LAND USE LAND COVER CHANGE DYNAMICS AND SOIL LOSS: GIS AND REMOTE SENSING BASED ANALYISIS, IN SHASHOGO WEREDA, HADIYA ZONE, SNNPRS, ETHIOPIA

M. Sc. THESIS

BY

YOSEPH DEBOCH HANKORE

HAWASSA UNIVERSITY, INSTITUTE OF TECHNOLOGY
HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE SCHOOL OF BIOSYSTEM AND ENVIRONMENTAL ENGINEERING, INSITUTE OF TECHNOLOGY, HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

IN PARITIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE WITH SPECIALIZATION IN SOIL AND WATER CONSERVATION ENGINEERING

MAY, 2018

APPROVAL SHEET-I

We, the undersigned, members of the Board of Examiners of the final open defense by YOSEPH DEBOCH HANKORE ID.No SGSs/010/08 have read and evaluated his thesis entitled "LAND USE LAND COVER CHANGE DYNAMICS AND SOIL LOSS: GIS AND REMOTE SENSING BASED ANALYISIS, IN SHASHOGO WEREDA, HADIYA ZONE, SNNPRS, ETHIOPIA ", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master's with specialization in Soil and Water Conservation Engineering.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

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STATEMENT OF THE AUTHOR

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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This MSc thesis has been submitted for examination with my approval as thesis advisor.

Name: Nigatu Wondrade (PhD)

Signature: _________________

Place: Hawassa University

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LIST OF ACRONYMS

CSA	Central Statistical Authority
DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
ENMA	Ethiopian National Meteorological Agency
ERDAS	Earth Resources Data Analysis System
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
IGBP	International Geosphere and Biosphere Program
IHDP	International Human Dimensions Program on Global Environmental Change
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectare
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Change
MSS	Multi Spectral Scanner
OLI	Operational Land Imagery
RS	Remote Sensing
RU	Research Unit
SCRP	Soil Conservation Research Programme
SNNPRS	South Nations, Nationalities and Peoples Regional State
SPSS	Statistical Package for Social Science
SWANRDO	Shashogo Wereda Agriculture and Natural Resources Development Office
t/ha/yr	tons per hectare per year
TM	Thematic Mapper
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator

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ABSTRACT

The relationship between land use land cover change dynamics and soil loss over the last four decades (1973-2015) was investigated using GIS and Remote Sensing data at Shashogo Wereda, Hadiya Zone, SNNPRS, Ethiopia. In order to achieve these, satellite data of Landsat 1 MSS for 1973, Landsat 5 TM for 1986, Landsat 7 ETM plus for 2000, and Landsat 8 OLI for 2015 have been obtained and pre-processed using ERDAS Imagine 2014 software. The Maximum Likelihood Algorithm of Supervised Classification has been used to generate LULC maps. Ancillary data were used to validate the classified LULC maps. For the accuracy of classified LULC maps, a confusion matrix was used to derive overall accuracy and results were above the minimum and acceptable threshold level. For change detection statistics, cross-tabulation matrices method was employed to identify gains and losses between LULC classes. The study analyzed the magnitude of spatial and temporal LULC changes for three consecutive periods; 1973 to 1986, 1986 to 2000, and 2000 to 2015. Moreover, the soil loss from the watershed was estimated using USLE employing GIS tools. Results of the study revealed that the study area has undergone substantial LULC changes. Over the 42yrs, the aerial coverage of cultivated land was increased from 43.9 to 63.0% between 1973 and 2015. Similarly, water body and wetland were increased from 0.6 to 3.9% and 4.4 to 6.7% respectively. Settlement area which was not found in the first and second period of study years, satellite image result have 2.9% proportion in 2015 LULC classification. On the other hand, grass land, bush land, and bare land were decreased from 16.1 to 6.5%, 28.6 to 12.4%, and 6.4 to 4.5% between 1973 and 2015, respectively. Following the land use change pattern, soil loss values were increased in 2015. The estimated soil loss rate in the watershed was 14.31t/ha/yr in 2015. The findings of this study suggested that the rate of LULC change over the study period, particularly intensively cultivated land, bare land, and soil erosion problems need to be given due attention to maintain the stability of the ecosystem.

Keywords: *Shashogo, Land Use Land Cover, Soil Loss, USLE, GIS, Remote Sensing, Ethiopia*

1. INTRODUCTION

1.1 Background

Land use and land cover change dynamics are widespread, accelerating, and significant processes driven by human actions but also producing changes that impact humans (Agarwal et al., 2002). These dynamics alter the availability of different biophysical resources including soil, vegetation, water, animal feed and others. Consequently, land use and land cover changes could lead to a decreased availability of different products and services for human, livestock, agricultural production and damage to the environment as well.

Land use and land cover change (LULCC) are associated with large negative impacts on ecosystems observed at local, regional and global scales. High rates of water, soil and air pollution are the consequences of observed LULCC. Biodiversity is reduced when land is changed from a relatively undisturbed state to more intensive uses like farming, livestock grazing, selective tree harvesting (Ellis, 2011). These changes alter ecosystem services and affect the ability of biological systems to support human needs, and also determine, in part, the vulnerability of places and people to climatic, economic and socio-political perturbations (Lambin & Geist, 2006). LULCC is a locally pervasive and globally significant ecological trend and has become an event of paramount importance to the study of global environmental change (Geist and Lambin, 2001). LULCC has increasingly become a key research priority for national and international research programs examining global environmental change. The series of scientific study programs, issued and promoted by International Geosphere Biosphere Program (IGBP) and International Human Dimensions Program (IHDP) in 1995, make the study of land use and land cover change (Turner et al., 1995) as one of the hot topics in the global environmental change. LULCC can affect biodiversity, biogeochemical cycles, soil fertility, hydrological cycles, energy balance, land productivity and the sustainability of environmental services provision (Lambin et al. 2001, Geist and Lambin, 2002).

Land use and land cover changes affect ecosystems in two major ways. The first is the direct effect on aquatic and terrestrial ecosystem change and the second is changing the climate by contributing to carbon emission. Therefore, the interest in land use and land cover change is driven by impacts on fundamental ecosystem characteristics and processes, including the productivity of the land, the biological diversity, and hydrological cycles and on climate (De Sherbinin, 2002).

Since the 1970s concerns over land use and land cover change emerged in the research agenda on global environmental change (Lambin et al., 2003). The main focus of researchers and policy makers around the world has become both monitoring and mediating the negative consequences of land use and land cover change and sustaining the production of essential resources (Ellis & Pontius, 2007).

In sub-Saharan Africa, a combination of growing populations and land degradation are increasing the vulnerability of people to both economic and environmental change (Millennium Ecosystem Assessment, 2005). Land degradation is a serious problem in Africa, but it is most severe in the densely populated highlands of East Africa (Pender et al., 2006).

The Ethiopian highlands are among the most densely populated agricultural areas in Africa (McGinley, 2008). In Ethiopia, too, fast population growth and uneven spatial distribution of population have been affecting resource use, leading to its gradual deterioration. Rapid population growth is resulting in increased demands for additional arable land which is surely not adequately available. Population growth leads further to unnecessary natural resource exploitation such as forest clearing both for farming and settlement purposes, short fallow periods, and land fragmentation which has a direct adverse effect on agricultural output (Mamo, 1990; Teferra, 2009).

Increase in population and a continuous decline in the amount of agricultural land have led to an indiscriminate exploitation of natural forests and fragile lands for agriculture, soil organic matter and soil nutrient depletion are among the major forms of soil degradation (Lemenih *et* al., 2005). Surface runoff in the Ethiopian highlands can thus be considered to increase with population growth, land use expansion, and intensification without soil and water conservation, as well as with accelerated land degradation (Hurni et al., 2005).

Land degradation results mainly due to population pressure which leads to intense land use without proper management practices. Over population makes people move towards sensitive areas like highlands. In such areas land use without considering the slope and erodibility leads to severe erosion and related problems.

Ethiopia has experienced recorded anthropogenic interference on ecosystems through land use change for four to five decades (Hailu, 2000). Environmental degradation is one of the major constraints impeding sustainable development in Ethiopia, which can be expressed in terms of land and water resources degradation as well as loss of biodiversity (Teketay, 2001). Most researchers are increasingly realizing the contribution of land degradation towards declining agricultural productivity and continuing food insecurity (Taddese, 2001).

Research on the Ethiopian highlands showed that, between 1860 and 1980, land under cultivation had increased considerably at the expense of shrub land, woodlands and forestlands, especially on steep slopes and in marginal areas. In the highlands of Ethiopia, LULCC has reduced the surface run-off and water-retention capacity and stream flow, leading to a loss of wetlands and the dying of lakes (Muluneh & Arnalds, 2011). The south-western part of Ethiopia, which accounts for 18% of the country's forest cover, has seen significant deforestation over the last two decades (Gole & Denich, 2001). Decline in forest area, shrub land and riverine tree cover resulted in the loss of fertile soil and biodiversity, and increased landslides as well as sediment loads in rivers, which are used for power generation (Reid et al., 2000; Dereje, 2007; Mengistu, 2008; Dessie & Christiansson, 2008; Kefelegn *et al*., 2009).

A number of LULCC studies have been carried in the southwest of Ethiopia at catchment, zone, watershed and village levels (Reid et al., 2000; Dereje, 2007; Mengistu, 2008; Dessie & Christiansson, 2008). The studies referred to have applied perception analyses, descriptive statistics, semi-structured and face-to-face interviews to identify the causes of the changes. The combined effects of population pressure, drought and migration, changes in settlement and land tenure policy, changes in the severity of the livestock disease trypanosomosis, poor institutional and socioeconomic settings, poor infrastructure development and expansion in large-scale plantations were identified as the major drivers of the conversion of forest and shrub land to agriculture. The above analyses could not produce enough evidence and consensus to generalize the land use change processes observed in the Southern Nations, Nationalities and People's Region of Ethiopia (SNNPR).

Knowledge of land use and land cover change, both on a local scale and a wider scale is essential in decision-making in relation to a wide range of issues, such as for reversing land degradation, deforestation, and climate change. Improving the understanding of land use and land cover change dynamics can lead to the projection of future land use and land cover change and to more appropriate policy interventions for achieving better land management (Lambin et al., 2001). ‘‘Failures to understand or acknowledge the historical background, the driving forces, and the local variations in land use in different communities have often resulted in implementation of unsuccessful strategies” (Sandewal et al., 2001,). Appropriate land use policies are essential for successful recovery or restoration of land (Lambin et al., 2003).

Many other studies demonstrate that LULC change has ecologically-important impacts on biophysical conditions such as soil moisture availability and loss (Li et al, 2000), hydrological processes (Ott and Uhlenbrook, 2004), length of growing season (White et al., 2002), periodic temperature range (Stone et al., 2003), temperature extremes (Marshall et al., 2003) and precipitation patterns (Changnon, 2003).

There is no LULC change dynamics study carried out before in the study area so far. Currently the study area, were affected by land cover conversions and characterized by land degradation, extensive flooding, soil erosion, and low agricultural productivity.

Land use land cover change dynamics and inappropriate land management systems are the main causes for the soil loss in a study area. Deforestation, poor farming practices, lack of resource and absence to incentives to farmers are cited as factors contributing to accelerate erosion and loss of productive land (Holden and Bereket, 1999; Shibru, 2002).

The aim of this study can be the relationship between land use land cover change dynamics and soil loss over the last four decades by using GIS and remote sensing based analysis. Natural resource managers may need to know sediment delivery in downstream in a watershed. One method of estimating sediment delivery is the use of USLE model. The USLE estimates the gross sheet and rill erosion (Elliot, 1995).

Therefore, these studies attempts to provide a holistic understanding that can help to formulate effective policies to achieve better land use management in the study area and the surrounding.

1.2 Statement of the problem

The major factors affecting sustainability of agricultural production are soil erosion and land use land cover changes. In most developing countries, like Ethiopia, anthropological or accelerated erosion and land use land cover changes which are mainly favoured by human activities are the major triggering factors for the loss of soil, water resources and climate change. To facilitate the urgent policy intervention that targeted soil degradation, studying the LULC change dynamics and soil loss using an appropriate tool especially geographic information system (GIS) and Remote Sensing (RS) is essential.

According to physiographic nature of the study area, Shashogo Wereda is one of the most flood affected and exposed to soil erosion area in Hadiya zone, SNNPRS, Ethiopia. The study area is mostly affected by frequent flooding that originating from highlands of neighboring zones, perennial rivers, ephemeral rivers and Boyo Lake. Consequently livestock and human causality, damage to flora, sediment deposition, wetland destruction, damage to crop farms, deforestation, expansion of cultivated land, over cultivation, over grazing, population size increment, and soil degradation in the form of soil erosion are the major problems reported from Shashogo Wereda Agriculture and Natural Resources Development Office (SWANRDO). The residents suffer from frequent floods during the rainy seasons (USAID, 2000) and migrate to other places with their livestock.

To understand the consequences and develop effective mitigation strategies, accurate and up-to-date data about the magnitude and rates of land use land cover change dynamics and estimate soil loss rate by using USLE were required. Such background data are poorly archived or totally lacking in the study area.

Therefore, this study attempts to fill a data gap and provide detail information on land use land cover change dynamics and rate of soil loss in the study area. Moreover it evaluates impacts of LULC change dynamics on estimated soil erosion using USLE model. The knowledge gained can be used by policy makers, any concerned bodies to take resource conservation measures and contributes knowledge towards planning natural resource management.

1.3 Objectives of the Study

The main objective of this study is to detect and analyze the spatiotemporal land use land cover change dynamics and soil loss by integrating GIS and Remote Sensing techniques.
The specific objectives were includes the following:

- To analyze spatial and temporal LULC change dynamics during the period 1973-2015 using coarse resolution Landsat images.
- To estimate the annual soil loss rate for the study area using Universal Soil Loss Equation (USLE) model for about the past four decades.

1.4 Significance of the Study

The pattern of land use and land cover is one of the indicators of sustainability of resource utilization and management, which provides a basis for conservation planning. Every year more and more agricultural land is being lost due to soil erosion and land degradation, seriously affecting the livelihoods of the farming community. If the current trends in land degradation continue in the study area, primarily the farmers' agricultural production will decline which consequently make the people to be food in secured. The lack of vegetation covers along the steep slope gradient and inappropriate management of land coupled with high erosive rain is exposing the area to high rates of soil erosion, frequent flooding and loss of soil fertility. On account of these facts studying the land use land cover change dynamics and soil loss occurred in Shashogo Wereda is a timely issue to avert the tricky situation that can happen in the study area. This particular study will help in identifying soil erosion hot spots that occurred in the study area to take conservation measures by any responsible body to minimize and to mitigate the risk that can happen from this serious problem in the study area.

2. LITERATURE REVIEW

2.1 Land Use Land Cover Change (LULCC)

2.1.1 Definitions and Rationale of Land Use and Land Cover Change Study

The terms land use and land cover is related, but they are distinct from one another. Land use is the term that is used to describe human uses of the land (Turner and Meyer, 1994), or the social, economic, cultural, political or other value and function of land resources. Land use is considered a central part of the functioning of the Earth system *(GLP, 2005)* and reflects human interactions with the environment at scales from local to global. In contrast, land cover refers to the biophysical properties of the land surface or the natural cover types that characterize a particular area (Turner et al., 1995).

Changes in land cover involves both conversion and modification of cover (Lesslie et al., 2006) and may be gradual or episodic (Lambin et al., 2003). Land cover change is associated with changes in biotic diversity, actual and potential primary productivity, soil quality, and runoff and sedimentation rates. Land covers and changes in them are sources and sinks for most of the material and energy flows that sustain the biosphere and geosphere (BAHC, 1993; Holligan and de Boois, 1993). Land cover is one of the most important elements for description and study of the environment as it changes quickly over time and is the basic geographic feature that other environmental applications can use as reference base. The main resource controlling primary productivity for terrestrial ecosystems can be defined in terms of land (and its cover). Land cover is also the easiest detectable indicator of human interventions on the land.

Land use affects land cover and changes in land cover affect land use. A change in either however is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply degradation of the land. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Riebsame et al., 1994). The quantity of internal trade of and flow matrixes of different LULC categories are indicators of the dynamics. The "from to" analysis shows that the estimated area that was changed to or gained from each LULC (Mekuria, 2005*)*.

Land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and management, urban and suburban construction and development. There are also incidental impacts on land cover from other human activities such as forest and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by troposphere ozone resulting from automobile exhaust (Lambin, 1997).

Contemporary global change consists of two broad types, systemic and cumulative. Systemic change operates directly on the bio-chemical flows that sustain the biosphere and, depending on its magnitude, can lead to global change, just as fossil fuel consumption increases the concentration of atmospheric carbon dioxide. Systemic change is largely associated with, but not limited to, the Industrial Age and thus has grown especially important over the more recent past (Turner and Butzer, 1992). Cumulative change has been the most common type of human induced environmental change since antiquity. Cumulative changes are geographically limited, but if repeated sufficiently, become global in magnitude. Changes in landscape, cropland, grasslands, wetlands, or human settlements are examples of cumulative change. Some cumulative changes reached continental, even global, proportions long before the 20th Century, including deforestation and the modification of grasslands (Turner and Butzer, 1992).

2.2 Studies Done on Land Use Land Cover in Ethiopia

Researches on land use and land cover change in Ethiopia involved in different regions and disciplines depending on the availability of data and tools to perform analysis and their interest. Most of the studies have focused on the expansion of cultivated land to land degradation, settlement, natural ecosystems, and forests as well as the associated consequences. In general almost all have reached to the conclusion that cultivated land, rural and urban settlements as well as open lands expanded in large amount at the expense of natural vegetation including forest, wooded land and shrub land.

Gete and Hurni (2001) reported an expansion of cultivated land at the expense of natural forest cover between 1957 and 1982 in Dembecha area, north-western Ethiopia. The study also investigated a series trend of land degradation resulted due to the expansion of cultivated land on steep slopes at the expense of natural forests. Woldeamlk and Solomon (2013) reported a reduction of natural vegetation cover, but an expansion of open grassland, cultivated areas and settlements in Gish Abay watershed, north-western Ethiopia. Mengistie *et al*. (2013) investigated a significantly reduction of natural forest cover and grasslands, but an increase of croplands between 1973 and 2012 in Munessa, Shashemene landscape of the Ethiopian Highlands.

Dessie & Kleman (2007) conducted a study in the south Central Rift Valley region of Ethiopia covering an area of 3060 km^2. They found that 16% of the total study area was covered with forests in 1972, but this cover diminished to only 2.8% in 2000, losing about 82% forest cover within 28 years. The main causes of the land cover change are thought to be the increasing expansion of small-scale farming, as has been the case in most other studies discussed above.

Another study at the Umbulo catchment came up with a similar trend of land cover change that reveals the loss of 100% of high vegetation between 1986 and 2000 (Awdenegest & Holden, 2009). The study also pointed out a slight increase in vegetation (10%) by the year 2000, which is attributed to recently introduced ''Enset'' perennial crop production in the area.

2.3 Causes of Land Use Land Cover Change

Recently, human activities and social factors were recognized to have a paramount importance for understanding of land use and land cover change (Geist and Lambin, 2002). Land use is never static; it constantly changes in response to the dynamic interaction between underlying drivers and proximate causes (Lambin and Geist, 2003). The conceptual understanding of proximate causes and underlying forces has a crucial importance to identifying the causes of land use and land cover changes (Turner and Meyer, 1994). The combination of proximate causes (agricultural expansion, excessive extraction of biomass, urbanization, and over grazing) and underlying drivers (population growth, policies, and biophysical conditions) triggers processes of habitat destruction (conversion), degradation (modification) and fragmentation which are the most important chains of events leading to worldwide species decline and extinction (Geist and Lambin, 2002).

2.3.1 Effects of Land Use Land Cover Change

2.3.1.1 Effects on Forest and Biodiversity

One obvious consequence of land use and land cover change, particularly of deforestation is the shortage of fuel-wood. As population increases household energy consumption also increases. For the poor in rural areas, it is not only a source of energy but a means of income generation too. "In many parts of the developing world, fuel is scarcer and more expensive than the food that is eaten..."(Williams, 1995). Globally, about 29 percent of the land surface was originally under forest cover. Presently, however, it is only a fifth of this original which remains undisturbed (FAO, 2001).

Land use and land cover change and changes in land cover due to land use are not necessarily land degradation (Turner and Meyer, 1994). The impact of the change on the land is measured in terms of the productivity of the converted land (Turner *et al*., 1995). A major impact of land use and land cover change is on soil and biotic resources. The loss of biodiversity due to land use and land cover changes takes place at multiple levels (landscape, ecosystem and species), and in multiple dimensions (structure and function) (Turner *et al*., 1995).

2.3.1.2 Effects on Soil

Since land cover determines the rate of soil loss, the removal of vegetation by conversion of land to cultivation reduces the protection of soil cover, minimizes the regrowth capacity of vegetation, and speeds up sheet and gully erosion (Zerihun & Mesfin, 1990). LULC patterns are interrelated with the types and properties of soils. The rate and severity of soil erosion and land degradation partly depends on land use pattern. The problem of soil erosion starts with the removal of land cover (natural vegetation) for various purposes. The relationship between land use and soils is two dimensional (land use affects soils and in reverse soils affect land use).

2.3.1.3 Effects on the Hydrological Flow Regime of the Watershed

Land use and land cover change modifies the hydrological cycle of a watershed area by altering both the balance between rainfall and evaporation and the runoff response of the area and subsequently affects water resources (Mengistu, 2009; Sahin & Hall, 1996). Hence, vegetation removal results in an increase in surface runoff and a decrease in evapotranspiration that may also in turn lead to lower rainfall in semi-arid areas (Savenije, 1995; Sahin & Hall, 1996). Use of experimental catchments for studying the hydrological impacts of land cover changes provide ample evidence for increased water yield as a result of land cover change in a catchment (Brown et al., 2005). A study conducted by Hurni et al. (2005) in the Ethiopian and Eritrean highlands assumed about 5–30 times higher runoff in spread agriculture than the originally forested land.

2.4 Impacts of Land Use Land Cover Changes in Ethiopia

Land use and land cover changes have been attracting increasing attention globally from both environmental and socio-economic points of view (Gashaw et al.,2014). Such changes have been occurring rapidly and involve large areas, especially in developing countries, and their impact on environment and welfare of people is severe. Land cover change is one of the challenges which strongly affect the process of agricultural development and food security in Ethiopia. This is a major concern, particularly in highlands which support the overwhelming majority of the population of the country. Land cover changes due to human activities drive land use and hence a single class of cover could support multiple uses (forest used for combinations of timbering, slash and burn agriculture, fuel wood collection and soil protection). On the other hand, a single system of land use can maintain several covers (as certain farming systems combine cultivated land, improved pasture and settlements).In most developing countries population growth has been a dominant cause of land use and land cover change than other forces (Sege, 1994). Similarly, in Ethiopia population pressure has been found to have negative effect on shrub lands, riverine vegetation and forests in Kalu district (Kebrom, 2000), riverine trees in Chemoga watershed (Woldeamlak, 2002), and natural forest cover in Dembecha Wereda north-western Ethiopia (Gete and Hurni, 2001). Deforestation is taking place at alarming rate and accelerating LULC change. The forest cover of Ethiopia declined from 40% in 1900 to 16% in 1954, 8% in 1961, 4% in 1975, 3.2% in 1980 and now estimated to be less than 3% (Bekele and Berhanu, 2001; Bishaw, 2001; FAO, 2003; Ango and Bewket, 2007; Mengistu, 2008; Bekele, 2001; Eshetu, 2013).

Impacts of land use land cover Change include: Shortage of wood and wood products for fuel and construction material, shortage of land, compelling the farming community to cultivate marginal and ecologically vulnerable areas such as steep hillsides and sensitive wetlands, potential effects on biomass burning, increasing CO_2 concentration, environmental pollution, and biodiversity loss, Disappearance of perennial rivers and deepening of the water table, irregular rain pattern and suppression of vegetation regrowth, and land degradation through erosion, nutrient loss, low agricultural productivity, and food insecurity.

2.5 Techniques of Change Detection

Change detection involves the use of multispectral data sets to discriminate area of land cover change between dates of imaging. Ideally change detection procedures should involve data acquired by the same or similar sensor and be recorded using the same spatial resolution, viewing geometry, spectral bands, radiometric resolution, and the time of day. Often the anniversary dates are used to minimize sun angle and seasonal differences (Singh, A., 1989). Timely and accurate change detection of earth`s surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making. Different change detection algorithms have their own merits and no single approach is optimal and applicable to all cases. Some aspects of change detection application using remote sensing are LULC change analysis, forest and vegetation change analysis, wetland change analysis, forest fire, landscape change.

A change detection research should provide the following information: (1) Magnitude and rate of change (2) Spatial distribution of change types (3) Conversion of land cover types, and (4) Accuracy assessment of the classification. When implementing a change detection project, four major steps can be involved: (1) Image pre-processing (2) Selection of suitable change detection techniques (3) Accuracy assessment (4) Post-processing. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, A., 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. There are four aspects of change detection which are important when monitoring natural resources (Macleod and Congation, 1998 cited in Zabair, 2006):

i. Detecting the changes that have occurred
ii. Identifying the nature of the change
iii. Measuring the area extent of the change
iv. Assessing the spatial pattern of the change

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power.

2.6 Processes and Mechanics of Soil Erosion

Soil erosion, soil loss, and sediment yield are terms with distinct meanings in soil erosion processes. Soil erosion is the gross amount of soil moved by drop detachment or runoff.
Soil loss is the soil moved off a particular slope or field. Sediment yield is the soil loss delivered to a point under evaluation. Soil erosion is a three-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents, such as water and wind. When sufficient energy is no longer available to transport the particles a third phase, deposition, occurs (Morgan, 2005). The principle of soil conservation is, therefore; to limit the detachment and transportation of soil particles by erosive agents. Brown (1981) noted that soil erosion is a natural process that has taken and will always take place. According to the same source, it even occurs on lands with grass or forest cover, and has been taking place long before agricultural civilization started as it is mentioned above. The normal rate of erosion under natural vegetation is, however, in approximate equilibrium with the rate of soil formation (Troeh et al., 1999). Problems arise when the natural process of soil erosion is accelerated due to human interventions that result in deviations from the equilibrium. Among the different human activities that accelerate soil erosion processes, agriculture is the most important and most soil erosion occurs on cultivated lands (Hudson, 1996).

2.7 Erosion by Water

Soil erosion by rainfall and runoff is termed “water erosion”. Nyle and Ray (2002) reiterated that soil erosion by water is fundamentally a three-step process involving the detachment, transportation of the detached particles downhill by floating, rolling, dragging, and splashing and deposition of the transported particles at some place lower in elevation. The water erosion process consists of discrete stages from rain drop impact to the formation of gully erosion. Each stage has its own processes and characteristics. Controlling or preventing water erosion requires an understanding of each step in the erosion process. According to (Toy et al., 2002) the following can be distinguished as the main types or forms of erosion that occur mostly in agricultural lands:

2.7.1 Splash Erosion (Raindrop Erosion)

Detachment of individual soil particles may occur when raindrops strike the surface and overcome the interstitial forces holding the soil particle together. This is commonly referred to as “rain splash” or “raindrop splash” (Thornes, 1990). As the inducing events continue, water infiltrates into the soil at a rate controlled by the intensity of the water hitting the surface and the infiltration capacity of the vertical soil profile.

The infiltration capacity is a function of several soil hydraulic characteristics that relate the spacing and bonding of soil particles to each other, and the effects of other micro-surface and subsurface characteristics. Water that does not infiltrate begins to pond on the surface. When sufficient depth is achieved on the surface, water will flow in the direction of the steepest unimpeded slope. This initiates the hydrological process referred to as “overland flow” or “runoff” (Schwab et al., 1981).

2.7.2 Sheet Erosion (Inter-rill Erosion)

Inter-rill erosion is due to detachment and transport by raindrop impact and overland flow. Sheet erosion has been shown to be approximately proportional to the square of the rainfall intensity. Sheet erosion can be described as the process of detachment and transport of soil by rain drops and very shallow flow (Sharma et al., 1996 cited in Toy et al., 2002). In rill erosion is constant over a slope as long as soil and surface properties remain constant (Young and Wiersma, 1973; Watson and Laflen, 1986, cited in Toy et al., 2002). Raindrop impact and inter-rill flow move sediment from the inter-rill areas to the rill areas.

Raindrops striking the soil surface splash soil particles in all directions, but the net movement are down slope and increases as inter-rill steepness increases. Most of the sediment delivered from inter-rill areas to rill areas, however is transported by the thin flow on inter-rill areas rather than by rain splash. Inter-rill process generally occurs within a meter or so of the point of a water drop, and delivers much material to nearby channels. Runoff in these nearby channels then delivers the inter rill material to points further downstream. If there is no flow in channel, the inter-rill material stays close to the point of detachment (Watson and Laflen, 1986, cited in

Toy et al., 2002). Sheet erosion is usually most apparent on row side slopes or in the case of soils with some surface protection, as pedestals led soil under protective cover to the washing away of adjacent unprotected soils. For short slopes, most erosion may be inter-rill erosion. As slope length and gradient increases, erosion due to channel process begins to dominate (Watson and Laflen, 1986, cited in Toy et al., 2002).

2.7.3 Rill Erosion

A rill is a shallow linear depression or channel in soil that carries water after a recent rainfall. Rill erosion are especially common on bare land, whether newly planted or in fallow. Rills are channels small enough to be smoothed by normal tillage, but the drainage is already done and the soil is lost. Rills are usually aligned perpendicular to the slope and occur in a series of parallel rill lines. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment. If detachment continues, or flow increases; rills will become wider and deeper (Lal, 1988).

2.8 Modeling Soil Erosion

A large variety of models can be found in literature that can be used in soil erosion risk assessment. The models can be classified as:

Empirical and Mechanistic Models: The empirical models describe a process based on empiricism. They are based on inductive logic and generally applicable only to those conditions for which the parameters have been calibrated. In contrast, mechanistic models attempt to represent the physical causes of response to condition.

Static and Dynamic Models: the difference between static and dynamic models is that dynamic models take account into time as an extra variable.

Deterministic and Stochastic Models: Deterministic models make definite predictions for quantities without any associated probability distribution. Stochastic models, on the other hand, contain some random elements or probability distributions. Except for the predicted value, stochastic models can also predict the variance.

Qualitative and Quantitative Models: Qualitative models predict values on quality levels such as not risky, risky or highly risky. The input data for a qualitative model can be both qualitative and quantitative. On the other hand, a quantitative model produces a numerical output.

The main criteria in order to choose one of the above models are: the purpose of use, the available data, the available time, and the cost. One of the most widely applied empirical models for accessing the sheet and rill erosion is the Universal Soil Loss Equation (USLE) model.

2.9 Parameters Estimation for USLE

In this research, the USLE soil erosion model is applied to predict amount of annual rate of soil loss in study area. The Universal Soil Loss Equation (USLE) developed by Wischmeier/Smith (1965, 1978) and Renard et al. (1997) is one of many erosion models and probably the most simple to determine long-term average soil losses on a specific plot. USLE was developed mainly for soil erosion estimation in crop lands or gently sloping topography. It was designed to be geographically universal in applicability and therefore called Universal Soil Loss Equation. USLE estimates soil loss from hill slope caused by raindrop impact and overland flow, plus rill erosion. It does not estimate gully or stream channel erosion. USLE has not been designed to operate at a field scale, however, it was noted that there is a room for improving the accuracy of the result by using more detailed Digital Elevation Models, satellite data, with enhanced geometric characteristics and more detailed soil information (Elliot, 1995).

Modeling soil erosion is a process of mathematically describing soil particles detachment, transport and deposition on land surface. Renschler (1999) defines a model as a simplification of processes and their interactions with the aim of extracting, evaluating and simulating the relevant processes. The objective of soil erosion models is either predictability or explanatory (Petter, 1992). Erosion models are currently the most feasible approach in generating data on erosion hazard. Models elucidate on erosion through mathematical equations in simplified form.

Soil erosion is a natural geological phenomena resulting from removal of soil particles by water or wind, transporting them elsewhere, while some human activities can significantly increase erosion rates. Erosion is triggered by a combination of factors such as steep slopes, climate and ecological disaster, inappropriate land use and land cover patterns, more over some intrinsic features, of soil can make it more prone to erosion (for example low organic content) (Elliot,1995).

The model encompasses six parameters, which are directly linked to variables (climate, topography, vegetation cover, management practices) that affect soil erosions. This model takes into account several determinant factors, such as Rainfall erosivity R factor, Soil erodibility K factor, Slope gradient S factor, Slope length L factor, Land cover and management C factor and Support practice P factor. The R factor expresses the erosivity occurring from rainfall and runoff at a particular location. An increase in the intensity and amount of rainfall results in an increase in the value of R. The K factor expresses inherent erodibility of the soil or surface material. It is a measure of susceptibility of soil particles to detachment and transport by rainfall and runoff. The value of K is defined as a function of the particle-size distribution, organic matter content, structure, and permeability of the soil or surface material. The LS factor expresses the effect of topography, specifically hill slope length and steepness, on soil erosion. An increase in hill slope length and steepness results in an increase in the LS factor. The C cover-management factor is used to express the effect of plants and soil cover. Plants can reduce the runoff velocity and protect surface pores. The C-factor measures the combined effect of all interrelated cover and management variables, and it is the factor that is most readily changed by human activities. The P factor is the support practice factor. It expresses the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing on soil loss at a particular site. A good conservation practice will result in reduced runoff volume, velocity and less soil erosion. The USLE concept has more recently been modified and adapted by a large number of researchers by including additional data and incorporating research results *(Elliot, 1995)*.

Sediment is a mixture of organic and inorganic material washed into lakes from catchment and generated within the lake. The most abundant component in the low land lakes is silt (soil) washed into from the catchment sediment natural in the lakes, and its presence is inevitable. There are problems associated with sediment deposit in the lakes. Land use issue, poor management and excessive erosion result in excessive quantity of sediment. Quantities of sediment from catchment will vary according to the size of the catchment, type of the soil, steepness of the slope , the nature of stream channels, the flow pattern, the opportunity for flooding and deposition of sediment before the lake reached, the type of farming and farming techniques. These causes change in land use and the only way of solving the problem. It is most important to reduce catchment sediment inputs, and to allow flooding and spilling out of main lake inflow before they reach the lake. There may be many natural silt traps to control the sediment flow into lakes (Singh PK, 2008). Erosion process results in soil loss from watershed and it is difficult to estimate soil loss as it arises from a complex interactions of various hydro-geologic processes. Estimating soil loss risk and its spatial distributions are one of the key factors for successful erosion assessment (Colombo et al., 2005).The accuracy of estimating soil risk depends on model and its factors.

2.10 Factors Affecting Soil Erosion

The soil erosion process is modified by biophysical environment comprising soil, climate, terrain, and ground cover and interactions between them. The effect of the biophysical processes governing soil erosion is influenced by economic, social and political causes.

2.10.1 Erosivity

Erosivity is a function of rainfall characteristics, includes drop size distribution and intensity of rain, amount and frequency of rainfall, run-off amount and velocity. Both rainfall and runoff factors must be considered in assessing a water erosion problems. Soil loss is closely related to rainfall partly through detaching power of raindrops striking the soil surface and partly through the contribution of rain to run-off (Morgan, 1995). This applies, particularly to erosion by overland and rill for which intensity is generally considered to be the most important characteristics. If the rainfall intensity is less than the infiltration capacity of the soil, no surface run-off occurs and the infiltration rate equals the rainfall intensity (Horton, 1945) as cited by Morgan (1995). If the rainfall intensity exceeds the infiltration capacity, the infiltration rate equals the infiltration capacity and the excess rainfall forms surface runoff. The effect of rainfall intensity on infiltration rate and runoff is modified by other soil characteristics like water content and soil moisture.

2.10.2 Soil Erodibility

Soil erodibility (K) is an estimate of the ability of soils to resist erosion, based on physical characteristics of each soil. Soils vary in their susceptibility to erosion. The soil erodibility factor

K represents the combined effect of susceptibility of soil to detachment, transportability of the sediment, and the amount and the rate of runoff given particular rainfall erosivity. Generally soils with faster infiltration rates, higher level of organic matter, and improved soil structure have greater resistance to erosion. Morgan (1995) prefers to examine erodibility in terms of the clay content, indicating the soils with restricted clay fraction, between 9 and 30% are the most susceptible to erosion.

Soil organic matter reduces the K factor because it produces compounds that bind soil particles and reduce their susceptibility to detachment by raindrop impact and surface runoff. Also organic matter increases soil aggregation to increase infiltration and reduce the runoff and erosion. Permeability of the soil profile affects K because it affects runoff. Soil structure affects K because it affects detachment and infiltration.

2.10.3 Topography

Important terrain characteristics for studying soil erosion rate are sloping gradient, length, aspect and shape. Naturally, steeper the slope of a field, the more it is pushed down-hill, faster than water runs and the greater will be the amount of soil loss from erosion by water. At low slope due to the low overland flow velocity of water, detachment or removal of soil surface into the water layer is due to rainfall detachment alone. Soil erosion by water also increases as the slope length increases due to greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope length with increased erosion potential, due to increased velocity of water which permits a greater degree of scouring (carrying capacity of sediment).

2.10.4 Ground Cover

Ground cover exerts a strong moderating impact on dissipating the energy supplied by agents of soil erosion. Soil erosion potential increases if the soil has no or very little vegetative cover of plants and/or crops residue. Plant and residue cover protects the soil from raindrop impacts and splash, tends to slow down the movement of surface runoff and allows excess surface water to infiltrate. The erosion-reducing effectiveness of plant and/or residue covers depends on type, extent, and quantity of cover. Vegetation and residue combination that completely covers the soil and which intercept all falling raindrops at and close to the surface and the most efficient in controlling soil.

2.10.5 Erosion Management Practice

The erosion management practice, P value, is also one factor that governs the soil erosion rate. The P-value ranges from 0-1 depending on the soil management activities employed in the specific plot of land. These management activities are highly dependent on the slope of the area. Wischmeier and Smith (1978) calculated the P-value by delineating the land in to two major land uses, agricultural land and other land. The agricultural land sub-divided in to six classes based on the slope percent to assign different P-value.

2.11 Soil Loss Tolerance

Since erosion is a natural process, it cannot be prevented but reduced to acceptable rate (Morgan, 1995). A tolerable soil loss is the maximum annual amount of soil, which can be removed before the long-term natural soil productivity is adversely affected. The maximum acceptable rate of soil erosion is known as soil loss tolerance. The only tolerable rate of soil loss equals the rate of soil formation. The tolerable range for different agro-ecological region of Ethiopia ranges 2t/ha/yr to 16t/ha/yr (Hurni, 1985). The impact of erosion on a given soil type, and hence the tolerance level, varies, depending on the type and depth of soil. Generally, soils with deep, uniform, stone-free topsoil materials and/or not previously eroded have been assumed to have a higher tolerance limit than soils that are shallow or previously eroded.

Natural resource managers sometimes find it helpful to determine a maximum level of erosion that can be allowed. By comparing the predicted erosion to maximum or tolerable level, the management system can be evaluated. The T values varies with the top soil depth and sub soil properties and range from 3 to 30tons/acre. There are maximum rate of soil erosion that will be permuted at a level of crop productivity to be sustained economically and indefinitely (Elliot, 1995).

3. METHODOLOGY

3.1 Description of Study Area

3.1.1 Location

The study was carried out in Shashogo wereda, Hadiya zone, SNNPR, Ethiopia and the area covers a total of 35,696.4 ha (356.9 km^2) and is located between 7^0 24' - 7^0 38' North latitudes and between 37^0 54' - 38^0 08' East longitudes. The study area is about 230 km South of Addis Ababa, 110 km West of Hawassa and 54 km East of Hosanna. The wereda has a total population of 116,287 people (CSA, 2007). Shashogo wereda is one of the densely populated weredas' in Hadiya zone. The wereda has a total of 34 PAs. Most of rivers originated from the highlands of the study area and the micro-watersheds within the study area were used for the study.
The map of the study area is shown in (Figure 3.1).

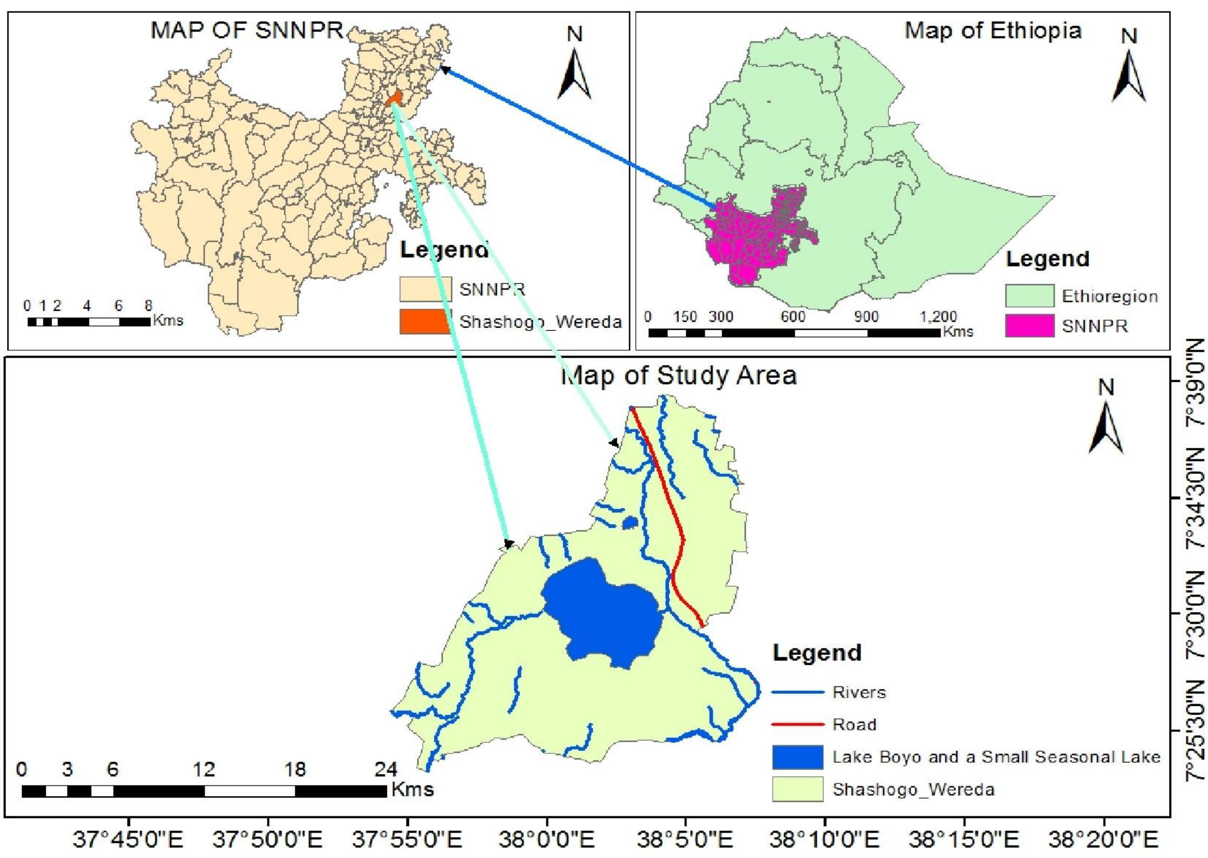

Figure 3.1: Map of Study Area

3.1.2 Rainfall and Temperature

The rainfall of the study area is highly influenced by the position of inter-tropical convergence zone (ITCZ) and the development of Tropical Easterly Jet (TEJ). The rainfall has a bimodal nature in which the months from June to September and March to May, while months from November to February are dry. The long rainy season in the area is between June to September, during which crop cultivation takes place in the area. The maximum rainfall reaches as high as 169.1mm in August and lowers to 20.9mm in December. The mean maximum temperature of study area is 26.4^{0}C occurred during February, while the mean minimum temperature is 11.5^{0}C occurred during December. The mean monthly rainfall and temperature distributions of the study area are shown in (Figure 3.2)

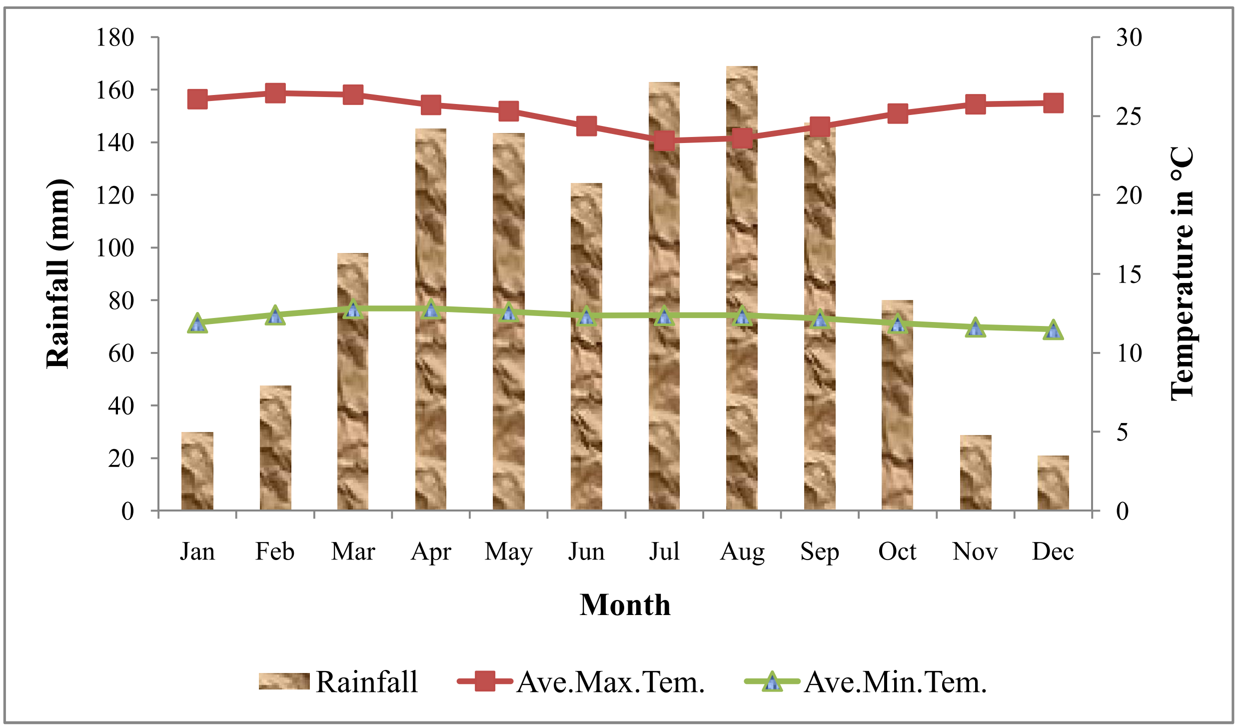

Figure 3.2: Mean monthly rainfall and temperature of the study area (1989-2016)

(Source: ENMA, 2016)

3.1.3 Topography

The study area is in the rift valley floor bounded to the North by Mount Hosiso Ambaricho Wulberag wereda, to the West by Mount Lisana An Lemo wereda, to the South by Mount Dato Damboya woreda, and to the East Halaba special wereda. The physiographic set up of the area is the result of rifting, erosion and deposition processes. Elevation ranges from 1800m to 2200m above sea level reports from Shashogo Wereda Agriculture and Natural Resources Office (SWANRO).

The study area is surrounded by highlands and is prone to soil erosion at higher altitudes and deposition at the centre. Guder and Bilate rivers are perennial rivers which empties (feeds) to the Boyo Lake. In many places small streams disappear in the floor before reaching the major drainage system. They originate from the Ambericho fault in Wulberag Wereda and dump their contents to Boyo plain before reaching Lake Boyo.

3.1.4 Slope

The slopes of study area ranges from gentle slopes (<5%) to very steep slopes (>30%) and dominated by gentle slope. The spatial distributions of different slope classes in the study area are shown in (Figure 3.3).

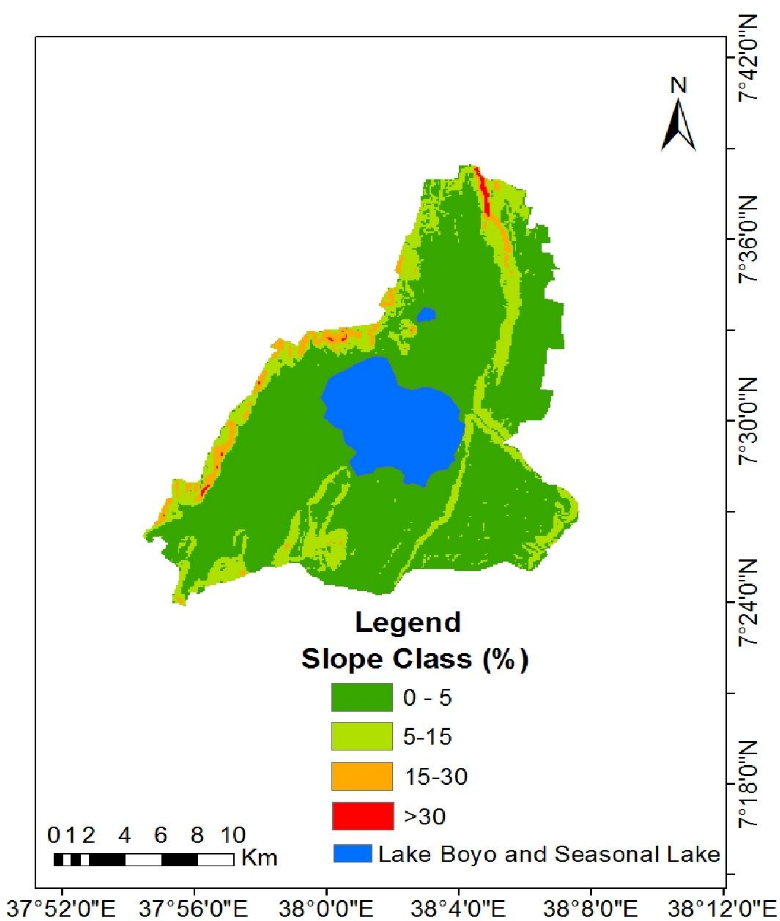

Figure 3.3: The slope classes map of the study area

3.1.5 Soil and Geology

The genesis of the soils in the study area is influenced by the interaction of the soil forming factors of climate, topography, organisms, parent material and time. According to the FAO soil classification of 1997, the major types of soil in the study area are Eutric Fluvisols, Vitric Andosols, Eutric Vertisols, Chromic Luvisols, and Humic Nitisols. From these soil types Eutric Fluvisols is the dominant soil type in the study area. Most of the study area is characterized by Pyroclastic rocks, and some other study area by Basic and Ultrabasic rocks, Undifferentiated unconsolidated sedements, and Undifferentiated igneous rocks. The major soil types of the study area are shown in (Figure3.4).

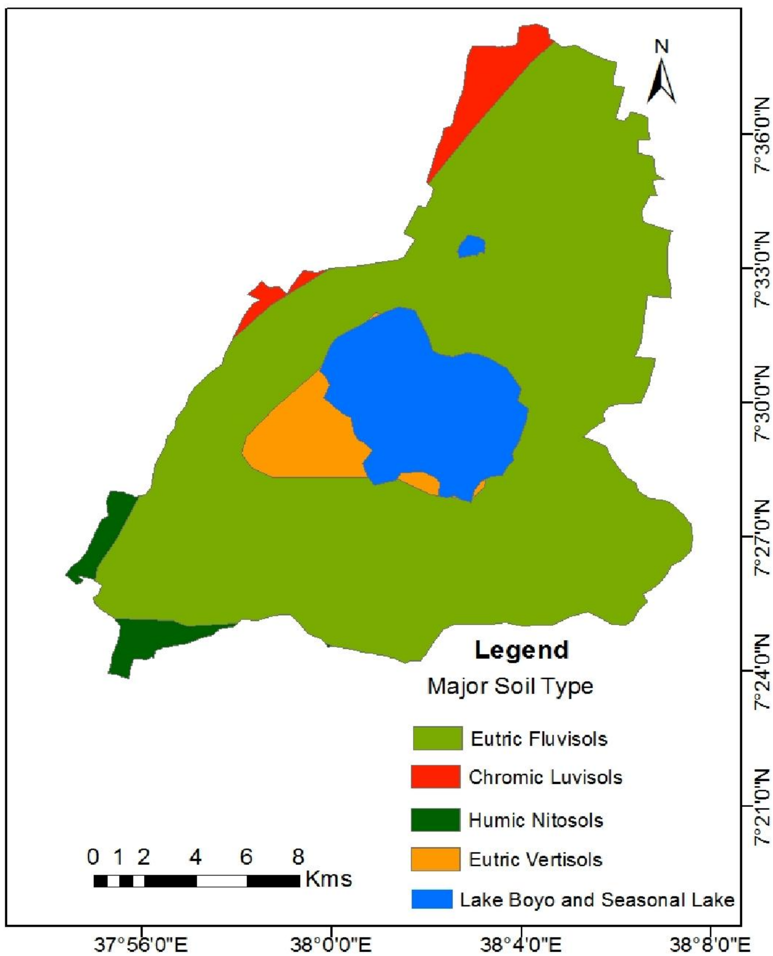

Figure 3.4: Major soil types of the study area (Source: FAO, 1997)

3.1.6 Vegetation

The spatial distribution of natural vegetation depends on many factors among which, climate, drainage pattern and soil types play a pivotal role. In Ethiopia, temperature and rainfall, which largely are altitude dependent, determine the type and density of vegetation (Tewolde-Berhan Gebre-Egziabeher, 1991). The commonly observed remnant tree species in the area are Acacia species, Cordia africana, and Eucalyptus species. These tree species are observed throughout the Wereda mostly scattered in the cultivated landscape. Because of long history of agriculture and high population in the area, vegetation cover is very low. Consequently, erosion hazards on the steep slope areas are enormous.

3.1.7 Agriculture

In the study area agriculture is the dominant economic activity, which includes crop farming and livestock production. Cropping patterns in the study area follow rainfall. Maize, tef, wheat, pepper, haricot bean, sorghum and millet are the dominant crops with regard to area coverage. Other than these crops, many other crops are also grown, but economically less important. In most cases, maize is grown in more than 50% of the cultivable land in the wereda, while all other crops account for the remaining 50% of the area. Pepper is the main cash crop in the area.

3.1.8 Catchment Characteristics

Groundwater recharge may be defined in a general sense as the downward flow of water reaching the water table, forming an addition to the groundwater reservoir. Recharge may occur naturally from precipitation, rivers, lakes, as man induced phenomena; irrigation, urban recharge. The groundwater recharge varies in a wide range governed by the rainfall distribution, topography, land use and geology. The major recharge to the aquifer comes from precipitation and river channel losses. Direct recharge take place in all areas except where at the steep slope (at the escarpment of the fault) and in areas where there is wide coverage of clay around Northern western part of the area and where the volcanic rocks are fresh. In the study area three types of recharges are identified; the first is direct recharge from precipitation which widely vary with the position of wind ward and lee ward, indirect recharge into the water table from the surface water sources such as Bilate, Guder rivers and Boyo Lake which has outlet and some other tributary which drain to Bilate and the last is localized recharge which comes from the highlands of the catchment without well defined channels.

3.2 Methods of Data Collection

3.2.1 Materials and Software

To achieve the objectives of the research: The 1976 Shashogo Wereda topographic maps with a scale of 1:50,000 has been purchased from Ethiopian Mapping Agency (EMA), Global Positioning System (GPS) for ground verification, Digital Camera, Google Earth satellite image for validation, ASTER 2011 DEM of 30m*30m resolution, Shape files, Rainfall and Temperature data from the Ethiopian National Meteorological Agency, FAO Soil data from the Ministry of Agriculture and Natural Resource Development were used. The four period's satellite imagery at different point in time 1973 Landsat 1 Multi-Spectral Scanner (MSS), 1986 Landsat 5 Thematic Mapper (TM), 2000 Landsat 7 Enhanced Thematic Mapper plus (ETM plus), and 2015 Landsat 8 Operational Land Imagery (OLI) image were analyzed using ERDAS Imagine 2014 software. The four period's satellite imagery and 2005 SPOT image were purchased from Ethiopian Mapping Agency. Moreover topographic sheet of with a scale of 1:50,000 have been mosaicked to digitize road, river, and lake and contour to generate slope in ArcGIS 10.1 software.

3.2.2 Field Works

Pre-field work

The major activities during this stage were selection of field area, collection of necessary materials for field work, preparation of questionnaire for primary data collection, preparation of formats for secondary data collection, listing and planning all activities to be done before, during and after field work. The topographic maps of the study area were scanned, geo-referenced, mosaicked, and then used to register all remotely sensed data. The satellite images were geo-referenced using the topographic map of the study area. Then preliminary image interpretation, band selection, layer stacking, subseting and image pre-processing were done in this phase. Secondary data such as rainfall and temperature data, soil map, and DEM were collected.

Field work

This involves mainly collecting primary and secondary data by using various data collection methods. It includes reconnaissance survey of the area to understand the land use, training areas and the ground truthing data collection for LULC classification and accuracy assessment of the maps. This phase includes the collection of primary data using questioner (open-ended questions and close-ended questions), interviewing experts and local elders by face to face, observations through discussions, review of documentation and secondary data from relevant offices.

Post field work

The main activities in this stage were analysis of collected data. The following activities were done after the field work. Supervised classification of satellite images, identification of appropriate change detection methods and analysis of LULC change, analysis of factors of USLE and generation of map layers for each factor, analysis of annual rate of soil loss by water erosion in the study area and comparison of the results with other results done in the same agro-ecological regions for accuracy, analysis of the rate of soil loss from each land use land cover classes, and analysis of rate of soil loss from each micro-watershed for 2015 were done.

3.3 Spatial Data Processing and Analysis

3.3.1 Data Acquisition and Source

This study was involved primary and secondary data collection techniques. Landsat satellite images of the study area were acquired for four periods. The Landsat images include: Landsat 1 Multi-Spectral Scanner (MSS), Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper plus (ETM+), and Landsat 8 Operational Land Imagery (OLI) images acquired in 1973, 1986, 2000, and 2015, respectively. The rationale of the choice of the study periods were the change of the political systems and the availability of different data. These images were purchased from Ethiopian Mapping Agency. The images were acquired from the period February, as this is a clear sky season in the region, reducing atmospheric and radiometric problems. The images were extracted to TIFF formats for processing and the detail of image properties are summarized in (Table 3.1) below.

Table 3.1: Data source Characteristics

No	Data Type	Sensor	Date of Acquisition	Path/Row	Processed Spatial Resolution
1	Landsat 1 image	MSS	01/02/1973	181/055	60m by 60m
2	Landsat 5 image	TM	09/02/1986	169/055	30m by 30m
3	Landsat 7 image	ETM+	10/02/2000	169/055	30m by 30m
4	Landsat 8 image	OLI	20/02/2015	169/055	30m by 30m

(Source: EMA)

Topographic normalization was not done since most of the study area has a flat topography.

Image Resampling

MSS images have low processed spatial resolution of about 60m but TM images have relatively a higher processed spatial resolution of 30m. For land cover change detection analysis using different years of images, date of data acquisition and resolution of images must be similar as much as possible. To overcome the variation in pixel resolution and to enable the overlay process, the output cell size of Landsat MSS was resampled to 30m, which is the processed spatial resolution of TM images. The overlay procedure in ERDAS Imagine 2014 software produced cross-tabulation matrices, which permitted to quantify changed and not changed land cover types between temporal instants over the study period.

3.3.2 Pre-processing

Pre-processing of image data is important to correct errors that are introduced during scanning, transmission and recoding of the data (Das, 2009). Particularly, pre-processing of satellite images prior to actual change detection is essential and has its unique goals the establishment of a more direct linkage between the data and biophysical phenomena (Coppin et al. 2004). Pre-processing of satellite images prior to image classification and change detection is important task that must be under taken by researchers. The pre-processing task involves those operations that are normally required to the main data analysis and extraction of information. Selection of appropriate satellite imagery is the first task in image data processing. To perform pre-processing, the reflective bands are stacked into a single multi-band image excluding the thermal band. The images projected to the Universal Transverse Mercator system (UTM WGS 84 Zone

37), were then geometrically corrected taking the scanned topographical maps as reference images. The subsets of corrected images were used for further analysis.

3.3.3 Image Classification and Methods of Data Analysis

Image classification serves as a specific goal: converting image data into thematic maps. In the application context, one is rather interested in thematic characteristics as an area (pixel) rather than reflectance values. Thematic characteristics such as LULC map was used for further analysis and input into GIS based models. In addition, image classifications can also be used for data reduction. The overall objective of image classification procedures is to automatically categorize all pixels in an image into LULC classes to extract useful thematic information (Boakye et al., 2008). Multispectral image classification is one of the most used methods to extract thematic information from satellite images (Sarma et al., 2008). Then, the LULC maps were produced from Landsat 1 MSS of 1973, Landsat 5 TM of 1986, Landsat 7 ETM plus of 2000, and Landsat 8 OLI of 2015.

There are two primary methods of image classification methods utilized by image analysts; unsupervised and supervised classification. Image classification was undertaken using supervised classification method. Supervised image classification is a method in which the analyst defines small training sites on the image, which are representative of each desired land cover category. The delineation of training areas representative of a cover type is most effective when an image analyst has knowledge of the geography of a region and experience with the spectral properties of the cover classes (Taylor and Francis, 2004).The researcher has been supported by ancillary data and knowledge of the study area. In this regard I was born in this study area, which facilitated the image classification. The image analyst then trains the software to recognize spectral values or signatures associated with the training sites. After the signatures for each land cover category have been defined, the software then uses those signatures to classify the remaining pixels (ERDAS Field Guide, 2000). Among different classification algorithms, maximum likelihood algorithms was used for supervised classification by taking 210 training areas for seven major LULC class categories for 2015 (30 training points for each LULC classes). Whereas, the reference points were generated with a stratified random sampling approach by taking 540 reference points for six major LULC class categories, for 1973, 1986, and 2000, and 210 reference points for seven major LULC class for 2015 (30 reference points for each LULC classes) and total reference points were 750. The annual rates of change were computed by dividing the temporal rates of change by the number of year's interval (Sleeter and Raumann, 2006; Zhang et al., 2010) which is calculated according to the formula: Ra=Rt/ΔY, and Rt=(Ac-Ap)/Ap*100, where Ra and Rt are the annual and temporal change rates of the target LULC type, respectively; Ac and Ap are the area of the target LULC type at the current and previous study points in time, respectively; and ΔY is the length of the study period measured in the unit of years. ERDAS Imagine 2014 and ArcGIS 10.1 software were used for satellite image processing and LULC change analysis.

3.3.3.1 Identification of Thematic Classes

A classification scheme effectively defines the classes that were used in LULC map of the study area. Some of common classification schemes were used to determine the thematic classes. There is numerous classification schemes used for land cover classification throughout the world. The classification schemes for digital analysis were identified as follows: The definitions of LULC are a modification of (Adopted from Abate, 2011) classification scheme.

Water body: Areas covered by manmade small dams, seasonal water bodies and permanent water bodies.

Grass land: Areas of land where small grasses are the predominant and natural vegetation usually used for grazing.

Bare land: Areas of land that are highly degraded and with little or no vegetation cover.

Bush land: Land covered with dense vegetation (low shrub with many branches).

Cultivated land: Areas allotted to rain fed and irrigated cultivation, including fallow plots, cultivated land mixed with some bushes, trees and the scattered rural settlements included within the cultivated fields.

Wetland: Represents most plain areas with frequent flooding event during the rainy season and water table is at, near, or above the land surface for a significant part of most years.

Settlement: Built-up area in urban occupied by small town including market places, roads, institution such as school, clinic, court and others.

3.3.3.2 Ancillary Data

Ancillary data both on raster and vector format were used for various purposes. To increase accuracy in classification of Landsat satellite images, other data sources were used. Some ancillary data include: The 1976 topographic maps of the study area, Google Earth satellite image, 2005 SPOT image, ASTER 2011 Digital Elevation Models (DEM). The 1976 topographical map and 2005 SPOT images procured from the Ethiopian Mapping Agency (EMA). These map sheets were scanned, geo-referenced, mosaicked, and then used to register all remotely sensed data. Both the 1976 topographical maps, Google Earth satellite image, 2005 SPOT images were used to validate 1973, 1986, and 2000 the classified LULC maps respectively. ASTER 2011 DEM was used to display the physiographic features and extract elevation data. The key informants included both male 79 (90.8%) and female 8 (9.2%). The respondents were selected based on purposive sampling because of their specific knowledge on the topic of interest. 47.1% of the respondents were above 55 years, 43.5% were between 50 and 55 years, and the rest 9.4% were between 45 and 50 years. Interview of the residents who lived more than 50 years were made in order to get additional information about LULCC and soil and water conservation structure during 1973-2015.

3.3.3.3. Accuracy Assessment

The fact that accuracy assessment is so important that it tells us to what extent the truth on the ground is represented on the corresponding classified image. Land cover maps derived from remote sensing always contain some sort of errors due to several factors which range from classification technique to method of satellite data capture.

In order to wisely use the land cover maps which are derived from remote sensing and the accompanying land resource statistics, the errors must be quantitatively explained in terms of classification accuracy. Whether the output meets expected accuracy or not is usually determined by the users themselves depending on the type of application the map product were used later. Accuracy levels that are acceptable for certain task may be unacceptable for others.

In remote sensing, accuracy assessment is mandatory (Okeke and Karnieli 2006), and is important for providing information about the quality of the produced classification. One of the most common ways of representing accuracy assessment information is in the form of an error matrix (Congalton 1991; Foody 2002, Congalton and Green 2009). The use of classification measures such as Overall accuracy, Producer's accuracy, and User's accuracy are quite common (ibid).

Before using the classification result for change detection, the Landsat-based thematic maps were accordingly assessed to evaluate the percentage of pixels classified correctly and incorrectly per land cover category. The accuracy assessment was performed using independent reference data created from topographic maps, finer resolution image, field data (Dewan and Yamaguchi 2009), and visual interpretation (Abd El-Kawy et al. 2010). For each map considered, the error matrix was created in ERDAS Imagine 2014 software and classification accuracy measures were derived. Flow charts for the general methodology for analysis of land use land cover change classification are shown in (Figure 3.5).

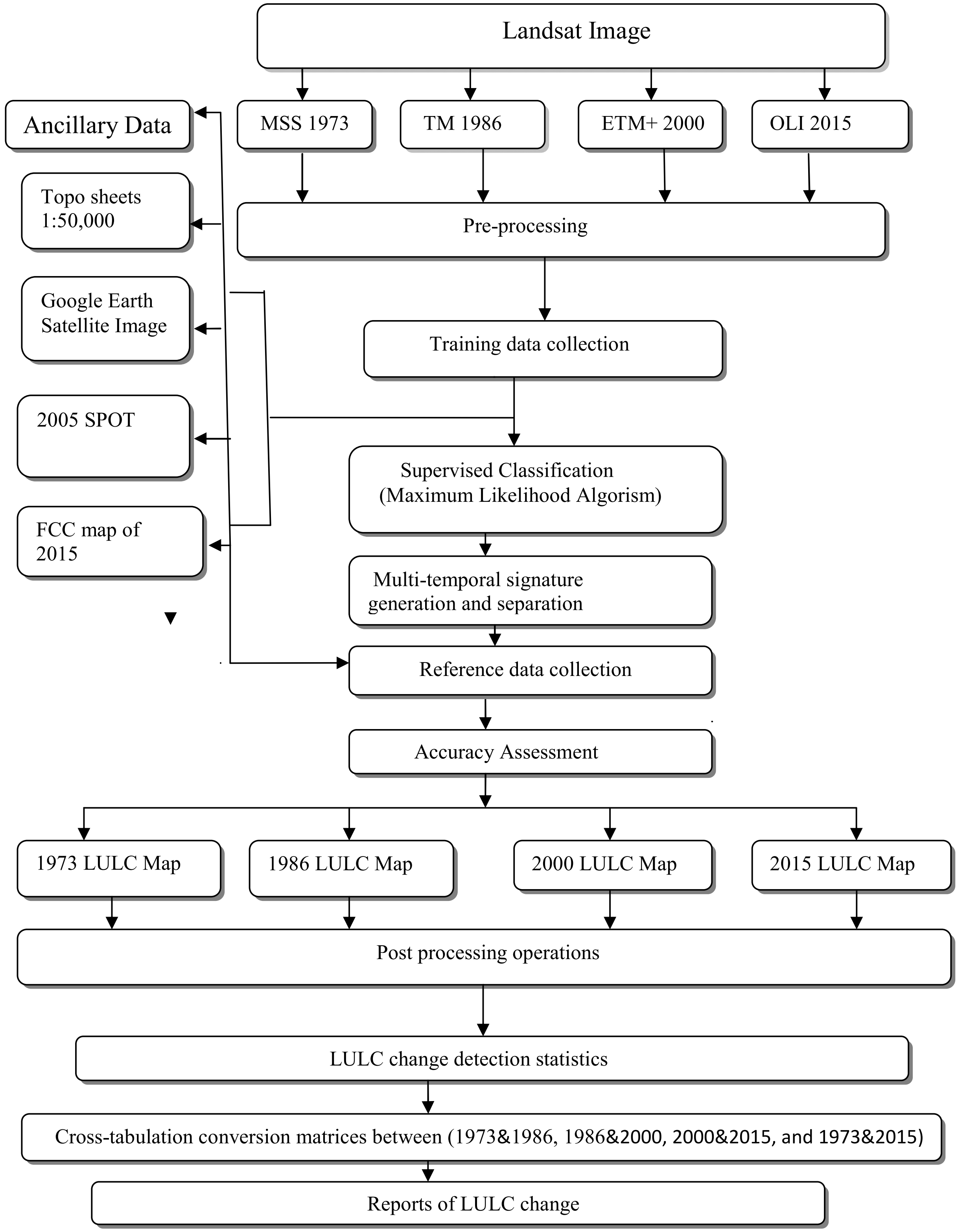

Figure 3.5: Flow chart for the general methodology for analysis of LULC classification

3.4 Estimation of USLE Factors

To predict the mean annual soil loss in tones per hectare per year [tons/ ha/year] of a certain area, all erosion factors have to be surveyed before their calculated numerical values are to be multiplied:

$A = R*K*LS*C*P$………………………………………………………………….. (Equation 1)

The model was modified and adapted to Ethiopian conditions based on recommendations of the Soil Conservation Research Project (SCRP) by Hurni (1985).

The methodology to be used in this sub-section is the universal soil loss equation (USLE) model in a raster GIS (grid-based) and remote sensing based approach to calculate the main factors controlling soil erosion namely climate (erosivity), soil characteristics, topography, land cover management and support practice. A software ArcGIS10.1 was used to generate all factors of USLE.

3.4.1 Estimation of Rainfall Erosivity (R) Factor

Rainfall erosivity Factor is a property of rainfall and can quantitatively evaluate the potential capacity of rain to cause erosion in given circumstances. It measures the combined effect of rainfall and its associated runoff. Through their kinetic energy, raindrops produce, essentially on previously moistened aggregates, a mechanical effect at the point of impact and they detach the fine particles on the very surface of the soil, carry them away in suspension or seal the topsoil. Intensity, drop size distribution, drop fall velocity, effect of wind, thunderstorm, and precipitation are the main characteristics of natural rainfall that influence its erosive potential. Rainfall intensity relates the total amount of rainfall to its duration. This characteristic is very important in the rainfall erosion process. When the intensity exceeds the maximum infiltration rate of the soil surface runoff results and a portion of the rainfall is lost (Krauer, 1988). However, rainfall kinetic energy and intensity data are not available in most cases. Therefore, the erosivity factor R was calculated according to the equation given by Hurni (1985), derived from a spatial regression analysis for Ethiopian conditions based on the easily available mean annual rainfall (P). It is given by a regression equation:

$R = -8.12 + (0.562 \times P)$……………………………………………………… (Equation 2)

Where R- rainfall erosivity factor, P - mean annual precipitation [mm/yr]

To compute R factor, 27 years (1989-2016) rainfall data of five stations which are at a distance of less than 30km from study areas were used to calculate the mean annual rainfall (P) and the rainfall erosivity factor using equation (2). The five stations which are within the altitudinal range of the study area were chosen. The average rainfall for each gauge stations was calculated and a point shape file was created using ArcGIS10.1 software. The created shape file was displayed on ArcGIS10.1 and the attribute field for mean rainfall data was added to point shape file and the average rainfall data for each gauge stations were added to the attribute column. Finally the point data shape file was interpolated using "kriging" method and raster rainfall data for study area was obtained.

Table 3.2: Rain-gauge Stations used to calculate rainfall erosivity R factor (1989-2016)

No	Station Name	Annual RF in mm	Erosivity (R factor)
1	Halaba Kulito	978.5	541.8
2	Angecha	1453.0	808.5
3	Fonko	1232.1	684.3
4	Hossana	1171.0	650.0
5	Wulberag	1191.2	661.4

(Source: ENMA, 2016)

Distribution of rainfall stations and rainfall erosivity map of the study area are shown in (Figure 3.6 and 3.7), respectively.

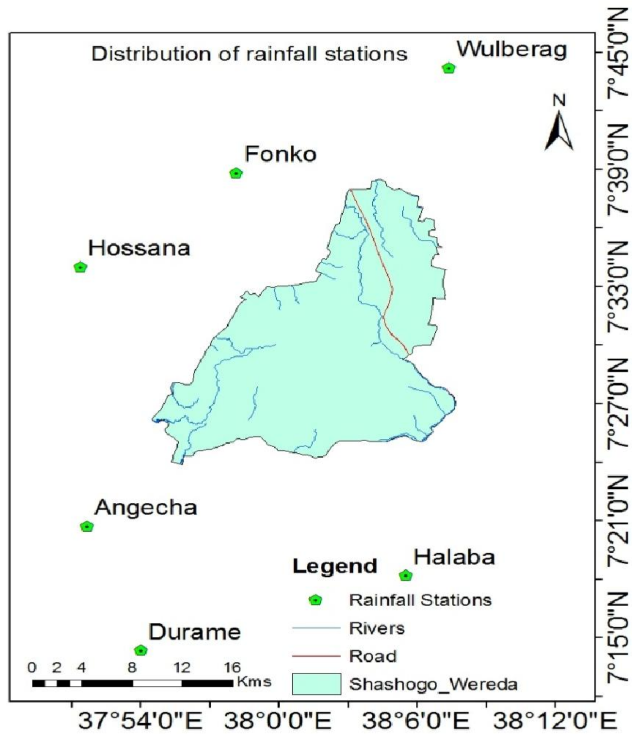

Figure 3.6: Distribution of Rainfall Stations

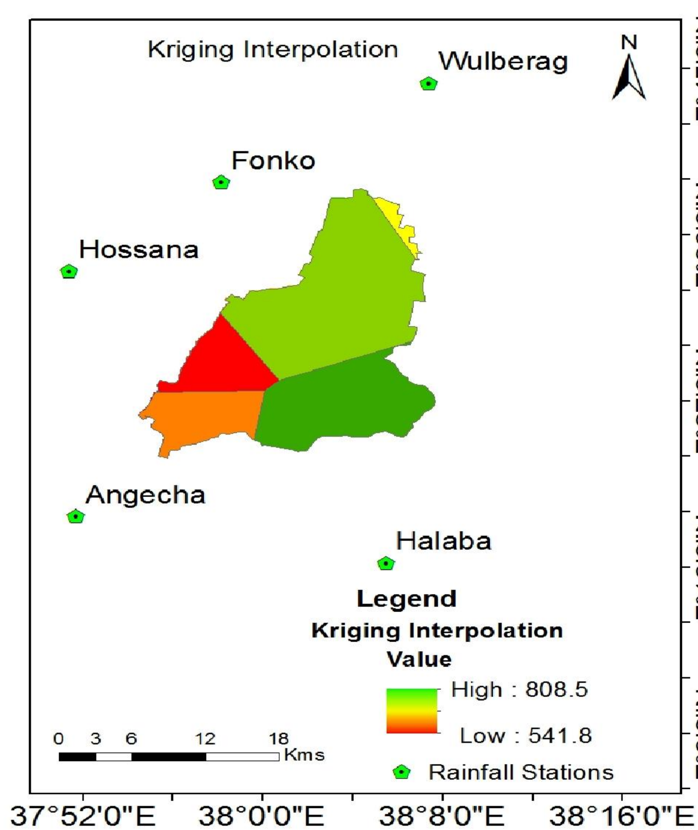

Figure 3.7: Rainfall Erosivity (R) Map

3.4.2 Estimation of Soil Erodibility (K factor)

Soil erodibility factor (K) defines mean annual rate of soil loss per unit of R for standard condition of bare soil, recently tilled up-and-down, no conservation practices and on a slope of 5^0 and 22 m length (Morgan, 1994). The value of K ranges close to 0 to 1. Values range from 1.0 (most eroded) to 0.01 (almost none eroded). Hellden (1987) developed a USLE for Ethiopian condition by adapting different sources and proposed the K values of the soil based on their colour. The K-factor can also be determined from the color of the soil (Helldery, 1987) as follows:

Table 3.3: Soil erodibility factor based on soil colour

Soil Colour	Black	Brown	Red	Yellow
K factor	0.15	0.20	0.25	0.30

(Source: Helldery, 1987)

The K factor defines the resistance of the soil to both detachment and transport. The K factor (soil erodibility factor) depends on the following soil parameters in combinations (Renschler C S, 1999) of Percentage of silt (very fine sand, clay and organic matter) structure and drainage.

The soil erodibility factor (K-factor) is derived on soil physical characteristics of particle size, permeability and structure. Since soil has different drainage capacity due to physical and chemical characteristics, the k values were assigned to the soil map. K value assignment to soil map was not done according to (Table 3.3) since the soil of the study area have brown color although there is difference in organic matter content and structure of soil.

From FAO 1997 database of soil, the type of soil in study area was found to be Eutric Fluvisols and Chromic Luvisols. The soil around Lake Boyo is a mixture of the two types because of erosion and deposition processes. The k-factor value according to the (Table 3.4) is the same for both soil types in the study area although the two soils types have different texture classes. The organic matter composition and soil texture was obtained from FAO database. Since the soil of the study area in their geomorphologic name, an attempt were made to classify the soil types of the study area based on Soil Conservation Research Project (SCRP) estimate of K value, the study area soil have the same k-value 0.2 as shown (Table 3.4). Therefore K-factor assignment is made on the basis of the texture of the soil and organic matter composition according to the (Table 3.5).

Table 3.4: K factor value based on SCRP estimate

No	Major Soil	Soil Colour	SCRP Estimate of K Value
1	Eutric Fluvisols	Mostly brown but variable	0.2
2	Eutric Vertisols	Dark grey or black	0.15
3	Eutric Cambisols	Brown or dark brown	0.2
4	Eutric Leptosols	Brown to yellowish brown	0.2
5	Haplic Luvisols	Brown/reddish brown	0.2
6	Haplic Nitosols	Reddish brown	0.25
7	Chromic Luvisols	Brown/reddish brown	0.2
8	Lithic Leptosols	Brown to yellowish brown	0.2

(Source: Soil Conservation Research Programme (2000d))

Table 3.5: The k-values according to specific soil parameters

No	Textural Class	Average OMC	Less than 2% OMC	More than 2% OMC
1	Clay	0.22	0.24	0.21
2	Clay Loam	0.30	0.33	0.28
3	Coarse Sandy Loam	0.07	____	0.07
4	Fine Sand	0.08	0.09	0.06
5	Fine Sandy Loam	0.18	0.22	0.17
6	Heavy Clay	0.17	0.19	0.15
7	Loam	0.30	0.34	0.26
8	Loamy Fine Sand	0.11	0.15	0.09
9	Loamy Sand	0.04	0.05	0.04
10	Loamy Very Fine Sand	0.39	0.44	0.25
11	Sand	0.02	0.03	0.01
12	Sandy Clay Loam	0.20	___	0.20
13	Sandy Loam	0.13	0.14	0.12
14	Silt Loam	0.38	0.41	0.37
15	Silty Clay	0.26	0.27	0.26
16	Silty Clay Loam	0.32	0.35	0.30
17	Very Fine Sand	0.43	0.46	0.37
18	Very Fine Sandy Loam	0.35	0.41	0.33

(source:http://www.omafra.gov.on.ca/English/engnineer/facts/00.001.htm)

According to the FAO classification 1997 of soil based on structure, the study area has clay and loam soils with organic matter content less than 2%. K-factors were selected from the structure since the two different soil types have different k-factor values according to (Table 3.5). A k-factor map was generated assigning the corresponding k-value for each soil types according to (Table 3.5).

Soil map of the study area was reclassified based on the soil type and converted to feature class. An attribute table for k-factor was created and the corresponding k-value for each soil type was assigned according to (Table 3.5). Finally feature class of study area was converted to raster (grid) using k-value attribute as value field and k-factor map of study area was obtained as displayed in (Figure 3.8).

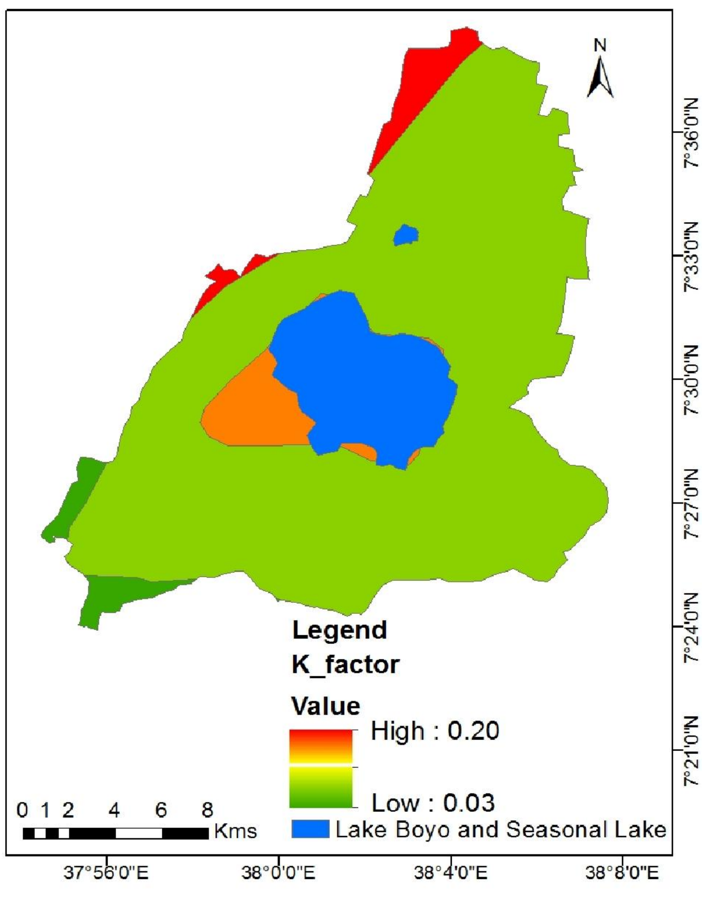

Figure 3.8: Soil Erodibility Map of the Study Area (FAO, 1997)

The value of k ranges close to 0 (almost none eroded) to 1 (most eroded) depending on physical and chemical property of the soils.

3.4.3 Estimation of Slope Length and Slope Gradient Factors (LS-factor)

Slope length is the distance from the crest of a hill to the point where either slope steepness decreases enough so deposition of transported material starts, or runoff enters in natural or prepared waterway. Longer slopes increase erosion because water accumulated and increase in speed, collecting more cutting sediment and doing proportionally more damage.

The LS-factor characterizes the effect of topography on erosion in USLE. By using DEM with finer resolution, it is possible to calculate slope length `L` and slope gradient `S` with greater accuracy than in previous assessments (Wischmeier and Smith,1978). It is important to note that there are number of problems unique to the DEMs that need to be addressed.

Length of slope (L-factor) and slope steepness (S-factor) attributes were derived from topographic information. The DEM of resolution 30m was used to derive the L and S factors for the study area using ArcGIS 10.1 software on raster calculator. These base data sets for mean slope gradient and slope length were then used as inputs to generate the L and S factor for the USLE. The L factor is defined as the ratio of soil loss from the field slope length to that from a 22.13 m length (Lu et al., 2001) and was derived using the equation:

$L = (Xh / 22.13)^{m}$ ………………………………………………………… (Equation 3)

Where, Xh is the horizontal slope length and m is a variable slope length exponent.

Table 3.6: m value for different slope ranges

m value	**Slope (%)**
0.5	>5
0.4	3-5
0.3	1-3
0.2	<1

The S factor is defined as the ratio of soil loss from the field slope gradient to that of 9% slope under identical conditions and was derived using the equations:

$S = 10.8 * \sin\theta + 0.03$ where $\sigma \leq 9\%$ …………………………………………… (Equation 4)

$S = 16.8 * \sin\theta - 0.5$ where $\sigma > 9\%$.. (Equation 5)

Where, θ is the angle of slope and σ is the slope gradient in percentage.

In the USLE, m varies from 0.6 for slopes >10% to 0.2% for slopes <1%. In modelling erosion in GIS, it is common to calculate LS in combination using the formula as:

$LS = [\text{Flow Accumulation} * \text{Resolution}/22.13]^{o.6} * [\sin(\text{slope} * 0.01745)/0.09]^{1.3}$…. (Equation 6)

Where, Flow accumulation is the number of cells contributing to flow into a given cell and resolution is the resolution of DEM. Therefore; LS can be calculated by using regression equation:

$LS = (\text{Flow Accumulation} * \text{cell resolution}/22.13)^{0.6} * (\sin(\text{slope} * 0.01745)/0.09)^{1.3}$… (Equation 7)

Then formula (equation 6) is used in raster calculator used as:

LS= Power ("Flow Accumulation"*Resolution/22.1, 0.6) * power (sin ("slope"*0.01745) / 0.09, 1.3)*1.3………………………………………………………………………… (Equation 8)

(Source: http://skagit.meas.ncsu.edu/~helena/gmslab/erosion/usle.html)

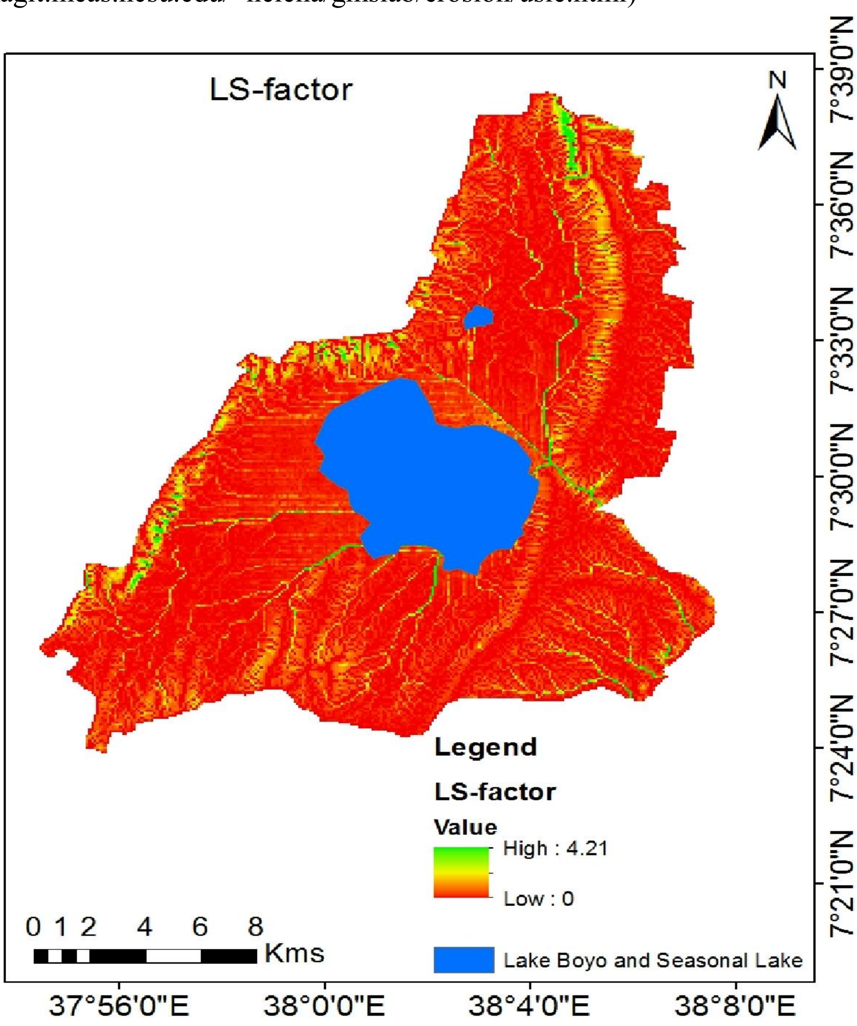

Figure 3.9: Generated Map of LS-factor of the study area

3.4.4 Estimation of Land Use Land Cover Factor Management (C-factor)

Crop factor, C measures the ratio of soil loss from a specific crop cover and residue management condition to loss from a tilled, continuous fallow under the same soil, slope and rainfall condition (Morgan, 1994). The type of land cover (crop type) and tillage make the greatest difference in the amount of erosion that occurs in a given area. Pasture and hay crops area effective in reducing erosion to a very low level. The more of the soil that is left uncovered during, before or after tillage, the greatest the risk of soil erosion by either wind or water. As Nyssen, (1997) commented, the land cover factor 'C' has a paramount importance in the determination of erosion hazard assessment because of the large difference between its minimum and maximum values therefore slight mistakes in land cover mapping can result in large over or under estimations of soil loss. For this reason up-to-date and accurate land use land cover map was used for analyzing the C-value.

The cover management factor (C-factor) reflects the effect of cropping and management practices on the soil erosion rate. The individual values of *C* vary between 0 for a completely non-erodible condition, to a value somewhat greater than 1.0. Values greater than 1.0 imply conditions more erodible than those normally experienced under Unit Plot conditions, which can occur for conditions with very extensive tillage, leaving a very smooth surface that produces much runoff and makes the soil especially susceptible to erosion.

The LULC map of 2015 was reclassified using the LULC classes as class field and converted to a feature class. Major land use land cover types described in this map were water body, cultivated land, bush land, grazing land, settlement, wetland and bare land. The Wereda covers Woina Dega climate type used to grow crops such as enset, maize, barley and potato. Whereas the Derek Woina Dega predominantly covers, grows crops such as maize, teff, wheat and sorgum.

After getting the classified image format has been changed in to vector format and a corresponding C-value was assigned to each land use land cover classes using editing menu of ArcGIS 10.1 software from the C-value adopted by Hans Hurni 1985 for USLE model. Then attribute fields were add to each feature classes (2015) to assign the C-value for each land use land cover classes.

Finally the feature classes of LULC were converted to raster using C-value attribute field as a value field. The C-value for each land use land cover was chosen from (Table 3.7).

Table 3.7: C-factor values for different land use land cover classes

No	Land cover land use class	C-factor	Source
1	Forest	0.001	Hurni, 1985
2	Bush land	0.1	Hurni, 1985
3	Grass land	0.01	Hurni, 1985
4	Dense grass	0.01	Hurni, 1985
5	Degraded grass	0.05	Hurni, 1985
6	Bare land	0.6	Hurni, 1985
7	Crop land as teff main crop	0.25	Hurni, 1985
8	Crop land, cereals/pulses	0.15	Hurni, 1985
9	Crop land, wheat /barely	0.15	Hurni, 1985
10	Cropland, sorghum/maize	0.1	Hurni, 1985
11	Afro-alpine	0.01	BCEOM, 1998
12	Open shrub land	0.06	Bewket and Teferri, 2009
13	Crop land/wooded crop land	0.15	Bewket and Teferri, 2009
14	Shrub land	0.02	Bewket ant Tefferi ,2009
15	Swamp	0.01	Bewket and Teferri, 2009

For cultivated land, average of o.1, 0.15 and 0.25 was used since agricultural production was mainly maize, teff and cereals. Land use land cover map and C-factor of the study area was shown in (Figure 3.10).

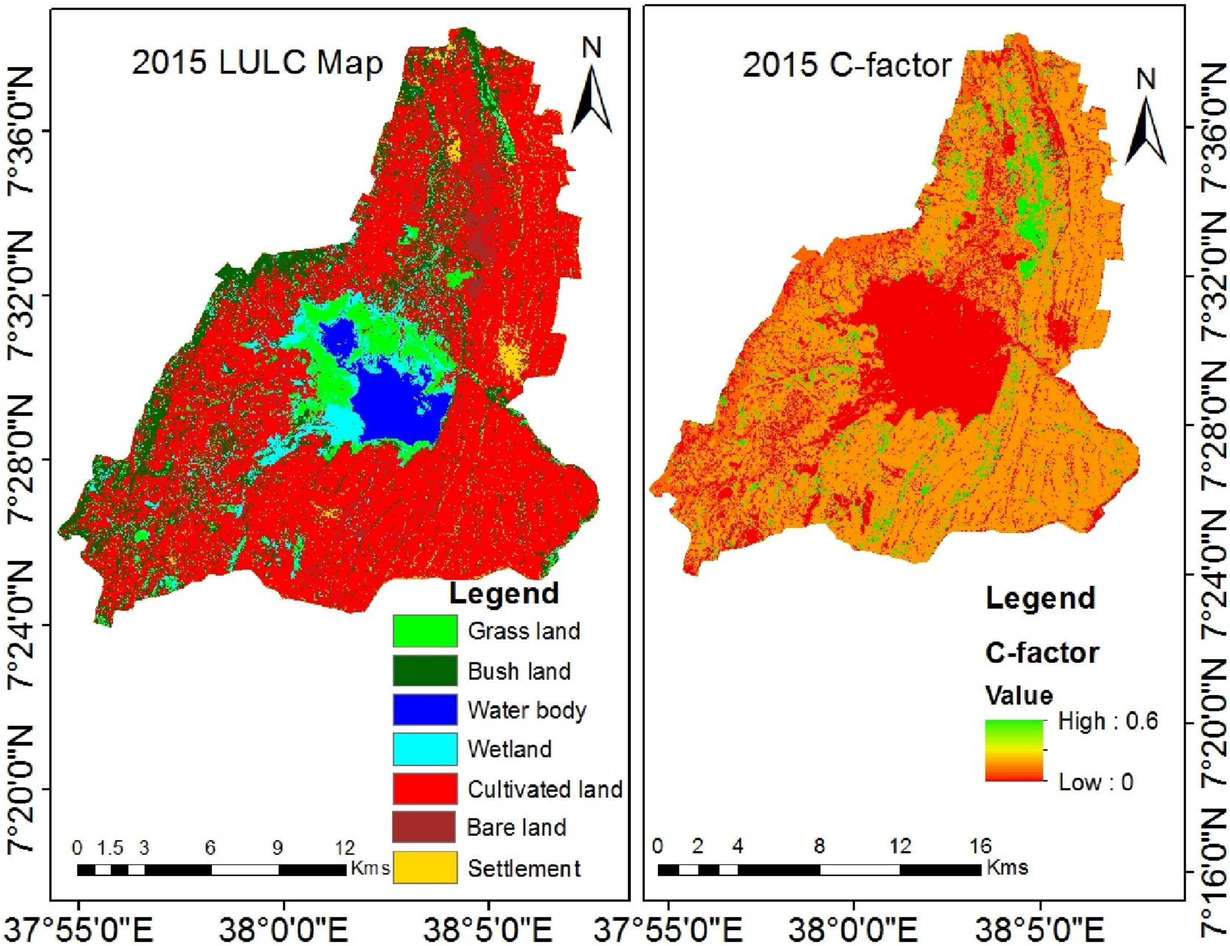

Figure 3.10: C-factor of the Study Area

3.4.5 Estimation of Erosion Management Practice Factor (P-value)

The conservation practice factor is the ratio of soil loss for a specific practice to the soil loss with up-and-down hill culture. The P-value ranges from 0-1 depending on the soil management activities employed in the specific plot of land. A value of 1 means no soil conservation practices are used, the lower p-value, the more effective conservation practices is deemed to be reducing soil erosion.

These management activities are highly depends on the slope of the area. The most important supporting practices are contour tillage, strip-cropping on the contour and terrace systems all needing stabilized waterways for the disposal of excess rainfall. The P Factor is reflecting the impact of supporting practices on the erosion rate. The effect of contouring and tillage practices on the soil erosion is described by supported practice factor (P-factor) within the USLE model.

According to the results of primary data collected from the study area, the farmers responded that they were used contour tillage for soil conservation practices after 2000 and terracing before 25 years ago. The appropriate value for each grid cells was assigned according to the slope range and soil conservation practices from (Table 3.8).

Table 3.8: P values for different supporting practices (Bewket and Tefferi, 2009)

No	**Slope (%)**	**P-factor value**	
		Contour Tillage	Terracing
1	1-2	0.6	0.1
2	3-5	0.5	0.1
3	6-8	0.5	0.1
4	9-12	0.6	0.12
5	13-16	0.7	0.14
6	17-20	0.8	0.16
7	>20	0.9	0.16

ASTER 2011 DEM of 30m*30m resolution was converted to generate slope map of study area. Then the slope map was reclassified with the slope range as defined by (Table 3.8) and converted to a feature class. An attribute field was added to the feature class so as to assign p-value for each slope range based on slope range and type of soil conservation practices used for each year according to (Table 3.8). Eventually the feature class was converted to raster (grid format) using p-factor value field for each year and a p-factor map was obtained as displayed by (Figure 3.11).

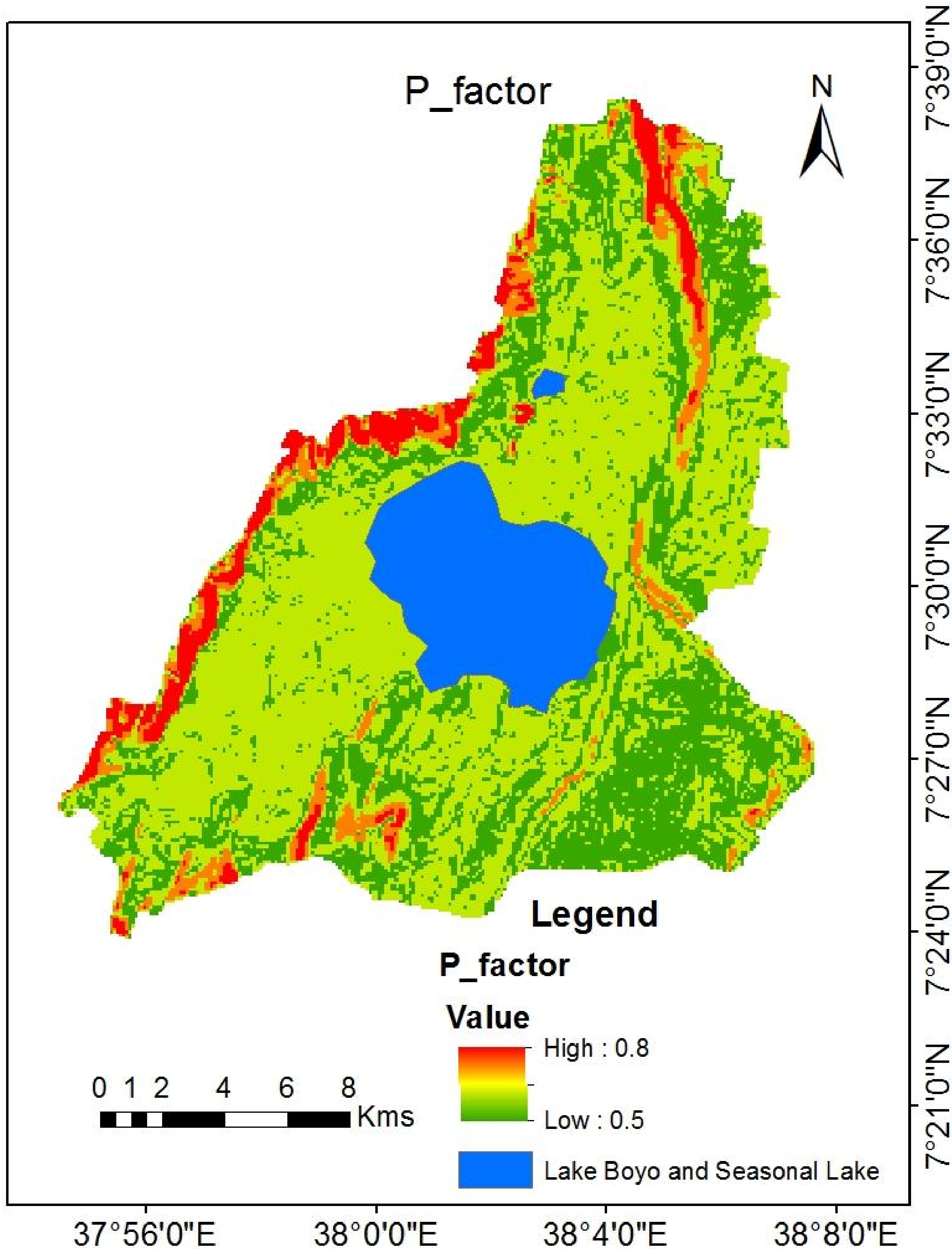

Figure 3.11: P-factor Map of the Study Area

Flow charts of the general methodology for estimation of USLE model are shown in (Figure 3.12)

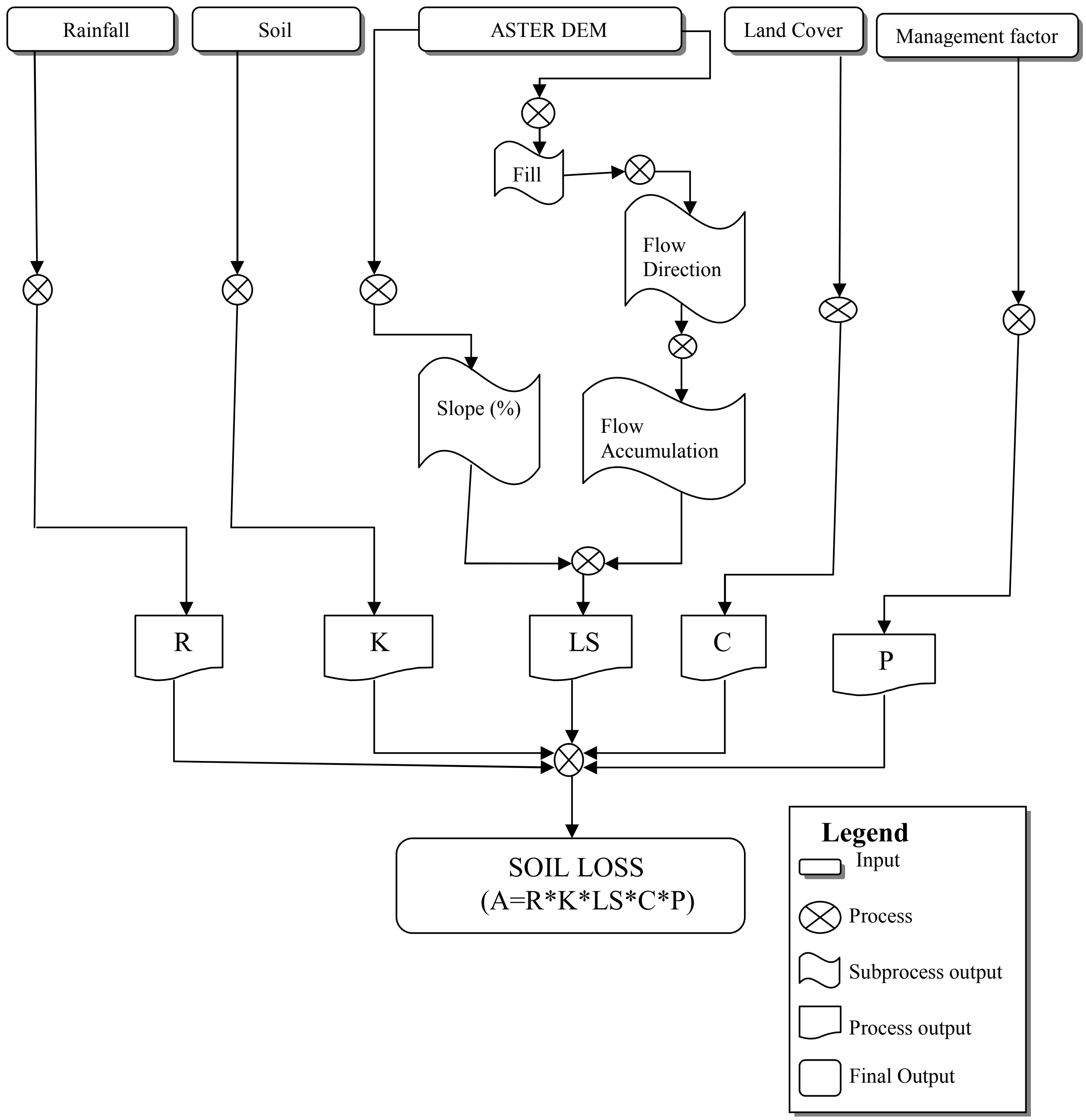

Figure 3.12: Flow chart of general methodology for Estimation of USLE Model

4. RESULTS AND DISCUSSIONS

4.1 Classification Accuracy Analysis

Overall accuracy is a descriptive statistic which is computed by dividing the total sum of correctly classified by the total number of reference pixels in the error matrix. The result of the accuracy assessment for the 1973, 1986, 2000, and 2015 land cover maps showed overall accuracy of 88.3%, 93.9%, 87.8%, and 88.6% respectively. The Confusion matrix and accuracy assessment measures for 1973, 1986, 2000, and 2015 are shown in (Table 4.1, 4.2, 4.3, and 4.4) respectively.

Table 4.1: Confusion matrix and accuracy assessment measures for 1973 image

	Land cover classes	**Reference data**						**Row Total**	**User's Acc. (%)**
		Grass land	Bush land	Water body	Wetland	Cultivated land	Bare land		
Classified data	Grass land	**26**	3	0	3	1	0	33	**78.8**
	Bush land	2	**27**	0	3	1	2	35	**79.4**
	Water body	0	0	**30**	0	0	0	30	**100.0**
	Wetland	2	0	0	**22**	0	0	24	**91.7**
	Cultivated land	0	0	0	2	**28**	2	32	**87.5**
	Bare land	0	0	0	0	0	**26**	26	**100.0**
	Column total	30	30	30	30	30	30	180	-
	Producer's acc. (%)	**86.8**	**90.0**	**100.0**	**73.3**	**93.3**	**86.7**	-	-
	Overall Classification Accuracy=**88.3%**								

Table 4.2: Confusion matrix and accuracy assessment measures for 1986 image

	Land cover classes	Reference data						Row Total	User's Acc. (%)
		Grass land	Bare land	Cultivated land	Water body	Wetland	Bush land		
Classified data	Grass land	**28**	0	0	0	1	2	31	**90.3**
	Bare land	0	**28**	2	0	0	0	30	**93.3**
	Cultivated land	0	2	**28**	0	0	0	30	**93.3**
	Water body	0	0	0	**28**	0	0	28	**100.0**
	Wetland	0	0	0	2	**29**	0	31	**93.5**
	Bush land	2	0	0	0	0	**28**	30	**93.3**
	Column total	30	30	30	30	30	30	180	-
	Producer's acc. (%)	**93.3**	**93.3**	**93.3**	**93.3**	**96.6**	**93.3**	-	-

Overall Classification Accuracy=**93.9**

Table 4.3: Confusion matrix and accuracy assessment measures for 2000 image

	Land cover classes	Reference data						Row Total	User's Acc. (%)
		Grass land	Wetland	Water body	Cultivated land	Bush land	Bare land		
Classified data	Grass land	**24**	2	0	0	2	0	28	**85.2**
	Wetland	4	**28**	2	0	1	0	35	**79.4**
	Water body	0	0	**28**	0	0	0	28	**100.0**
	Cultivated land	0	0	0	**27**	0	3	30	**90.0**
	Bush land	2	0	0	0	**27**	1	30	**90.0**
	Bare land	0	0	0	3	0	**26**	29	**89.7**
	Column total	30	30	30	30	30	30	180	-
	Producer's acc. (%)	**76.7**	**90.0**	**93.3**	**90.0**	**90.0**	**86.7**	-	-

Overall Classification Accuracy=**87.8%**

Table 4.4: Confusion matrix and accuracy assessment measures for 2015 image

	Land cover classes	Reference data							Row Total	User's Acc. (%)
		Bare land	Settle ment	Grass land	Wetland	Water body	Bush land	Cultivated land		
Classified data	Bare land	**26**	0	0	0	0	0	2	28	**92.8**
	Settlement	0	**26**	0	0	0	0	0	26	**100.0**
	Grass land	0	0	**26**	3	0	2	0	31	**83.8**
	Wetland	0	0	3	**25**	2	0	0	30	**83.3**
	Water body	0	0	0	0	**28**	0	0	28	**100.0**
	Bush land	0	0	1	1	0	**27**	0	29	**93.1**
	Cultivated land	4	4	0	1	0	1	**28**	38	**73.6**
	Column total	30	30	30	30	30	30	30	210	-
	Producer's acc. (%)	**86.6**	**86.6**	**86.6**	**83.3**	**93.3**	**90.0**	**93.3**	-	-

Overall Classification Accuracy=**88.6%**

As mentioned by Anderson *et al*. (1976) for a reliable land cover classification, overall accuracy and accuracy for all classes are acceptable if greater than 85%. Accordingly, the overall accuracies of all maps were obtained within 88.3% and 93.9%. The overall classification accuracy of produced thematic maps for 1973, 1986, 2000, and 2015 ranged from 88.3% to 93.9%. The achieved levels of accuracy indicated a supervised classification method was a reasonable alternative for mapping the fragmented and heterogeneous landscape of the study area.

User's accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels that were classified in that category of the classified image (row total). It represents the probability that a pixel classified into a given category actually represents that category on the ground. Results of user's accuracy in 1973 ranged from 78.8 to 100%, in 1986 ranged from 90.3 to 100%, in 2000 ranged from 79.4 to 100%, and in 2015 ranged from 73.6 to 100% as indicated in (Tables 4.1, 4.2, 4.3, and 4.4) respectively. The lowest values of class accuracy were misclassified due to spectral property similarities among other land cover classes. As shown in (Table 4.1) the user's accuracy was lowest for grass land as some of the grass land was misclassified as bush land, wetland and cultivated land. Again as shown in (Table 4.3) the user's accuracy was lowest for wetland as some of the wetland was misclassified as grass land and bush land. Similarly as shown in (Table 4.4) the user's accuracy was lowest for cultivated land as some of the cultivated land was misclassified as bare land.

Producer's accuracy refers to the number of correctly classified pixels in each class (category) divided by the total number of pixels in the reference data to be of that category (column total). This value represents how well reference pixels of the ground cover type are classified. As shown in (Table 4.1), wetland was largely misclassified with accuracy of 73.3% and in (Table 4.3), grass land was became a low accuracy of 76.7% whereas wetlands had been relatively properly classified. The lowest values for wetland areas in (Table 4.1) was misclassified due to the similar spectral properties of different land cover classes such as grass land, bush land and cultivated land. In (Table 4.3), grass land was misclassified due to the similar spectral properties of different land cover classes such as wetland and bush land.

4.2 Analysis of Land Use Land Cover Change Dynamics

Water body, grass land, bare land, bush land, cultivated land, wetland, and settlement were the major land use land cover classes used during the study periods (1973-2015). The spatial coverage and proportion of land cover classes resulted from classified images are shown in (Table 4.5)

Table 4.5: Spatial coverage and proportion of land cover classes resulted from classified images

LULC classes	1973		1986		2000		2015	
	Area of LC (ha)	(%)	Area of LC (ha)	(%)	Area of LC (ha)	(%)	Area of LC (ha)	%
Grass land	5732.6	16.1	4684.9	13.1	3724.5	10.4	2322.9	6.5
Bush land	10192.3	28.6	6682.5	18.7	4707.3	13.2	4415.9	12.4
Water body	219.0	0.6	282.7	0.8	648.9	1.8	1393.8	3.9
Wetland	1569.5	4.4	1475.6	4.1	2312.3	6.5	2392.1	6.7
Cultivated land	15682.8	43.9	17889.3	50.1	20686.8	57.9	22457.6	63.0
Bare land	2300.3	6.4	4681.4	13.1	3626.5	10.6	1609.6	4.5
Settlement	-	-	-	-	-	-	1042.1	2.9
	35696.5	**100.0**	**35696.4**	**100.0**	**35706.2**	**100.0**	**35634.1**	**100.0**

- The total area of images is not the same due to change in pixel size.

Analysis of the 1973 image revealed that cultivated land constituted the largest proportion of land in the Wereda with a value of 15682.8 ha (43.8%), followed by bush land which accounts for 10192.3 ha (28.6%). Grass land, bare land, wetland and water body constituted for 5732.6 ha (16.1%), 2300.3 ha (6.4%), 1569.5 ha (4.4%) and 219 ha (0.6%) respectively.

As can be seen in between 1973 and 1986, the proportion of land allocated for cultivated land increased to 17889.3 ha (50.1%). Similarly, bare land and water body increased to 4681.4 ha (13.1%) and 282.7 ha (0.8%), respectively. However, the proportions of bush land, grass land and wetland have decreased to 6682.5 ha (18.7%), 4684.9 ha (13.1%) and 1475.6 ha (4.1%), respectively.

The classification result of the images between 1986 and 2000, revealed that cultivated land was the dominant proportion of land class and increased to 20686.8 ha (57.9%), followed by wetland and water body which accounts for 2312.3 ha (6.5%) and 648.9 ha (1.8%) respectively. As a result again bush land, grass land and bare land have decreased to 4707.3 ha (13.2%), 3724.5 ha (10.4%) and 3626.5 ha (10.6%) respectively.

Between the year 2000 and 2015 image analysis of study area showed that cultivated land was the major land class and again increased to 22457.6 ha (63.0%). Similarly, wetland and water body increased to 2392.1 ha (6.7%) and 1393.8 ha (3.9%) respectively. However, the proportion of bush land, grass land and bare land decreased to 4415.9 ha (12.4%), 2322.9 ha (6.5%) respectively. At previous classified image, settlement which was not found accounted 1042.1 ha (2.9%). Grass land, bush land, and bare land, which covered 16.1, 28.6, and 6.4% of the area in 1973, respectively, diminished to 6.5, 12.4, and 4.5% in 2015. The classified LULC map of the 1973, 1986, 2000, and 2015 are shown in (Figure 4.1) below.

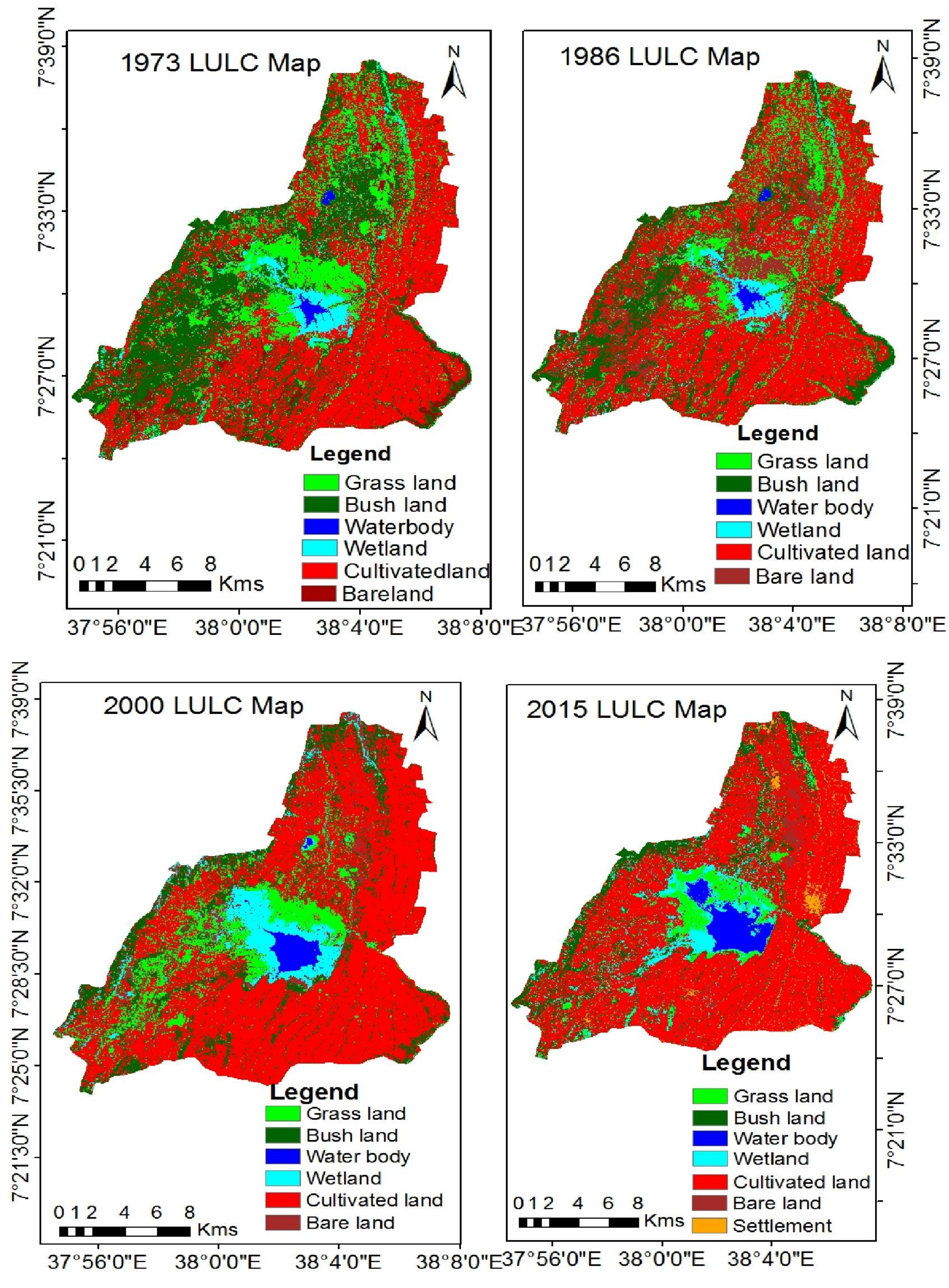

Figure 4.1: LULC Classification Map of 1973, 1986, 2000, and 2015

4.3 Land Use Land Cover Change Dynamcs: Trend, Rate and Magnitude

An important aspect of change detection is to determine what is actually changing to what i.e. which land use class is changing to which other classes. This information reveals both the changes (additions and reductions) and classes that are relatively stable overtime. This information will also serve as a vital tool in management decisions. This process involves a pixel to pixel comparison of the study year images through overlays.

4.3.1 LULC Conversions between 1973 and 2015

Table 4.6: Cross-tabulation matrices showing LULC conversions (in ha) between two dates (1973&2015)

LULC Classes	**Year 2015**							
Year 1973	GL	BuL	WB	WL	ST	CL	BL	**Total (1973**
Grass Land (GL)	**1056.5**	548.6	233.2	801.8	115.0	2536.3	426.7	5718.2
Bush Land (BuL)	584.2	**2316.0**	117.7	720.1	191.1	5843.3	384.8	10157.0
Water Body (WB)	16.4	9.5	**167.3**	10.5	0.1	11.2	3.2	218.3
Wetland (WL)	145.9	165.0	731.7	**189.6**	10.1	298.5	30.2	1571.0
Settlement (ST)	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0
Cultivated Land (CL)	390.8	1137.2	137.1	571.7	621.7	**12258.6**	536.0	15653.0
Bare Land (BL)	99.6	238.6	6.0	97.9	59.8	1569.9	**217.1**	2288.9
Total (2015)	2293.4	4415.0	1393.0	2391.7	997.8	22517.7	1597.9	35606.3

The change detection statistics table provides a detailed tabulation of changes between two classification images. The statistics tables list the initial state classes in the rows and the final state classes in the columns. This is required for a complete accounting of the distribution of pixels that changed classes. Each cell of the main diagonal of the matrix contains the surface area (in ha) of each class that remained unchanged during the time period evaluated, while the remaining cells contain the estimated surface area of a given LULC class that changed to a different class during the same period (Mendoza et al., 2011). The tables facilitated the determination of the quantity of LULC conversions taking the advantage of “from-to” change information for each of the seven established cover classes. Recent studies (IPCC, 2003; Zhou et al., 2008) have shown that remote sensing is the most direct and cost-effective tool that can be used for verification of LULC classes and conversions.

The image difference is the difference in the total number of equivalently classed pixels in the two images, computed by subtracting the initial state class totals from the final state class totals. An image difference that is positive indicates that the class size increased and a negative indicates decreased in class size. The magnitude of LULC change dynamics between two dates (1973 and 2015) are shown in (Figure 4.2).

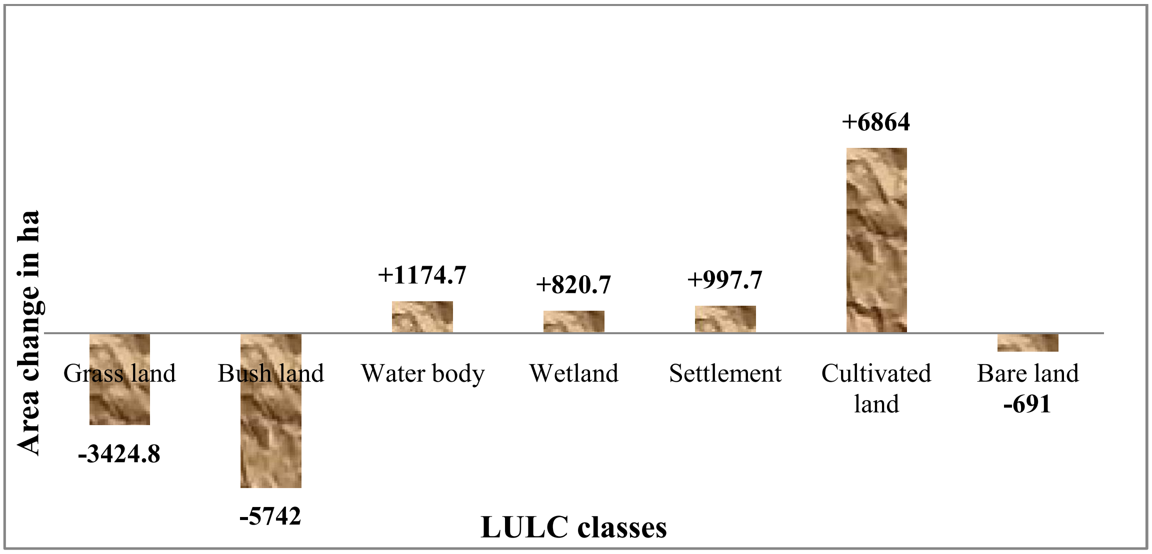

Figure 4.2: The magnitude of LULC change dynamics between two dates (1973 & 2015)

During the period between 1973-2015 LULC classes cultivated land, water body, settlement, and wetland were increasing by 6864 ha, 1174.7 ha, 997.7 ha, and 820.7 ha respectively, while bush land, grass land, and bare land were decreasing by -5742 ha, -3424.8 ha, and -691 ha respectively. The cultivated land increased with the highest magnitude while bush land decreased with the highest magnitude in the same period. From the total study area, in (Table 4.6), unchanged areas were indicated in diagonal cells. The total unchanged areas were 16,205.1 ha while changed areas were 19,401.2 ha from the total study area. As anticipated, the cross-tabulation matrices containing LULC conversions revealed a considerable increase (43.9%) in cultivated land between 1973 and 2015, the largest in spatial coverage.

During 1973-2015, 2536.3 ha from grass land, 5843.3 ha from bush land, 11.2 ha from water body, 298.5 ha from wetland, and 1569.9 ha from bare land LULC were transitioned to cultivated land. This indicates that human pressure has a leading cause for the land use land cover change in the study area. In the same period, from grass land, bush land, wetland, cultivated land, and bare land 233.2 ha, 117.7 ha, 731.7 ha, 137.1 ha, and 6.0 ha LULC were converted to water body respectively. Also in the same period, from grass land, bush land, water body, cultivated land, and bare land 801.8 ha, 720.1 ha, 10.5 ha, 571.7 ha, and 97.9 ha LULC were changed to wetland respectively. Again in the same period, from grass land, bush land, water body, wetland, cultivated land, and bare land 115.0 ha, 191.1 ha, 0.1 ha, 10.1 ha, 621.7 ha, and 59.8 ha LULC were converted to settlement respectively. On the other hand, grass land lost its area to bush land, water body, wetland, cultivated land, and bare land 584.2 ha, 16.4 ha, 145.9 ha, 390.8 ha, and 99.6 ha LULC were converted respectively. In the same period, bush land lost its area to grass land, water body, wetland, cultivated land, and bare land 548.6 ha, 9.5 ha, 165.0 ha, 1137.2 ha, and 238.6 ha LULC were changed respectively. Likewise, bare land lost its area to grass land, bush land, water body, wetland, and cultivated land 426.7 ha, 384.8 ha, 3.2 ha, 30.2 ha, and 536.0 ha LULC were converted respectively. From this we can understand LULC conversions were multi-directional and significant in magnitude.

4.3.2 LULC Conversions between 1973-1986

Table 4.7: Cross-tabulation matrices showing LULC conversions (in ha) between two dates (1973-1986)

LULC Classes	**Year 1986**							
Year 1973	GL	BuL	WB	WL	ST	CL	BL	**Total (1973)**
Grass Land (GL)	**3157.9**	302.6	10.3	10.5	0	268.0	1974.3	5723.7
Bush Land (BuL)	132.7	**5013.8**	0.3	19.0	0	3659.6	1363.7	10189.1
Water Body (WB)	0.7	0.0	**216.5**	1.5	0	0.0	0.0	218.7
Wetland (WL)	11.4	33.5	55.6	**1379.9**	0	94.1	1.0	1575.4
Settlement (ST)	0.0	0.0	0.0	0.0	**0**	0.0	0.0	0.0
Cultivated Land (CL)	723.7	704.1	0.0	64.2	0	**13748.1**	440.8	15680.8
Bare Land (BL)	657.3	625.8	0.0	0.2	0	113.6	**901.4**	2298.3
Total(1986)	4683.7	6679.8	282.7	1475.3	0	17883.4	4681.2	35686.2

The magnitude of LULC change dynamics between two dates (1973 and 1986) are shown in (Figure 4.3).

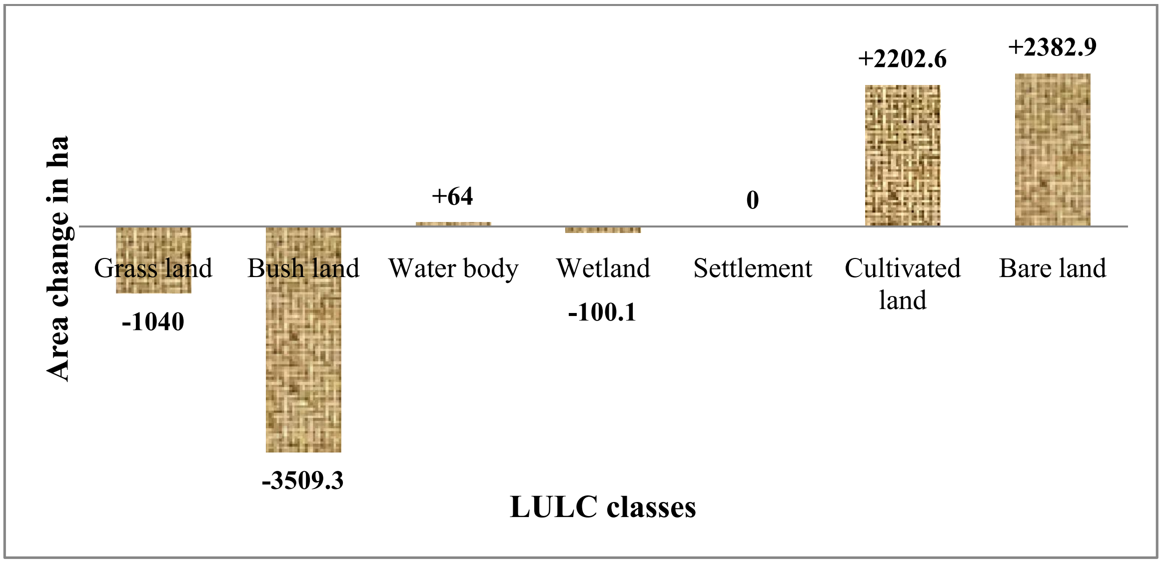

Figure 4.3: The magnitude of LULC change dynamics between two dates (1973-1986)

During the period between 1973-1986 LULC classes cultivated land, water body, and bare land were increasing by 2202.6 ha, 64 ha, and 2382.9 ha respectively, while bush land, grass land, and wetland were decreasing by -3509.3 ha, -1040 ha, and -100.1 ha respectively. The total unchanged areas were 24417.6 ha while changed areas were 11268.6 ha from the total study area.

During the period between 1973 and 1986, 268.0 ha from grass land, 3659.6 ha from bush land, 94.1 ha from wetland, and 113.6 ha from bare land LULC were converted to cultivated land. Cultivated land was dominant at entire period of the study. In the same period, 10.3 ha, 0.3 ha, and 55.6 ha from grass land, bush land, and wetland LULC were transitioned to water body. Again in the same period, 1974.3 ha, 1363.7 ha, 1.0 ha, and 440.8 ha from grass land, bush land, wetland, and cultivated land LULC were changed to bare land. The main cause for increment of bare land was inappropriate use of land management, human pressure, and deforestation. On the other hand, bush land, grass land, and wetland lost their area to other LULC classes.

4.3.3 LULC Conversions between 1986-2000

Table 4.8: Cross-tabulation matrices showing LULC conversions (in ha) between two dates (1986-2000)

LULC Classes	**Year 2000**							
Year 1986	GL	BuL	WB	WL	ST	CL	BL	**Total (1986)**
Grass Land (GL)	**561.1**	615.7	14.7	590.0	0	2401.7	496.4	4679.6
Bush Land (BuL)	925.3	**1447.6**	9.0	425.2	0	2663.0	1191.3	6661.5
Water Body (WB)	4.5	4.3	**234.8**	27.8	0	4.5	6.8	282.7
Wetland (WL)	80.5	170.1	381.6	**469.9**	0	217.8	154.8	1474.7
Settlement (ST)	0.0	0.0	0.0	0.0	**0**	0.0	0.0	0.0
Cultivated Land (CL)	911.9	2091.8	7.4	443.7	0	**13360.7**	1050.6	17866.0
Bare Land (BL)	1247.9	362.8	0.9	355.5	0	1988.1	**723.9**	4679.2
Total (2000)	3731.2	4692.3	648.4	2312.1	0	20636.0	3623.8	35643.8

The magnitude of LULC change dynamics between two dates (1986 and 2000) are shown in (Figure 4.4).

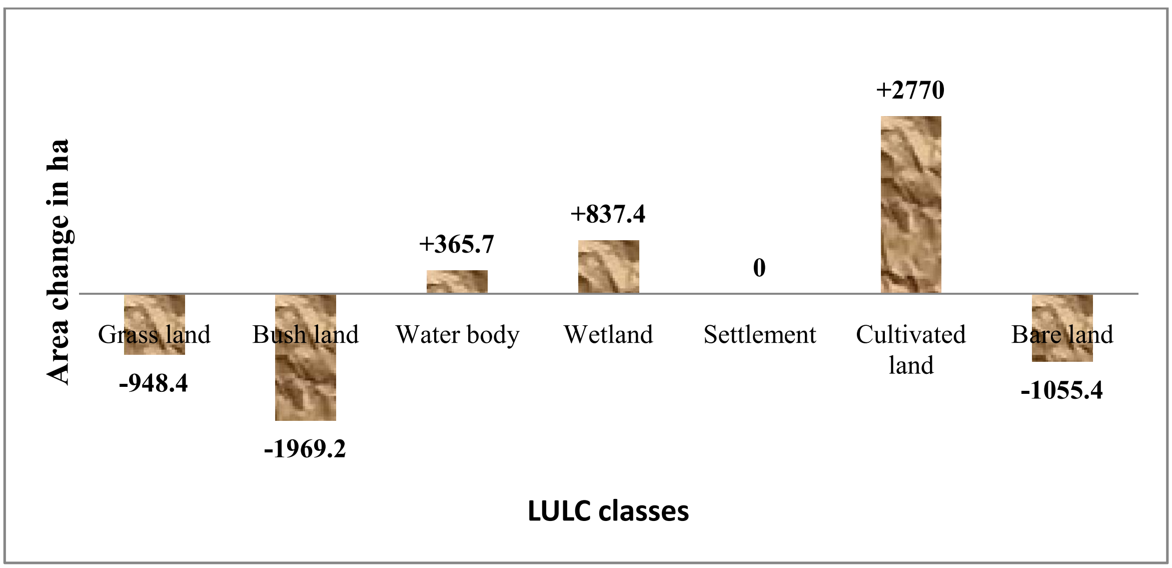

Figure 4.4: The magnitude of LULC change dynamics between two dates (1986-2000)

During the period between 1986-2000 LULC classes cultivated land, water body, and wetland were increasing by 2770.0 ha, 365.7 ha, and 837.4 ha respectively, while bush land, grass land, and bare land were decreasing by -1969.2 ha, -948.0 ha, and -1055.4 ha respectively. The total unchanged areas were 16798.0 ha while changed areas were 18845.8 ha from the total study area.

During the period between 1986 and 2000, 2401.7 ha from grass land, 2663.0 ha from bush land, 4.5 ha from water body, 2178 ha from wetland, and 1988.1 ha from bare land LULC were transitioned to cultivated land. Similarly, 14.7 ha, 9.0 ha, 381.6 ha, 7.4 ha, and 0.9 ha from grass land, bush land, wetland, cultivated land, and bare land LULC were converted to water body respectively. Also, 590.0 ha, 425 ha, 27.8 ha, 443.7 ha, and 355.5 ha from grass land, bush land, water body, cultivated land, and bare land LULC were changed to wetland respectively. Likewise, grass land, bare land, and bush land lost their area to other LULC classes.

4.3.4 LULC Conversions between 2000-2015

Table 4.9: Cross-tabulation matrices showing LULC conversions (in ha) between two dates (2000-2015)

LULC Classes	**Year 2015**							
Year 2000	GL	BuL	WB	WL	ST	CL	BL	**Total (2000)**
Grass Land (GL)	**834.4**	482.5	28	611.6	16.1	1640.3	107.9	3721
Bush Land (BuL)	228.1	**1224.0**	1	422.9	187.5	2389.9	229.4	4683
Water Body (WB)	7.5	7.9	**614**	16.5	0.0	2.9	0.2	649
Wetland (WL)	591.8	332.2	730	**464.2**	7.0	172.5	12.2	2309
Settlement (ST)	0.0	0.0	0	0.0	**0.0**	0.0	0.0	0
Cultivated Land (CL)	355.4	1404.5	0	614.0	729.5	**16562.9**	964.5	20631
Bare Land (BL)	276.8	962.7	21	261.7	58.3	1753.2	**284.0**	3617
Total (2015)	2293.9	4413.8	1393	2390.9	998.5	22521.6	1598.1	35610

The magnitude of LULC change dynamics between two dates (2000 and 2015) are shown in (Figure 4.5).

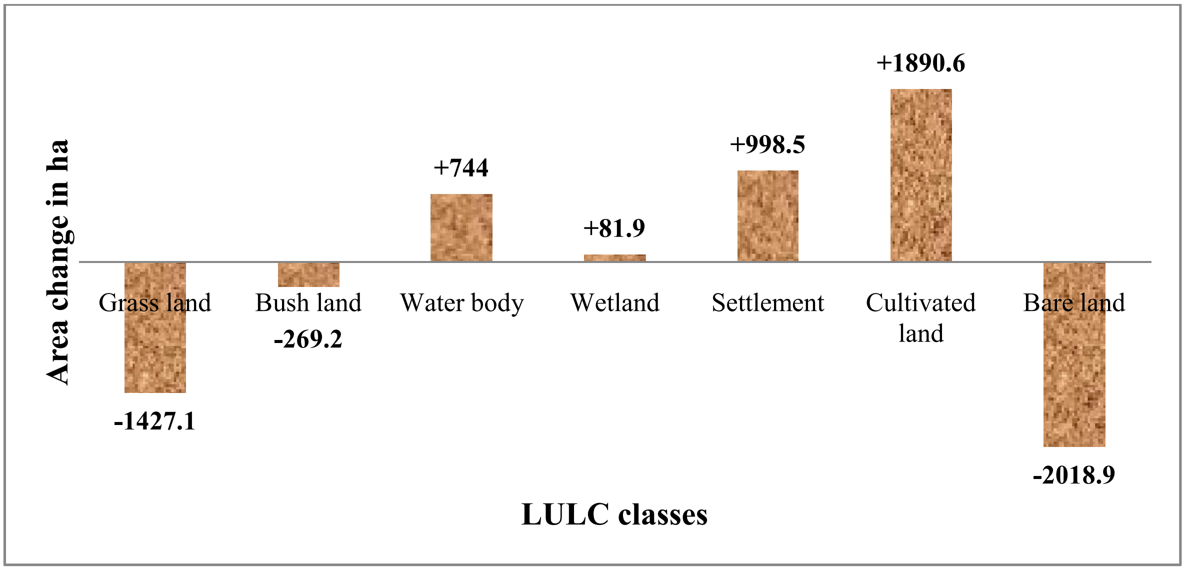

Figure 4.5: The magnitude of LULC change dynamics between two dates (2000-2015)

During the period between 2000-2015 LULC classes cultivated land, water body, wetland, and settlement were increasing by 1890.6 ha, 744.0 ha, 81.9 ha, and 998.5 ha respectively, while bush land, grass land, and bare land were decreasing by -269.2 ha, -1427.1 ha, and -2018.9 ha respectively. The total unchanged areas were 19983.5 ha, while changed areas were 15626.5 ha from the total study area.

At the interval between 2000 and 2015, 1640.3 ha, 2389.9 ha, 2.9 ha, 172.5 ha, and 1753.2 ha from grass land, bush land, water body, wetland, and bare land LULC were converted to cultivated land respectively. In all the entire period of the study cultivated land was the dominant class. Similarly, 161.1 ha from grass land, 187.5 ha from bush land, 7.0 ha from wetland, 729.5 ha from cultivated land, and 58.3 ha from bare land LULC were changed to settlement. In the same period also, 28.0 ha from grass land, 1.0 ha from bush land, 730.0 ha from wetland, and 21.0 ha from bare land LULC were transitioned to water body. Again in the same period, 611.6 ha, 422.9 ha, 16.5 ha, 614.0 ha, and 261.7 ha from grass land, bush land, water body, cultivated land, and bare land LULC were converted to wetland respectively. On the other hand, bare land, grass land, and bush land lost their area to other LULC classes.

4.3.5 Discussions on LULC Change Dynamics

Agriculture has been the greatest force of land transformation on this planet. Nearly a third of the Earth's land surface is currently being used for growing crops or grazing cattle. Much of this agricultural land has been created at the expense of natural forests, grasslands, and wetlands that provide valuable habitats for species and valuable services for human kind (Millennium Ecosystem Assessment, 2005). In Ethiopia, before 1974, the relationship between land users and owners was based on a feudal system (Desta et al., 2000) under which the ownership of land was limited to a few individuals. Most inhabitants were only eligible to get access to farmland through share cropping. During this period, it was highly likely that a portion of the land was left abandoned. The human population was relatively low with low pressure on the land and associated resources in general and with prevalence of fallow lands.

Cultivated land: Cultivated land constituted 43.9%, 50.1%, 57.9, and 63.0% in the years 1973, 1986, 2000, and 2015, respectively (Table 4.5). The temporal and the annual change rate of cultivated land was 43.2% and 1% between 1973 and 2015, respectively (Table 4.10). This shows cultivated land was increased sharply during the entire period of the study. The predominant land cover class was found to be cultivated land, which accounted for 43.9% in 1973 and increased to 63.0% in 2015 (Fig 4.1). This finding corroborates other studies performed in the region (Garedew et al.2009; Ali et al. 2011; Wondrade et al. 2014). Similarly, cultivated land expansion appears to be typical for the area and was in agreement with the findings of Gete and Hurni (2003) in Anjeni area of north western Ethiopian highlands, Solomon (2005), in Headstream of Abay watershed, and that of Fikir et al. (2009) in Eastern Tigray, Ethiopia between 1965 and 2005. The majority expansion of cultivated land was on the expense of grass land 2536.3 ha and bush land 5843.3 ha (Table 4.6) between 1973 and 2015. The expansion of cultivated land as shown on the satellite images in the wereda was confirmed by inhabitants that indicated the land conversion was caused by the high numbers of the youths, who were looking for land because no employment opportunities outside agriculture were available.

Grass land: Grass land constituted 16.1%, 13.1%, 10.4%, and 6.5% in the years 1973, 1986, 2000, and 2015, respectively (Table 4.5). Through the entire period of the study, grass land was decreased from 16.1 to 6.5%, 1973 and 2015, respectively (Table 4.5). The temporal and the annual change rate of grass land was -59.5% and -1.4% between 1973 and 2015, respectively (Table 4.10). Grass land lost the majority of its area to cultivated land and other LULC classes. This finding shows that strong agreement with Wondrade et al. 2014, in the Lake Hawassa Watershed, Ethiopia and it contrary from reports of Gete and Hurni (2001) and Solomon (2005), who indicated an increase of grassland cover in Anjeni area and Headstream of Abay Watershed respectively, both in northwest Ethiopia.

Bush land: Bush land accounted 28.6%, 18.7%, 13.2%, and 12.4% in the year 1973, 1986, 2000, and 2015, respectively (Table 4.5). The major conversions observed were mainly to cultivated land and other LULC classes. Bush land loss its area to cultivated land 1137.2 ha, to grass land 548.6 ha, to bare land 238.6 ha, to wetland 165 ha, and to water body 9.5 ha (Table 4.6). The temporal and the annual change rate of bush land was -56.7% and -1.3% between 1973 and 2015, respectively (Table 4.10).

Bare land: Bare land constituted 6.4%, 13.1%, 10.6%, and 4.5% in the years 1973, 1986, 2000, and 2015, respectively (Table 4.5). During the first period the coverage of bare land was increased from 6.4 to 13.1% between 1973 and 1986, respectively. The temporal and the annual change rate of bare land was -30% and -0.7% between 1973 and 2015, respectively (Table 4.10).The main cause for increment of bare land was loss of vegetation cover, inappropriate land use management, lack of soil and water conservation structure, and population pressure. During the second and third period of study, the coverage of bare land was decreased.

Water body: It is evident from the cross-tabulation matrices that the area occupied by water body was increased from 0.6 to 3.9% between 1973 and 2015, respectively. The coverage of water body constituted 0.6%, 0.8%, 1.8%, and 3.9% in the year 1973, 1986, 2000, and 2015, respectively (Table 4.5). Water body increased on the expense of the wetland, grass land, cultivated land, bush land, and bare land which accounted 731.7 ha, 233.2 ha, 137.1 ha, 117.7 ha, and 6.0 ha, respectively (Table 4.6). Wetland was the dominant transitioned LULC class to water body followed by grass land, cultivated land and bush land. From own observation, from the result of LULC classification, and from the elders responded the coverage of water body increased through the entire period of the study. The physiographic nature of the study area were dominated by gentle slope, it is found in the rift valley floor, and which is bounded by mountains at in all boundaries of the study area were the associated cause for increment of water body.

Due to this reason from surrounding wereda's and zone's during the rainy season perennial, ephemeral, and tributary rivers were drained to the study area and brought the sediment deposit to the Boyo plain and it increases the coverage of the water body and expands the size of Lake Boyo. During the years of abundant rainfall, a rise in the lake levels were recorded (USAID, 2000), which caused inundation of the surrounding area.

Wetland: Globally wetlands are among the most threatened ecosystems by uncontrolled and unsustainable human intervention (Hardlife et al. 2014). Wetlands frequently are associated with topographic lows, even in mountainous regions. Examples of wetlands include marshes, mudflats, and swamps situated on the shallow margins of Lake Boyo and extensive parts of Guder and Bilate rivers flood plains qualify as wetlands, as overflow areas. Wetlands play a major role in flood control, sediment trapping, and shore line stabilization. Wetland coverage constituted 4.4%, 4.1%, 6.5%, and 6.7% in the year 1973, 1986, 2000, and 2015, respectively (Table4.5). During the first period wetland decreased from 4.4 to 4.1% between 1973 and 1986, but increased during the second and third period 6.5 and 6.7% between 1986 and 2000, 2000 and 2015, respectively. Wetland increased on the expense of the grass land, bush land, cultivated land, bare land, and water body which accounts 801.8 ha, 720.1 ha, 571.7 ha, 97.9 ha, and 10.5 ha, respectively (Table 4.6). Grass land was the dominant transitioned LULC class to wetland followed by bush land and cultivated land (1973-2015). From the result of LULC classification, from own observation, and from the result of discussion with local elders indicated that deposition of sediments (flood plains) on Lake Boyo plain were shifting the coverage of water body to grass land, cultivated land, and others. At the same time grass land, bush land, cultivated land, and water body contributes for increment of the coverage of wetland during the rainy season and area coverage of wetland increased during the second and third period of the study area.

Settlement: Settlement constituted 2.9% only during the third period of study between 2000 and 2015 (Table 4.5). Bonosha town, almost at the boarder of the wereda, is part of the study area. Even if there is information from the elders about the existence of the town in 1973, it has not any sign of town on the Landsat image. On 2000 Landsat image there are few pixels that indicate the town but their significance on the supervised classification was negligible and cannot come up as a separate class from the output. This is because the houses at a time were corrugated steels and huts that make the reflectance similar with cultivated land and partitioning with it. Surprisingly, the size of this town has changed during the third study period and on the 2015 Landsat image, it was not difficult to identify Bonosha town and small towns like Doesha, Jemaya, Hiriko, and Shemo which are also visible from the 2015 satellite imagery, but there was no sign of settlement in the previous period of study 1973, 1986, and 2000 images. Own observation and the satellite imagery showed that currently there are also other small villages which contain primary schools, health centers, and offices of different government sectors. Settlement constituted 2.9% by expense of cultivated land and grass land.

4.3.6 LULC Change Dynamics Rate and Trend

The comparison of the LULC statistics assisted in identifying the percentage change, trend and rate of change between 1973 and 2015. In achieving this, the first task was to develop a table showing the area in hectares and the percentage change for each year (1973, 1986, 2000, and 2015) measured against each LULC type. Attributable to unequal length of the temporal intervals (13, 14, and 15) and undoubtedly uneven distribution of LULC conversions within each temporal interval, it was necessary to estimate the average temporal and annual rates of change of LULC type for the purpose of comparison. The annual rates of change were computed by dividing the temporal rates of change by the number of year's interval (Sleeter and Raumann, 2006; Zhang et al., 2010), which is calculated according to the formula: $Ra=Rt/\Delta y$, and $Rt=(Ac-Ap)/Ap*100$, where Ra and Rt are the annual and temporal change rates of the target LULC type, respectively; Ac and Ap are the area of the target LULC type at the current and previous study points in time, respectively; and Δy is the length of the study period measured in the unit of years. For first period 1973-1986 (13 years), for second period 1986-2000 (14 years), and for third period 2000-2015 (15 years) which identifies the annual location and magnitude of change.

% Temporal change rate (Rt) = (Ac-Ap)/Ap*100………………………….. (Equation 9)

% Annual rate of change (Ra) = (Ac-Ap)/AP*100*1/$\mathbf{\Delta y}$ …………………. (Equation 10)

Where: Ac= current area of LULC, Ap= previous area of LULC, and Δy = is the length of the study period measured in the unit of years. Temporal and annual rate of LULC change between two dates are shown in (Table 4.10).

Table 4.10: Temporal and annual rates of LULC change between two dates

LULC classes	GL	BUL	WB	WL	CL	BL	ST
LULC change(1973-1986)							
Difference (ha)	-1047.7	-3509.8	63.7	-93.9	2206.5	2381.1	-
Temporal change rate (%)	-18.3	-34.4	29.1	-6	14.1	103.1	-
Annual change rate (%)	-1.4	-2.6	2.2	-0.5	1.1	8	-
LULC change(1986-2000)							
Difference (ha)	-960.4	-1975.2	366.2	836.7	2797.5	-1054.9	-
Temporal change rate (%)	-20.5	-29.6	129.5	56.7	15.6	-22.5	-
Annual change rate (%)	-1.5	-2.1	9.3	4.1	1.1	-1.6	-
LULC change(2000-2015)							
Difference (ha)	-1401.6	-291.4	744.9	79.8	1770.8	-2016.9	1042.1
Temporal change rate (%)	-37.6	-6.2	114.8	3.5	8.6	-55.6	-
Annual change rate (%)	-2.5	-o.4	7.7	0.2	0.6	-3.7	-
LULC change(1973-2015)							
Difference (ha)	-3409.7	-5776.4	1174.8	822.6	6774.8	-690.7	1042.1
Temporal change rate (%)	-59.5	-56.7	536.4	52.4	43.2	-30	-
Annual change rate (%)	-1.4	-1.3	12.8	1.2	1	-0.7	-

- **GL**=Grass land; **BUL**=Bush land; **WB**=Water body; **WL**=Wetland; **CL**=Cultivated land; **BL**=Bare land; **ST**= Settlement

4.4 Analysis of Annual Soil Loss Rate Estimation

All map layers were generated for implementation of Universal Soil Loss Equation (USLE) in a raster GIS environment (grid-based approach) for the study area for the year 2015. USLE model was developed as an equation of the main factors controlling soil erosion, namely Rainfall Erosivity (R-factor), Soil Erodibility (K-factor), Slope Length (LS-factor), Land Cover Management (C-factor), and Support Practice (P-factor) for soil conservation. Then all the factors were multiplied in raster calculator (ArcGIS10.1) and the result (output) layer was generated which gives the rate of soil loss by erosion at a pixel level in a raster format.

From the result of the analysis of the soil loss rate in study area using a USLE model, it was found that the mean annual soil loss rate of the study area is 14.31t/ha/yr in 2015. The result was compared with other relevant study results for validity. Different studies have been carried out on soil erosion assessment in Ethiopia and estimated different rates of erosion. The average rate of soil loss in Ethiopia is estimated to be 12t/ha/yr, and it can be higher than this on steep slopes with soil loss greater than 300 tons per hectare per year, where vegetation cover is scant (USAID, 2000). The current result of the study area agrees with USAID report of the 2000. The result of study area also falls below the ranges of findings of FAO (1984). According to the estimate of FAO (1984), the annual soil loss rate of Ethiopia ranges from 1248-23400 million tons per year from 78 million of hectare of pasture, ranges and cultivated fields throughout Ethiopia. The Ethiopian Highlands Reclamation Study (FAO, 1984) also suggested the average annual soil loss of 100t/ha/yr for the Ethiopian high lands, the estimated soil loss by the study area is by far below the suggested values of the previously conducted studies.

To analyze the annual soil loss rates at upstream of the Guder River and identify micro-watersheds which needs prioritization for integrated watershed management. The study area was subdivided into thirty micro-watersheds as illustrated in (figure 4.6).

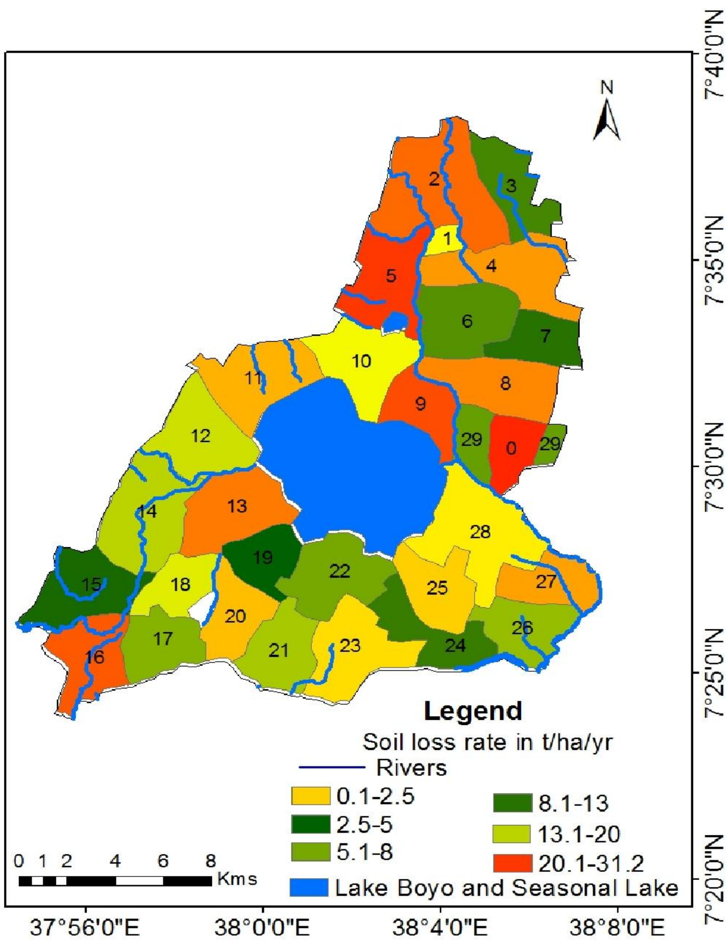

Figure 4.6 : Annual mean soil loss from each Micro-watershed (in t/ha/yr)

Table 4.11: Categorization of different erosion potentials with some modifications

Mean soil loss (in t/ha/yr)	Severity Classes	Micro-watersheds
0	No soil loss	-
1-5	Very low	0, 1
5-8	Low	9, 13, 18, 19, 29
8-10	Moderate	17, 24, 25
10-15	Moderately sever	6, 7, 12, 22, 26, 27, 28
15-25	Sever	2, 4, 5, 14, 16, 20, 23
25-31	Extreme sever	3, 8, 10, 11, 15, 21

(Source: FAO, 1986)

Micro-watersheds in upstream of Guder River have high annual rates of soil loss per hectare per year. The rates of soil loss from some upstream micro-watersheds of Guder are higher than the upper limits of soil loss tolerance according to Hurni (1985). About 40% of the total of micro-watershed were prone to high erosion severity and needed a high priority for the implementation of soil conservation measure (micro-watersheds 2, 3, 4, 5, 8, 10, 11, 15, 16, 20, 21, 23) has the mean annual soil loss rate above the upper limit of tolerable range according to Hurni (1985) and about 60% of the total of micro-watershed (0, 1, 6, 7, 9, 12, 13, 14, 17, 18, 19, 22, 24, 25, 26, 27, 28, 29) below the upper limit of tolerable range. The annual soil loss rate of each micro-watershed is given by (Appendix 5). The soil loss severity was higher on areas where less or no vegetation cover due to deforestation and overgrazing problems, steep slopes and areas under intensive agriculture. The highly and very severely eroded locations with high erosion rates leading to land degradation where soil and water conservation measures are required and integrated watershed management planning strategies need to be developed. These adversely affected areas due to high erosion rate are potential areas for the declining of crop yield.

Over the study periods, it has been observed that, all classified land units have different magnitude of soil loss and categorized under different erosion levels. Each land use land cover annual soil loss was analyzed for the study area as shown in (Table 4.12).

Table 4.12: The annual soil loss rate of study area in t/ha/yr from each LULC classes

No	Land use land cover	Mean soil loss (t/ha/yr)	Total area (ha)	Soil loss (tons/yr)
1	Grass land	14169.7	2322.9	6.1
2	Bush land	19871.6	4415.9	4.5
3	Water body	0	1393.8	0
4	Wetland	8133.1	2392.1	3.4
5	Settlement	2917.9	1042.1	2.8
6	Cultivated land	943219.2	22457.6	42
7	Bare land	112672	1609.6	70

The result obtained was compared with other results by Hurni (1987) and Gununo soil laboratory results as shown in (Table 4.13).

Table 4.13: Annual soil loss from different LULC classes in t/ha/yr

No	LULC classes	Soil loss rate (t/ha/yr)	Source
1	Forest land	1	Hurni, 1987
2	Cultivated land	42	Hurni, 1988
3	Grass land	6.93	Gununo RU
4	Bush land	5	Hurni, 1987
5	Shrub land	5	Hurni, 1987
6	Bare land	70	Hurni, 1988

The results for annual soil loss for bush land, grass land, cultivated land, and bare land were strongly correlated with the results of Hurni (1987) and Gununo Research unit, respectively. Whereas the annual soil loss for cultivated land was done in Wolayita, which have relatively similar rainfall, soil characteristics and farming systems. The results show good agreement with findings of Gunten (1993) and Eyasu (2002) as cited by Makuria (2005). Gunten (1993) reported a soil erosion rate of 13t/ha/yr on a cultivated field. For the same area Eyasu (2002) reported a range of soil loss rate 6-13t/ha/yr from the cultivated field using USLE. The finding of the annual rate of soil loss for the study area on cultivated land shows not agreed with results of Gunten (1993) and Eyasu (2002). Makuria (2005) conducted research on the rate of soil loss from the cultivated field in Shomba (kaffa) subicatchment and obtained the annual soil loss rate 13.5 tons per hectare. The findings of the result in Shomba show not agreed with the findings of study area.

Inappropriate land use accelerates rate of soil erosion beyond the tolerable limit, which is threshold value assumed to be equivalent to rate of natural soil formation (Lal, 1990). This value varies from different soils. From the current works in tropics, maximum tolerable value of 10t/ha/yr is commonly taken as a guideline (young, 1998). Hurni (1985) reported the tolerable soil loss level for various ecological zones of Ethiopia from 2-16 t/ha/yr. From the current result (14.31t/ha/yr) it can be observed that rate of soil erosion in the study area is above the upper tolerable limit according to Young guideline for tropics but lower than that of the upper limit given by Hurni (1985). This result reflects that appropriate land use management and soil and water conservation measures must be taken in the study area.

Significant difference in soil loss rate in study area in 2015 reflects that LULC change dynamics and poor soil conservation management practices contributed for the accelerated rate of soil loss above the tolerable limit according to Young guideline.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

LULC change dynamics have wide range of consequences at spatial and temporal scales. Because of these effects and influences it has become one of the major problems for natural resource management. The analysis of land use land cover changes at different spatial and temporal scales provides an up-to-date land cover conversion information. Such information is useful for sound planning, set decision making mechanisms and construct alternative scenarios.

This study has been conducted to detect and analyze the spatiotemporal land use land cover change dynamics and soil loss by integrating GIS and Remote Sensing. Remote sensing is the most direct and cost-effective tool that can be used for verification of LULC classes and conversions. In order to detect and analyze changes in LULC classes, these techniques were implemented. Satellite data of Landsat 1 MSS, Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI for the study periods of 1973, 1986, 2000, and 2015, respectively were used and Remote Sensing techniques applied to generate LULC maps through a maximum likelihood supervised image classification algorithm. The classification accuracy analysis and change detection processes has also been done. The overall accuracy of land use land cover maps generated in this study had got an acceptable value of above the minimum threshold. Classification of the study area showed significant change in the LULC over the last four decades.

All the identified LULC types have undergone both spatial and temporal changes: sharp decrement for grass land, bush land, and bare land whereas, sharp increment for cultivated land, water body, wetland, and settlement. Population pressure for natural resources, inappropriate land management, and expansion of Lake Boyo have all found to be the root causes of land use land cover change dynamics and problems associated to it.

Moreover, the soil loss from the watershed was estimated using USLE employing GIS tools. The average annual soil loss in the study area was estimated 14.31t/ha/yr in 2015. The result of annual soil loss rate estimation analysis by LULC classes, showed that bare land was found to be erosion hot spot area, followed by intensively cultivated land and other LULC classes. In general, the study revealed that, the sharp increment of cultivated land and the diminishing of grass land and bush land coverage in the wereda at high rate and caused formation of erosion prone area which is highly susceptible to soil erosion. This is one of the main factors to land degradation in the study area. Moreover, highly erosion susceptible areas of the wereda resulted with maximum soil loss. Therefore, the results of the study model helps to protect soil erosion and it may help in giving priority for adopting measures accordingly.

5.2 Recommendations

Improvement of present agricultural land management practices and introduction of appropriate soil conservation measure are essential for mitigating erosion and for improving the welfare of the local community. Unless, all these may result in land degradation that can put the sustainability of agriculture and availability of natural resources in the area at risk. In the light of these findings, the following recommendations are forwarded.

- Intensively cultivated lands and bare land areas, which contributed much soil erosion of the watershed, should be treated as erosion-prone areas and priority shall be given to such areas during implementation of the watershed management practices.
- Create awareness and understanding of environmental and resource issues among the local community to reverse the rapidly increasing land use land cover change dynamics and high soil erosion problems by giving more attention to erosion prone areas.
- There should be an appropriate land use planning with impact studies and scenarios, in order to use a given land with its maximum output and in a sustainable manner.
- Population pressure has played a major role on LULC change dynamics and there should be strong family planning awareness creation campaigns with adequate health services from all concerned body.
- Using fine resolution image data in the future research could produce better results for planning and informed decision making in natural resource management.

REFERENCES

Abate, S. (2011). Evaluating the land use and land cover dynamics in Borena Woreda of South Wollo highlands, Ethiopia. Journal of Sustainable Development in Africa, 13 (1): 87- 105.

Agarwal, C., Green, G. M., Grove, J. M., Evans, T. P., and Schweik, C. M. (2002). A Review and Assessment of Land-Use Change Models:Dynamics of Space, Time, and Human Choice.General Technical Report NE-297. Newtown Square, Pennsylvania: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 61 pp.

Ali, H., Descheemaeker, K., Steenhuis, T., & Pandey, S. (2011). Comparison of land use land cover changes , drivers and impacts for a moisture-sufficient and drought-prone region in the Ethiopian highlands. *Experimental Agriculture, 47(S1), 71-83.*

Anderson, J. (1976). A Land Use and Land Cover Classification System for Use with Remote Sensor Data.Geological Survey Professional Paper No. 964, U.S.Government Printing Office, Washington D.C.

Andy, D. Ward, Willian J. Elliot, (1995). Environmental hydrology. Lewis publishers, USA

Awdenegest Moges & Holden, N. M. (2009). Land cover change and gully development between 1965 and 2000 in Umbulo Catchment, Ethiopia. *Mountain Research and Development, 29*, 265–276.

BAHC. (1993). Biospheric Aspects of the Hydrological Cycle (BAHC): The Operational Plan. *IGBP Report No. 27*. BAHC Core Project Office, Berlin.

Balling, R.C., Cerveny, R.S. (2003). Vertical dimensions of seasonal trends in the diurnal temperature range across the central United States. Geophysical Research Letters 30: Art No. 1878

Bayramin, I., O.Dengiz., O.Baskan, M. Parlak. (2003). *Soil Erosion Risk Assessment with ICONA Model; Case Study: Beypazari Area*. Turk Journal of Agriculture and Forestry 27(2003).

Bishaw, B. (2001). Deforestation and Land Degradation in the Ethiopian Highlands. *NortheastAfrican Studies, 8*, 7–26.

Brown, L. R. (1995). Who will feed China? Wake-up call for a small planet, Worldwatch Environmental Alert Series. W. W Norton: New York.

Brown, L.R. (1981). Eroding the base of civilization. *Journal of Soil and Water* conservation 36(5): 255-261

Changnon, S.A. (2003). Urban modification of freezing-rain events. Journal of Applied Meteorology 42:863–870

Chen, K., (2002). An approach to linking remotely sensed data and areal census data. International Journal of Remote Sensing 23 (1), 37–48.

Chen, K., (2002). An approach to linking remotely sensed data and areal census data. International Journal of Remote Sensing 23 (1),P 37–48.

Colombo, S., Hanley, N. and Calatrava,J. (2005). Designing policy for reducing the off-farm effect of soil erosion using choice experiments. Journal of agriculture economics, vol 56, P81-95

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remot sensed data. *Remote Sensing of Environment* 37: 35–46.

Congalton, R., and K. Green. (1999). Assessing the Accuracy of Remotely Sensed Data:Principles and Practices. Lewis Publishers, Boca Raton, FL.

De Sherbinin, A. (2002). *Land-Use and Land-Cover Change*. A CIESIN Thematic Guide, Palisades, NY.Center for International Earth Science Information Network of Columbia University. Retrieved July 27,2010 from http://sedac.ciesin.columbia.edu/tg/guide_main.jsp

Dessie, G. & Christiansson, C. (2008). Forest decline and its causes in the south-central Rift Valleyof Ethiopia: Human impact over a one hundred year perspective. *Ambio, 37*, 263–271.

Dessie, G. & Kleman, J. (2007). Pattern and magnitude of deforestation in the South Central RiftValley region of Ethiopia. *Mountain research and development, 27*, 162–168.

Desta, L., Kassie, M., Benin, S., and Pender, J., (2000). Land degradation and strategies for Sustainable development in the Ethiopian highlands:Amhara Region. Socio-economics and policy research working paper 32.ILRI (International Livestock Research Institute), Nairobi, Kenya.122 pp.

Dereje T, 2007. Forest cover change and socio-economic drivers in SW Ethiopia. MSc thesis, Centre of Land Management and Land Tenure, Technical University Munich, Germany.

Ellis, E. & Pontius, R. (2007). Land use and land cover change. In C. J. Cleveland (Ed.), *Encyclopedia of Earth*. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment. Retrieved July 29, 2010 from http://www.eoearth.org/article/land-use_and_land-cover_change

FAO, (1984). Land-use, Production regions and farming systems: Assistance to land-use planning. Technical report No. 3, Rome.

FAO.(1984). Ethiopian Highland reclamation Study (EHRS). Final Report, Vol 1-2.Rome Fu, B.J., Chen, L.D., Ma, K.M., Zhou, H.F., and Wang, J., 2000. The relationships between land-use and soil conditions in the hilly area of the Loess Plateau in northern Shaanxi, China. Catena 36, 69–78.

Fikir, A., Nurhussen, T., Nyssen, J., Atkilt, G., Amanuel, Z., Mintesinot, B., Deckers, J., poeson, J., (2009).The impacts of watershed management on land use and land cover dynamics in Eastern Tigray (Ethiopia). *Rersources, Conservation and Recycling, 53, 192-198.*

Foody, G.M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment, 80, 185-201.*

Garedew, E., Sandewall, M., Soderberg, U., & Campbell, B.M. (2009). Land-use and land-cover dynamics in the Centeral Rift Valley of Ethiopia. *Environmental Management, 44, 683-694*

Geist, H.J. and Lambin, E.F., (2001). What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on sub-national case study evidence. LUCC Report No.4. CIACO, Louvain-la-Neuve. Pp116.

Geist, H., and E Lambin. 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52(2): 143–150.

Gete Zeleke and Hurni, H.(2003). Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the Anjeni area Northwestern Ethiopian Highlands. *Mountain Research and Development*, 21:184–191.

GLP, (2005). Science Plan and Implementation Strategy. IGBP Report No. 53/IHDP Report No. 19. IGBP Secretariat, Stockholm. 64pp.

Hailu, G. (2000). Environmental Law of Ethiopia. International Encyclopaedia of Laws, Kulwer Law International. Leuven, Belgium.

Hardlife, Z., David, C., Godfrey, M., Somandla, N., & Proud, M. (2014). The implications for loss and degradation of wetland ecosystems on sustainable rural livelihoods: Case of Chingombe Community, Zimbabwe. *Greener Journal of Environmental Management and Public Safty, 3(2), 43-52.*

Holden ST and Berkete , (1999). Incentives for sustainable land management in the peasant agriculture in Ethiopian highlands. In : Sanders DW , Huszar PC , Sombatpanit S, Enters T (eds), incentives in soil conservation: from theory to practice. World association of soil and water conservation, Oxford and IHN publishing, New delhi.

Holligan, P.M. and H. de Boois. (1993). Land-Ocean Interactions in the Coastal Zone (LOICZ). *IGBP Report No. 25*. International Geosphere-Biosphere Programme, Stockholm.

Hudson, N.W.(1996). *Soil Conserva tion*. 3rd .ed. B.T Batsford Limited. London.UK.

Hurni H . (1985). Soil conservation manual for Ethiopia. Ministry of agriculture, Addis Ababa Lal, R. 1988. *Methods for Assessment of Soil Degradation.* Soil and Water Conservation Society. Madison, USA. pp.558

IPCC, (2003). Good Practice Guidance for Land use, Land-Use Change and Forestry. Global Environmental Strategies for the IPCC, Japan.

Kefelegn G, Von Rompaey A & Poesen J, 2009. Detection and spatial analysis of recent land use changes in Southwest Ethiopia. Doctoral research project, Physical and Regional Geography Research Group,Leuven,Belgium.

Lambin, E.F., Ehrlich, D., (1997). Land-cover changes in Sub-saharian Africa (1982-1991): application of a change index based on remotely sensed surface temperature and vegetation indices at a continental scale. Remote Sensing of Environment 61:181-200.

Lambin, E.F., Turner II, B.L., Geist, H., Agbola, S., Angelsen, A., Bruce, J.W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Ska°nes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T., Vogel, C., Xu, J., 2001. Our emerging understanding of the causes of land-use and - cover change. Global Environ. Change 11, 261–269.

Lambin, E., Geist, H. & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources, 28*, 205–241.

Lesslie, R., Barson, M., and Smith, J. (2006). Land-use information for integrated natural resources management—a coordinated national mapping program for Australia. *Journal of Land-use Science* 1(1),45–62.

Lillesand, T.M. and kiefer, R.W. (1994) Remote sensing and image interpretation. John Wisely and sons Inc., new York.

Makuria Agaw, (2005). Forest conversion, soil degradation, farmers perception nexus, implication for sustainable land use in south west of Ethiopia. Ecology and environment series. No26 P61-86.

Marshall, C.H., Pielke, R.A., Steyaert, L.T. (2003). Wetlands: crop freezes and land-use change in Florida. Nature 426:29–30

McGinley, M. (2008). ''Ethiopian montane moorlands.'' In C. J. Cleveland (Ed.), *Encyclopedia of Earth*. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment. Retrieved August 20, 2010 from http://www.eoearth.org/article/Ethiopian_montane_moorlands

Mendoza, M.E., Grandos, E.L., Geneletti, D., Perez-Salicrup, D.R., Salinas, V., (2011). Analyzing land cover and land use change processes at watershed level: A multi-temporal study in the LakeCuitzeo Watershed, Mexico (1975-2003). *Applied Geography, 31, 237-250*

Mengistie Kindu, Schneider, T., Demel Teketay and Knoke, T. (2013). Land Use/Land Cover Change Analysis Using Object-Based Classification Approach in Munessa-Shashemene Landscape of the Ethiopian Highlands. *Remote Sensing*, 5:2411–2435

Mengistu, K. T. (2008). *Watershed Hydrological Responses to Changes in Land Use and Land Cover, and Management Practices at Hare Watershed, Ethiopia*. Dissertation, Universität Siegen Fakultät Bauingenieurwesen, Research Institute for water and Environment, Germany.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.

Morgan, R.P.C. (1995). *Soil Erosion and Conservation*.Edinburgh: Addison-Wesley Longman.pp. 198.

Morgan, R.P.C. (2005). *Soil Erosion and Conservation*. 3rd ed. National Soil Resources Institute. Cranfield University. Blackwell Publishing, UK. pp.304

Okeke, F., Karnieli, A. (2006). Methods for fuzzy classification and accuracy assessment of historical aerial photographs for vegetation change analysis. Part I: algorism development. *International Journal of Remote Sensing. 27(1-2), 153-176.*

Oldemal LR, Hakkeling RTA, Sombroak WG (1991) World map of the status of human induced soil degradation. UNEP/ISRIC GLASSOD project, Wageningen, The Ntherlands.

Ott B., Uhlenbrook S. (2004): Quantifying the impact of land use changes at the event and seasonal time time scale using a process-oriented catchment model. *Hydrology and Earth System Science*, 8, 1, 62-78.

Pender, J., Place, F. & Ehui, S. (2006). S*trategies for sustainable land management in the East African highlands.* Washington DC: International Food Policy Research Insitute.

Petter, P. (1992). GIS and Remote Sensing for Soil Erosion Studies in Semi-arid Environments PhD, University of Lund, Lund Renschler C S 1999. Evaluating spatial and temporal variability in soil erosion risk-rainfall erosivity and soil loss ratios in Andalusia, Spain. Catena , 34, p209-225

Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C. J. & Mulatu, W. (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: The case of southwestern Ethiopia*. Landscape Ecology, 15*, 339–355.

Reusing,M., T. Schneider and U. Ammer. (2000). *Modelling Soil Loss rates In the Ethiopian Highlands by Integratation of High Resolution MOMS-02/D2-Streao-data in a GIS*. Int. Journal of Remote Sensing. Vol.21 (9)

Riebsame , W.E, Meyer, W.B, and Tuner , B.L. II. (1994). Modelling land-use and land-cover as part of global environmental change. A climate change. Vol.28. P 45

Sandewall, M., Ohlsson, B. & Sawathvong, S. (2001). Assessment of historical land-use changes for purposes of strategic planning – A case study in Laos. *Ambio, 30*, 55–61.

Sarma P, Lahkar B, Ghosh S, Rabha A, Das J, Nath N, Dey S, Brahma N (2008). Land-use and land-cover change and future implication analysis in Manas National Park, India using multi-temporal satellite data. Current science, 95(2): 1-5.

Schwab, G.O., (1981). Frevert, R.K., Edminister, T.W. and Barnes, K. K. *Soil and Water Conservation Engineering*. John Wiley and sons. 3rd edition. pp. 525.

Shibiru, (2002). An investigation of physical and socio-economic determinants of soil erosion in the Hararghe highlands, eastern Ethiopia. Land degradation and development vol 14 P 69-81

Singh, A. (1989), Digital change detection techniques using remotely sensed data. International journal of remote sensing Vol 10, P989-1003, Sign PK , 2008. A sediment graph model based on SCS-CN method. J hydrology 349, P244-255.

Sleeter, B.M., Raumann, C.G., (2006). Land-cover trends in the Mojave Basis and range ecoregion. *Science for a Changing World, 1-15.*

Soil Conservation Research Programme (2000d). Area of Gununo, Sidamo, Ethiopia: Long-term Monitoring of the Agricultural Environment 1981-1994. Soil Erosion and Conservation Database. Centre for Development and Environment, University of Berne.

Solomon Abebe (2005). Land Use/Land Cover Change in the Headstream of Abay Watershed.MA Thesis,Addis Ababa University, Addis Ababa, Ethiopia.

Stone, D.A., Weaver, A.J. (2003). Factors contributing to diurnal temperature range trends in twentieth and twenty first century simulations of the CCCma coupled model. Climate Dynamics 20:435–44445

Taddese, G. (2001). Land degradation: A challenge to Ethiopia. *Environmental Management 27*, 815–824.

Teketay, D. (2001). Deforestation, Wood Famine, and Environmental Degradation in Ethiopia's Highland Ecosystems. *Northeast African Studies, 8,* 53–76.

Thornes, J.B. (1990). *Vegetation and Erosion: Processes and Environments*. Wiley, Chichester, London, UK.

Toy, J.T. Foster, G.R. and Renard, K.G. (2002). *Soil Erosion, Processes, Prediction, Measurement and Control*. New York. USA. pp.338

Troeh, F. R., Hobbs, J. A., and Donahue, R. L. (1999). *Soil and Water Conservation: Productivity and Environmental Protection*, 3rd edition. Prentice Hall, New Jersey. USA.

Turner, B.L. II and B.L. Meyer. (1994). "Global Land-use and Land-cover Change: An Overview." In *Changes in Land-use and Land-cover: A Global Perspective*, eds. W.B. Meyer and B.L. Turner II, 3-10. Cambridge: Cambridge University Press.

Turner, B.L. II, D. Skole, S. Sanderson, G. Fischer, L. Fresco, and R. Leemans. (1995). *Land-Use and Land-Cover Change; Science/Research Plan*. IGBP Report No.35, HDP Report No.7. IGBP and HDP, Stockholm and Geneva.

Turner, M. G.,(1995), Landscape Ecology: the effect of pattern on process, *Annual Review of Ecology and Systematics,* 20, 171–197

USAID, (2000). Strengthening emergency response abilities. Disaster management and preparedness commission (DPPC), United states for international development (USAID). Southern Nations, Nationalities and Peoples Region.

Wahl, Freidrich, M. (1987) Digital Image Signal Processing**.** Artech House, Boston White, M.A., Nemani, R.R., Thornton, P.E., Running, S.W. 2002. Satellite evidence of phenological differences between urbanized and rural areas of the eastern United States deciduous broadleaf forest. Ecosystems 5:260–277

White, M.A., Thornton, P.E. and Running, S.W., (1997), A continental phenology model for monitoring vegetation responses to inter-annual climatic variability. Global Biogeochemical Cycles, 11, pp. 217–234.

Wischmeir, W.H., Smith, D.D., (1978). Predicting rainfall erosion losses, a guide to conservation planning. Agricultural hand book . No. 537, USA department of agriculture, Washington DC.

Woldeamlak Bewuket and Solomon Abebe (2013). Land-use and Land-cover Change and its Environmental Implications in a Tropical Highland Watershed, Ethiopia. *International Journal of Environmental Studies*, 70:126–139.

Wondrade, N., Dick, Ø. B., & Tveite, H. (2014). GIS based mapping of land cover changes utilizing multi-temporal remotely sensed image data in Lake Hawassa Watershade, Ethiopia. *Environmental Monitoring and Assessment, 186(3), 1765-1780.*

Young A, (1998). Land resource now and for the future. Cambridge University press. Cambridge, UK. http://cast.uark.edu/home/research/environmental-studies/lulc-change-in-carrollcounty/literature-review.html#lulc

Zhang, X., Kang, T., Wang, H., Sun, Y., (2010). Analysis on spatial structure of land use change based on remote sensing and geographical information system. *International Journal of Applied Earth Observation and Geoinformation*, 12S, S145-S150.

Zhou, W., Troy, A., Grove, M., (2008). Object-based land cover classification and change analysis in the Baltimore Metropolitan area using multi-temporal high resolution remote sensing data. Sensors,8,1613-1636.

APPENDICES

Appendix 1: Mean yearly rainfall data from five stations (in mm) (1989-2016)

Year	Halaba kulito	Angecha	Fonko	Hossana	Wulberag
1989	1083.0	1543.2	1424.6	1055.5	1178
1990	901.5	1495.1	1036.4	1089.6	1266.7
1991	1007.2	1113.6	1023.9	1025.5	1410.8
1992	1149.4	1351.9	1560.9	1387.9	1525.7
1993	1261.4	1462.2	1511.0	1297.4	1377.4
1994	806.1	919.7	891.9	920	1027.2
1995	956.7	1649.4	946.1	1163.7	1127.9
1996	1158.3	1447.3	1375.4	1173.2	1429.9
1997	1193.2	1503.3	1664.9	1429.5	1152.4
1998	1251.0	1345.1	1367.7	1446.1	1383.7
1999	763.4	1152.3	1154.0	1003.6	1136.4
2000	879.0	1386.2	1184.6	991.9	1663
2001	944.2	2407.6	1417.0	1093.9	1228.9
2002	796.0	1668.5	1406.1	1250.9	1183.6
2003	941.1	1922.5	1466.6	1146.3	1176.5
2004	992.7	1714.2	1195.8	1162.5	954.3
2005	856.1	1931.4	1225.5	1175	1060.2
2006	873.8	1830.3	1200.1	1197.7	1530.8
2007	1051.6	1892.8	1110.7	1178.9	1143.6
2008	950.3	1443.6	1269.2	1210.6	1227.5
2009	850.3	1259.9	1009.0	1178	987.7
2010	1105.8	1234.3	1253.3	1121.59	1212.2
2011	956.0	1323.1	1064.4	1140.5	811.1
2012	710.2	1129.7	1082.8	1006.1	1132.6
2013	1177.9	1284.8	1169.8	1165.57	1075.7
2014	1037.1	1112.9	1056.2	1499.1	1139.1
2015	531.3	684.2	1112.1	952.6	666.5
2016	1211.9	1475.2	1318.7	1324.3	1145.2

Appendix 2: Average Max.Tem. (c^0) and Min.Tem. (c^0) data from four rainfall stations (1989-2016)

Year	Halaba kulito	Angecha	Hossana	Wulberag	Year	Halaba kulito	Angecha	Hossana	Wulberag
1989	26.9	25.8	21.5	25.9	**1989**	7.3	15.8	10.2	10.9
1990	27.4	25.3	21.9	26.0	**1990**	8.8	15.5	10.5	10.9
1991	27.1	25.8	22.5	26.1	**1991**	8.7	16.0	10.9	11.1
1992	27.1	25.7	21.8	25.7	**1992**	9.1	16.0	10.8	10.6
1993	26.5	25.1	21.9	25.6	**1993**	8.2	15.7	10.6	10.3
1994	27.5	25.0	22.1	25.8	**1994**	13.3	15.1	10.7	10.1
1995	27.7	25.2	22.5	25.8	**1995**	13.6	15.4	10.8	9.5
1996	27.3	24.8	22.2	25.7	**1996**	13.3	15.2	10.7	10.0
1997	27.9	24.3	22.8	25.2	**1997**	13.8	14.8	11.1	7.3
1998	27.5	23.8	22.4	25.8	**1998**	14.2	13.5	11.3	6.4
1999	27.8	23.8	22.7	26.1	**1999**	12.6	12.4	10.4	9.0
2000	27.6	23.2	22.8	26.0	**2000**	13.5	13.2	10.2	11.5
2001	27.4	23.1	22.3	25.6	**2001**	13.5	12.8	10.8	11.4
2002	28.2	23.5	22.8	25.9	**2002**	14.1	13.2	10.7	11.4
2003	28.2	23.4	22.8	25.6	**2003**	13.8	13.6	11.1	11.1
2004	28.2	23.5	22.6	25.6	**2004**	13.3	13.4	10.7	11.0
2005	28.1	22.9	22.8	25.8	**2005**	13.4	13.2	11.1	11.1
2006	28.0	23.4	22.8	25.6	**2006**	14.0	13.2	11.3	11.3
2007	28.2	23.6	22.9	25.3	**2007**	13.4	13.1	11.2	10.7
2008	28.9	23.5	23.0	25.2	**2008**	13.1	13.3	10.4	10.5
2009	29.7	23.7	23.5	25.2	**2009**	13.5	13.3	10.5	10.6
2010	28.6	23.5	22.7	25.2	**2010**	14.1	13.3	11.0	10.5
2011	29.1	23.6	23.4	25.2	**2011**	13.9	13.1	10.0	10.9
2012	29.4	23.7	23.5	25.2	**2012**	13.9	13.2	9.8	10.9
2013	28.9	23.6	23.1	25.4	**2013**	15.6	13.4	9.8	11.1
2014	29.4	23.5	23.0	25.4	**2014**	16.9	13.5	10.8	11.3
2015	31.1	24.3	24.1	25.4	**2015**	19.6	13.1	11.5	11.3
2016	29.3	23.6	23.3	25.4	**2016**	19.2	13.5	11.5	11.1

Appendix 3: Ground Control Points for Image Interpretation and Classification

No	LULC	X	Y	Z
1	Cultivated Land	0393720	0836833	1956
2	Cultivated Land	0396197	0843071	1974
3	Cultivated Land	0397159	0844401	1972
4	Cultivated Land	0395086	0840928	1963
5	Cultivated Land	0401752	0837846	1987
6	Cultivated Land	0400498	0841395	2065
7	Cultivated Land	0397608	0838040	1900
8	Cultivated Land	0398010	0835697	1901
9	Cultivated Land	0398160	0834324	1895
10	Cultivated Land	0399122	0832893	1922
11	Cultivated Land	0398601	0830612	1945
12	Cultivated Land	0394920	0831863	1894
13	Cultivated Land	0394225	0833009	1899
14	Cultivated Land	0393621	0833468	1907
15	Cultivated Land	0392979	0834940	1938
16	Cultivated Land	0388805	0831719	1896
17	Cultivated Land	0391873	0832961	1894
18	Cultivated Land	0398116	0828417	1922
19	Cultivated Land	0388923	0822261	1957
20	Cultivated Land	0387665	0820868	1982
21	Cultivated Land	0389468	0820946	2015
22	Cultivated Land	0389757	0820883	2024
23	Cultivated Land	0390025	0822248	1931
24	Cultivated Land	0390274	0821864	1953
25	Cultivated Land	0390025	0821704	1964
26	Cultivated Land	0392839	0824977	1895
27	Cultivated Land	0399677	0827240	1911
28	Cultivated Land	0400148	0826454	1913
29	Cultivated Land	0402446	0824337	1877
30	Cultivated Land	0402187	0822399	1857

No	LULC	X	Y	Z
1	Bare Land	0393186	0837084	2042
2	Bare Land	0395485	0840752	1938
3	Bare Land	0399985	0836904	1974
4	Bare Land	0400129	0837884	2008
5	Bare Land	0400008	0838011	1999
6	Bare Land	0399944	0838078	1998
7	Bare Land	0399612	0838443	1982
8	Bare Land	0399599	0828688	1932
9	Bare Land	0399487	0828270	1920
10	Bare Land	0398580	0828614	1913
11	Bare Land	0398369	0828894	1913
12	Bare Land	0398232	0828552	1911
13	Bare Land	0399036	0827871	1903
14	Bare Land	0388431	0822205	1938
15	Bare Land	0387470	0821208	1953
16	Bare Land	0388351	0820811	1980
17	Bare Land	0388778	0821059	2018
18	Bare Land	0388910	0821155	2022
19	Bare Land	0389190	0821139	2016
20	Bare Land	0389653	0820783	2019
21	Bare Land	0391574	0833942	1982
22	Bare Land	0394452	0834512	1931
23	Bare Land	0401395	0821557	1841
24	Bare Land	0389771	0821502	1981
25	Bare Land	0389633	0821368	1989
26	Bare Land	0389918	0821391	2005
27	Bare Land	0390439	0821781	1945
28	Bare Land	0389653	0820783	2019
29	Bare Land	0390206	0821834	1955
30	Bare Land	0400024	0827048	1905

No	LULC	X	Y	Z
1	Water Body	0395154	0835347	1897
2	Water Body	0395098	0835382	1899
3	Water Body	0401844	0837842	1986
4	Water Body	0400973	0838393	2013
5	Water Body	0400538	0841430	2055
6	Water Body	0398923	0836406	1901
7	Water Body	0394708	0828960	1893
8	Water Body	0389476	0832049	1895
9	Water Body	0399510	0828453	1921
10	Water Body	0393310	0826195	1891
11	Water Body	0396208	0826002	1884
12	Water Body	0399283	0827796	1890
13	Water Body	0387329	0823105	1901
14	Water Body	0401345	0833941	1958
15	Water Body	0401345	0833941	1958
16	Water Body	0401129	0837674	1992
17	Water Body	0395446	0842062	1914
18	Water Body	0395997	0833666	1899
19	Water Body	0400082	0823627	1882
20	Water Body	0401446	0820536	1798
21	Water Body	0396623	0821444	1923
22	Water Body	0394348	0826514	1878
23	Water Body	0393096	0827036	1889
24	Water Body	0394123	0827756	1863
25	Water Body	0394448	0825914	1901
26	Water Body	0395257	0827685	1922
27	Water Body	0400056	0830650	1896
28	Water Body	0395470	0830751	1951
29	Water Body	0390334	0832236	1933
30	Water Body	0400451	0832333	1894

No	LULC	X	Y	Z
1	Wetland	0394912	0835306	1883
2	Wetland	0398711	0836418	1902
3	Wetland	0398624	0833255	1899
4	Wetland	0396086	0830286	1891
5	Wetland	0395679	0830356	1892
6	Wetland	0395422	0829729	1896
7	Wetland	0394721	0829988	1888
8	Wetland	0394834	0829115	1893
9	Wetland	0394144	0832928	1896
10	Wetland	0390295	0832350	1887
11	Wetland	0392075	0832819	1888
12	Wetland	0393095	0825922	1891
13	Wetland	0385736	0828103	1892
14	Wetland	0393012	0826291	1884
15	Wetland	0393065	0826870	1891
16	Wetland	0393204	0826129	1890
17	Wetland	0396243	0825970	1886
18	Wetland	0387337	0823193	1899
19	Wetland	0382375	0821365	1910
20	Wetland	0382842	0821741	1910
21	Wetland	0381789	0822513	1910
22	Wetland	0382430	0821555	1911
23	Wetland	0395688	0841617	1917
24	Wetland	0396068	0830644	1982
25	Wetland	0395438	0831111	1893
26	Wetland	0393372	0830800	1924
27	Wetland	0393061	0831163	1978
28	Wetland	0392128	0831474	1981
29	Wetland	0390521	0831318	1906
30	Wetland	0389277	0830592	1947

No	LULC	X	Y	Z
1	Grass Land	0394525	0834921	1889
2	Grass Land	0395220	0835108	1881
3	Grass Land	0395515	0835940	1904
4	Grass Land	0393448	0836807	1980
5	Grass Land	0393371	0837073	2000
6	Grass Land	0401902	0837982	1983
7	Grass Land	0397576	0837853	1902
8	Grass Land	0397730	0836336	1902
9	Grass Land	0398537	0835745	1900
10	Grass Land	0398224	0834736	1902
11	Grass Land	0393481	0833404	1903
12	Grass Land	0386498	0830903	1901
13	Grass Land	0388073	0830783	1894
14	Grass Land	0388471	0830576	1893
15	Grass Land	0389416	0830029	1893
16	Grass Land	0388984	0831266	1893
17	Grass Land	0399354	0828053	1913
18	Grass Land	0399145	0828350	1909
19	Grass Land	0398648	0828532	1917
20	Grass Land	0398109	0828984	1900
21	Grass Land	0398075	0828778	1909
22	Grass Land	0398193	0828466	1918
23	Grass Land	0398615	0828244	1905
24	Grass Land	0398876	0828005	1917
25	Grass Land	0399070	0827976	1898
26	Grass Land	0399158	0827732	1906
27	Grass Land	0399322	0827708	1898
28	Grass Land	0389099	0821321	2012
29	Grass Land	0389967	0820825	2005
30	Grass Land	0390325	0821961	1947

No	LULC	X	Y	Z
1	Bush Land	0393069	0837475	2045
2	Bush Land	0396325	0843287	1984
3	Bush Land	0396228	0843485	1995
4	Bush Land	0397671	0844188	1981
5	Bush Land	0394532	0841252	1993
6	Bush Land	0399937	0834998	1962
7	Bush Land	0400114	0835511	1973
8	Bush Land	0399562	0840012	2025
9	Bush Land	0399229	0840416	2002
10	Bush Land	0392815	0834953	1945
11	Bush Land	0385903	0830974	1936
12	Bush Land	0398852	0828436	1913
13	Bush Land	0387749	0821667	1954
14	Bush Land	0390109	0821601	1987
15	Bush Land	0390296	0821585	1979
16	Bush Land	0400207	0826885	1899
17	Bush Land	0401280	0825644	1877
18	Bush Land	0403251	0822925	1836
19	Bush Land	0395598	0842185	1931
20	Bush Land	0395616	0841784	1917
21	Bush Land	0388921	0833715	1973
22	Bush Land	0390019	0833656	1995
23	Bush Land	0390134	0833283	1949
24	Bush Land	0401389	0820752	1818
25	Bush Land	0383910	0829657	2011
26	Bush Land	0384673	0829049	1960
27	Bush Land	0402759	0822517	1827
28	Bush Land	0384014	0820462	1924
39	Bush Land	0380564	0823338	1992
30	Bush Land	0379572	0822138	1937

No	LULC	X	Y	Z
1	Settlement	0400252	0829402	1950
2	Settlement	0400495	0829359	1948
3	Settlement	0400392	0829593	1949
4	Settlement	0400390	0829800	1948
5	Settlement	0400591	0830490	1953
6	Settlement	0400373	0830253	1953
7	Settlement	0400025	0830425	1957
8	Settlement	0399837	0830438	1956
9	Settlement	0396876	0840591	1928
10	Settlement	0397020	0839910	1927
11	Settlement	0397043	0838948	1912
12	Settlement	0393363	0820209	1939
13	Settlement	0391010	0823199	1906
14	Settlement	0391278	0822879	1903
15	Settlement	0396935	0839199	1915
16	Settlement	0400048	0829167	1945
17	Settlement	0396970	0839365	1914
18	Settlement	0397103	0839136	1914
19	Settlement	0397260	0839925	1910
20	Settlement	0397286	0838829	1911
21	Settlement	0397191	0839182	1915
22	Settlement	03 97158	0839447	1920
23	Settlement	0400004	0829087	1947
24	Settlement	0399832	0829102	1941
25	Settlement	0399628	0829055	1942
26	Settlement	0399444	0829174	1945
27	Settlement	0399369	0829522	1947
28	Settlement	0399353	0829926	1953
39	Settlement	0399297	0830357	1960
30	Settlement	0399380	0830959	1962

Appendix 4: Reference points for accuracy assessment

- For 1973 LULC

No	LULC	X	Y	No	LULC	X	Y	No	LULC	X	Y
1	Cultivated land	397942	821429	1	Bush land	380675	822189	1	Grass land	397891	836012
2	Cultivated land	399208	824619	2	Bush land	383764	822340	2	Grass land	395461	836569
3	Cultivated land	399512	826341	3	Bush land	383916	824974	3	Grass land	397841	836063
4	Cultivated land	398297	828518	4	Bush land	383764	826594	4	Grass land	398499	835658
5	Cultivated land	400879	830645	5	Bush land	385890	825379	5	Grass land	400119	835861
6	Cultivated land	401284	833177	6	Bush land	386245	826037	6	Grass land	398550	838240
7	Cultivated land	401639	835354	7	Bush land	386397	826797	7	Grass land	397841	840570
8	Cultivated land	401284	837481	8	Bush land	387258	826898	8	Grass land	396220	841279
9	Cultivated land	400930	839152	9	Bush land	388118	828062	9	Grass land	400119	835911
10	Cultivated land	400119	840570	10	Bush land	388118	829531	10	Grass land	398297	832924
11	Cultivated land	400474	841532	11	Bush land	385840	830898	11	Grass land	391916	832265
12	Cultivated land	400525	842899	12	Bush land	388321	830290	12	Grass land	392929	832012
13	Cultivated land	398854	843709	13	Bush land	387055	833784	13	Grass land	394246	830949
14	Cultivated land	396372	842291	14	Bush land	388625	833987	14	Grass land	395005	830594
15	Cultivated land	395106	841026	15	Bush land	393385	833126	15	Grass land	395663	829885
16	Cultivated land	397183	839810	16	Bush land	390549	834747	16	Grass land	396929	830037
17	Cultivated land	395511	838899	17	Bush land	394195	833278	17	Grass land	392676	827505
18	Cultivated land	394195	836975	18	Bush land	395866	835607	18	Grass land	392271	828164
19	Cultivated land	393081	836519	19	Bush land	397233	836266	19	Grass land	391916	828721
20	Cultivated land	393739	834544	20	Bush land	395663	837633	20	Grass land	389688	829480
21	Cultivated land	389283	832569	21	Bush land	398297	837430	21	Grass land	387612	828569
22	Cultivated land	393790	825024	22	Bush land	394803	840874	22	Grass land	387764	830746
23	Cultivated land	395258	824467	23	Bush land	397638	844418	23	Grass land	387663	828518
24	Cultivated land	395815	821935	24	Bush land	398297	843152	24	Grass land	386853	827303
25	Cultivated land	397233	820720	25	Bush land	399157	836367	25	Grass land	384928	826543
26	Cultivated land	392828	819961	26	Bush land	398297	837633	26	Grass land	381181	821480
27	Cultivated land	381941	821581	27	Bush land	399562	828771	27	Grass land	387258	822340
28	Cultivated land	386853	827303	28	Bush land	391410	819049	28	Grass land	397841	840570
29	Cultivated land	388524	385536	29	Bush land	392271	832265	29	Grass land	398550	842342
30	Cultivated land	384878	821986	30	Bush land	386802	827404	30	Grass land	394043	825834
1	Wetland	391764	831253	1	Bare land	383156	820771	1	Water body	395208	835861
2	Wetland	398651	842899	2	Bare land	383308	821226	2	Water body	394954	835455
3	Wetland	399411	840772	3	Bare land	381283	822695	3	Water body	393790	828619
4	Wetland	393233	829379	4	Bare land	382954	823961	4	Water body	393537	828417
5	Wetland	393790	829075	5	Bare land	383561	824619	5	Water body	393638	828214
6	Wetland	394549	828923	6	Bare land	383966	822138	6	Water body	393790	827860
7	Wetland	395208	828721	7	Bare land	385536	821277	7	Water body	393891	827505
8	Wetland	395866	828822	8	Bare land	388574	824467	8	Water body	393840	827202
9	Wetland	396119	828265	9	Bare land	390347	819707	9	Water body	394296	827354
10	Wetland	396474	826797	10	Bare land	391967	819201	10	Water body	393942	827961
11	Wetland	395917	827607	11	Bare land	392929	822138	11	Water body	394094	827556
12	Wetland	395309	827202	12	Bare land	401082	821226	12	Water body	394296	828113
13	Wetland	394701	827050	13	Bare land	402196	824062	13	Water body	394499	828214
14	Wetland	393992	826847	14	Bare land	398297	836569	14	Water body	394651	827911
15	Wetland	393385	827455	15	Bare land	397993	832468	15	Water body	395056	827961
16	Wetland	393182	828569	16	Bare land	398955	836367	16	Water body	393587	828265
17	Wetland	387410	821378	17	Bare land	398651	837329	17	Water body	394904	835354
18	Wetland	384169	820011	18	Bare land	398043	838949	18	Water body	395157	835658
19	Wetland	382599	825176	19	Bare land	389688	831405	19	Water body	393435	828974
20	Wetland	381283	825024	20	Bare land	388321	830949	20	Water body	393739	828771
21	Wetland	387359	821075	21	Bare land	389638	831405	21	Water body	393840	827100
22	Wetland	390043	821733	22	Bare land	390144	832215	22	Water body	395056	827961
23	Wetland	396423	826594	23	Bare land	391005	832721	23	Water body	393233	828214
24	Wetland	394954	827657	24	Bare land	400423	820518	24	Water body	393790	828366
25	Wetland	394549	827455	25	Bare land	391967	819252	25	Water body	393638	828012
26	Wetland	389941	831860	26	Bare land	403411	823201	26	Water body	394043	828265
27	Wetland	398297	844165	27	Bare land	390296	819707	27	Water body	393840	828468
28	Wetland	394549	825936	28	Bare land	392423	819302	28	Water body	394701	828113
29	Wetland	397638	830746	29	Bare land	389283	832569	29	Water body	394246	827961
30	Wetland	396929	828214	30	Bare land	401082	836721	30	Water body	393689	827860

- For 1986 LULC

No	LULC	X	Y	No	LULC	X	Y	No	LULC	X	Y
1	Grass land	391663	832215	1	Cultivated land	400626	841583	1	Wetland	396423	826645
2	Grass land	392018	831911	2	Cultivated land	393537	834038	2	Wetland	393992	825885
3	Grass land	392068	828923	3	Cultivated land	401537	835455	3	Wetland	394246	826290
4	Grass land	392220	828214	4	Cultivated land	401436	833227	4	Wetland	393486	826543
5	Grass land	392271	827404	5	Cultivated land	399765	831506	5	Wetland	394195	826797
6	Grass land	390093	827708	6	Cultivated land	395360	832316	6	Wetland	394954	826797
7	Grass land	391359	825379	7	Cultivated land	393486	833987	7	Wetland	396018	827303
8	Grass land	396271	829025	8	Cultivated land	391866	833329	8	Wetland	395866	827809
9	Grass land	397132	829784	9	Cultivated land	392551	842848	9	Wetland	394397	828974
10	Grass land	395056	831050	10	Cultivated land	389182	831911	10	Wetland	393992	829176
11	Grass land	397183	833683	11	Cultivated land	390498	825632	11	Wetland	394549	827303
12	Grass land	399512	833835	12	Cultivated land	389030	823303	12	Wetland	394904	827708
13	Grass land	400119	835962	13	Cultivated land	381890	821530	13	Wetland	395410	828012
14	Grass land	398854	837228	14	Cultivated land	393486	820821	14	Wetland	394246	827050
15	Grass land	398600	838291	15	Cultivated land	394853	822897	15	Wetland	393182	828518
16	Grass land	398195	839557	16	Cultivated land	396676	821125	16	Wetland	391612	831202
17	Grass land	396879	843608	17	Cultivated land	398043	824012	17	Wetland	395511	827860
18	Grass land	396271	829126	18	Cultivated land	399309	823201	18	Wetland	394195	828468
19	Grass land	390600	834139	19	Cultivated land	400018	823910	19	Wetland	393739	829126
20	Grass land	391461	825429	20	Cultivated land	399613	825683	20	Wetland	384371	819505
21	Grass land	399714	843304	21	Cultivated land	401537	824619	21	Wetland	394600	826999
22	Grass land	396828	843557	22	Cultivated land	399765	821733	22	Wetland	391612	831405
23	Grass land	387967	824569	23	Cultivated land	398094	826543	23	Wetland	394246	826999
24	Grass land	399360	821277	24	Cultivated land	393486	834038	24	Wetland	395005	828619
25	Grass land	399664	828164	25	Cultivated land	392676	819252	25	Wetland	395866	827911
26	Grass land	394499	831303	26	Cultivated land	390498	825683	26	Wetland	395309	827961
27	Grass land	390650	834190	27	Cultivated land	397334	822594	27	Wetland	394803	828569
28	Grass land	394499	839203	28	Cultivated land	399309	820923	28	Wetland	395056	826999
29	Grass land	386144	827759	29	Cultivated land	387106	822391	29	Wetland	396423	826645
30	Grass land	380523	822189	30	Cultivated land	395967	830544	30	Wetland	393992	825885
1	Bare land	393435	830493	1	Water body	395157	835861	1	Bush land	399411	840823
2	Bare land	395157	830341	2	Water body	394954	835354	2	Bush land	389941	831860
3	Bare land	396068	830392	3	Water body	395258	835658	3	Bush land	380472	822239
4	Bare land	395562	830847	4	Water body	393334	828214	4	Bush land	380523	823151
5	Bare land	396524	830037	5	Water body	393689	827860	5	Bush land	383460	822340
6	Bare land	398145	835000	6	Water body	393790	827252	6	Bush land	383814	822796
7	Bare land	398651	834544	7	Water body	394246	827252	7	Bush land	382346	825277
8	Bare land	398448	835506	8	Water body	394195	827809	8	Bush land	383561	825024
9	Bare land	397740	836519	9	Water body	394600	827961	9	Bush land	384574	824923
10	Bare land	395309	836519	10	Water body	395056	827961	10	Bush land	385131	821226
11	Bare land	387004	822543	11	Water body	394600	828214	11	Bush land	387359	820568
12	Bare land	386397	823151	12	Water body	393992	828366	12	Bush land	400778	820264
13	Bare land	384219	826088	13	Water body	393739	828619	13	Bush land	401284	820821
14	Bare land	385182	826999	14	Water body	393435	828822	14	Bush land	401436	821632
15	Bare land	387004	829379	15	Water body	394600	828670	15	Bush land	402449	822239
16	Bare land	387612	831101	16	Water body	393587	826847	16	Bush land	403158	823151
17	Bare land	389182	833835	17	Water body	393638	828214	17	Bush land	403461	824315
18	Bare land	386954	822492	18	Water body	393790	827860	18	Bush land	401385	825683
19	Bare land	386447	823100	19	Water body	393942	827455	19	Bush land	385941	827404
20	Bare land	387308	823100	20	Water body	394094	827961	20	Bush land	387258	827759
21	Bare land	385333	823708	21	Water body	394448	828062	21	Bush land	388676	828619
22	Bare land	385333	826948	22	Water body	394094	828164	22	Bush land	387055	833784
23	Bare land	384321	826797	23	Water body	393739	828316	23	Bush land	388777	834544
24	Bare land	381131	822746	24	Water body	393840	827911	24	Bush land	392473	835101
25	Bare land	385384	826948	25	Water body	393891	828164	25	Bush land	397740	844469
26	Bare land	387004	829328	26	Water body	393790	828265	26	Bush land	398297	843355
27	Bare land	387713	831101	27	Water body	394195	828012	27	Bush land	400373	826797
28	Bare land	389182	833784	28	Water body	395258	827759	28	Bush land	396423	835658
29	Bare land	391461	824012	29	Water body	391916	830290	29	Bush land	394904	841684
30	Bare land	401487	833683	30	Water body	393739	828771	30	Bush land	393132	822239

- For 2000 LULC

No	LULC	X	Y	No	LULC	X	Y	No	LULC	X	Y
1	Grass land	386643	823046	1	Wetland	392823	825883	1	Water body	395103	835812
2	Grass land	387200	823097	2	Wetland	395103	825832	2	Water body	394951	835356
3	Grass land	383097	821020	3	Wetland	393532	826238	3	Water body	391253	831556
4	Grass land	385275	826795	4	Wetland	394394	826389	4	Water body	392925	828162
5	Grass land	386137	827352	5	Wetland	395001	826744	5	Water body	393026	829277
6	Grass land	387707	827605	6	Wetland	396217	826592	6	Water body	393938	829024
7	Grass land	389784	828264	7	Wetland	396015	827251	7	Water body	394900	828466
8	Grass land	391810	826643	8	Wetland	396622	827707	8	Water body	395508	828466
9	Grass land	392063	827200	9	Wetland	396167	828162	9	Water body	395660	827909
10	Grass land	390949	827808	10	Wetland	396369	829581	10	Water body	395407	827352
11	Grass land	388416	829783	11	Wetland	394090	829733	11	Water body	394343	826997
12	Grass land	387808	830797	12	Wetland	393228	829935	12	Water body	394140	828061
13	Grass land	393887	830594	13	Wetland	391557	392317	13	Water body	395103	827859
14	Grass land	393380	831202	14	Wetland	392519	831405	14	Water body	393786	828669
15	Grass land	393076	831759	15	Wetland	391658	832012	15	Water body	393532	827960
16	Grass land	392671	832722	16	Wetland	390848	831860	16	Water body	394647	827504
17	Grass land	397129	829682	17	Wetland	390341	830949	17	Water body	393583	828264
18	Grass land	397180	833431	18	Wetland	383553	826136	18	Water body	395153	828162
19	Grass land	397484	835862	19	Wetland	398041	843967	19	Water body	393532	827656
20	Grass land	395356	835305	20	Wetland	395204	841840	20	Water body	394140	828720
21	Grass land	395457	835964	21	Wetland	399054	841181	21	Water body	395153	827656
22	Grass land	398801	828466	22	Wetland	392823	828770	22	Water body	394039	827099
23	Grass land	383198	825072	23	Wetland	391557	830949	23	Water body	393684	828466
24	Grass land	395356	831151	24	Wetland	395812	827504	24	Water body	395457	827200
25	Grass land	392621	397129	25	Wetland	392874	828720	25	Water body	393076	828213
26	Grass land	389632	828213	26	Wetland	390696	832215	26	Water body	395609	828213
27	Grass land	393887	830189	27	Wetland	393127	829783	27	Water body	394343	826896
28	Grass land	385782	826389	28	Wetland	390037	830087	28	Water body	393684	828922
29	Grass land	390949	831911	29	Wetland	391911	827251	29	Water body	392063	829682
30	Grass land	389784	821577	30	Wetland	383198	821982	30	Water body	395153	828922
1	Cultivated land	400979	840472	1	Bush land	384667	819804	1	Bare land	379551	822236
2	Cultivated land	397180	840979	2	Bush land	381527	824920	2	Bare land	381223	822641
3	Cultivated land	398851	843663	3	Bush land	383249	827048	3	Bare land	384161	826288
4	Cultivated land	398851	838243	4	Bush land	384262	828821	4	Bare land	386137	822286
5	Cultivated land	394900	837787	5	Bush land	384971	830138	5	Bare land	394292	825934
6	Cultivated land	399966	833026	6	Bush land	386846	832924	6	Bare land	388872	829733
7	Cultivated land	401739	830594	7	Bush land	389328	834292	7	Bare land	397940	833127
8	Cultivated land	398142	827960	8	Bush land	391962	834849	8	Bare land	398243	834849
9	Cultivated land	400827	825123	9	Bush land	394090	839915	9	Bare land	398243	835660
10	Cultivated land	397028	821982	10	Bush land	396369	843511	10	Bare land	397788	844423
11	Cultivated land	392519	823907	11	Bush land	387048	822337	11	Bare land	398345	843410
12	Cultivated land	395711	821881	12	Bush land	387352	820969	12	Bare land	398649	842042
13	Cultivated land	397940	820463	13	Bush land	389834	821577	13	Bare land	395052	842144
14	Cultivated land	390594	819500	14	Bush land	392925	821982	14	Bare land	398750	843056
15	Cultivated land	386187	821324	15	Bush land	400624	820209	15	Bare land	395103	842093
16	Cultivated land	385782	830037	16	Bush land	401536	821628	16	Bare land	389581	834241
17	Cultivated land	393482	835406	17	Bush land	403512	823249	17	Bare land	393887	839206
18	Cultivated land	380970	822995	18	Bush land	402043	825174	18	Bare land	395001	825528
19	Cultivated land	387808	820817	19	Bush land	390240	821982	19	Bare land	389429	830543
20	Cultivated land	392266	825123	20	Bush land	386440	824718	20	Bare land	389075	830695
21	Cultivated land	397534	838598	21	Bush land	384161	823147	21	Bare land	394697	835761
22	Cultivated land	393836	823907	22	Bush land	385731	826389	22	Bare land	398243	835609
23	Cultivated land	402701	833887	23	Bush land	385529	827605	23	Bare land	398598	842245
24	Cultivated land	393279	837179	24	Bush land	390037	831962	24	Bare land	389429	830493
25	Cultivated land	398091	840877	25	Bush land	397078	843866	25	Bare land	380260	822185
26	Cultivated land	388264	822540	26	Bush land	384465	820260	26	Bare land	385529	821425
27	Cultivated land	398547	831708	27	Bush land	381375	818436	27	Bare land	398851	843157
28	Cultivated land	398193	833026	28	Bush land	385022	827149	28	Bare land	386086	821932
29	Cultivated land	398345	843359	29	Bush land	384313	823401	29	Bare land	397028	841131
30	Cultivated land	383705	825022	30	Bush land	383198	825072	30	Bare land	398953	820767

- For 2015 LULC

No	LULC	X	Y	No	LULC	X	Y	No	LULC	X	Y
1	Bare land	393162	822302	1	Grass land	383301	822049	1	Water body	392252	831657
2	Bare land	398068	833225	2	Grass land	384515	820127	2	Water body	391797	831000
3	Bare land	398422	833478	3	Grass land	383149	821037	3	Water body	392252	830899
4	Bare land	398725	834388	4	Grass land	395185	825791	4	Water body	392404	830342
5	Bare land	398422	834742	5	Grass land	390431	827864	5	Water body	393162	829280
6	Bare land	398068	834843	6	Grass land	391696	828623	6	Water body	393567	826701
7	Bare land	398472	834995	7	Grass land	391493	829179	7	Water body	395286	826347
8	Bare land	398321	835248	8	Grass land	391139	830342	8	Water body	396450	827308
9	Bare land	398371	835905	9	Grass land	390836	832011	9	Water body	396804	828067
10	Bare land	398574	836209	10	Grass land	391797	832062	10	Water body	395590	828623
11	Bare land	397866	836057	11	Grass land	392960	832113	11	Water body	395843	829331
12	Bare land	397764	836512	12	Grass land	393769	830747	12	Water body	395135	828926
13	Bare land	398725	836108	13	Grass land	394578	830747	13	Water body	394578	829179
14	Bare land	398776	837321	14	Grass land	395691	830292	14	Water body	395084	827005
15	Bare land	398725	837928	15	Grass land	396551	829129	15	Water body	393870	828724
16	Bare land	398725	838181	16	Grass land	396753	829887	16	Water body	393618	827814
17	Bare land	398270	838333	17	Grass land	397208	833427	17	Water body	394326	827460
18	Bare land	398169	839395	18	Grass land	397916	833781	18	Water body	395286	827055
19	Bare land	397764	840963	19	Grass land	395438	835653	19	Water body	395944	826701
20	Bare land	397512	838586	20	Grass land	392960	832062	20	Water body	396247	827258
21	Bare land	397764	840862	21	Grass land	396551	829230	21	Water body	394022	828320
22	Bare land	393213	822302	22	Grass land	395236	831253	22	Water body	394629	827713
23	Bare land	393264	836563	23	Grass land	394932	825285	23	Water body	395438	827258
24	Bare land	389622	829129	24	Grass land	392201	832618	24	Water body	394224	827106
25	Bare land	390937	824173	25	Grass land	391595	833984	25	Water body	393719	827864
26	Bare land	389572	829129	26	Grass land	393820	830798	26	Water body	392151	830899
27	Bare land	389686	829951	27	Grass land	392960	825993	27	Water body	395843	827814
28	Bare land	398321	834894	28	Grass land	392808	832062	28	Water body	395691	827612
29	Bare land	400356	835210	29	Grass land	383351	824982	29	Water body	392555	829837
30	Bare land	387283	825096	30	Grass land	389218	825589	30	Water body	393618	829483
1	Settlement	399471	830431	1	Wetland	389167	825538	1	Bush land	380469	822200
2	Settlement	400078	830406	2	Wetland	390280	826600	2	Bush land	380317	822959
3	Settlement	400179	830128	3	Wetland	391949	826297	3	Bush land	381278	824830
4	Settlement	400078	829647	4	Wetland	391797	827460	4	Bush land	383351	825336
5	Settlement	399598	829344	5	Wetland	392404	827055	5	Bush land	383554	826297
6	Settlement	399648	829951	6	Wetland	392808	827308	6	Bush land	384161	827460
7	Settlement	399901	830102	7	Wetland	391746	827612	7	Bush land	384515	828876
8	Settlement	400028	829293	8	Wetland	390027	830899	8	Bush land	385981	831202
9	Settlement	397246	839458	9	Wetland	390229	831708	9	Bush land	387144	833984
10	Settlement	397474	839129	10	Wetland	387701	823262	10	Bush land	387953	833478
11	Settlement	397398	839660	11	Wetland	390280	821796	11	Bush land	388712	834388
12	Settlement	397271	839231	12	Wetland	401659	821088	12	Bush land	389673	834591
13	Settlement	391582	822997	13	Wetland	387347	821037	13	Bush land	391241	834692
14	Settlement	391683	823098	14	Wetland	381430	824628	14	Bush land	395135	841974
15	Settlement	384603	820949	15	Wetland	394831	832365	15	Bush land	397815	844503
16	Settlement	384704	820873	16	Wetland	392695	835261	16	Bush land	398220	843188
17	Settlement	397322	840116	17	Wetland	395729	829116	17	Bush land	398472	842581
18	Settlement	397069	843959	18	Wetland	381012	824236	18	Bush land	399724	839812
19	Settlement	396766	843302	19	Wetland	390191	820797	19	Bush land	396614	837815
20	Settlement	396589	843479	20	Wetland	394591	832252	20	Bush land	398359	834173
21	Settlement	396487	843706	21	Wetland	392695	835261	21	Bush land	388092	833465
22	Settlement	395602	842366	22	Wetland	386980	829571	22	Bush land	383769	824843
23	Settlement	399699	830102	23	Wetland	388447	825778	23	Bush land	399269	828585
24	Settlement	399926	829723	24	Wetland	389104	826284	24	Bush land	398991	828181
25	Settlement	400053	831038	25	Wetland	389888	825905	25	Bush land	381417	821530
26	Settlement	399926	830077	26	Wetland	392214	827270	26	Bush land	384350	828079
27	Settlement	400192	833883	27	Wetland	387233	820569	27	Bush land	397828	844642
28	Settlement	399041	827447	28	Wetland	392100	826904	28	Bush land	389521	834591
29	Settlement	398131	826689	29	Wetland	391582	829849	29	Bush land	390672	834274
30	Settlement	400331	835261	30	Wetland	388017	824489	30	Bush land	383971	824843

No	LULC	X	Y
1	Cultivated land	393112	820734
2	Cultivated land	391291	823768
3	Cultivated land	386386	830848
4	Cultivated land	382896	820026
5	Cultivated land	389673	820177
6	Cultivated land	387347	825083
7	Cultivated land	387650	829129
8	Cultivated land	393264	835248
9	Cultivated land	394629	839850
10	Cultivated land	397764	841974
11	Cultivated land	400091	839850
12	Cultivated land	400748	837777
13	Cultivated land	402114	836209
14	Cultivated land	401456	833781
15	Cultivated land	398371	831961
16	Cultivated land	398118	826448
17	Cultivated land	403176	823869
18	Cultivated land	401456	822150
19	Cultivated land	397866	822706
20	Cultivated land	391544	823718
21	Cultivated land	389622	820127
22	Cultivated land	387043	822403
23	Cultivated land	387397	827308
24	Cultivated land	396450	842025
25	Cultivated land	394224	838181
26	Cultivated land	393719	833933
27	Cultivated land	391392	823718
28	Cultivated land	389572	823262
29	Cultivated land	398675	838232
30	Cultivated land	393162	822251

Appendix 5: The annual soil loss rate of each micro-watershed

No	Micro-watershed number	Soil loss rate 2015 in t/ha/yr
1	0	3.8
2	1	3.1
3	2	18.5
4	3	27.2
5	4	18.1
6	5	19.3
7	6	12.0
8	7	11.3
9	8	25.2
10	9	5.7
11	10	25.7
12	11	25.7
13	12	13.1
14	13	6.8
15	14	15.3
16	15	25.7
17	16	16.5
18	17	7.7
19	18	6.8
20	19	6.8
21	20	17.5
22	21	26.7
23	22	13.0
24	23	18.0
25	24	7.4
26	25	7.4
27	26	12.1
28	27	13.3
29	28	12.9
30	29	6.7

Appendix 6: A Survey Questionnaire

This questionnaire is prepared to collect primary data about land use and land cover Change dynamics and soil loss at Shashogo wereda, Hadiya Zone, Southern Ethiopia for the study periods extending from 1973 to 2015 G.C. It is expected to generate and provide helpful information for policy makers and development practitioners about magnitude and trends of land use and land cover change dynamics and soil loss. Therefore, your inputs as a stakeholder to fill this questionnaire is highly appreciated and information provided will stay confidential and your right to involve or not is also respected.

Part I-General Background Information

1. Date of interview………………….
2. Name of interviewee……………………….....Age……..Position/occupation…………
3. District ……………… Kebele ……………..
4. Total number of family members ………. F........ M..........
5. Educational background………………………….
6. Total land owned ……………….. (ha)
7. Code No……………….

Part II-Soil and Water related issues

8. What are the major problems associated with soil in your locality?

……………………………………………………………………………………………….
……………………………………………………………………………………………….

9. Is land degradation a problem in your locality? Yes, No

10. If your answer is Yes, for question No 9, what is the mechanism you use to protect land degradation? The answer could be one or more.

1. Fallow — 2. Contour farming
3. Strip cropping — 4. Terracing
5. Soil bund — 6. Stone bund
7. Others, specify

11. What types of land, in your view, are vulnerable to land degradation? The answer could be one or more.

1. High vegetated area — 2. Land with scarce vegetation cover
3. Bare land — 4. Water stressed land
5. Over grazed land — 6. Intensively cultivated land
7. Others (specify)

12. How do you evaluate trend of land degradation over time?

	Now/2015	**15 years ago/2000**	**28 years ago/1987**	**42 years ago/1973**
Severity of land degradation 1				
Extent of land degradation 2				
Signs of land degradation 3				

1 1: light; 2: moderate; 3: sever; 4: very sever
2 1: absent; 2: present on vulnerable land units; 3: widespread everywhere
3 1: soil erosion; 2: gully formation; 3: vegetation decline; 4: soil fertility degradation; 5: flooding; 6: others (specify)

13. What soil and water conservation practices are present in your locality and which ones are your preferences? The answer could be one or more.

1. Soil bund   2. Stone bund
3. Contour farming   4. Fallow
5. Terracing   6. Fanyajuu
7. Others, specify

Part Ш. Crop production and land use

14. List major crops, in order of importance, those easily grow in your area (Rank)

1.________________   2.________________
3.________________   4.________________

15. Did the total area you cultivated from year to year
Increase_________ Decrease____________ Show no Change_____________

16. It is increased or decreased, state reason (s):
1.______________________ 3.__________________
2.______________________ 4.__________________

17. What measures do you take when the productivity of your land (farm) declines?
1. Look for additional land________________   2. Improve the fertility ________
3. Fallow _____________________   4. Other (specify) ____________

18. If you look for additional land, what kind of land do you have for?
1. Clear forest__________   3. Fallow land____________
2. Grazing land_________   4. Both _____________

19. Is fallowing practiced in your area?________0= No l=Yes

20. If yes, how land should it rest before being used again?

Part IV. Land tenure

21. How did you get the holding which you have now?
1. Inherited from my parents
2. by redistribution from PA
3. I bought it
4. Buy renting
5. Others specify

22. Because of land reform of 1975
1. I am liberate from tenant ship
2. I lost some of land used to own
3. No gain or no lost of land and I lost the right of ownership and selling
4. Other specify

23. The existing land tenure policy
1. Has been harmless to me
2. It made me in secured regarding with land holding and forest
3. Denies the right of selling with exchange, it has created the sense of environmental protection
4. Made me not to invest on long living structures and measure of environmental protection.
5. Created the fear that if I do not have children the land I hold may be passed to other.
6. Any others, specify

24. Do you wish the present government based land ownership continue?
A. yes B. yes, but with modification

25. If you wish the change, to which

A. Private ownership of land
B. Community ownership of land

26. If your answer is change with modification, the change should be
   A. With right to rent or lease
   B. With the right to rent or lease but not right to sell
   C. Others specify
27. Under what condition you wish (if) land to be held privately?
   A. With the right to rent and /or lease to anyone.
   B. With the right to rent and / or lease to anyone but no selling
28. How many times did redistribution of land take place since 1974 revolution? Specify the years_________
29. In your opinion, what were the criteria used for redistribution? Explain according to the years______________

Part V. Questions used for Discussion with Elders, LPA Leaders and Government Officials at Various Levels.

1. Environmental Issues

1.1. What are some of the problems that are connected with environment? Such as
- Loss plant density and diversity
- Soil erosion
- Water scarcity

1.2. Which conditions have aggravated the problem of land degradation?
1.3. Do individuals and the community actively participate in conservation activities? How?
1.4. Do NGOs and the government contribute to the effort of environmental management? How?

2. Land use land cover change and competition

2.1. Which land use land cover unites show strong competition?
2.2. What factors have contributed to the changing land use land cover change in your locality?

3. Production Problem

3.1. What are the main agricultural problems in the area?
3.2. Has production increase or decrease?
3.3. What are the main factors that have made production to increase or decrease?
3.4. What is the impact of low agricultural production on vegetation?
3.5. Have you benefited from agricultural extension services?

4. Did you get any benefit from extension services regarding with
- Merit of biodiversity
- Soil and water conservation

5. Land Tenure policy and others

1. Is the rate of land tax fair?
2. What are the merit and demerit of the current land tenure system?
3. How do you decrease rural poverty and improve living standard of the rural people?

BIOGRAPHICAL SKETCH

The author was born on 10 September 1965 G.C in Shashogo Wereda, Hadiya Zone, South Nations Nationalities and Peoples Regional State. He attended his education in Urbecha Junior Secondary School and Angecha and Halaba High School from 1975 to 1985. For one year, 1986, he attended Teacher Training Institution (TTI) in Hawassa. After graduation, he was employed in the Ministry of Education and worked as a teacher and school leader at Wolaita and Shashogo Wereda from 1987 to 2005.

He was graduated with Diploma in Biology from 2001 to 2004 at Hawassa Teacher Training College. Also he was graduated with BSc in Natural Resources Management (NRM) at Wondo Genet College of Forestry and Natural Resources from 2006 to 2011. Also he was employed in Ministry of Agriculture and Rural Development and worked as an expert of soil and water conservation development from 2006 to 2015.

During his service year, the author had gained lots of practical experiences and knowledge through technical trainings on watershed management, GIS, and others. After twenty nine years of service in various capacities, he joined the School of Graduate Studies at Hawassa University, Institute of Technology, School of Biosystem and Environmental Engineering in 2016 to pursue his MSc studies with specialization in Soil and Water Conservation Engineering.