43	0.44	1.6	32.9
12	1648 /18	GF3D2	6.42	19	29	52	Clay	1.57	2.71	0.12	9.85	7.84	2.70	1.06	1.02	33.5
13	1649 /18	GG1D1	5.52	13	21	66	Heavy clay	1.41	2.43	0.13	6.77	6.42	1.41	0.86	1.38	29.8
14	1650 /18	GG1D2	5.76	13	21	66	Heavy clay	1.28	2.20	0.11	4.54	5.84	2.40	1.1	1.54	21.7
15	1651 /18	GG2D1	5.53	13	19	68	Heavy clay	1.44	2.49	0.13	5.31	4.78	1.97	0.65	1.3	26.8
16	1652 /18	GG2D2	5.55	15	25	60	Clay	1.24	2.13	0.11	6.08	5.1	2.07	1.11	1.26	16.6
17	1653 /18	GG3D1	5.36	25	33	42	Clay	1.61	2.78	0.18	5.31	5.8	2.04	0.87	0.88	19.4
18	1654 /18	GG3D2	5.47	27	31	42	Clay	1.04	1.79	0.09	5.31	6.8	2.18	1.27	0.72	17.9
19	1655 /18	GP1D1	5.34	23	19	58	Clay	1.67	2.88	0.14	6.08	4.5	2.49	0.48	0.65	22.3
20	1656 /18	GP1D2	5.61	21	25	54	Clay	1.28	2.20	0.11	5.31	4.04	1.14	0.73	0.82	26.8
21	1657 /18	GP2D1	4.8	37	31	32	Clay loam	1.15	1.99	0.10	4.54	3.99	1.06	0.35	0.49	29.5
22	1658 /18	GP2D2	5.09	45	29	26	Loam	1.12	1.93	0.10	4.54	4.15	1.85	0.71	0.46	23.3
23	1659 /18	GP3D1	4.75	31	25	44	Clay	1.07	1.85	0.10	7.62	5.3	1.43	0.34	0.63	25.6
24	1660 /18	GP3D2	5.07	39	35	26	Loam	0.84	1.44	0.07	4.54	5.2	1.65	0.51	0.52	20.3

Name of Technician Name Getaneh D.
Date 10/04/2011
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Date 10/04/2011
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BIOGRAPHYICAL SKETCH

The author was born in 1988 at *Shime Mariame* kebele, southern Gonder, Amhara national regional state. He attended his elementary education in Shime Mariame Elementary School from1997 to 2004. Then, he moved to *Anbessame* primary school to pursue primary education and *Woreta Georgies* secondary school to pursue secondary education from 2005 to 2008. Following the completion of his secondary education in 2008, he joined the Hawassa University Wondo Genet College of forestry and natural resource and Graduated with BSc in General forestry in 2011. He was then assigned land administration and use office in the *Dera* woreda where he served as forestry expert until he joined the school of graduate studies of Bahirdar University to pursue has MSc. degree in Watershed Management and Soil and Water Conservation program in October 2017.