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LAND USE LAND COVER CHANGE AND ITS EFFECT ONSELECTIVE SOIL PROPERTIES IN THE EASTERN LAKE TANA BASIN, A CASE STUDY IN ENKULAL CATCHMENT, ETHIOPIA

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COLLEGE OF AGRICUTLURE AND ENVIRONMENTAL SCIENCES

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M.Sc Thesis

By

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science (MSc.) in "Environment and Climate Change"

Major Advisor: Derege Tsegaye (PhD)

Co-Advisor: Habtamu Assaye (MSc)

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Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) Thesis open defense examination, we have read and evaluated this thesis prepared by **Alelign Gardew Denekew** entitled "**LAND USE LAND COVER CHANGE AND ITS EFFECT ON SELECTIVE SOIL PROPERTIES IN THE EASTERN LAKE TANA BASIN, A CASE STUDY IN ENKULAL CATCHMENT, ETHIOPIA".** We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) Environment and Climate Change.

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DECLARATION

This is to certify that, this thesis entitled **‘‘LAND USE LAND COVER CHANGE AND ITS EFFECT ON SELECTIVE SOIL PROPERTIES IN THE EASTERN LAKE TANA BASIN, A CASE STUDY IN ENKULAL CATCHMENT, ETHIOPIA”** submitted in partial fulfillment of the requirements for the Masters of Science in **Environment and Climate Change** to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. **Alelign Gardew Denekew** (ID. NO. BDU1018333PR) is the original work done by me under the supervision of **Dr. Derege Tsegaye** and **Mr. Habtamu Assaye** and this thesis has not been published or submitted elsewhere for the requirement of a degree program to the best of my knowledge and belief.

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LIST OF ABRIVATION

BD	Bulk Density
CEC	Cation Exchange Capacity
DEM	Digital Elevation Model
FGD	Focus Group Discussion
LU/LC	Land use/ Land cover
REDD+	Reducing Emission from Deforestation and Forest Degradation.
SMC	Soil Moisture Content
SOC	Soil Organic Carbon
SOM	Soil Organic Matter

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ABSTRACT

The land use and land cover change have a negative impact on both the environment and socioeconomic settings. This study focused on the investigation of the trends of land use/ land cover change and its effect on soil properties in the upland sediment source area of the Eastern Lake Tana Basin. Two different years' satellite images (Sentinel-2 for 2017 and spot for 2007) and one year (1982) of aerial photograph, were used to analyze the trends of LU/LCC. Disturbed and undisturbed soil samples were collected from different land uses (paired ones) with to the depth of 0-30 cm. About LU/LC classification, produced eight different LU/LC types namely croplands, eucalyptus plantation, grazing lands, natural forest, riverine, scattered shrubs, bare land and settlement. The result showed an increasing trend for eucalyptus plantation, while, natural forest and open shrub lands decreased. The land use/ land cover change dynamic indicates that, eucalyptus plantation was exerting an incredible pressure on another cover, in particular agricultural lands and grazing land. The ANOVA results showed that soil bulk density, soil moisture content, sand and clay content of soil, SOM, CEC, availability of phosphorus and total nitrogen varied strong land use types. In general, natural forest had strongly significant difference with all selected land use types. According to the spatial distribution of land cover prediction, the eucalyptus woodlot land cover extends up to 271.38 ha and the agricultural cultivated land and grazing land will be decreased to 510.03 ha and 158 ha in the year of 2030 respectively. The communities and government will look for alternative means of livelihood like non-farm /off-farm income generating activities due to limited capacity of agriculture land to accommodate population. Activities of land use change can be based on land capabilities and suitability class is very important. To predict the future land use change, use LU/LC change models in the watershed to describe the spatial distribution of land use conversion is the recommended one.

Key Words; *eucalyptus plantation, Image classification, Land use Land cover, Land uses change trends, soil properties*

Chapter 1. INTRODUCTION

1.1. Background and Justifications

Land use and land cover change affect the magnitude and rates of soil degradation (Mulugeta Lemenih *et al*. 2005). The land use and land cover changes have a significant impact on deteriorating the physical and chemical properties as well as the biological activity of the soil (Bahrami. *et al*. 2010; Kizilkaya, and Dengiz. 2010). Inappropriate land use and land cover change like deforestation, overgrazing, and expansion of agricultural lands has significant consequences on the capability of the land, which reduces the biomass (vegetation cover) and results a decline in soil organic matter content, availability of nutrients and soil moisture (Mao and Zeng, 2010). However, an increase in soil organic matter enhances the maintenance of aggregate stability by increasing the cohesion of aggregates, which reduces the loss of fine soil particles (Chenu *et al*. 2018) and content of organic matter, nitrogen mineralization also increases (Mao and Zeng, 2010). Organic matter may also maintain the soil pH. Soil pH manipulates the availability of essential soil nutrients, which affect plant growth and soil quality as a whole (Wong *et al.* 2003).

Forestry activities changed the top soil surface structure (Enez *et al*. 2015). Changes in land cover have a drastic effect on physical, chemical, and biological properties of soil and hence change the quality of soil (Irshad *et al*. 2015). Soil is a key component of the Earth System that control the Bio-Geo-chemical, hydrological cycles and also offers to the human societies many resources, goods and services (Keesstra *et al.* 2012).

Land use cover has a significant effect on the amount and diversity of biomass returned to the soil, which also disrupt the richness of nutrient restored to the soil (Iwara *et al.* 2011), as the land use, systems significantly affect the clay, silt and sand fractions. The proportion of sand and silt declines with the soil depth. Soil pH, total N, organic carbon, available P, exchangeable *Ca*, exchangeable Al, sum of bases, CEC and Al saturation significantly differed with the land-use systems. Al saturation increased with soil depth, and the top soils presented acidity problems while, the sub-soils exhibited Al toxicity (Agoumeand Birang, 2009).

Land use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing biological transformations in the rooting zone. For instance, cultivation of forests diminishes the soil carbon, within a few years of initial conversion and substantially lowers mineralizable of nitrogen (Majaliwa *et al*. 2010). Soil quality is a concept that integrates soil biological, chemical and physical factors into a framework for soil resource evaluation Khormali *et al*. (2009), investigated the effects of land use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia. Results showed deforestation and then long-term cultivation caused organic matter and total nitrogen decreased and also changes in soil surface (0-10 cm) indicated phosphorous, potassium, available potassium, Ca^{+}, Mg, saturation point and cation exchange capacity.

Environmental degradation is the most frequently occurring and rapidly accelerating problem related to agricultural activities. In practice, most agricultural programs tend to place a heavy emphasis on increasing productivity, less attention on resource management and conservation. The social and environmental implications of increased pressure on natural resources remain overlooked until a serious degradation occurs (Makhanya, 2004). Because of the population and livestock growth, and heavy economic activity concentration, land suitable for cultivation is running short in much of the highland region of the country (Nyssen *et al*. 2009).

In *Tana* basin, cropland expansion increases up to 4.2% in the year between 1985 and 2003, which largely occurred at the expense of grasslands and shrub lands (Amare Sewunet and Wubneh Belete, 2017). In the upper catchment of Lake *Tana* between the years 2004 and 2014, the expansion of farmland and settlement was observed for areas gained from shrubs and grasslands although some of the initial extent largely has been converted into plantation. This lowest rate of increment was reflected in the expansion of eucalyptus and other trees planted at household level around homesteads (Ebrahim Esa and Mohamed Assen, 2017).

1.2. Statement of the Problems

Land use land cover change has its impacts on terrestrial ecosystems, including forestry, agriculture, and biodiversity (Solomon Melaku, 2016). The expansion of croplands and rural settlements and the decrement of forestlands were occurring because of population pressure, which sometimes is exacerbated by local migration (Alem-meta Assefa and Singh, 2017). Deforestation and then long-term cultivation cause reduction in organic matter, total nitrogen and changes in soil surface condition (Khormali *et al.* 2009).

In Lake *Tana* basin, there are fragmented management interventions to conserve the natural resource. The major conservation effort so far has been the soil and water conservation campaign of the Amhara region bureau of agriculture, which mobilizes about 4–5 million farmers every year since the last few years. Still, these efforts do not stop the basin from degradation. There are also management interventions to control the spread of water hyacinth. Very recently, Lake *Tana* has been nominated as a new biosphere reserve under the UNESCO and the biosphere program. The farming system in the basin is predominately crop production, mixed with animal production. Due to improved awareness and economic interest of the local community, new farming systems have been introduced, *e.g*. Rice and eucalyptus production (Amare Sewunet and Wubneh Belete, 2017).

Most of the land under human control is used for the purpose of agriculture, animal grazing and urbanization. The local communities have also modified the existing land cover by moving certain number of species from their original habitat to other parts. Eucalyptus plantation has very rapidly land coverage in recent decades at *Enkulal* catchment in the study area. Eventually, it is also taking some fertile places for crops production. More than half a million hectares of land are covered by industrial plantation and eucalyptus woodlots in Ethiopia (Daniel Jaleta, *et al.* 2016). However, the consequence of land use/ land cover changes on soil properties is not proper understood.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study is to investigate major land use changes and its effect on selective soil properties and predict future land use/land cover change and sustainability of the upland area of the Lake *Tana* Basin (*Enkulal* catchment).

1.3.2. Specific objectives

The specific objectives of our study were includes: -

1. To investigate major land use changes, trends and its drivers.
2. To analyze the effect of land use changes on the selective physical and chemical properties of soil.
3. To predict the future land use land cover change and its possible effect on sustainability.

1.4. Research Questions

The study concerns the following research questions:

What are the major land use types, land use/land cover change, and those trends from the previous to present?

What is the effect of land use changes on soil properties at the study area?

What is the implication of recent land use changes on sustainability?

Chapter 2. LITERATURE REVIEWS

2.1. Land Cover and Land Use Change

Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. Land use is a more complicated term. Natural scientists define land use in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity (Robert, 2007). Land is very important natural resource on the earth's surface (Mikias Biazen, 2015). Despite of it today, humans are using it haphazardly. Now a day, the increase in population and human activities are increasing the demand on the land and soil resources for agriculture, urban and industrial uses (Samal and Gedam, 2016). Land cover refers to the physical characteristics of the earth's surface like vegetation, water, soil, forest, hills and others. Land use refers changes done by anthropogenic activities (Prasad *et al*., 2016). Land use and land cover change study are very essential for determining the current scenario and for the management of natural resources and environmental problem (Ali *et al*. 2015).

Knowledge about land use/land cover has become important to overcome the problem of biogeochemical cycles, loss of productive ecosystems, biodiversity, and deterioration of environmental quality. The main reason behind the land use/land cover (LU/LC) changes include rapid population growth, rural to urban migration, reclassification of rural areas as urban areas, lack of valuation of ecological services, poverty, ignorance of biophysical limitations, and use of ecologically incompatible technologies (Praveen and Jayarama, 2013).

According to (Ashebir Wolde *et al*. 2017), soil erosion and land degradation are the most notable effects of LU/LC changes. They considered soil erosion and degradation as the main reasons for the decline of agricultural production, especially in the highlands**.** The land use/ land cover change is related to the continued expansion of cultivated and settlement over years in *Ribb* river watershed. This has brought a significant decrease in water bodies, forest and bush LU/LC classes (Nurelegn Mekuriaw and Amare Sewnet, 2014).

2.2. Remote Sensing in Land Use Change

2.2.1. Image correction

Image is a group of pixels with certain values that represents the amount of emission or reflection of spatial object recorded by censers. When an image is to be utilized, it is necessary to conduct geometric and radiometric correction attached in the image (Danoedoro, 2012). According to (Coppin *et al*. 2004), the image preprocessing is necessary to establish direct links between the images and biophysical phenomena, to remove image noise and data acquisition error from the image noise affects the change detection capacities or even create false change phenomena.

2.2.2. Image classification

Danoedoro (2012), described image classification (multispectral classification) as a method that is designed to derive thematic information that mostly used mappings of land cover and land use by grouping phenomena by certain criteria. In manual classification, some criteria are used such as the similarity of tone or color, texture, shape, pattern, relief and others, which are applied as a whole set at the same time. However, in multispectral classification, only one criterion is used, spectral values (brightness value) in some bands at once. Two kinds of image classification are widely used, supervised and unsupervised classification. Supervised classification comprises a group of algorithms, which are based on an input object's sample (training area). Whereas unsupervised classification lets the computer to group the pixels without being interfered by the operator.

According to (Danoedoro, 2012), the result of image classification is also a thematic map that needs to be validated. The evaluation of accuracy of the classification can be applied in two aspects: the depth of information (detail of information) and truth in reality. Accurate results of image classification with the reality equals to accuracy of land cover and land use compared to real ground cover.

2.2.3. Accuracy assessment of image classification

Accuracy assessment is the key to spatial data related work (Congalton, 2001). Accuracy assessment is needed to know the reliability of the image classification in order to compare quantitatively with other methods, used in some analysis and decision-making process. According to (Congalton, 2001), one of the techniques for the accuracy assessment is quantitative accuracy assessment. The key in this quantitative accuracy assessment is the application of error matrix. An error matrix is an effective way in describing the accuracy because the error matrix describes both commission and omission error for each class.

2.2.4. Land use change detection

Change detection is one of the landscape ecological aims. Planning landscape characteristics maps can help to determine the change detection (sreenivasulu *et al*. 2010). Many change detection methods have been developed and used for various applications. However, they can be broadly divided into two approaches: post classification and special change detection (Xiuwan, 2002).

In another study (Suneela, and Mamatha, 2016), change detection is the process of measuring differences in the condition of land features by observing it at various times. The classified images of the dates can be utilized to figure the area of various area covers and observe the progressions that are occurring in the span of time. It is a comparative analysis of independently produced classification of different data via a simple mathematical combination pixel by pixel.

2.2.5. Land use land cover change trends

Fasika Alemayehu *et al.* (2018), studied LULC changes between 1985 and 2017 of *Somodo* watershed, and found that forestland, agricultural land, home garden agroforestry/settlement and grassland showed a fluctuating trend between the study periods. Forestland showed the largest decline with a rate of 60.57 ha and home garden agroforestry/settlement showed an increase by an estimated 49.77 ha in the period from 1985 to 2017. On the other hand, (Temesgen Gashaw *et al*. 2014), revealed that forest, shrub and grassland cover were transformed into cultivated and degraded land in the *Dera* district in accordance with the classified classes between 1985 and 2011.

Belay Zerga and Abreham Berta (2016), found that improving access to rural road network had associated with expanding eucalyptus woodlot plantations in *Eza* district where there are relatively good road networks compared to the other rural areas of the Southern Region. From the total *kebeles* found in the district, 26% of them are accessible by all-weather road. The rest is accessible by dry weather road. Such opportunities encouraged farmers to plant eucalyptus trees in their land holdings along all weather and dry weather roads to transport poles and logs to the markets easily. Tsegaye Bekele (2015), showed that *Eucalyptus globulus* is used for a wide range of household uses; such as construction of houses, household utensils, cooking, heating, and handles of farm implements. The income generated from eucalyptus is by far higher than the income generated from cereal crops, although many people felt that the livelihood of the farmers totally depends on agricultural activities accounting for the largest proportion of land for agricultural activities.

2.2.6. Land use change dynamics

Land use, land cover (LU/LC) change dynamics is a widespread, accelerating, and significant process driven by human actions. Belay Zerga and Abreham Berta (2016), found that eucalyptus-holding size has increased more in farmers who have large landholding particularly in *Dega* and *Woinadega* areas. In this respect, land use competition between eucalyptus woodlot and other food crops and grazing land is striking and serious. Thus, due to landholding diminution, eucalyptus tree farming becomes more important land use practice to small landholders than the larger ones.

2.3. Physical Properties of Soil

Soil is an extremely complex and variable medium. Soil is important for the existence of living species on our planet and carries out a series of functions making it essential for maintaining the environmental balance. Despite this, it is to often perceived only in terms of support to agricultural production and as a physical base on which to develop human activities. Soil functions must be protected because of both their socioeconomic and environmental importance (Leginio and Fumanti, 2010).

In the study of Kobal *et al.* (2011), the cultivation and over grazing affected soil properties and resulted in significant decreases in the soil organic matter (SOM), bulk density (BD), and infiltration rate. The values of BD were affected by the land use type which correlated strongly with SOM and carbon concentration in different land use. The solid inorganic fraction defines the soil's texture, the amount of sand, silt, and clay. Solid particles were arranged into aggregates to form diverse structures of biological, chemical and physical processes. Structure describes the size, organization, and shape of the soil aggregates. Consistence and strength are how the soil deforms under pressure. Texture and structure influence porosity and bulk density and gases or solutions occupy the soil pores (FAO, 2015).

2.3.1. Effect of LU/LC change on Soil texture

According to the study of (Fanuel Laekemariam *et al.* 2016), soil physical and chemical properties showed considerable variation along farming topographies. The soil particle size distribution was significantly influenced by the landscape position. The trend of distribution of sand was in the following order: lower slope (<4%) >middle slope (4–8%) >upper slope (>16%). Meanwhile, the trend on silt was not steady; however, the amount seems higher on the lower slope compared to upper slope position.

On the other hand, Alemayehu Adugna and Assefa Abegaz (2016), found that, textural classes of topsoil of forest land, cultivated land and grazing land are sandy loam, clay and clay loam respectively. The sand content of soils of forestland (73.6 %) is the highest and the lowest is on soils of cultivated land (29.6 %) while the clay content is the highest on cultivated land (42.9 %) and the lowest on soils of forestland (15.6%). On the other hand, though the differences are not statistically significant, silt fraction is the highest in the forestland (32.8 %) and the lowest in grazing land (26.8 %). The percentage changes in the sand particle size distribution are higher in cultivated land (-43 %) than the change in grazing land (-26 %) compared to forestland. On the other hand, clay fraction of cultivated land and grazing land increased by 169% and 123 %, respectively, compared to forestland. A lower content of sand and higher content of clay fractions in the cultivated land may be attributed to the process of plowing, clearing, disposing and leveling of farming fields.

2.3.2. Effect of LU/LC change on Bulk density

Land use types affect the bulk density of the soil. According to (Mengistu Chemeda *et al.* 2017), the highest bulk density was recorded on the cultivated land and the lowest value recorded under the grassland. Compaction resulting from intensive cultivation might have caused the relatively higher bulk density values in the surface soil layers of the cultivated land than that of the respective soil depths in the grassland.

Yihenew G/Selassie and Getachew Ayanna (2013), found that highest BD (0-15 cm) was found in the cultivated land followed by the soil under eucalyptus plantations in two *kebeles* in North *Achefer* district. In contrast, the lowest BD values of 1.18 and 1.08 Mg m^{-3} were observed under the natural forest at the respective sites. Higher bulk density under cultivated lands was due to the trampling effects. According to (Terefe Tolessa and Feyera Senbeta, 2018), bulk density was significantly influenced by type of land use and soil depth. Higher bulk densities were observed in degraded land and subsoil, due to higher soil compaction, higher erosion rate, lack of inputs, and low soil fertility.

Chauhan *et al.* (2014), found that soil bulk density was not significantly affected by land use systems. However, the highest soil bulk density (1.41 g cm^{-3}) was observed from cereal based (cultivated) upland and the lowest (0.99 g cm^{-3}) from the pastureland. The reason for the high soil bulk density from cereal based upland could be due to the high sand content and destruction of soil aggregates by intensive tillage operation. Due to higher contents of clay particles and, organic matter in the pastureland had the lowest soil bulk density.

2.3.3. Effect of LU/LC change on Soil moisture content

Soil moisture is an important component used as a medium for supply of nutrients for growing plants. According to (Fikadu Getachew *et al.* 2012), soil moisture content in percent differed significantly ($P < 0.05$) between the soils of the different land uses/land cover for the surface 0-15 cm and deeper layer of 30-60 cm. In all the layers, the soil under *Eucalyptus saligna* plantation has low moisture contents compared to the other land uses/land covers including the natural forest. Total available water was the highest in natural forestland followed by grassland in both soil sampling depths and sites. At field capacity (FC), natural forest retained the highest moisture content of 35.67 and 35.98% at 15 to 30 cm (Yihenew G/Selassie & Getachew Ayanna, 2013).

2.4. Chemical Properties of Soil

Soil provides habitats for organisms, moisture and nutrients for the basic requirements of plant growth. It is the basis of the production in agriculture and forestry, and an important component of the human environment. Soil is characterized by physical, chemical and biological properties. The chemical properties of soils include organic matter, cation exchange capacity, and soil reactions, acidic soils, and basic cations etc. Fikadu Getachew *et al.* (2012), found that, land use changes caused changes in soil chemical properties such as organic carbon content and available phosphorus, which showed higher mean values in the soils under *Eucalyptus saligna* and farmland, respectively compared to the soil under the natural forest. These observations were evident in short period, often up to 5 years, where significant degradation responses can be observed for tropical soils when exposed to a different kind of land use changes.

2.4.1. Effect of LU/LC change on Cation exchange capacity (CEC)

The soil particles due to the presence of charges adsorb and exchange ions in solution. When fertilizers are added to agricultural soils or ponds, most of the nutrients in the fertilizer (cations as well as anions) are adsorbed on the negatively and positively charged sites of the soil or pond mud and released slowly into the soil water or pond water over a long period of time. The quantity of cations, which are adsorbed on the muds, is expressed as millti-equivalents of cations per 100 g (meq/100 g) of dry mud and is termed the cation exchange capacity (CEC). CEC is a measure of the total negative charges in the soil. CEC increase with increase in pH, percent clay and organic matter content in the soil

Lalisa Alemayehu *et al*. (2010), result indicate that the cation exchange capacity did not show any significant difference between the land uses. However, the homestead has the highest CEC value (18.00 cmolc.kg^{-1}) followed by cereal farm (16.41 cmolc.kg^{-1}), woodlot (14.59 cmolc.kg^{-1}) and pastureland (13.04 cmolc.kg^{-1}). The CEC decreased with depth in all the land uses with a 19% sharp decline across the depth in pasturelands.

2.4.2. Effect of LU/LC change on Soil organic matter (SOM)

The clearing of forests for annual crop production invariably results in a loss of SOM because of the removal of large quantities of biomass during the land cleaning, a reduction in the quality and quantity of organic inputs added to the soil and increasing SOM decomposition rates (Celik, 2005). Soil organic matter is an important and dynamic property of soil. It affects most of the soil properties like water holding capacity, cation exchange and the nutrient supplying capacities of soil (Chauhan *et al*. 2014).

Chauhan *et al*. (2014), showed that soil organic matter was affected significantly by changes in land use systems. The highest amount of soil organic matter (4.69%) was recorded from the pastureland, whereas the lowest (2.40%) was from the farmer's field. Cultivation intensifies soil organic matter decomposition whereas non-cultivated land preserves it. Hence, the pasture and forest lands and fruit orchard contained more SOM than croplands.

Tilahun Chibsa and Asefa, T'aa (2009), state that within similar depths, higher organic carbon contents were recorded in natural forest followed by grasslands. The lowest SOC was recorded in cultivated fields irrespective of the depths considered. The highest SOC in natural forest as compared to other land use might be due to the addition of SOM foliage. The lowest SOC in cultivated land, on the other hand, could be due to reduced inputs of organic matter, reduced physical protection of SOC as a result of tillage and increased oxidation of SOM.

2.4.3. Effect of LU/LC change on Soil pH

The most important effect of pH in the soil is on ion solubility, which in turn affects microbial and plant growth. A pH range of 6.0 to 6.8 is ideal for most crops because it coincides with optimum solubility of the most important plant nutrients. In acid soils, hydrogen and aluminum are the dominant exchangeable cations. The latter is soluble under acid conditions, and its reactivity with water (hydrolysis) produces hydrogen ions. Calcium and magnesium are basic cations; as their amounts increase, the relative amount of acidic cations will decrease (Brady, 1990). According to (Kiakojouri, 2014), comparison with the amount of the soil acidity in surface soil it shows that farming land had higher acidity rather than pasture but in subsurface soil this difference is higher in the pasture. Many important factors, such as rainfall, vegetation type and temperature can affect the soil acidity. According to (Yihenew G/Selassie & Getachew Ayanna, 2013), the highest soil pH values of 5.61 and 5.52 in surface soil were found under the grassland; whereas, the lowest pH values of 5.06 and 5.01 were registered under the Eucalyptus plantation. The soil pH range of 5.01-5.61 indicated moderately acidic soil condition under all the land use systems. Soils under Eucalyptus plantations were more acidic, owing to more uptakes of basic cations by the trees and poor return rate to the soil.

2.4.4. Effect of LU/LC on Total nitrogen (TN)

Deforestation and fragmentation are the two most important factors affecting the forest thereby reducing the ecosystem services such as soil organic carbon (SOC) and total nitrogen (TN) regulation accumulation ((Echeverria *et al.* 2006). According to (Terefe Tolessa and Feyera Senbeta, 2018), tree species with different plant characteristics and stands can impact retention and sequestration of soil organic carbon and nitrogen. Yihenew G/Selassie and Getachew Ayanna (2013), total N contents of the soil were highly affected by the different land use types.

2.4.5. Effect of LU/LC change on Availability of Potassium and Phosphorus

According to Lalisa Alemayehu *et al.* (2010), the availability of K has no significant difference between the pastureland and cereal farm, which indicates the improvement either of the abandoned pastureland through time due to animal wastes, or the declining quality of the cereal farms due to intensive cultivation. On the other hand, Mulugeta Tufa *et al.* (2019), found that, the available K of soil was significantly ($P \leq 0.001$) affected by land use types. According to (Mengistu Chemedathe, 2017), the content of available P in the cultivated land appeared to be significantly higher than the other two land use types. The higher in available P contents in soils of cultivated land were due to continuous application of mineral P fertilizer for few years as indicated by different farmers in the area. The available P contents were recorded at the surface soil layer of the cultivated and subsurface soil layer of the grass lands, respectively. According to (Fikadu Getachew *et al.* 2012) available phosphorus, for instance, showed higher mean values in the soils under *Eucalyptus saligna* and farmland, respectively compared to the soil under the natural forest.

2.5. Future prediction of Land Use Land Cover Change

Land use and land cover (LULC) are intricately linked with human societies that depend on the goods and services they provide. Land cover is the directly observable biological and physical characteristics of the land surface that interact with myriad Earth system processes, like hydrology, ecosystem function, and land-atmosphere interactions. Changes in land cover play a fundamental role in the Earth system, regulating biogeochemical flows of carbon, nitrogen, and other nutrients, and influencing climate and physical hydrology (Daniel *et al.* 2015).

Land use change is strongly influenced by market forces, and conservation policies on wildlife habitats is a top priority to inform future conservation planning (Pereira *et al*. 2012). The location and magnitude of LULCC are two important issues that are addressed in modeling it. Further, LULCC models show part of the complication of land use systems. Thus, temporal and spatial changes in a specific area can be evaluated by future LULCC simulation (Veldkamp and Lambin, 2001). Type of prediction of future LULC image can be helpful in the field of management of natural resources. CA-Markov modeling has provided promisingly accurate and reliable results. Furthermore, the versatility of remote sensing, GIS and LULC change model that can be used as an efficient tool for mapping and monitoring the alterations of LULC (Hamad *et al.* 2018).

Chapter 3 MATERIAL AND METHODS

3.1. Description of the study area

3.1.1. Geographic location

This study was conducted in the upland sediment source area of Lake *Tana* basin at *Dera* district, Ethiopia, which is found approximately 80 km to East of *Bahir Dar*. Geographically, it is located between 11˚36´55ʺ-11˚38´35ʺ N latitude and 37˚45´39ʺ - 37˚48´49ʺ E longitude and elevation from 2200 m to 2600 m a. s. l. Topographically, the area exhibited plateau at the upper limit to gentle slope in the lower limit (Temesgen Gashaw *et al*. 2014). The specific study area is the upper catchment of *the* watershed called *'Enkulal'* watershed, which covers 1050ha. The area was selected by Land Resilience Team of the Bair Dar University Institutional University Cooperation program (BDU-IUC) for analysis of the land degradation and resilience in the upland areas of the *Gumara* River, Northwest Lake *Tana* basin, Ethiopia. (Figure 3.1).

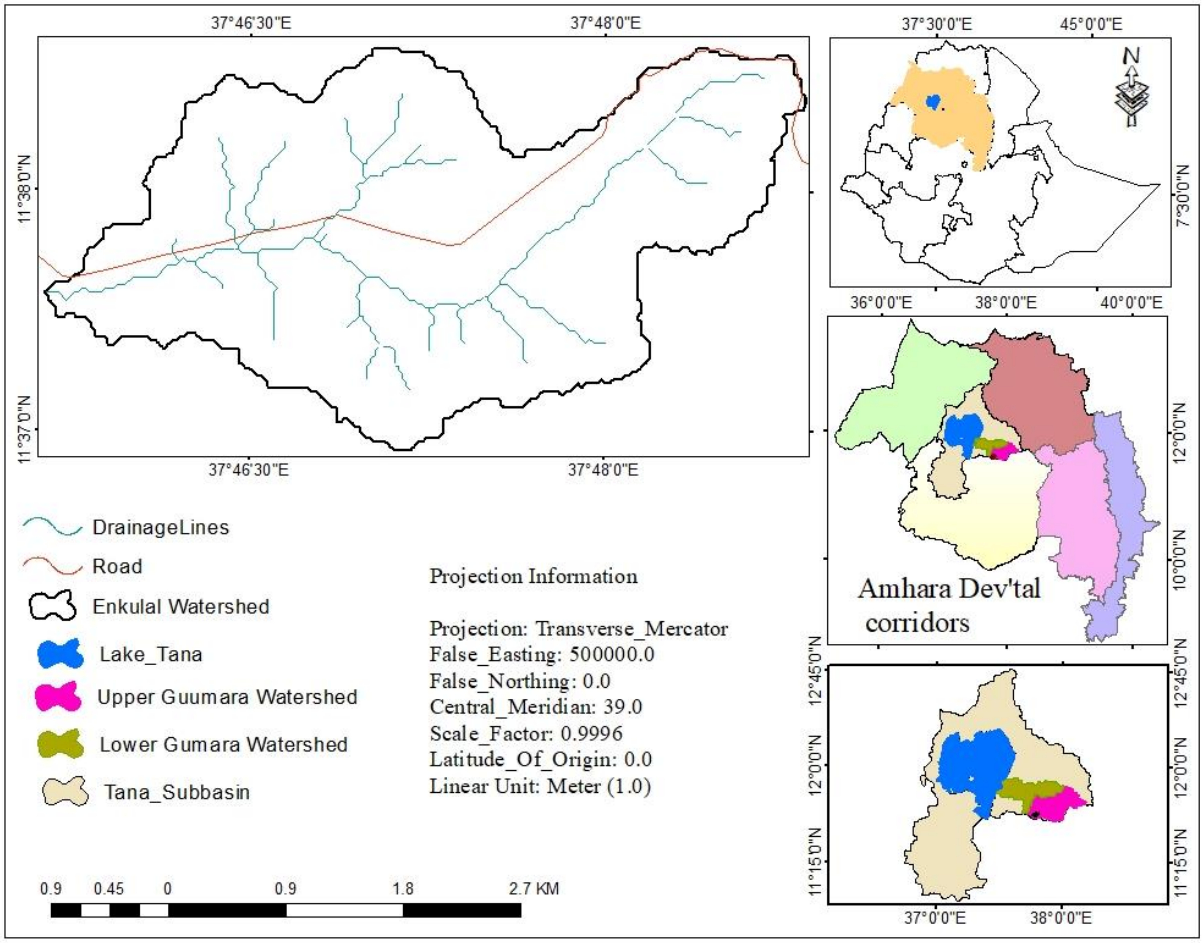


Figure 3.1. The map of the study watershed

3.1.2. Climate

The annual average rainfall of the study area is 1250 mm with the rains mainly falling from the end of May to September. Rainfall over the *Enkulal* watershed is mono-modal and most of the rainfall is concentrated in the season (Bezawit Adane, *2011*). Nevertheless, there are rains in the summer season of the year from highly cover of clouds letting additional moisture for the forest. There is a high amount of rainfall from June to September. The maximum and minimum temperatures of the *kebele* are 25^{oC} and 18^{oC}, respectively.

3.1.3. Land uses land cover and agricultural practice

The present land cover and land use of study watershed is shown in table 3.1. This watershed is dominated by annual cropland using the system of mixed agricultural practice (crop production and livestock production). In recent years, eucalyptus plantation is expanding for the purpose of income generation, especially along the roadside. The major land use/land cover in the watershed were cropland, eucalyptus plantation woodlot, grazing land, natural forest and open shrub grassland.

Table 3.1. Land use, land cover types and its coverage

FID	Class Name	Area (ha)	Area cove %
1	Bare lands	3.27	0.31
2	Cropland	545.49	51.95
3	Eucalyptus plantation	191.93	18.28
4	Grazing lands	189.11	18.01
5	Natural forest	44.84	4.27
6	Riverine vegetation	8.55	0.81
7	Settlement and road	15.77	1.50
8	Scattered Shrubs	51.09	4.87

A= Eucalyptus plantation, B= cropland, C=Natural forest, D= Grazing land

Figure 3.2. Major land use/land cover types of study watershed

Table 3.2. Description of land use/land cover types identified in *Enkulal* watershed

	Class types	Description
1	Bare lands	Refers to those land surface features devoid of any type of vegetation cover. On the land already degraded its productivity potential.
2	Cropland	Areas allotted to extended rain fed crop production used for growing annual crops such as wheat, Teff and finger millet.
3	Grazing land	Both communal and\or private grazing lands that are used for livestock grazing (the land is covered by small grasses).
4	Eucalyptus plantations	Areas planted with exotic species trees, mainly eucalyptus like a woodlot at the farm and grazing lands. This plantation was done along the roads as woodlot and homesteaded as life fence.
5	Natural forest	Areas that are covered with dense growth of trees with closed canopies. The forest covers indigenous species, which have broad life. The forest governed by government.
6	Riverine trees	Trees grown along stream courses, including indigenous tree species.
7	Settlement	The residential areas of communities, which mostly found along the top of streams.
8	Open shrub land	Areas with a cover of scattered shrubs and short trees mixed with grasses.

Source: -FAO. Last Updated November, 2017

3.1.4. Slope and soil types

The landscape consists of ridges, hills, and gorges with moderately steep-to-steep slopes. Slope forms are usually concave in the upper part and more convex in the lower part, but other more complex forms occur as well. As shown in the slope map of the catchment, the range slope percent falls from 5% to 49%. More than 80 percent of the total area become within the moderately steep slope. Due to the nature of the landscape, the high population pressure and mismanagement of the land, soil erosion is prominent and forms a major threat to the environment (Mekonen Getahun, 2015).

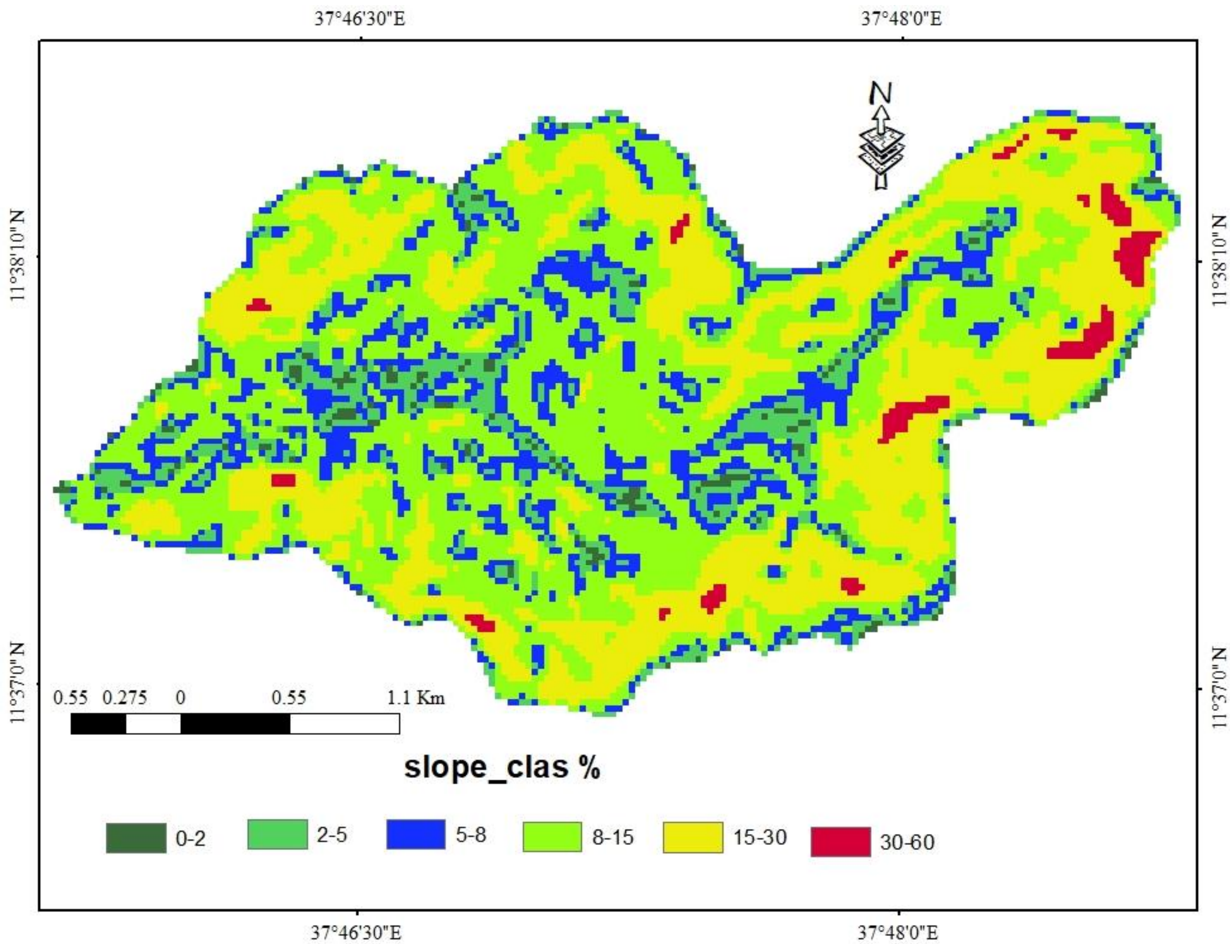


Figure 3.3. The slope class (%) of *Enkulal* watershed

Most of the watershed covered by *Luvisols* and *Leptosols*. These areas are part of the dissected volcanic plateau. The soils are shallow to very shallow and generally, they are young, which are limited by a thin *epipedon* horizon over an initial development of *endopedon* horizon or directly over the unaltered basalt parent rock. They are somewhat excessively drained, reddish brown (5YR3/3) in the topsoil. The structure is mainly weakly to moderately developed fine to medium sub-angular blocky. Topsoil's consistence is friable (moist) and slightly sticky and plastic when wet. Land use is arable crop production. As observed water erosion is a serious problem at study watershed. They mainly support land cover of scattered woods (Mekonen Getahun, 2015).

3.1.5. Population of the site

The total population of the watershed, including *Gelawdewos Kebele* is 7,338 out of this 3,793 are male and 3,545 are female. The number of households in the *kebele* was estimated to be 1,616 of which 1,411 are male headed and 205 are female headed (Molla Tafere *et al*., n.d.).

3.2. Materials and Methodology

3.2.1. Data types and methods of collection

Data sources used for this study include digital elevation model (DEM), geospatial shape file maps and two different years' satellite images (Sentinel-2 and spot) of the study area. In addition, one year (1982) of aerial photograph was used to get the trends of LU/LC change and the present complete land coverage of the study area. Here, the Sentinel-2 image was acquired on 28 December 2017 with 10m × 10m resolution from free earth explorer (*https://earthexplorer.usgs.gov/*) and the spot image was bought from the Ethiopian Mapping Agency (EMA) with the acquired date on 15 December 2007 with 5m × 5m one-pixel dimension and both images have cloud cover less than 10%. The Red, Green and Blue (RGB) and Near-Infrared (NIR) bands ofSentinel-2 and the spot were used for classification of different LU/LC. ERDAS Imagine and ArcGIS software were utilized in order to reprocess the images and analyzes for LU/LC change.

The aerial photograph was acquired on January 15, 1982 with their solution or the pixel size of 3m × 3m and white and black colors. The Sentinel_2 image was a radio metrically corrected and had a spatial resolution of 10 m. Aerial photos had better resolution and the only source of spatial data in image form prior to the coming of satellite imagery, while the satellite image was used because there were no recent aerial photographs available for comparison with older photographs.

3.2.2. Soil sample collection methods

Planning, surveying and appropriate sampling are important considerations when conducting analysis of soil chemical and physical properties to accommodate spatial variation. Primarily, a general visual field survey of the area was carried out to have a general view of the variations in the study area and identified areas of recent land cover changes. Representative soil sampling sites was selected based on the different land cover (Mengistu Chemeda *et al.*, 2017). After the land use changes were detected through the image analysis and discussion with communities, soil-sampling points were selected on such sites, which used to be one land use in the past and become different land use currently. Hence, the soil sampling point was created as paired sampling technique so that the changes in the soil properties due to land use changes could be examined. Using Geographical Information System (GIS) point data of different land use was created and overlaid in each land use land cover.

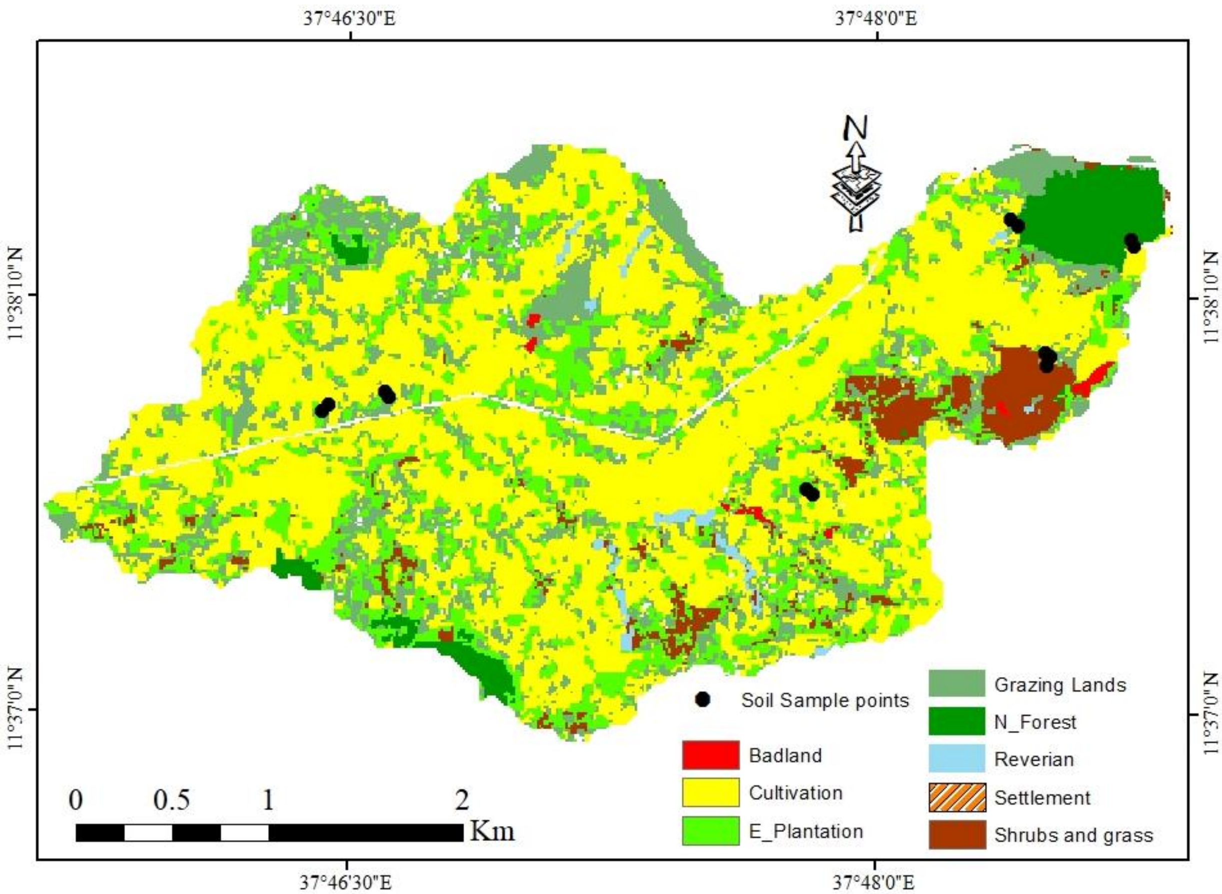


Figure 3.4. The soil sample points in each land use land cover

Disturbed and undisturbed soil different land uses (paired ones). The study area was generally characterized as gentle to steep slope. So, the soil samples were selected from two replicates (upper steep slope and lower gentle slope sites) generally, there were six prevalent land use types which are natural forest, grazing, Eucalyptus plantation, rehabilitated shrub land, cultivated fields and bad land. Soil samples were selected from different land use/land covers, which are native forest, pasture, plantation woodlots and cultivated fields. Soil samples were taken at the surface soil (0 – 30 cm) which is affected by surface soil activities such as cultivation, grazing, erosion etc.

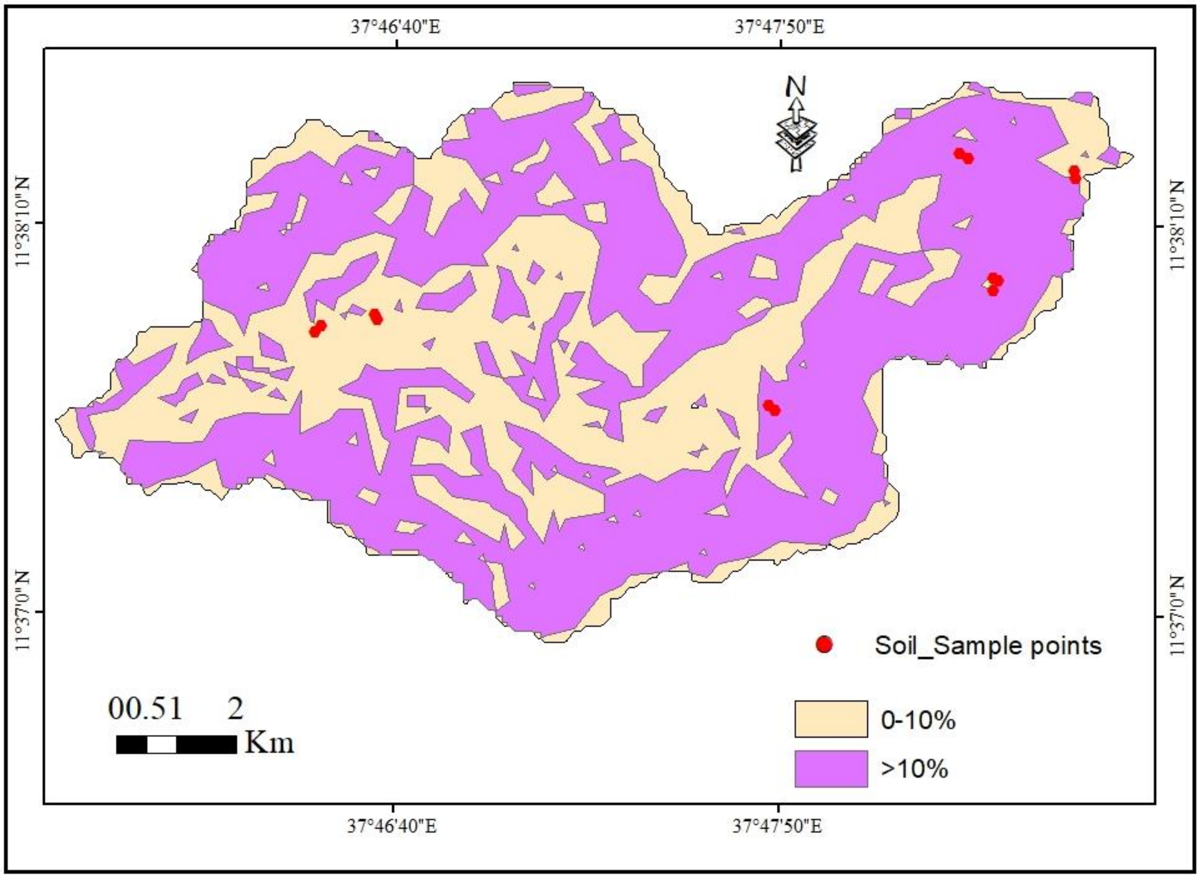


Figure 3.5. The soil sample points in different slope class (%)

3.3. Data Analysis Methods

3.3.1. Image classification for LULC change

The overall objective of image classification procedures is to automatically categorize all pixels in an image into LU/LC classes to extract useful thematic information (Boakye *et al.*, 2008). To evaluate changes in the LU/LC, data from both aerial photographs and satellite images were systematically processed, involving georeferencing, interpretation, digitization, and mapping. Multispectral image classification is one of the most used methods to extract thematic information from satellite images (Sarma *et al.*, 2008). Then, the LU/LC maps were produced from different satellite images (sentinel-2 and spot, the years of 2017 and 2007) respectively and aerial photograph of 1982.

The Sentinel-2 image was enhanced before classification using Layer stack in ERDAS Imagine 2014 for band combination to improve the image quality and increase visualization for better classification accuracy. The Sentinel-2 satellite image has 12 spectral bands, which provides a great amount of information for remote sensing applications and ground features. To this end, all12 bands were further treated as features for classification by analyzing layer stack approach, where the band combination results are shown (Figure3.6 and 3.7).

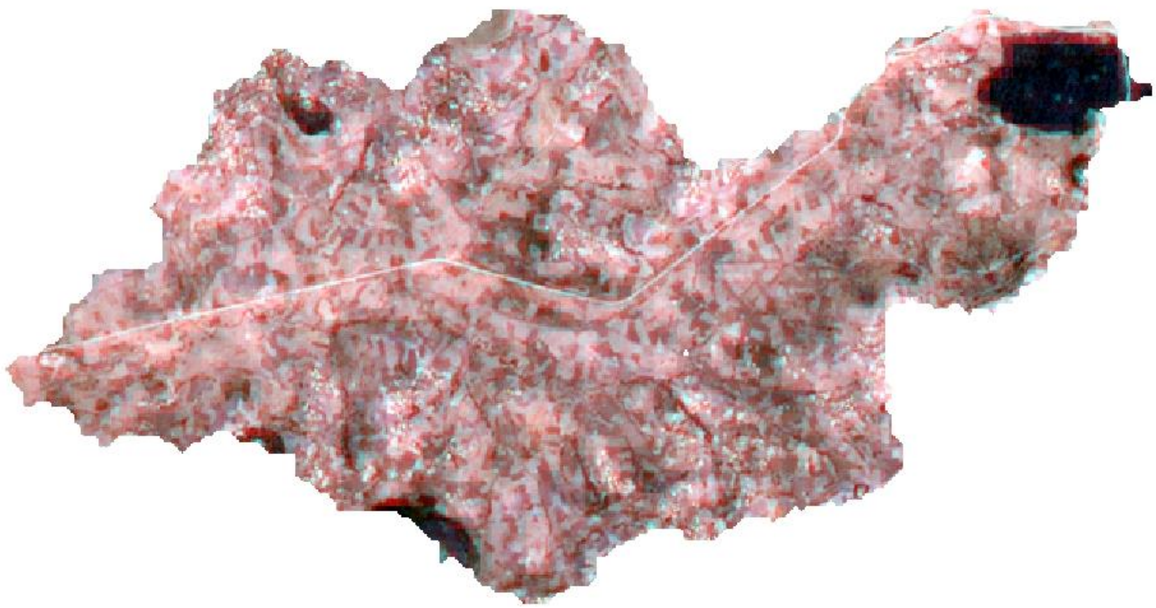


Figure 3.6. The Sentinel-2 image true color band combination (3 2 1)

Figure 3.7. The Sentinel-2 image with false color band combination of (4, 3, 2)

In supervised classification, spectral signatures points are developed from Ground Control Points (GCPs) specified locations in the image. These specified locations were given the generic name “training sites” of the current land cover and were defined by the user. The training sites help to develop spectral signatures in the outlined areas (Praveen and Jayarama, 2013).

Aerial photographs were scanned and saved as JPEG format.The aerial photographs was geo-referenced by image processing software and were used for further analysis. Raw digital images or aerial photographs, usually contain significant geometric distortions that cannot be used directly as a base map without preprocessing. Photographs were georeferenced with ERDAS software (Morshed, 2002). Then, the interpretation and the LULC classification processwere performed by establishing a preliminary legend based on visual interpretations using a mirror stereoscope and its textural class for aerial photographs, followed by screen digitization.

3.3.2. Accuracy assessment

To verify to what extent the produced classification is compatible with what actually exists on the ground, it is important to evaluate the accuracy of classification results for two image classes.Areal photograph of the year 1982 classified by mannually on screen. During satellite image classification the reference data used for accuracy assessment were obtained from GPS points called GCP during field work for the current land cover and visual identification of an image color tone and the textural roughness was used to identify the land cover types. The GPS points used in the classification accuracy assessment were independent of the ground truths used in the classification results. In general, to produce accuracy assessment matric we used the producer's and user'smetrix from image signiture or training of supervised classification of each image and kappa coefficient was calculated. Kappa: estimated as the reflects of the difference between actual agreement and the agreement expected by chance.

$$Kappa = \frac{\text{Observed accuracy} - \text{chance agreement}}{1 - \text{chance agreement}} \qquad \text{(eq.1)}$$

$$\text{Total Accuracy} = \frac{\text{Number of correct plots}}{\text{Total number of plots}} \qquad \text{eq. (2)}$$

- Observed accuracy determined by the diagonal in error matrix.
- Chance agreement incorporates offthe diagonal. (Abubaker Haroun Mohamed *et al.*, 2013)

3.3.3. Land use land cover change dynamic

The land use dynamic degree refers to the rate of change in land use types for a specific time horizon, including quantitative changes in land resources and spatial changes in land use patterns. An index describes the regional difference in the rate of LULC change and reflects the comprehensive influence of social and economic activities on LULC change. The land use dynamic degree (S) in the period t is calculated as follows:

$$S = \sum [(\Delta S_{i-j} / S_i)] \times (1/t) \times 100\% \qquad \text{eq. (3)}$$

Where: - Si is the area of land type i in the beginning of the period,

ΔSi-j is the total area of land type i converted into other types and

t is the study period (Wang, *et al.*, 1999).

3.4. Soil Sampling and Analysis

The soil samples were collected from the field in each selected land use/land cover types in the study catchment collect totally, 26 disturbed and undisturbed soil samples from 13 sampling points. For disturbed soil samples, a composite sample from five small pits (0-30 cm) was taken. For undisturbed soil samples, the sample was taken from center of GPS coordinate points by core sampler and all samples were taken to laboratory at *Amahara* Design and Supervision Works Enterprise (ADSWE) and processed as the following procedures.

- ✓ **Drying, grinding and sieving (soil pre preparation)**

Soil samples were spread out serially on trays with similar labels contained in the bags. Samples were set to air dry on shelves and direct sunlight was avoided. Mixing was done daily with a clean spoon to expose wet surfaces, to accelerate drying and makes drying more uniform throughout the sample. The nature of the analyses to be conducted, plus the presence of rocks or limestone concretions, dictates initial steps to soil crushing. Samples designated for particle size analyses were crushed with a wooden rolling pin after removing all stony material from the soil. Further crushing was done with a flail-type grinder, a power-driven mortar and pestle. Samples were crushed until a major portion of the sample passes a 2 mm opening sieve. Crushing to pass a finer mesh sieve may be desirable for analyses utilizing less than one gram of soil.

1. **Soil texture**

Soil particle size analysis was carried using the hydrometer methods. In hydrometer analysis, a soil specimen was dispersed in water. In a dispersed state in the water, the soil particles settle individually. We used the equipment of analytical balance, 100 g capacity, Standard hydrometer, reciprocating horizontal mechanical shaker, capable of 180 oscillations per minute, Sedimentation cylinder with 1.0 litters and Shaker bottle 200 milliliters and cap (polypropylene or glass) with the reagents were deionized water, Amyl alcohol and Sodium Hexametaphosphate. General laboratory procedures are as follows:

- Weigh 40.0g of air-dried soil pulverized to pass 10 mesh sieves (<2.0mm) into 200 ml container,
- Quantitatively transfer the suspension to the sedimentation cylinder and add deionized water to bring to 1.0 L final volumes,
- Allow the suspension to equilibrate to room temperature for two (2) hours,
- Insert plunger and thoroughly mix contents, dislodging sediment from the bottom of the cylinder, Finish stirring with two or three smooth strokes,
- Lower the hydrometer carefully into the suspension after thirty (30) second sand takes a reading after forty (40) second sand record to the nearest ±0. 5 g,
- Remove the hydrometer carefully, and record temperature of the suspension with a thermometer,
- Take both hydrometer and temperature readings for the blank too,
- Take the reading on the scale to the nearest 0.5 units on the top of the meniscus and
- After the first hydrometer reading at 40 seconds, let the cylinder stand for two hours and take the second reading for both the sample and the blank. Also, take the temperature readings. This second reading gives the percent of clay (particles < 2 microns) suspension (Dewis and Freitas, 1984).

2. Bulk density (BD)

Bulk density (BD) was analyzed using the core sampler method; one core soil samples were taken from each soil layer (Grossman & Reinsch 2002). The core sampler was brought out of the hole by pulling straight up on the handle. Then excess soil at the top was removed by knife and samples were weighted and collected with plastic bag. Then the soil samples were oven dried in the laboratory at 105^0 C and finally the dry sample was weighted. The soil bulk density was then calculated using the formula:

$$Soil\ bulk\ density\left(\frac{g}{cm3}\right) = \frac{Oven\ dry\ weight\ of\ soil}{Volume\ of\ Soil} \qquad \text{eq.4)}$$

3. Soil moisture content

Soil moisture content derived from the undisturbed soil sample before analysis, soil bulk density to use immediate field moisture contents balanced of soil sample. To calculate soil moisture content, we used the formula:

$$Moisture\ conent = \frac{Weight\ of\ moist\ soil - Weight\ of\ dry\ soil}{Weight\ of\ moist\ soil} * 100 \qquad \text{eq. (5)}$$

(Canada-Manitoba Soil Survey, 2006**)**

4. Soil pH

Soil pH was measured potentiometrically in the supernatant suspension with a 1:2.5 soil, water suspension using a pH meter. The materials, pH-meter with glass-calomel combination electrode, reciprocating shaking machine, potassium chloride solution, water and buffer solution pH 4.00and 7.00. The main procedures are:

- Weight 20g fine soil into a 100ml polythene wide-mouth type bottle,
- Add 50ml liquid water and 1 M KCL solution then,
- Shake for 2 hours, and
- Immerse electrode in the upper part of the suspension and take the reading when the solution has stabilized (accuracy 0.1 units) (Reeuvwijk, 2002).

5. Soil chemical analysis

The Olsen method was used to determine the available phosphorus (Av.P) content. The sample was extracted with a sodium bicarbonate solution at pH 8.5. Phosphate in the extract was determined calorimetrically after treating it with ammonium moly date sulfuric acid reagent with ascorbic acid as reducing agent (Reeuwijk, 2002). Soil organic carbon (SOC) was analyzed using wet digestion with the Walkley-Black method SOC was oxidized under standard conditions with potassium dichromate in sulfuric acid solution. Soil organic matter (SOM) was calculated by multiplying SOC by 1.724 assuming 58% of SOM is SOC (Dewan and Neguse, 1987).

The Kjeldahl procedure was used on the principle that the organic matter was oxidized by treating the soil with concentrated sulfuric acid, nitrogen in the organic nitrogenous compounds being converted into ammonium sulfate during the oxidation. The acid traps NH_4^+ ions in the soil, which are liberated by distilling with NaOH. The amount of ammonia traps, was determined to calculate the total nitrogen in the soils (Bremner, 1996).

The primary method of determination of potassium in acid soil with cation exchange capacities of less than 20 meq/100g. Under this procedure, the sample was extracted with Morgan's solution and K in extract was measured by flame photometer. For cation exchange capacity (CEC), the sodium acetate method was used. To do this, 5 g of soil was treated by sodium acetate and ethanol, and then extracted by ammonium acetate solutions. The ammonium amount of sodium (Na^+) using a flame photometer to calculate the CEC of the soil (Thomas 1982).

3.5. Statistical Data Analysis

Two factors ANOVA was used to analyze the effect of slope and land use/land cover on soil properties. Frequency, mean, range and percentage were computed for different variables (soil properties in different slopes and land use /land cover). Data analysis was carried out using R software.

The comparison between two adjacent land uses was used to show the variation in soil properties due to land uses changes by taking the cropland and eucalyptus as reference groups respectively. Hence, for a given soil chemical property, the variation expresses how much it increased or decreased in percent relation to the reference group by using the following formula.

$$VEp = [VaEu - va.\ Cu] / va.cu \times 100 \qquad \text{eq. (6)}$$

(Lalisa Alemayehu, *et al*., 2010).

Where: - VEp = Variation of Eucalyptus plantation

Va.Eu = value of Eucalyptus

Va.cu = Value of cultivated land

3.6. Estimation of Future Land Cover Change

The land use /land cover trends indicate the future land capability and feature of land cover in 2030 with considering the anthropogenic and natural effects. By using the information from local experts, and discussion with local people, the drivers of land use change were identified. For producing future projections of land-cover change are also being identified and taken into account and future land cover were drawn. The land use land cover prediction was developed in parallel with information gathering, in a relatively unstructured fashion, by iteratively incorporating new details and pursuing new information sources as questions emerged from internal conversations, interviews from FGD, or input from subject matter experts. Historical trends of land use cover change with the time series were developed from satellite images and aerial photograph in different decayed in spatial distribution of different land use systems.

3.7. Social Data Using for Verify Image Interpretation

In our study, group discussion is an important technique to verify and refine or support the result that were the three decayed image interpretation. In addition to this, expert interviews at district and *kebele* levels were also describe the factors that accelerated the land use change. It is useful in order to rule out any exaggeration or underestimation of the situations. As to organized the appropriate social data, we organized two focus group discussion from the stakeholders of *Enkulal* catchment, one each *Gelawudios* and *Shemie kebeles*. Expert interviews was done from district, selected sectors like, agricultural input distribution head, agronomy expert and natural resource management head and *kebele* levels, agronomy, land administer and environmental protection and cooperative experts.

The general land use land cover interpretation and analysis of the cover change was drowning the following flowcharts.

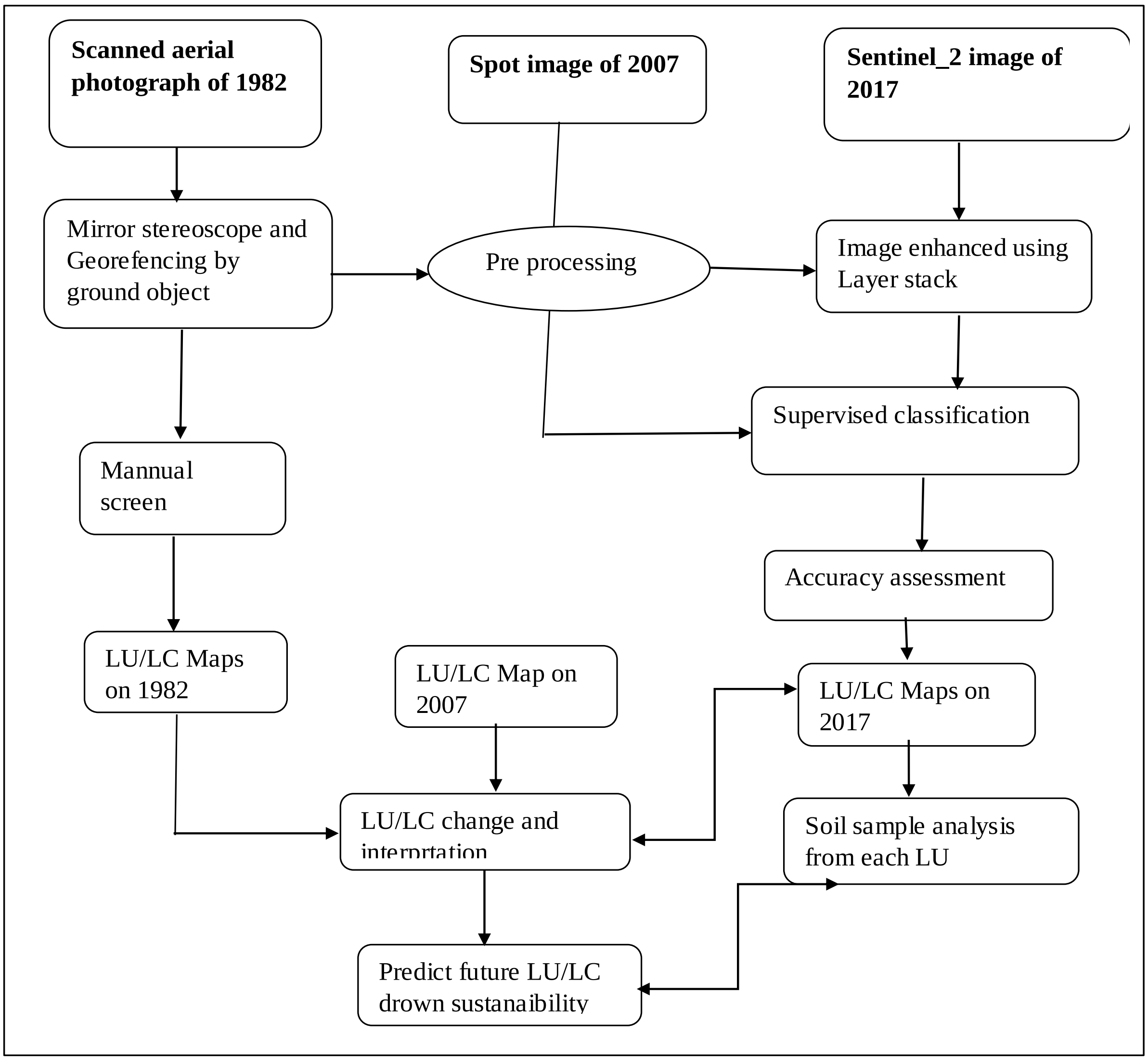


Figure 3.8. Summary of major steps during satellite image and aerial photograph analysis for land use and land cover change detection

Chapter 4. RESULT AND DISCUSSION

4.1. Land Use/ Cover Classification and Accuracy Assessment

4.1.1. Classification of land uses land cover change

The result of land use/cover maps of the three periods of 1982, 2007 and 2017 shown in (table 4.1) and the spatial distribution of land cover change in (figure 4.1).

Table 4.1. The Land Use and Land Cover area coverage in different years and its difference

LU Name	**1982**		**2007**		**2017**		**1982-2017**		Annual change (ha)
	Area ha	**%**	Area ha	**%**	Area (ha)	**%**	Area (ha)	**Area %**	
BL			3.71	0.35	3.27	0.31	3.27	0.83	0.09
CL	594.7	56.6	702.99	66.9	545.49	52	-49.21	-12.56	-1.41
EP	7.56	0.72	70.66	6.73	191.93	18.3	184.37	47.07	5.27
GR	273.08	26	120.97	11.5	189.11	18	-83.97	-21.44	-2.4
NF	58.04	5.53	54.95	5.23	44.84	4.27	-13.2	-3.37	-0.38
R	28.42	2.71	15.43	1.47	8.55	0.81	-19.87	-5.07	-0.57
SR	7.43	0.71	24.44	2.33	15.77	1.5	8.34	2.04	0.24
SHr	80.88	7.7	56.96	5.42	51.09	4.87	-29.79	-7.61	-0.85
Total	1050.11	100	1050.11	100	1050.1	100			

Note: BL= Badland, CL= Cropland, EP= Eucalyptus plantation, GR= Grazing land, NF= Natural forest, R= Riverine tree, SR= Settlement and road, SHr= open shrub lands

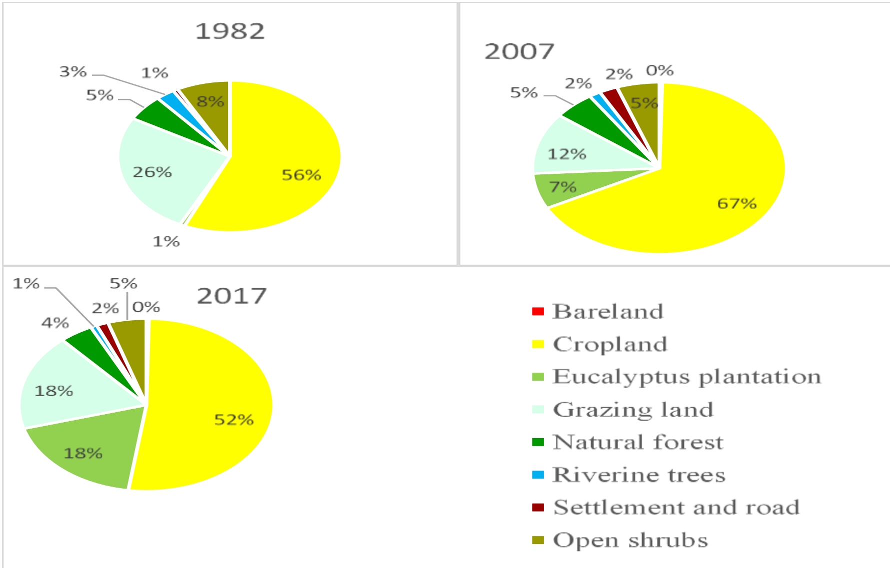
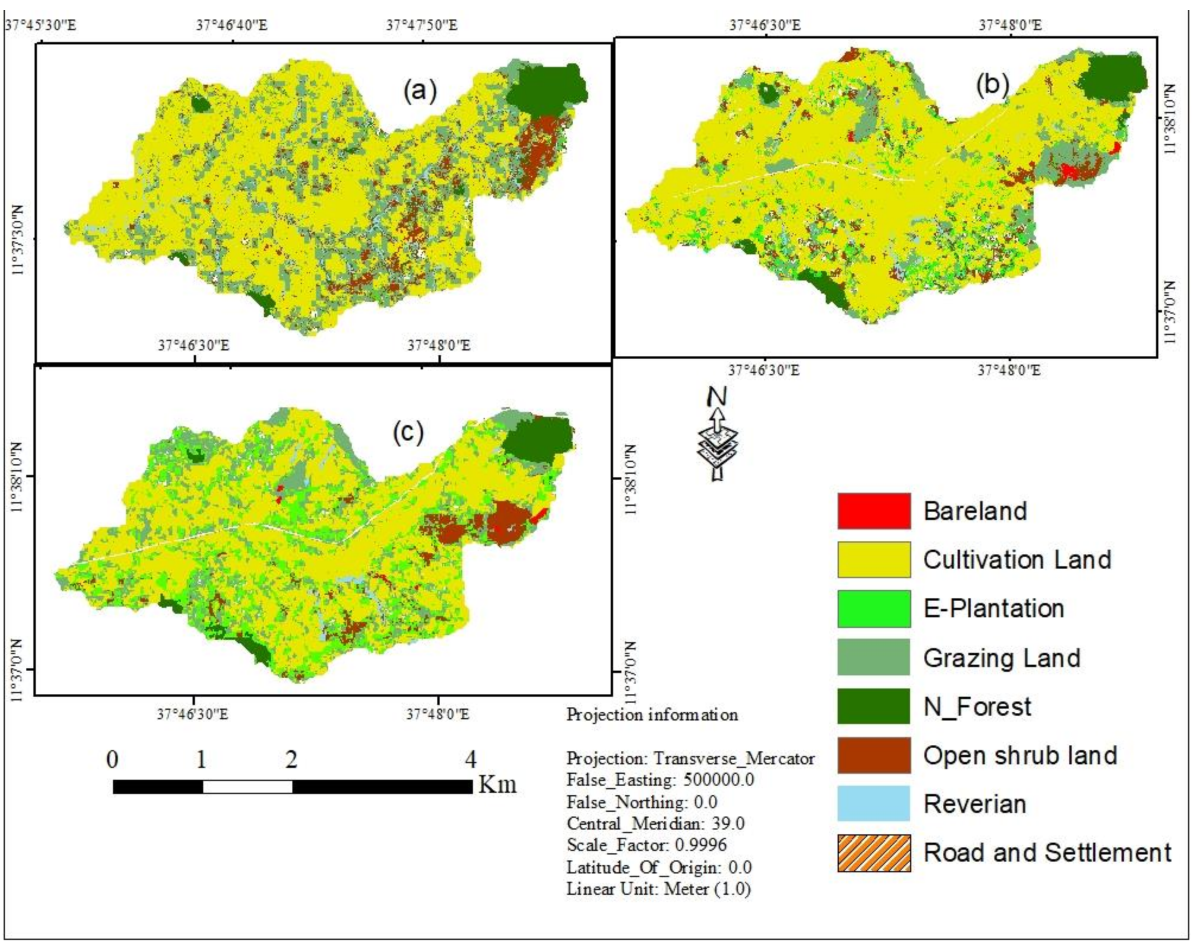


Figure 4.1. Land use type coverage in % of the study area (1982, 2007 and 2017)



Note: (a) =LU/LC of 1982, (b) = LU/LC of 2007 and (C) = LU/LC of 2017

Figure 4.2. LU/LC map of the study area (1982, 2007 and 2017)

In 1982 seven, major LU/LC types were identified by using the scanned Arial photograph data. These were croplands, eucalyptus plantation, grazing lands, natural forest, riverine, scattered shrubs and settlement. (Table 4.1). Agricultural land and grazing land had large area coverage which extends 56.63% and 26% respectively. The smallest land covers were settlement and eucalyptus plantation (0.70% and 0.72%) respectively. In those years, eucalyptus was not planted only as a woodlot; it was planted around homestead as boundary tree more like a live fence. On the other hand, Bare land was not observed in the aerial photograph and open shrub land covers was evenly distributed in most of the catchment. In general, the forest vegetation cover including riverine trees, scattered shrubs, natural forest and plantation were 171.9 ha.

LU/LC types in the spot image of 2007 also produced eight different LULC adding Bare land from the previous land use/land cover classes. In this year, cropland covered a large part of the catchment 702.99 ha (66.94%). The expansion of agricultural land and the reduction of the grazing land from 273.08 ha to 120.97 ha, had led to degradation of grazing land due to overstocking of livestock on the remaining land. In a similar study, Temesgen Gashaw *et al.* (2014), found that, forest, shrub and grassland cover were transformed and degraded land between 1985 and 2011. This showed that, changes in LU/LC aggravate land degradation.

In the 2017 sentinel_2 image, the watershed was classified into eight LU/LC types. During this year, the expansion of eucalyptus plantation woodlot covered most part of the roadsides and increased at an exponential rate from the previous decade. Daniel Jaleta *et al.* (2016), found that eucalyptus is expanding very rapidly in many places in Ethiopia. Grazing land also increased from 120.9 ha to 189.1 ha. There are two possible reasons that respondents pointed. The size of communal grazing land is shrinking and some of these grazing lands are currently protected from free grazing which might force farmers to allocate part of their cropland to grazing. In addition, when the productivity of agricultural land becomes marginal land would be transformed into grazing or eucalyptus plantation. From our site observation, in areas which have steep slopes, significant stones cover and shallow soil, the cropland have been converted to grazing land.

4.1.2. Accuracy assessment of image classification

One of the most important steps at classification process is accuracy assessment. The aim of accuracy assessment is to quantitatively assess how effectively the pixels were sampled into the correct land cover classes. Moreover, for accuracy assessment emphasis was given to pixel selection on areas that could be clearly identified on satellite images with high resolution images. During LU/LC classification, supervised classification used the training samples were in each image, 167 and 208 for 2007 and 2017 respectively. The error matrix shown in (table 4.2) in each classified year.

Table 4.2. LULC classes and accuracy assessment of the classified images

	2007		2017	
Classified	Producer's %	User's %	Producer's %	User's %
Badlands	100.00	80.00	100.00	83.00
Cropland	87.50	85.00	97.67	85.70
E. plantation	84.62	78.57	81.25	83.87
Grazing land	80.77	75.00	76.32	74.36
Natural forest	100.00	91.67	100.00	91.66
Riverine	83.33	76.92	76.19	76.19
Settlement &road	84.62	78.57	75.00	85.71
Open shrubs	84.62	81.48	85.71	88.24
Overall accuracy		**81.44**		**82.20**
Kappa C		0.73		0.79

The accuracy assessment matrix result indicated that, the overall accuracy was 81.44%, and 82.20% and the kappa coefficient was 0.73 and 0.79 for the years 2007 and 2017 respectively. Tables (4.1) show a matrix (accuracy assessment) of a LULC classification. The columns of the matrix produce user accuracy to which classes the pixels are in the validation set belong ground truth and the row's data produce to the producer's accuracy which classes the image pixels have been assigned to in the image. The diagonal or correct values produce the overall accuracy of image classification. Pixels that are not assigned to the proper class do not occur in the diagonal and give an indication of the confusion between the different land-cover classes in the class assignment.

4.1.3. Land Use Land Cover Change Patterns

Land use change can describe by the complex interaction of behavioral and structural factors associated with the demand, technological capacity, social relations affecting demand and capacity. It indicates the change of land cover from its origin in the derived demand of human and makes the arrangement and shape of the given catchment.

Table 4.3. LULC change, transition matrices of the watershed (1982-2007)

		Change to 2007 (ha)								
	LU/LC	BL	CL	EP	GR	NF	R	SR	SHr	Total
Change from LULC 1982 (ha)	BL									
	CL	1	539.45	48.2	5.63	0	0	0.25	0	594.7
	EP	0	0	6.56	1.24	0	0	0	0	7.56
	GR	2.11	104.28	11.37	105.28	8.67	6.49	4.07	31.09	273.08
	NF	0	2.78	0.25	1.65	43.28	0	0	10.08	58.04
	R	0	8.48	1.25	2.6	0	8.54	3.8	3.35	28.42
	SR	0.6	3.89	0	1.58	0	0	1.36	0	7.43
	SHr	0	43.9	3.04	2.5	3	0.4	15.6	11.85	80.88
	Total	3.71	702.99	70.66	120.97	54.95	15.43	24.44	56.96	1050.1

Table 4.4. LULC change transition matrices of the watershed (2007-2017)

Change from LULC 2007 (ha)	LU/LC	Change to 2017 (ha)								
		BL	CL	EP	GR	NF	R	SR	SHr	Total
	BL	0.65	0.57	0	0.61	0	0	0.26	1.62	3.71
	CL	0.62	502.1	86.71	82.6	1.18	1.23	11.89	15.9	702.99
	EP	0	0	68.62	0	0	0	0	2.04	70.66
	GR	1.16	23.3	19.24	68	1.5	2.9	1.62	2.5	120.97
	NF	0	5.25	2.61	4.65	39.4	0	0	3	54.95
	R	0	5	1.6	4.11	0	4	0	0.34	15.43
	SR	0	2.23	0.41	5.07	0	0	1.36	15.6	24.44
	SHr	0.84	6.67	12.14	23.99	2.83	0.35	0	10.1	56.96
	Total	3.27	545.49	191.93	189.11	44.84	8.55	15.77	51.09	1050.11

The land use change matrices show the changes in extent and directions in LU/LC classes. As evident from Table 4.3, there has been substantial increase in the area of agricultural land (702.99 ha) during 1982-2007, although some portion of its extent was converted to eucalyptus plantation (48.2 ha), and to grazing lands (5.63 ha). In contrast, a shrinkage was evident in the area of open shrub lands (43.9 ha), riverine vegetation (8.48 ha), grazing land (104.28 ha) and natural forest (2.87 ha) between 1982 and 2007, although, at the same time eucalyptus plantation gained areas from cropland, shrub land, riverine and grazing (48.2 ha), (3.14 ha), (1.25 ha) and (11.37 ha) respectively. These changes continuously alter the spatial patterns of the land cover, and greatly modify the entire land use types of the basin.

In the second study period, 2007-2017, different patterns were observed than the first one, the area of agricultural land, open shrub land, riverine vegetation, and natural forest decreased. Most of this conversion was to eucalyptus plantation, from agricultural land (86.71 ha), grazing land (19.24 ha), shrub land (12.14 ha). Similarly, grazing land also expanded from cropland, shrub land riverine vegetation and natural forest. The main cause of the expansion of grazing land was the farmers change its own farmland to grazing due to decreasing of natural or communal grazing lands. In the other hand, when the land productivity, decreased through time, it is converted to grazing and eucalyptus plantation.

4.1.4. Trends of land use land cover change

Land use land cover change from 1982 to 2017 were not the same for all land use, natural forest and riverine decrease continuously on the other hand eucalyptus plantation cover increased alarmingly from 7.56 ha (0.72%) to 191.93 ha (18.28%). Natural forest has declined from 58.04 ha to 44.84 ha and the riverine from 28.42 ha to 8.55 ha from 1982 to 2017. Consequently, the expansion of agricultural land and deforestation from riverside and scattered shrub lands shrinked and most part of the riverbanks are either open or covered only with grass. Cropland expanded from 594.7 ha to 702.99 ha during the period 1982 to 2007. This sharp expansion in cropland probably happened after the establishment of the 1997 new landholding which redistributed cropland to address fare access of land to all inhabitants. To make more land available to all inhabitants, part of natural forest, grazing lands shrubs land covers were changed to cropland. Bare lands observed in this decade were due to expansion of grazing land. This finding is in agreement with other similar studies in the basin, Temesgen Gashaw *et al.* (2014), who found that, in the *Dera* district forest, shrub and grassland cover were transformed into cultivated and degraded land during 1985 and 2011. This showed how changes in LU/LC aggravate land degradation.

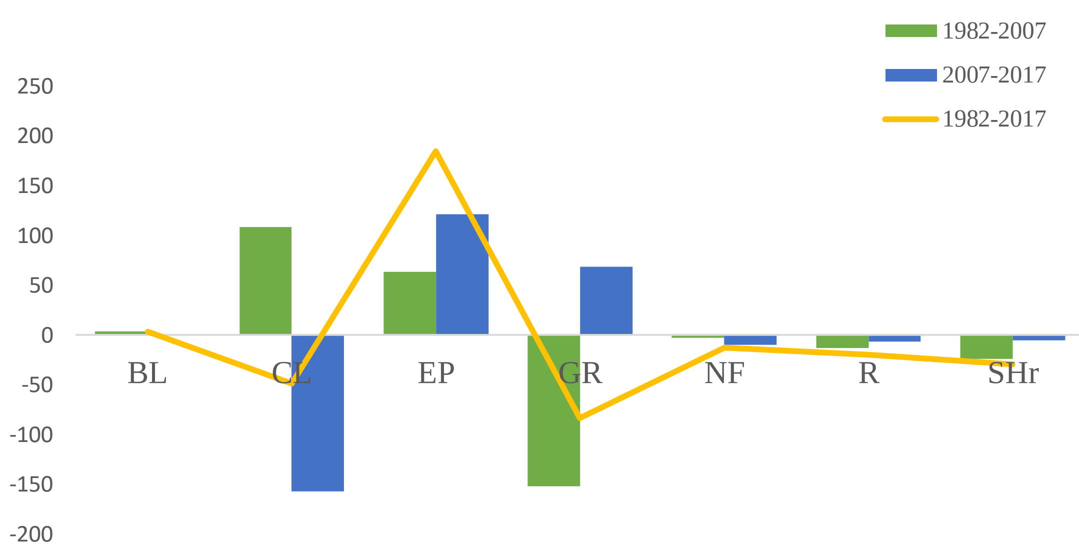


Figure 4.3. LU/LC Change trends in each study years of *Enkulal* watershed

In the study area the land use land cover change trend indicates positive (increasing) and negative (decreasing) trends (Fig. 4.2). The negative or decreasing tends to include cultivated land, grazing, natural forests, riverine trees and open shrub lands. Cultivated and grazing land showed a mild reduction change; cultivated lands -157.5 ha from 2007 to 2017and -49.21 ha from 1982 to 2017 and grazing lands -152.11 ha from 1982 to 2007 and -83.97 ha of land were declined respectively. Continuous decline was observed in natural forest, riverine trees, and open shrub lands. In the natural forest cover change recorded -3.09 ha and -10.11 ha from 1982 to 2007 and 2007 to 2017 respectively, while, in total study years from 1982 to 2017, it declined at rate of -13.2 ha per annual.

Eucalyptus plantation has expanded continuously in all periods, through recent expansions are at a much faster rate. The coverage of eucalyptus plantation land increased by 63.1 ha from 1982 to 2007 and by 121.27 ha from 2007 to 2017. It has continuously increasing trend up to the last study year of 2017 with the average annual change of 5.27ha each year in the last thirty-five years. After the construction of all-weathered road along the study area to East *Estie* district around 1999, the expansion of eucalyptus plantation has alarmingly increased. This indicated that, availability of road is one of the driving forces for establishing plantation forest. Belay Zerga and Abreham Berta (2016), found also rapid expansion of eucalyptus in, *Eza* district where there are relatively good road networks compared to the other rural areas of the Southern Region. From the total *Kebeles* found in the district, 26% of them are accessible by all-weather road. The rest is accessible from the dry weather road. Therefore, such opportunities, initiate farmers to plant eucalyptus trees in their land holdings along all weather and dry weather roads to transport poles and logs to the markets easily.

According to, the respondents of the focal group discussions, the main reason for preferring eucalyptus trees was increasing of community awareness to eucalyptus plantation, its growth rate and good market demand. As management of eucalyptus is not as demanding as crop production, farmers whose parcel are far from homestead tend to plant eucalyptus than cropland. In the central highlands of Ethiopia (*Oromia, Amhara,* and SNNP) regions Tsegaye Bekele (2015), showed that *Eucalyptus globulus* is used for a wide range of household uses. Farmers stated some of the major benefits for households: construction of houses, household utensils, cooking, heating, and handles of farm implements. According to the focus discussion, the income generated from eucalyptus is by far higher than the income generated from cereal crops, although many people felt that the livelihood of the farmers totally depends on agricultural activities accounting for the largest proportion of land for agricultural activities.

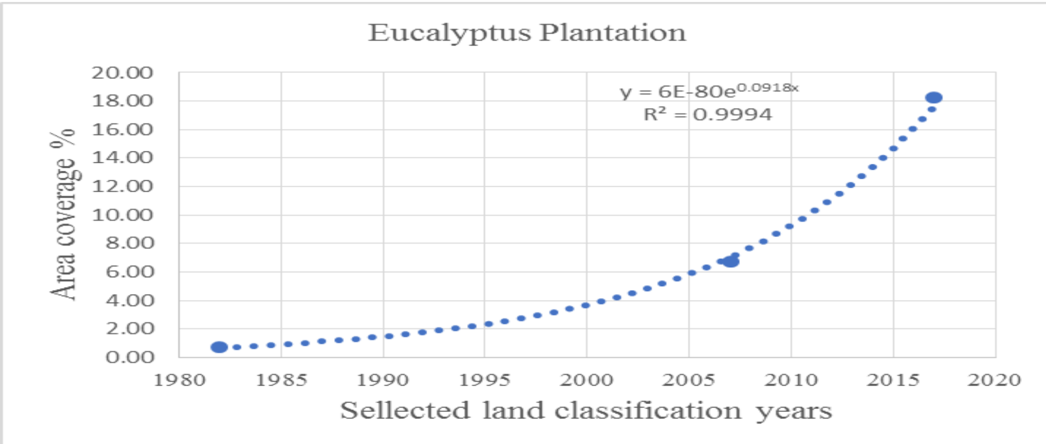


Figure 4.4. Eucalyptus plantation area coverage of each study years of study watershed

Eucalyptus trees have grown widely and have become the dominant tree type in the most accessible to market and eroded (along gully embankment) area. The respondents in the focal group discussions indicated that the main reason for preferring eucalyptus trees was their fast growth and tolerance of environmental stress. In addition to this, eucalyptus tree has direct or indirect contribution to natural ecosystem conservation. The direct benefits for ecosystem conservation buffered to degrade lands and the tree plantation contributes to as forest carbon stock. An indirect benefit of this plantation reduces deforestation from natural forest by fulfilling the local demand for construction and firewood. Eucalyptus is feared for its ecological hazards and ecosystem degradation, but eucalyptus is an important tree in fostering an ecosystem, serving as conservation tree at the beginning of the restoration process of degraded sites. Daniel Jaleta *et al.* (2017), found that eucalyptus stand generated less surface runoff compared to cultivated land. This is also due to the interception of raindrops by the stand. Eucalyptus plantation has contributed to reduce the rate of deforestation in natural forest in one way and in other hand facilitates the process of forest succession by providing a nurse effect for the colonizing native species and attracted seed dispersal agents. The general LU/LCC effects or final results with its trend are shown Figure 4.4.

4.1.5. Land use land cover change dynamics

Land use dynamic indicates an annual variation rate of the area of land use type, which is an important index of land use change.

Table 4.5. Land use a dynamic of the study area (%/year)

	LULC types						
Year	BL	CL	EP	GR	NF	R	SHr
1982-2007		+0.73	+37.39	-2.23	-0.22	-1.83	-1.18
2007-2017	-1.19	-2.24	+17.16	+5.63	-1.84	-4.46	-1.03
1982-2017		-0.24	+69.68	-0.88	-0.65	-2.00	-1.05

The results suggest that in each study period, the trend of change for eucalyptus plantation is always positive with the maximum annual variation rate up to 37.39% during the period 1982 to 2007, while during the total study period, (1982 to 2017) eucalyptus woodlot plantation recoded the dynamics degree of 69.68% per year. This indicated that the expansion of eucalyptus plantation is at the expense of the cultivated lands and grazing lands. Consequently, it has a vital contribution to local community income as a cash crop and reduce the problem of natural forest degradation due to its supplement to the needs of house construction and fire wood consumption. Belay Zerga and Abreham Berta (2016), found also that, eucalyptus holding size is increasing more rapidly in farmers whose total land holding size is greater than those with smaller land holdings. In this respect land use, competition between eucalyptus woodlot, other food crops and grazing land is striking and serious in the former than the later. Thus, due to the landholding diminution, eucalyptus tree farming became more important land use practice to small landholders than the larger ones. The variation direction in natural forest, riverine and scattered shrub lands were negative with an expression of total area decreasing and the maximum annual loss rate of riverine vegetation up to -4.46%.

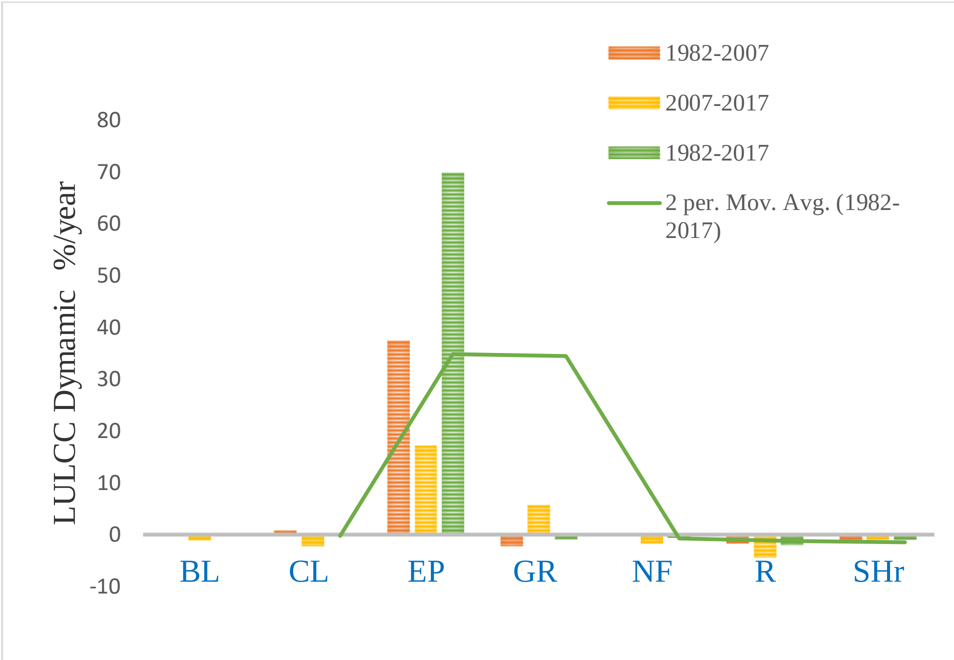
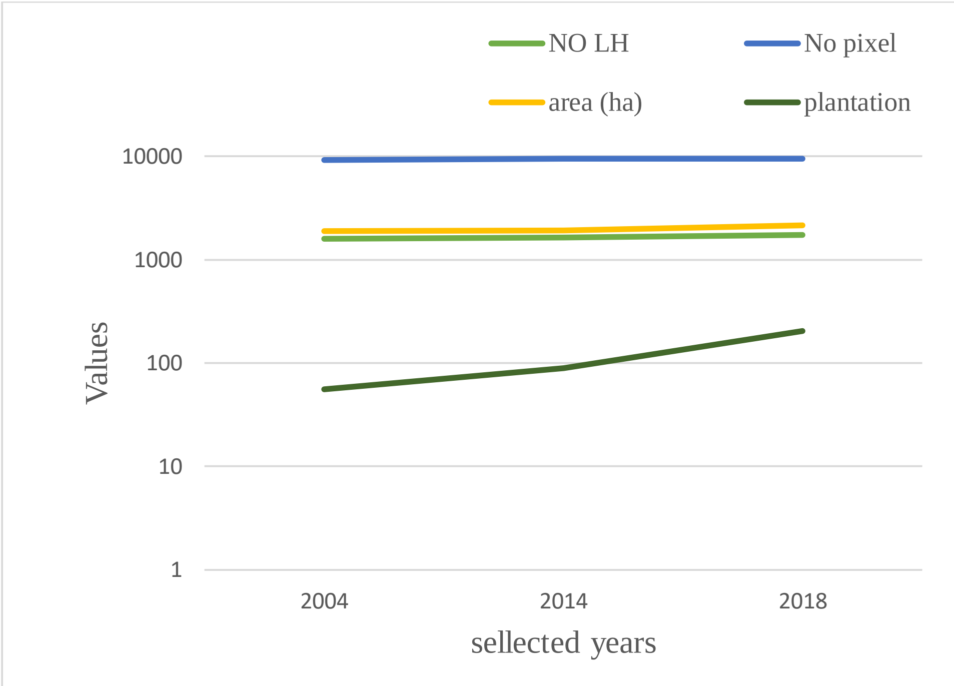


Figure 4.5. LU/LC Change dynamic (%) of the period from 1982 to 2017

This value indicated that the dramatic land cover change in the category of eucalyptus plantation was exerting an incredible pressure on another cover, in particular agricultural lands and grazing land. Expansion of the already existing woodlots through small fragments of land holding of farmland, along road and due to high demand of construction and industrial inputs for exports out of local consumption. The negative degree of LUC dynamics indicates that the degradation of natural forest, the riverbank vegetation and the scattered shrub due to the expansion of croplands.

4.1.6. Driver of land use change

According to our respondents from the focus group discussions (FGD) the major driver forces of conversion of land cover were increasing population pressure, decreasing land productivities, accessibility or road network, increase agricultural input price (inorganic fertilizer), and increase the demand of wood products. Due to the population pressure, the landholding fragmentation had increased and the expansion of eucalyptus plantation in to small woodlots also increased.



Where: - LH = landholding, plantation = eucalyptus

Figure 4.6. Landholdings with number of plots at *Gelawdios kebele*

Demographic factors are characteristics, mainly population growth and density are indirect factors for LULC conversion through the growing need for additional lands for farming and grazing as well as demands for tree products (fuel and construction wood). In our respondent perception, the population growth is the main factors for increasing the land fragmentation of watershed and it drive the land conversion of arable land to plantation woodlot. In this case, land fragmentation of *Gelawdios kebele* increased through the time series, the number of total landholdings in the 2004, 2014 and 2018 were 1601, 1636 and 1730 respectively. In addition to this, average number of plot or pixel per household increased from 5.7 to 5.8 between the years of 2004 and 2014 respectively. Due to the above reason, FGD members argue that farmlands become small, farmers change land use cover to eucalyptus woodlot and they change their farming capacity (they plough for only their consumption). On the other side, population density leads to increase the demand of wood product for construction house and as source of energy like firewood.

The agricultural input like improved seed, organic fertilizer and herbicide price increase in each cropping season. From un-publishing data from *Arb gebeya* farmer's cooperative management committee, the price of fertilizer (DAP) in the year 2000s farmers can buy the range of 600-1000 ET Birr per Quintal. Today (2019), one Quintal NPS fertilizer price is 1514 ET Birr. Due to this reason, the smallholder farmers change his/her farmland to eucalyptus plantation woodlot.

4.2. Effect of Land Use Change on Soil Properties

4.2.1. Soil physical properties

The result of the physical properties of soil analysis on soil texture, bulk density (BD), particle density (PD) and percentage of soil moisture content on selected land use, land cover at study catchment showed that the land use changes cause changes in soil physical properties (Table 4.6).

Table 4.6. The statistical values of land use change effect on selected soil physical properties

Parameters	F- value	P-value	Significant value
Sand	6.191	0.0176	*
Silt	2.921	0.1	N
Clay	5.504	0.024	*
SMC	7.676	0.00971	**
DB	7.669	0.00771	**

- ✓ **Effect of LULC change on soil texture**

Soil texture refers to the proportion of the soil "separates" that make up the mineral component of soil. The soil texture of the study area has different numerical values in clay, silt and sand proportions at each LU/LC. The textural fraction of sand was found to significantly differ in the different LULCs. The natural forest was found to have a significantly higher sand fraction than the other land uses, however, there was no significant difference among the other land uses (p=0.0176). Besides, sand proportion has shown no significant difference between slope classes. Mulugeta Sebhatleab (2014), found that, the sand percentage showed a significant difference between the LULC (p = 0.004). In other research (Alemayehu Adugna, and Assefa Abegaz, 2015), found that, textural classes of topsoil of forest land, cultivated land and grazing land are sandy loam, clay and clay loam respectively. The sand content of soils of forestland (73.6 %) is the highest and the lowest is on soils of cultivated land (29.6 %). The contradictory findings were reported by (Mulugeta Tufa *et al*. 2019), who revealed that there was no significant difference on the sand particle under different land use types.

Within the paired samples, the sand in natural forest recorded 79% in the steep slope and 75% of gentle slope; while at cultivating lands have 29% and 43% in steep and gentle slope respectively. In the same ways, the land use changes from cropland to eucalyptus woodlot has increased the soil, sand fraction of 19% to 25% at a gentle slope. During the rainy season, soil erosion over the study sites have selectively transported and/or leached fine fractions from the forest dominated cover and eucalyptus woodlot leaving behind sand fractions. On the other hand, the forest soil has rich of organic matter and the surface runoff can easily get the fine texture and the remaining textural soil proportion of sand was become higher. The surface soil in the forest cover has good moisture content, good particle aggregate and then the fine size and clay soil will be leach to ground and accumulated to subsurface.

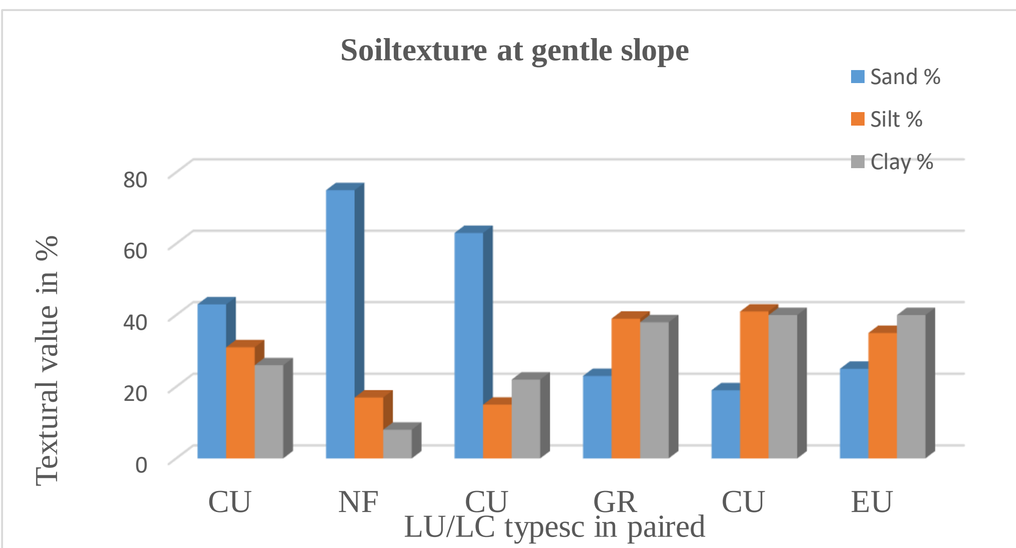


Figure 4.7. The soil textural proportions of different LU/LC in gentle slope

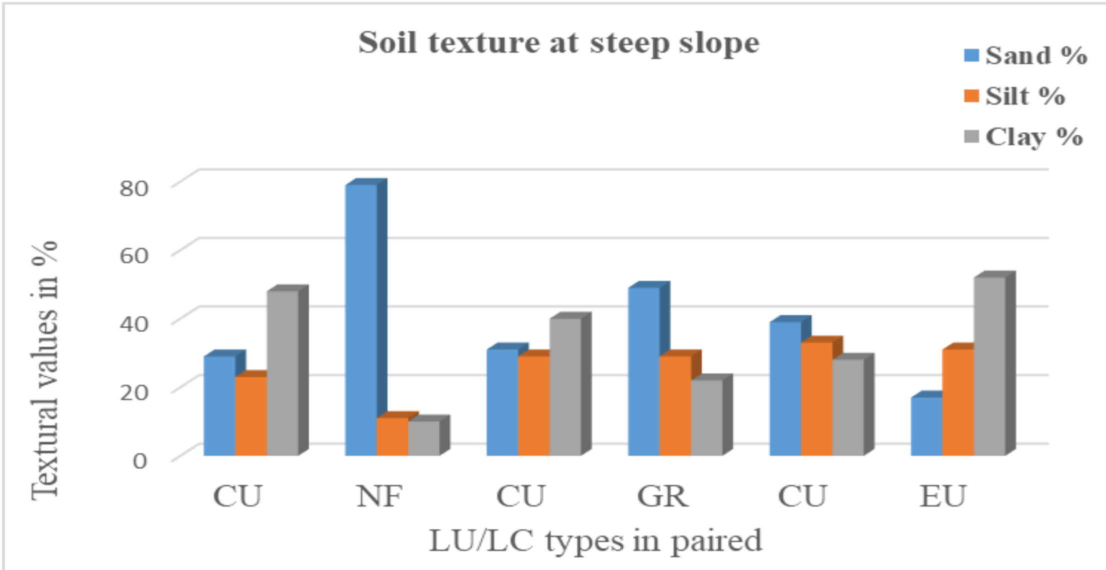


Figure 4.8. The soil textural proportions of different LU/LC in steep slopes

Silt-sized particles, which have separated that range intermediate class (0.002 to 0.05 mm), clay and sand texture. The silt content of different land uses showed no statistically significant difference both land use and slope difference.

The highest proportion of clay content was found in cropland (48%) in steep slope as compared to the paired natural forest (10%). No significant difference was found in clay fraction due to conversion of cropland to eucalyptus. In general, analysis of variance (ANOVA) indicated that clay proportion was significantly different among different land uses, (p=0.024. The mean separation of indicated that the forest land has lower clay content as compared to the land uses, which implicitly mean that conversion of forest land to cropland increases the clay proportion. This could be due to different reasons. In cropland both the silt and sand could be eroded by the rain drop impact (detachment) and runoff from the surface because the cultivated land has no surface covers and obstacles for soil erosion and the clay left in the open land and the soil was susceptible surface erosion. (Salako, 2003), said that, soil susceptibility to erosion is influenced by properties such as texture, aggregate stability, water transmission characteristics, and organic matter content. The process of soil erosion involves detachment, transportation and deposition. Thus, soils which are susceptible to detachment and transportation can be easily eroded.

The second reason may be as compared to the surface layer of natural forest; the cultivated lands have lost the surface layers of the soil due to long term cultivation practice what is now surface layer is sued to be actually subsurface layer. The clay content increase with depth vertically or soil horizons due to vertical leaching of fine fraction of soil. According to (Alemayehu Adugna, and Assefa Abegaz 2016), the clay fraction of cultivated land and grazing land increased compared to forestland, but the change is greater in cultivated land than grazing land. The lower content of sand and higher content of clay fractions in the cultivated land may be attributed to the process of plowing, clearing, and the leveling of farming fields. Because the clay particles are very small, silt, and sand fractions could be removed by runoff from the cultivated land. According to (Mulugeta Tufa *et al.* 2019), results of analysis of variance silt and clay particles were significantly ($P \leq 0.05$) affected by land use types Although there was no statistical disparity on soil, sand particles amongst land use types, there was the numerical variation across the land use types.

- ✓ **Effect of LULC change in soil bulk density**

The highest BD at steep slope was found in cultivated land (1.48 gm cm^{-3}). In the other hand, the lowest BD value was recorded in natural forest (0.80 gm cm^{-3}). That means when the land converted from forest cover to cropland the BD is increased by 0.68 gm cm^{-3}. In the second slope class (>10%) of the watershed BD indicated that, cultivated land records 1.48 gm cm^{-3} and at eucalyptus plantation BD in gentle slope (<10%) and steep slope (>10%) have almost similar (1.28 gm cm^{-3} and 1.27 gm cm^{-3}) respectively. The ANOVA results also showed that soil bulk density significantly varied with land use types ($P=0.007$). The comparison of each land use indicated that, natural forest has significant differences from cropland and eucalyptus plantation ($p=0.006$ and 0.037) respectively. Mulugeta Tufa *et al.* (2019), found that, the soil bulk density value was significantly ($P \leq 0.001$) affected by land use and by their interaction effects. On another author (Mulugeta Sebhatleab, 2014), also found that, bulk density of the upper soil layer (0 - 30 cm) had been significantly affected by LULC ($p < 0.001$). Among the LULC classes, bulk density of forest was significantly different from cropland ($p < 0.001$) and badland ($p = 0.02$). Grassland was also significantly different from cropland ($p = 0.005$). The cropland had the highest average bulk density and forestland the lowest of all LULC types.

Cropland had 0.3 gcm-3 higher BD than forestland and a 0.2 gcm-3 higher BD than grassland. The bulk density of each selected land use shown in the figure below.

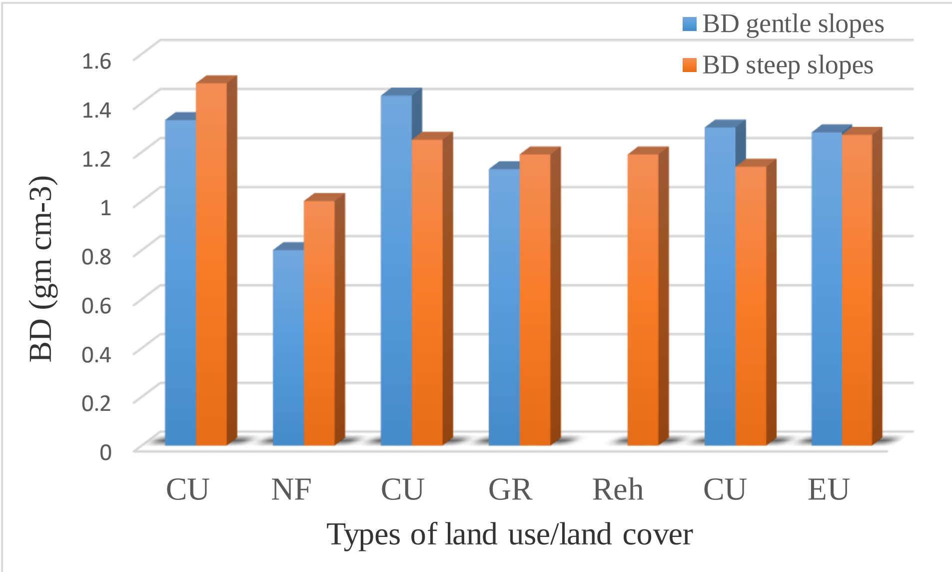


Figure 4.9. Soil bulk density in the difference land use/land cover

Generally, at all slope, the soil under natural forest had a lower bulk density, which compared with the other land uses/land cover types. The soil which are under grazing land, eucalyptus plantation, and farmland have an increased order of bulk density values. Yihenew G. Selassie and Getachew Ayanna (2013), found that in North *Achefer* district the highest BD (0-15 cm) was found in the cultivated land at both *Abechikeli Mariam* (1.41 Mg m^{-3}) and *Aferfida Georgis* (1.40 Mg m^{-3}) *kebeles* followed by the soil under eucalyptus plantations. In contrast, the lowest BD values of 1.18 and 1.08 Mg m^{-3}were observed under the natural forest at the respective sites. Higher bulk density under cultivated lands was due to the trampling effects.

- ✓ **Effect of LULC change on soil moisture contents**

The soil moisture content of natural forest has the highest values as compared to cultivated lands in both slope classes. On the other hand, the rehabilitated degraded grazing land has higher SMC (16.71%) than free grazing land (13.13%)and cultivated land (14.11%) in the same slope classes.

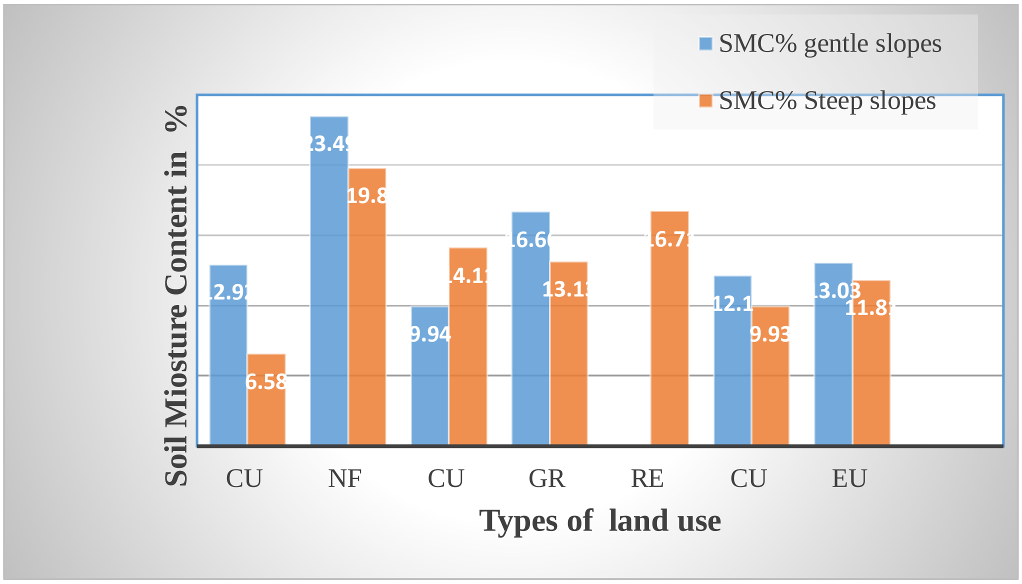


Figure 4.10. Moisture content of different LULC

The statistical results also show that soil moisture content significantly varied with land use types (P= 0.009). The mean separation indicated that significant difference found between natural forest with cropland and eucalyptus plantation. Fikadu Getachew *et al*. (2012), argued that soil moisture content differed significantly ($P < 0.05$) between the soils of the different land uses/land cover for the surface (0-15 cm) and deeper layer of (30-60 cm). In all the layers, the soil under *Eucalyptus saligna* plantation has low moisture contents compared to the other land uses/land covers including the natural forest. The SMC of eucalyptus plantations (13.03%) was less than that of natural forest and grazing land, but greater than croplands at both slope classes. Total available water was the highest in natural forest followed by grassland in both soil sampling depths and sites. At field capacity (FC), natural forest retained the highest moisture content of 35.67 and 35.98% at 15 to 30 cm (Yihenew G/Selassie & Getachew Ayanna, 2013).

4.2.2. Soil chemical properties

The result of effect of land use/land cover on soil chemical properties showed variability on different parameters. A significant effect was found on the CEC, OM TN and available Phosphorus. Whereas, PH, and available K were not affected by land use/land cover (Table 4.6).

Table 4.7. The statistical values of land use change effect on selective soil chemical properties

Parameters	F- value		Significant value
PH	0.931	0.7763	
CEC	12.38	0.00225	**
OM	28.9	0.000121	***
TN	12.38	0.00225	**
AV. K	1.441	0.309	
AV. P	4.299	0.044	*

- ✓ **Effect of LULC change in soil pH**

Soil pH for all the land uses is found to be under moderate acidic soil category, although the soil at grazing land in gentle slope showed a relatively low pH (4.52) and higher values was found in cultivating land (5.3). On the other hand, strong acid (3.91) found in cropland at steep slope. The soil pH ranges from about 3.91 to 5.3, indicated strong acidic soil condition under all the land use. Soils under cropland in steep slope were more acidic, due to leaching of basic cations by water erosion, the application of artificial fertilizer and poor return rate of the soil. According to (Yihenew G/Selassie and Getachew Ayanna, 2013), found that soils under eucalyptus plantations were more acidic, owing to more uptakes of basic cations by the trees and poor return rate of the soil. Similar to this study, the land use changed from cropland to eucalyptus woodlot had lower pH in both slope classes. However, statistical analysis of variance depicted that the effect of land use change on soil PH has no significant effects. This finding differs from the finding of (Lalisa Alemayehu, 2010), who found that the result pH (H_2O), to significantly differ among different land use/land covers ($p = 0.001$).

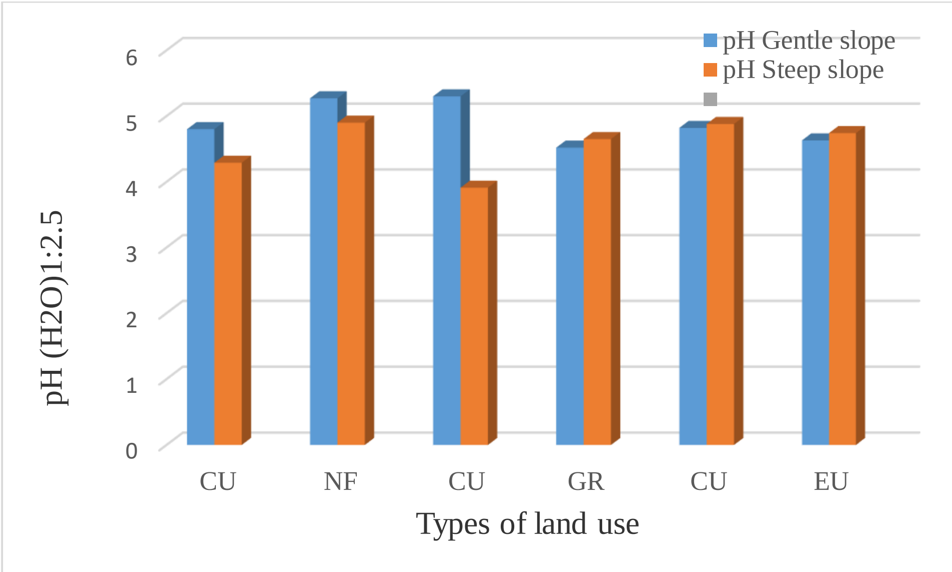


Figure 4.11. Soil pH of paired LULC in two-slope class

- ✓ **Cation exchange capacity (CEC)**

The cation exchange capacity has a significant difference among the land uses (p=0.002). The mean value of CEC under grazing land, cultivated, natural forest and eucalyptus plantation were 24.8, 24.5, 46.8 and, 23.2 (cmol (+) kg^{-}) respectively. The higher and lower values of CEC in forest and eucalyptus plantation might be due to high soil organic matter in forestland while it was less in eucalyptus plantation. Mulugeta Tufa *et al.* (2019), also found similarly that, that the cation exchange capacity (CEC) of the significantly ($P \leq 0.05$) affected by the land use types. On the contrary, Lalisa Alemayehu *et al.* (2010), found that cation exchange capacity did not show any significant difference among the different land uses/land covers though the homestead has the highest CEC value (18.00 $cmolc.kg^{-1}$) followed by cereal farm (16.41 $cmolc.kg^{-1}$), woodlot (14.59 $cmolc.kg^{-1}$) and pastureland (13.04 $cmolc.kg^{-1}$). However, they found that the CEC decreased with depth in all the land use with a 19% sharp decline across depth in pasturelands.

- ✓ **Effect of LULC change on SOM**

High SOM recorded at natural forest (6.25% and 5.45% in gentle and steep slope respectively), and lowest at eucalyptus plantations in a gentle slope (1.61%). The comparison of the adjacent land uses showed variation in SOM across land uses. In the gentle slope

(>10%) the cultivated land use and eucalyptus plantation in reference to natural forest gives -17.4% and -67.68% reduction respectively. Statistically, OM was found to significantly vary with land use change (P=0.0001). Among the different land use/land covers, natural forest was found they have a significantly higher value than cropland, eucalyptus plantation and grazing land. In another similar study by Tilahun Chibsa and Asefa Ta'a (2009), amount of organic carbon contents in different land uses of the soil surface layer was in the order of virgin forest > virgin grass> cultivated land. This indicated that, the SOM decreases through the land use change from natural forest to cultivated land and from cultivated land to eucalyptus plantation woodlot respectively. The SOM of virgin forest land was higher than the virgin grasslands most probably because of differences in management practices between the two-land use systems. Soils of the forest sites were well protected with little disturbance, but that of the virgin grassland was poorly managed; heavily overgrazed, and mostly they were susceptible to surface erosion and water logging (Yifru; Abera, and Taye Belachew, 2011).

In addition to this, the variation in percentage of SOM due to the conversion from cropland to open grazing is 44%, but the change from natural grazing on cropland at a gentle slope was only by -3.8%. From statistical analysis, the land use change to eucalyptus plantation has no effect on OM probably due to decomposition. Hence, the accumulation of OM depends on the number of years that particular land use has used, where most eucalyptus plantations have a relatively recent history.

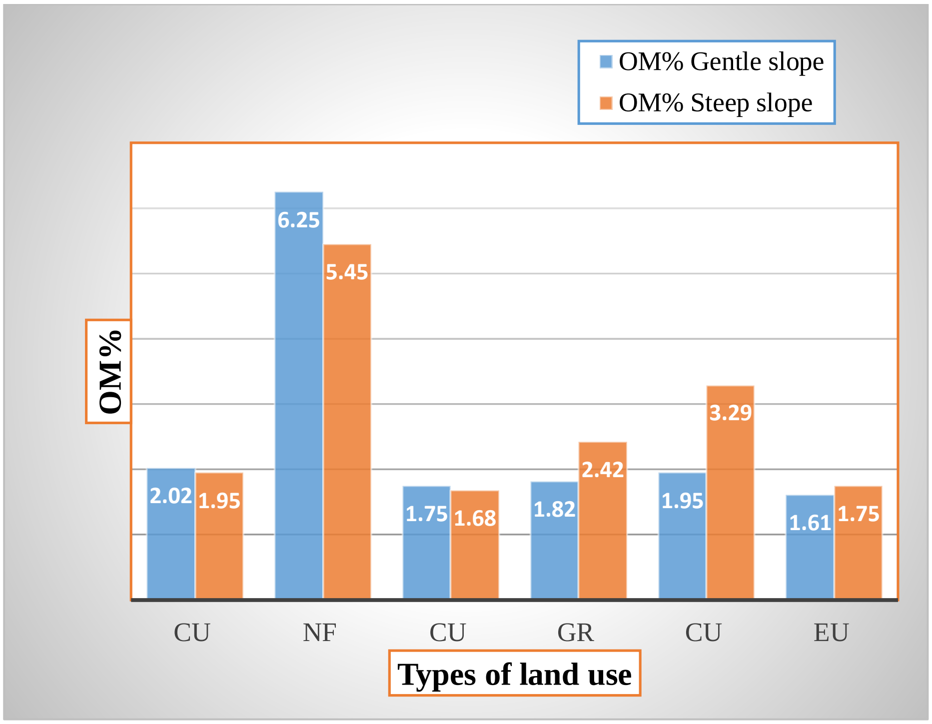


Figure 4.12. OM contents of selected LULC

In similar studies Tilahun Chibsa and Asefa Taa, (2009), found that, within similar depths, higher organic carbon contents were recorded in natural forest followed by natural grasslands compared to croplands. Conversion of natural forest to cropland has reduced the soil organic matter content by -67.6%. Conversion of cropland to eucalyptus plantation woodlot also caused a reduction by -17.4%. At steep slope (>10%) the variation of cultivated land from natural forest also recorded as -64.2% and the variation of eucalyptus plantation woodlot from agricultural cultivated land was -46.8%. This indicated that land use change affects SOM content of the soil.

- ✓ **Effect of LUC on nitrogen (N)**

Total N contents of the soil also affected by the change of LULC systems. Similar to organic carbon, there were significant variations in total nitrogen among different land use (p= 0.002). In addition to this, a multiple comparison result revealed that natural forest has significant differences from cropland, eucalyptus plantation and grazing land. Yihenew G/Selassie and Getachew Ayanna (2013), found that, total N contents of the soil were highly affected by the different land use types. In our study, total soil N at the gentle slope varied from (0.45%)

under natural forest to (0.11%) in cropland. Similarly, in steep slope the forestlands have (0.39%) and the neighboring cropland only (0.09%). The land cover changes from cropland to eucalyptus woodlot showed no significant difference (0.13% and 0.13% respectively in gentle slopes). Mulugeta Sebhatleab (2014), found that, at the 0 - 30 cm depth, forests were significantly different from bare land ($p = 0.001$) and farm land ($p < 0.003$). Grassland also significantly different from bare land ($p < 0.001$) and farmland ($p = 0.001$).

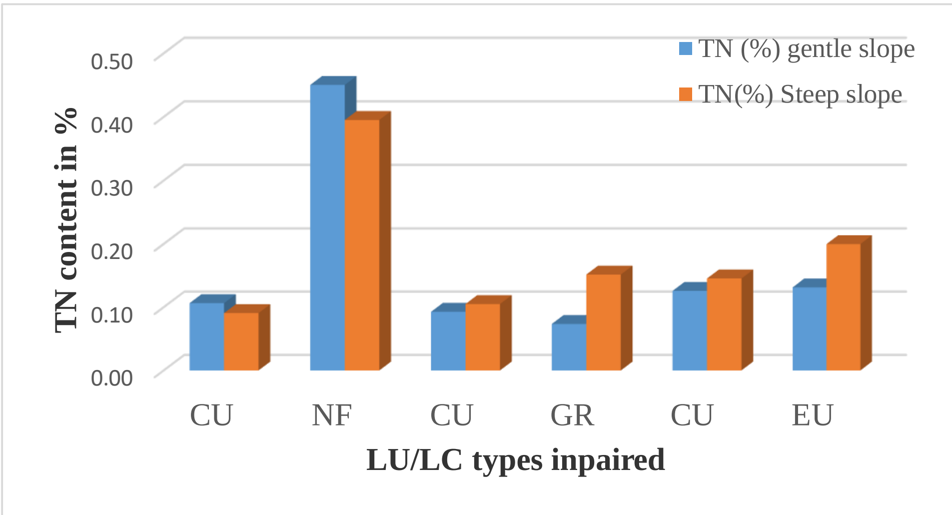


Figure 4.13. TN% contents of selected LU/LC

- ✓ **Effect of LUC on potassium (K)**

The available potassium (AK) content of the selected land use systems recorded range from (645 ppm) natural forest to (24.25 ppm) cropland which paired with eucalyptus plantation at the gentle slope. As the comparative land use, the grazing land has 615 ppm and when converted to cropland it decreased to (320 ppm). On the other hand, the land use land converted from cropland (24.25 ppm), to eucalyptus plantation raised the AK to (240 ppm). These results indicated that conversion of land from the forest to grazing and cropland diminishes AK, whereas the change from cropland to plantation recovers AK amount closer to the original status.

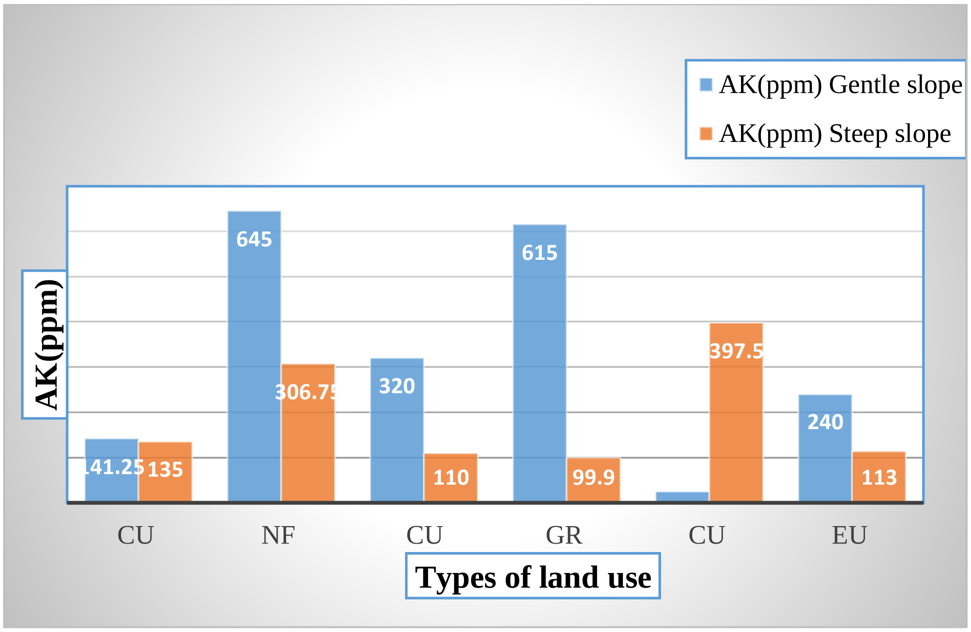


Figure 4.14. AK contents of selected LU/LC

Comparison of the two adjacent land uses at a gentle slope (>10%) revealed that conversion from natural forest to cropland causes reduction of available K by (-78.1%), while conversion of cropland to eucalyptus plantation increased by (889.6%). At steep slope (>10%) conversion from natural forest to cropland resulted reduction in available K by (-55.9%) and the variation from eucalyptus plantations is about (-71.5%). This indicated that the effect of the slope of the land also affects the available K in the given land use change but, analysis of variance (ANOVA) showed that, available K had no significant differences in land use types. In similar study Lalisa Alemayehu *et al.* (2010), found that, there is no significant difference between the pastureland and cereal farm, which indicates the improvement either of the abandoned pastureland through time due to animal wastes, or the declining quality of the cereal farms due to intensive cultivation. On the contrary, Mulugeta Tufa *et al.* (2019), found that, the available K of soil was significantly ($P \leq 0.001$) affected by land use types.

- ✓ **Effect of LUC on phosphorus (AP)**

The available phosphorus (AP) content of selected land use systems range from (4.2 ppm to 24.2 ppm) in eucalyptus plantation woodlots in steep slopes and natural forest in gentle slope respectively. In adjacent land uses the natural forest has (24.2 ppm) and the cropland (20.42 ppm). Whereas conversion from cropland to eucalyptus plantation led to a reduction from

(9.2 ppm, to 7.9 ppm). Accordingly, the analysis of variance indicated that, the available P was significantly affected (P =0.044) by land use types. According to Mulugeta Tufa, *et al.* (2019), available P was significantly ($P \leq 0.001$) affected by land use types.

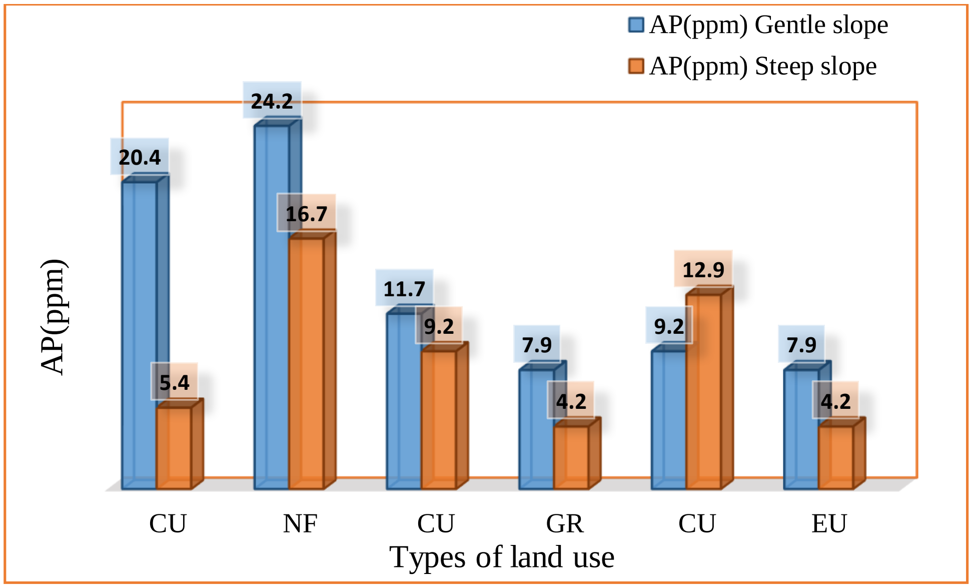


Figure 4.15. AP contents of selected LU/LC

In general, our finding indicated that conversion of forestland to cropland, and then to eucalyptus plantation causes continuous reduction in available P in both slope classes. Mulugeta Sebhatleab (2014), also found that, the level of available phosphorus differed significantly for the LULC categories at a depth of 0 - 30 cm (p = 0.004). Among the LULC categories the bare land was significantly different from forestland p = 0.004) and grassland (p = 0.022) of average forestland, soil had twice the level of phosphorus than in bare land at a soil depth of 0 – 30 cm.

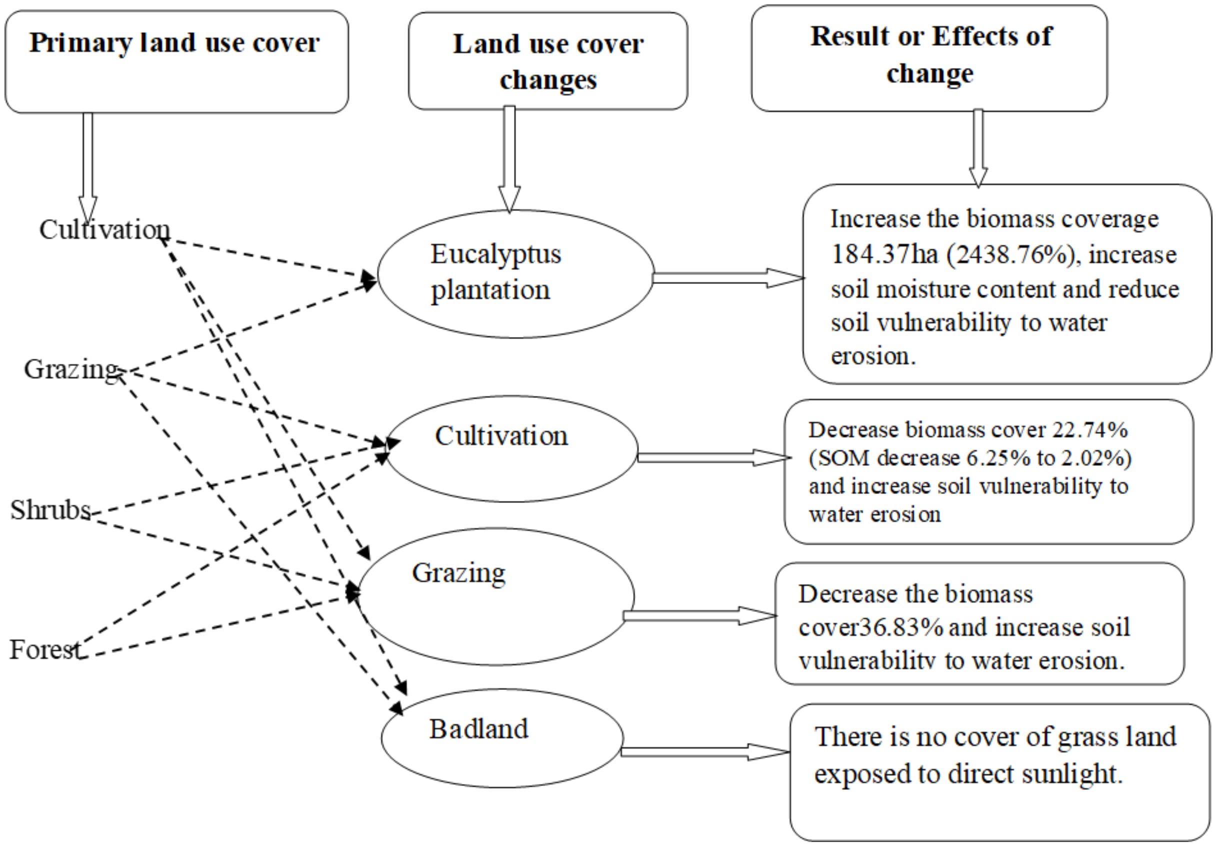


Figure 4.16. The land use land covers change flows and its effects

4.3. Land use Change Prediction and Sustainability

4.3.1. Future land use land cover change prediction

According to the above LU/LC classification, the result indicated that, declining trend of the natural forest ecosystem, riverine forest and scattered shrub land due to the expansion of grazing and agricultural farmland in the first decade. However, in the last decade, cropland and grazing lands have been converted to eucalyptus plantation. The image classification result indicates the expansion of eucalyptus plantation woodlot at the expense of cropland and the grazing lands particularly along the main roads. According to our respondents of the FGD, the expansion of plantation woodlot increased due to decreasing soil fertility which increased the demand of fertilizer application per ha growths from 100 kg ha^{-} to 200 kg ha^{-}. This increment indicates that the smallholder farmers shifted their interests from production of annual crops to growing perennial cash crop like eucalyptus woodlot. Such trend of conversion of land first from natural forest to cropland, and later from cropland to the plantation when land productivity became low was reported in other studies (Mulugeta Lemenih *et al.* 2004).

In addition to this, due to urban expansion, the demand of construction wood has increased wining farmer's decision in terms of economic advantages. According to wood merchants in the *Dera* district, one piece of wood which have a diameter of 12 cm which is used for roof construction, market price increased from 5 to10 ET Birr in 2007 to 40 to 60 ET Birr in 2017. This rise in the price of wood has caught the interests of youth farmers to plant their fragmented pixel land to plant with eucalyptus woodlot, and look for other alternative income generating activities. On the other hand, other opportunities such as REDD+ project and closer support of the government in the provision of seedlings has supported many farmers to plant more eucalyptus woodlots. In this year alone, REDD+ project covered more than 11.5ha by eucalyptus seedling in the study catchment. According to Bekele Lemma (2006), the expansion of fast growing native and exotic tree species plantation is with the intention of delivering the current market demand of quality timber and other wood products in Ethiopia.

Figure 4.17. Farmer carrying eucalyptus seedlings on the way to his planting site

Due to the above justification in the scenario of Business as Usual (BAU) based on past and recent (1982–2017) trends the spatial distribution of land use change for the next decade (2030), eucalyptus is expected to expand more at the expense of even productive croplands.

According to the spatial distribution of land cover prediction, the eucalyptus woodlot land cover will be extended up to 271.38 ha and the agricultural cultivated land and grazing land will be decreased to 510.03 ha and 158 ha by 2030 respectively. As shown in the LU/LC change trends, eucalyptus plantation extends parallel to the road network and it is expected to expand even at a fast rate when considering recent intervention of supportive agents like REDD+. FDRE Ethiopia (2011), CRGE (climate resilient, green economy) strategic plan indicated that, the Government of Ethiopia (GoE) identified the forestry sector as one of the four pillars of the green economy that the country is planning to build by 2030. The government also sets the following major targets for the forestry sector: afforestation on 2 million ha, reforestation on 1 million ha and improved management of 3 million ha of natural forest. Through proper management of 5 million, ha of forests and woodlands, Ethiopia hopes to achieve 50% of its total domestic greenhouse gas (GHG) emissions reduction potential by 2030.

Figure 4.18. Photo of new plantation expansion along the roadside

4.3.2. Sides of sustainability to *Enkulal* watershed

Recent trends in global demand for food and bioenergy change which are closely linked to food and energy price spikes and volatility have raised concerns about the impact of LUCC change on biodiversity and other environmental impacts (Sustainable Development in the 21st century, 2012).

In general, the vegetation coverage increased through time, especially in the years from 2007 to 2017 forest cover increased from 198 ha to 296 ha. This indicated that the environmental sustainability of the study area increased due to increase carbon stoke, decrease aggravated to soil erosion specially soil detachment erosion. In addition to this plantation of eucalyptus, the land was free from intensive cultivation practice and decreases the causes of soil erosion like, exposed to land to direct sunlight and raindrop effects. According to (UNDESA., 2012), report an environmental Kuznets curve, which shows a decline in forest extent as the economy grows, and subsequently an increase after reaching a threshold explains LU/LC change trends in most countries. Forest extent, density, and biodiversity also reveal an environmental Kuznets curve pattern. Many countries in the tropics are in phase two increasing forest extent, density, and biodiversity. However, the environmental Kuznets curve of forest extent has not been observed in many countries due to a number of reasons, including strong timber markets, civil wars, government policies, etc.

On other hand, the shrinking of agricultural land lead to an increase in demand of food production due to decreasing the supply of production and increased load on the rest cultivated land to produce maximum crop yield. From respondent's idea, they use more artificial fertilizer to produce or increase land productivity currently and it makes their land become degraded. The land productivity also decreases due to intensive cultivation without fallow and increase ploughing interval and the soil become more susceptible to erosion. In otherwise, crop rotation interval also decreases because they produce selective crop types due to arable land shortages. In this case environmental sustainability decrease and land degradation also become the main problem for the next years. According to Waceke and Kimenju (2007), intensive crop production in nutrient depleted soils has been convincingly associated with severity of particularly soil born pests and diseases and the pest population increased with increase in nitrogen fertilizer application, its effect on the yield was not significant and bean yield was higher in fertilized than in the unfertilized crop.

CHAPTER 5. CONCLUSION AND RECOMMONDATION

5.1. Conclusion

The result of land use/cover maps of the three periods of 1982, 2007 and 2017 classified eight, major LU/LC types which were identified by GIS and ERDAS software using the row data of satellite images and scanned Arial photograph. The LU/LC change trend from 1982 to 2017 were not the same direction for all land use, natural forest and riverine decrease continuously on the other hand eucalyptus plantation cover increased alarmingly from 7.56 ha (0.72%) to 191.93 ha (18.28%). From observation of result, the farmer changes its income source from intensive cultivation to cash tree planting of eucalyptus due to the reduction of his/her land productivities and increasing the cost of fertilizer.

Effect of land use change on soil properties were investigated on selected physical and chemical properties (Bulk density, soil particle (texture), soil moisture content, pH, CEC, soil organic matter, total Nitrogen, available Phosphorus, and available Potassium) on paired neighboring land uses, which are used to be similar previously. From physical properties, bulk density, indicated that the soil quality deteriorated from baseline (natural forest) to grazing and croplands respectively, and eucalyptus plantation has reversed the trend back to original condition. Due to this, the vegetation cover increases the soil moisture content and decrease soil susceptibility to intensive erosion when the land cover change from cultivation to eucalyptus plantation. The ANOVA analysis indicated that, natural forest has significant differences from other land use/land cover for most soil properties. This indicated that, the natural ecosystem sustainability deteriorated due to a shirking of natural vegetation cover. In general, the slope difference has no statistically significant change for all selected soil properties. This could be due to narrow differences in the two slope classes while selecting paired land uses that had similar land cover/ land use in the past.

Eucalyptus plantation has increased rapidly, particularly in recent years at the expense of cropland. Due to this result, communities and government will look for alternative means of livelihood like non-farm/off-farm income generating activities due to limited capacity of agriculture to accommodate additional population and for sustainable development, especially to increase productivity and sustainability of the environment. The spatial distribution of land cover prediction, the eucalyptus woodlot land cover will be extended up to 271.38 ha and the agricultural cultivated land and grazing land will be decreased to 510.03 ha and 158 ha by 2030 respectively. This implies that, for next period the most productive land to annual cropland will covered by eucalyptus plantation due to increasing the farmer interest and the increase the demands of wood production.

5.2. Recommendations

- Based on the study findings, the following recommendations are drawn: -

- Designating interventions or activities that can be synchronized to land use plan with the use of land based on land capabilities and suitability class is very important, as an effort to improve the livelihood of the community in the study area and to increase the economic importance of such areas. In *Ekulal* watershed, community participation in planting eucalyptus woodlot without considering the scientific suitability analysis may not only hamper agricultural production, but it could also compromise sustainable growth and food security of the area. This activity sided to only the economic growth of individual landholding and lacks consideration of sustainable development. Therefore, the community participation on forest restoration on communal degraded land and planting on their own land should be supported with land use plans that guide what activities that farmers use their land for both environmental and economical sustainable development.

- Moreover, were commend that farmers should have a trend to give more attention to the management of their own and communal land by applied integrated soil fertility management practices. As the result of soil laboratory of Soil physical properties specially soil particle or textures of farm land accumulated by high clay contents which indicated that, soil has no mulching effect and highly affected by rain drop splash erosion. Therefore, land use changes must be traced and measured as they have consequences on soil properties, productivity and sustainability.

- For further studies, the researcher uses high-resolution images to identify small land fragments or parcels, detailed soil profile description addition to ploughing layers to increase the statistical precision and accuracy of soil result. To study land use change scenario, use LU/LC change models in the watershed describe the spatial distribution of land use conversion and taking the result for discussing land use sustainability.

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APPENDIX

Appendix table 1. Soil sample points in paired land use types of study area

Soil sample points at the upper catchment of *Gumara* watershed

	Coordinates	
Sample code	**X**	**Y**
S1CU	370510	1286898
S1NF	370522	1286860
S1CU	366652	1286108
S1GR	366669	1286081
S1CU	366323	1286009
S1EU	366358	1286046
S2RE	369928	1286968
S2CU	369883	1286998
S2GR	369883	1286998
S2CU	370066	1286371
S2NF	368345	1285011
S2CU	368335	1285036
S2EU	370068	1286241

Appendix table 2. Soil sample laboratory results of study area

Amhara Design & Supervision Works Enterprise
Laboratory Service
Soil Chemistry and water quality section

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ላቦራቶሪ አገልግሎት
የአፈር ኬሚስትሪና የውሃ ጥራት የስራ ክፍል

Soil Analyses of Laboratory Report
Client:- BDU IUC Programme (Alelegn Gardew)

Sr.	Lab.	Cleint	pH (H_2O)	EC	Texture				CEC	OC	OM	TN	Av.K	Av.P
No.	No.	Code	1:2.5	dS/m	%sand	%Silt	%Clay	Class	cmol(+)/kg	%			ppm	
1	1684/18	S2REVsGR	4.61	0.08	43	29	28	Clay Loam	35.60	1.17	2.02	0.099	112.50	4.15
2	1685/18	S1CUVsGR	3.91	0.061	31	29	40	Clay	26.00	0.975	1.68	0.105	110	9.15534
3	1686/18	S2CUVsNF	4.29	0.064	29	23	48	Clay	29.20	1.131	1.95	0.0907	135	5.4018
4	1687/18	S2NFVsCU	4.9	0.248	79	11	10	Sandy Loam	45.40	3.159	5.45	0.3952	306.75	16.6624
5	1688/18	S1CUVsNF	4.8	0.082	43	31	26	Loam	26.80	1.17	2.02	0.1064	141.25	20.416
6	1689/18	S2GRVsREVsCU	4.65	0.09	49	29	22	Loam	32.40	1.404	2.42	0.1515	99.9	4.15062
7	1690/18	S1NFVsCU	5.27	0.381	75	17	8	Sandy Loam	46.80	3.627	6.25	0.4503	645	24.1695
8	1691/18	S2CUVsGR	5.3	0.082	63	15	22	Sandy Clay Loam	28.40	1.014	1.75	0.0927	320	11.6577
9	1692/18	S1CUVsEU	4.82	0.076	19	41	40	Silt Loam	20.80	1.131	1.95	0.1257	24.25	9.15534
10	1693/18	S1GRVsCU	4.52	0.122	23	39	38	Clay Loam	24.80	1.053	1.82	0.0734	615	7.90416
11	1694/18	S2CUVsEU	4.88	0.067	39	33	28	Clay Loam	30.40	1.911	3.29	0.1454	397.5	12.9089
12	1695/18	S2EUVsCU	4.74	0.079	17	31	52	Clay	32.80	1.014	1.75	0.0997	113	4.15062
13	1696/18	S1EUVsCU	4.63	0.075	25	35	40	Clay	23.20	0.936	1.61	0.1313	240	7.90416

Name of Technician Getaneh Desalegn Checked by Haily Getahun Yimer Soil Chemistry & Water Quality Team Leader Approved by Haily Getahun Yimer Soil Chemistry & Water Quality Team Leader
Date 23/04/11 Date Date
Sign Sign Sign

Appendix table 3. Soil physical properties of each paired land use land covers

Gentle Slope <=10%					
Sample code	Texture			BD	MC%
	%sand	%Silt	%Clay	$gmcm^{-3}$	
S1CU: NF	43: 75	31: 17	26: 8	1.33: 0.8	6.58: 23.49
S1CU: GR	63: 23	15: 39	22: 38	1.43: 1.13	9.94 :16.66
S1CU: EU	19: 25	41: 35	40: 40	1.3: 1.28	12.1: 13.03
	Steep Slope >10%				
S2RE: GR	43 :49	29: 29	28: 22	1.19: 1.19	16.71 :13.13
S2CU: GR	31 :49	29: 29	40: 22	1.25 :1.19	14.11:13.13
S2CU: NF	29: 79	23: 11	48: 10	1.48: 1	12.92 :19.8
S2CU: EU	39: 17	33: 31	28: 52	1.14: 1.27	9.9: 11.81

Notes: -

S1CU: EU	Slope 1 Cultivation pair with Eucalyptus plantation
S1CU: GR	Slope 1 Cultivation pair with grazing land
S1CU: NF	Slope 1 Cultivation pair with Natural forest
S1EU: CU	Slope 1 Eucalyptus plantation pair with Cultivation
S1GR: CU	Slope 1 Grazing land pair with Cultivation
S1NF: CU	Slope 1 Natural forest pair with Cultivation
S2CU: EU	Slope 2 Cultivation pair with Eucalyptus plantation
S2CU: GR	Slope 2 Cultivation pair with grazing land
S2CU: NF	Slope 2 Cultivation versus Natural forest
S2EU: CU	Slope 2 Eucalyptus plantation pair with Cultivation
S2GR: CU	Slope 2 Grazing land pair with Cultivation
S2NF: CU	Slope 2 Natural forest pair with Cultivation
S2RE: GR	Slope 2 Rehabilitation pair with grazing lands

Appendix 4. Soil chemical properties of each paired land use land covers

Gentle Slope <=10%					
Sample code	PH (H2O) 1:2.5	OM (%)	TN (%)	Av.K (ppm)	Av.P (ppm)
S1CU: NF	4.8: 5.27	2.02: 6.25	0.11: 0.45	141.25: 645	20.42: 24.17
S1CU: GR	5.3: 4.52	1.75: 1.82	0.09: 0.07	320: 615	11.66: 7.9
S1CU: EU	4.8: 4.63	1.95:1.61	0.13: 0.13	24.25: 240	9.16: 7.9
	Gentle Slope >10%				
S2RE: GR	4.61: 4.65	2.02: 2.42	0.10: 0.15	112.5: 99.9	4.15: 4.15
S2SU: GR	3.91: 4.65	1.68: 2.42	0.11: 0.15	110: 99.9	9.16: 4.15
S2CU: NF	4.29: 4.9	1.95: 5.45	0.09: 0.4	135: 306.75	5.4: 16.66
S2CU:EU	4.88: 4.74	3.29: 1.75	0.15: 0.2	397.5: 113	12.91: 4.15

Appendix table 5. Data prepared for R software analysis

LU	SLOPE	SAND	SILT	CLAY	SMC	BD	PH	CEC	OM	TN	Av. K	Av. P
Agri	1	43	31	26	6.58	1.33	4.8	26.8	2.02	0.11	141.25	20.42
Agri	1	63	15	22	9.94	1.43	5.3	28.4	1.75	0.09	320	11.66
Agri	1	19	41	40	12.1	1.3	4.82	20.8	1.95	0.12	24.25	9.16
Agri	2	31	29	40	14.11	1.25	3.19	26	1.68	0.11	110	9.16
Agri	2	29	23	48	12.92	1.48	4.29	29.2	1.95	0.1	135	5.4
Agri	2	39	33	28	9.93	1.14	4.88	30.4	3.29	0.15	397.5	12.91
F	1	75	17	8	32.49	0.8	5.22	46.8	6.25	0.45	645	24.17
F	2	79	11	10	19.8	1	4.9	45	5.45	0.4	306.75	16.66
GR	1	23	39	38	16.66	1.13	4.52	24.8	1.82	0.02	615	7.9
GR	2	49	29	22	13.13	1.19	4.65	32	2.42	0.15	99.9	4.15
EU	1	25	35	40	13.03	1.28	4.63	23.2	1.61	0.13	240	7.9
EU	2	17	31	52	11.81	1.27	4.74	32	175	0.2	113	4.15

Appendix table 6. Error confusion matrix of spot image on 2007

				error matric	2007					
	Classified	Bare land	Cultivated	E. Plantation	Grazing land	Natural forest	Riverine	Settlement	Shrubs and grass	Total
1	Bare land	4	1	0	0	0	0	0	0	5
2	Cultivated	0	35	0	3	0	0	2	0	40
3	E. Plantation	0	0	22	1	0	1	0	2	28
4	Grazing land	0	2	0	21	0	0	0	5	28
5	Natural forest	0	0	0	0	11	0	0	1	12
6	Riverine	0	0	2	0	0	10	0	1	13
7	Settlement & road	0	3	0	0	0	0	11	0	14
	Shrubs and grass	0	0	2	1	0	2	0	22	27
	Total	4	40	26	26	11	12	13	26	167

Appendix table 7. Error confusion matrix of spot image on 2017

				error matric	2017					
	Classified	Bare land	Cultivated	E. Plantation	Grazing land	Natural forest	Riverine	Settlement & road	Shrub land	Total
1	Bare land	5	1	0	0	0	0	0	0	6
2	Cultivated	0	42	0	5	0	0	2	0	49
3	E. Plantation	0	0	26	0	0	3	0	2	31
4	Grazing land	0	4	2	29	0	0	0	2	39
5	Natural forest	0	0	0	0	11	1	0	0	12
6	Riverine	0	0	2	0	0	16	0	3	21
7	Settlement & road	0	1	0	3	0	0	12	0	16
8	Shrub lands	0	0	2	1	0	1	0	30	34
	Total	5	43	32	38	11	21	14	35	208

Appendix 8. FGD Check lists

1. What are the main driver forces to land use land cover changes specially expansion of Eucalyptus plantation?
2. From the underline factors, which one is the major to aggravate to land use/land cover change?
3. How to understand the local community about land use/land cover change?
4. What do you mean about the expansion Eucalyptus plantation?

BIOGRAPHY

Alelign Gardew was born in *Pawi* district, a *Metekel* zone of *Beshangul Gumuz* Regional State, Ethiopia, in 1987. He attended the first primary Education in *Pawi* (up to grade 6^{th}) "*L_2M_{24}*" primary first level school and $7^{th}$and 8^{th} education at "L_2 M_{14}" Full primary School. Then he has followed *Pawi* Senior secondary and Preparatory School and then he joined *Kombolcha* Agricultural College in 2007 where he got Diploma the field of Natural Resource. On the first, he was employed as Natural Resource Extension expert at *Dangila* district, BSc Degree in Natural Resource Management from Bahir Dar University in July 2013. In 2014, he was jointed *Amhara* Design and supervision Work Enterprise as junior soil expert. In 2015, he employed as Project specialist soil surveyor in Addis Ababa in the organization of the Ethiopian Agricultural Transformation Agency (ATA) up to the last 2017. Then; he has joined at Bahir Dar University, College of Agriculture and Environmental Sciences, Department of Natural Resources Management in the regular program as a candidate for Master of Science degree in Environment and Climate change in 2018/19 by self-sponsored. By the time of research working, he became the employee of *Amhara* REDD+ project as a forest expert at *Kewet* district in North *Shewa* project units. Now a day he is the member Organization for Development and Rehabilitation in *Amhara* (ORDA) through the project of Forest and Landscape Restoration as the position of forest and land use officer at *Libokemkim* district project Office.