ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

GIS AND REMOTE SENSING BASED ASSESSMENT OF LAND USE LAND COVER CHANGE AND ITS IMPACT ON SOIL EROSION IN CHERCHER WATERSHED: WEST HARERGE, ETHIOPIA.

A Thesis submitted to School of Civil and Environmental Engineering Graduate Studies of Addis Ababa Institute of Technology in Partial Fulfillment of the Requirement for the Degree Masters of Science in Geodesy and Geomatics (specialization in Geomatics)

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October, 2019

Addis Ababa University

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This is to certify the Thesis Prepared by **Tamerat Sema Muleta,** Entitle: as **"GIS and Remote sensing based Assessment of Land Use Land Cover Change and its Impact on Soil Erosion in Chercher Watershed**: **West Harerge, Ethiopia."** Is Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geodesy and Geomatics (Specialization in Geomatics) Compiles with the Regulations of the University and Meets the Accepted Standards with its Originality and Quality.

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Acknowledgements

First of all, I would like to thank the almighty God for giving me strength and courage to continue my study.

Second, my genuine gratitude goes to my research advisors, Dr. Daniel Alemayehu for their unreserved advice, guidance and constant encouragement. The careful and precise comments I have received from them throughout my thesis work helped me. It was their skillful contribution and constant encouragement that made me strong to face every ups and down with confidence during the research study.

Third, my special thanks also go to my friends, Mr. Istifanose Abera for their unreserved and tireless sharing of knowledge and advice in every aspect of my thesis work.

Forth, I would also like to give my gratitude to Oda Bultum Woreda Natural resource Administration Offices, officials and community groups in the watershed for providing me the available data for the work. The community members of the watershed were so open and generous in providing their valuable time and knowledge.

Fifth, I am also thankful to the Ministry of Water resource and Energy of Ethiopia and the National Meteorological Agency of Ethiopia for providing to me all the relevant data used as an input for my research findings.

Five, Words cannot express my sincere thanks I have for the whole family for encouraging and supporting me throughout the study period.

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LIST OF ACRONYMS AND ABBREVIATION

CBPWD: Community Based Participatory Watershed Management.

DEM: Digital Elevation Model

EIAR: Environmental Impact Assessment Report

EPA: Environmental Protection Authority of Ethiopia

ERDAS: Earth Resources Data Analysis System

ETM: Enhanced Thematic Mapper

FAO: Food and Agriculture Organization of the United Nations

GIS: Geographic Information Systems

GPS: Geographical Positioning System

LDCM: Landsat Data Continuity Mission

LULCC: Land Use Land Cover Change

MoWE: Ministry of Water and Energy of Ethiopia

RS: Remote Sensing

RUSLE: Revised Universal Soil Loss Equation

SCRP: Soil Conservation Research Project

SRTM: Shuttle Radar Topographic

SWAT: Soil and Water Assessment Tool

SWC: Soil and Water Conservation

TM: Thematic Mapper

USGS: United States Geological Survey

UTM: Universal Traverse Mercator

ABSTRACT

Soil erosion is a common land degradation problem and has causing great damage on natural ecosystems and human life. Therefore, this study aims to asses land use/land cover change and the associated impacts on soil erosion potential in Chercher watershed by using Landsat images and ancillary data. The Analyses result show that the watershed was dominantly covered by cultivated land (52.8%), bare land (20.6%) shrubs (18%), grazing land (5.3%), forests (2.7%), settlement (0.5%) and Water body (0.2%) Since 1987 57% of land use land cover has changed. Land covers change and a heavy rainfall event in the study area has resulted in increased soil loss from 32.91 t $ha^{-1}yr^{-1}$ in the year 1987 to 45.83 t $ha^{-1}yr^{-1}$ in the year 2018. The Spatial analysis revealed that the fragmentation of forest cover from Mountainous area and disappearance of shrubs from relatively flat and moderate slope areas, increased in bare land in High slope, and intensification of cultivation practice in relatively more erosion prone soil were the main factors contributing toward the increased soil erosion potential of the watershed. The result of land use dynamics indicated that Change of other land use land cover (LULC) categories to Cultivation and bare land was the most detrimental for increase the potential of soil erosion while any transition from bare and cultivation to grass, forest and shrub radiuses and retards soil loss of the watershed. The results generated from this study recommends that awareness of spatial and temporal patterns of high soil loss risk areas can help deploy site-specific soil conservation measures and can serve as a spatial decision support tool, and as input for decision makers and conservation planners for future intervention measures in highly affected areas.

Key words: *GIS, Remote sensing, LULCC, RUSLE model, Soil erosion, Chercher Watershed.*

CHAPTER - I

1. INTRODUCTION

1.1. Background

Land use and land cover change (LULCC): Also known as land change) is a general term for the human modification of Earth's terrestrial surface. Though humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of LULCC are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. These changes encompass the greatest environmental concerns of human populations today, including climate change and the pollution of water, soils and air. Natural as well as anthropogenic LULC change have significant impacts on regional or local soil degradation, including soil erosion, soil acidification, nutrient leaching and organic matter depletion (Arabinda et al., 2010). Land use change in Africa accounts a conversion of 75 million hectares of forest to agriculture and pasture between the years 1990 and 2010 (FAO, 2010). More importantly, in East Africa, nearly 13 million hectares of original forest were lost over the same 20 year period and the remaining forest is fragmented and continued to be under threat (FAO, 2010). Land cover change over the last three centuries due to human activities in general and agriculture, in particular, modify or change the environment of the given landscape (Ramankutty, 2004).

Soil erosion is one of the principal causes of land degradation and it has an adverse impact on the environment by threatening the natural environment, agriculture and the economy (Lal, 1998). Specially, its effects are visible in developing countries because of the incapacity of their farming population to replace lost soils and nutrients (Erenstein, 1999). To alleviate this problem Ethiopia started to plan in a watershed bases starting from 1980’s. But it was mostly unsatisfactory due to lack of effective community participation, unmanageable planning units and lack of deep study about the watersheds (CBPWD, 2005).

The problem of land degradation and loss of food production potential in less developing country rural economies with fast growing populations has be given increasing attention in recent years

(Anderson and Thampapilai, 1990). Soil erosion and following land degradation of agricultural land is a serious environmental and socio-economic challenge in the highlands of Ethiopia. In these areas the annual soil loss reaches to 200 - 300 ton per hectare, while the soil loss movement can reach to 23400 million ton per year (FAO, 1984; Hurni, 1993). The impact of this loss of fertile soil in Ethiopia is having many facets. It is still affecting 50 percent of the rural area and 88 percent of the total population of the country (Sonneveld et.al, 1999). As a result soil erosion becomes one of the key characteristics of the wabeshebale basin it put at risk the productive capacity of the basin. Hence there is an urgent need for policy interventions and soil conservation practices to alleviate soil degradation.

Soil erosion has strong correlation with land cover and land use, percentage change in land use affects the amount of soil loss (Wijitkosum; 2012 Alkaharabisheh et al., 2013). The impact of land cover change on soil erosion potential depends on the type of changes happened to the land use. If land use change increases agricultural activities and decreases forest cover, then sedimentation caused by soil loss will also increase (Boix-fayos et al., 2008). Therefore, the analyzing of LULC change and its impact is important.

Watershed deterioration is the common phenomena in most parts of the world. Among several causes for this, improper and unwise utilization of watershed resources without any conservation work is the leading and this is more severe in developing countries (FAO, 1985). The deterioration occurs generally in terms of forest loss and land degradation by soil erosion. Among several factors, the major one is land use/land cover change and unsuitable agricultural practices. Therefore, it is necessary to develop a sustainable land management system that does not cause the degradation of such worth resources. This is especially important in a predominantly mountainous area like chercher watershed.

Understanding watershed characteristics and watershed management is very important part to maintaining healthy productive rivers. In a watershed management program due to time and financial limitation, it is difficult to make rehabilitation of soil and forest conservation work at one time in all places thus it is important to study the LULC change of the area and make ordering by their impact on erosion (Tripathi et al., 2003).

Recently watershed is started to be studied in scientific ways by using different models, Remote Sensing (RS) and Geographical Information System (GIS). These include the scale of small watersheds and global scale (Ghebreyesus, 2014; Cebecauer et al., 2008). Effects of LULC change on soil erosion have been studied at temporal scale of few years to number of decades (Szilassi et al., 2006). Different researches are undertaken to analyses the impact of LULCC on soil erosion risk and mapping erosion risk areas using remote sensing and GIS with RUSLE model and it showed its efficiency in estimating rate of LULC Change and soil erosion. For instance, (Wijitkosum, 2012; Alkaharabisheh et al., 2013), (Boix-fayos et al., 2008) Showed the potential of using a combination of remote sensing, GIS, and RUSLE in identified a strong influence of LULC Changes on soil erosion and sediment transport rates. All these studies identified a strong influence of LULC changes on soil erosion and sediment transport rates.

Chercher watershed is one of the vulnerable watersheds in Eastern Ethiopia which needs micro watersheds vulnerability studies. Therefore, in this study the land use land cover change and its impacts on soil erosion in Chercher watershed will be assessed by Using RUSLE model formulated by (Wischmeier & Smith et al., 1978), GIS and RS Techniques. These technics are important for planning and implementation of watershed management, degraded land restoration and environmental protection programs by giving attention for more erosion prone micro-watersheds to protect from further land degradation and for the proper planning and management of soil, water and land use. It has also be a valuable input for decision makers and other institutions who are working on environmental protection, watershed management, irrigation, water harvesting and others the integrated of GIS, remote sensing and RUSLE allows relatively easy, fast, and cost-effective Methods for analyses the LULC change and estimation of spatially distributed soil erosion. This provides a useful and efficient tool for assessing LULC and its impacts on soil erosion for conservation support practices.

1.2. Statements of the Problem

Chercher is one of the largest watersheds those discharge to Wabishebele basin. It has a total area of 1562 km^2. In Wabishebele basin, the fertility of soil in crop field’s area degraded largely because of water erosion and the change of land use on steep slope. Landscapes are extremely prone to soil erosion. Most of the rugged topographies are found to be threatened by severe soil erosion. In Chercher watershed, gully formation and sheet erosion with exposure of rock and stones on previously cultivated steep upper slopes are the most visible evidence to show erosion problem. Active deforestation, overgrazing, heavy and intense rainfall and steep slopes accelerate the speed of runoff in the watershed. Soil fertility is declining fast in the upstream caused by active LULC change and continuous cultivation this makes severe soil erosion. Chercher watershed has been subjected to prolonged use for agriculture without conserving natural resources, clearing of forest cover and changing the land use. Thus it causes very severe soil erosion. In the lower stream, there is an incidence of flooding caused primarily by certainly minimal LULC treatment on upper watershed (Muleta et al., 2005). To alleviate these problems with minimum cost and time, it is important to investigate the potential impacts of LULC change on soil erosion potential at a watershed scale. In addition the micro watersheds that contribute more for erosion must be identified and used for the recommendation of proper watershed management techniques. Recently, environmental change has become a key issue in Ethiopia. Land use changes takes place rapidly due to population increase, and the rate of deforestation has been high.

Throughout the world there are a number of studies carried out to estimate the potential effects of LULCC on soil erosion (Leh et al., 2011; Alfred, 2010 and Campbell, 2003). There are some studies conducted in Ethiopia concerning on estimating the potential impact of LULCC on soil erosion by applying GIS and remote sensing for instance Land use/Land cover and Soil Erosion Risk Analysis in Antsokia-Gemza Woreda (Abiy, et al., 2010), Implications of land use/cover dynamics on soil erosion potential of agricultural watershed, northwestern highlands of Ethiopia (Ebrahim,2018), Impact of land use land cover change on soil erosion risk: the case of denki river catchment (Aklile, et al., 2014) identification of critical micro watersheds which are under very high and high category and recommendation for intervention of conservation measures in Mojo river watershed (Kiflu, et al., 2010) and other but no specific study is done concerning the Impact of Land Use Land Cover change on Soil erosion potential in Chercher watershed. All those studies identify the strong impacts of land use land cover changes on soil erosion potential.

The rapid increase of the population in Chercher watershed make the expansion of agricultural land particular by converting forest and shrub land this led forest degradation and serious soil erosion. Deforestation, especially in steep slope mountainous and marginal areas, has led to serious environmental degradation. Chercher Lake, in Chercher watershed was disappeared the area was converted to cultivated land and grazing land before few years. But, currently there is an evidence of watershed reclamation that the water is ponding on its original place. Therefore, it is important to understand the functioning of this sensitive catchment and its soil erosion response under different land use and land cover change. The result of this research is crucial to sustainably enhance the benefits of land resources and diminish the adverse impacts of land degradation. Therefore, the aim of this study was to assess the impact of land cover change on soil erosion in the watershed and identify areas requiring immediate soil erosion management practices.

This study is although very important for the decision makers, NGOs and experts who are working on soil and water conservation, land management and environmental protection works to make their projects in an exact place, cost effective and well-timed manner.

1.3. Objectives

1.3.1. General Objective

The overall objective of this study was to assess the impact of land cover change on soil erosion in Chercher watershed from 1987 to 2018 using GIS and remote sensing techniques.

1.3.2. Specific Objectives

i. To quantify the land use land cover dynamics of the study watershed between 1987 - 2018
ii. To estimate potential soil loss in the study area using RUSLE model
iii. To identify high erosion risk areas in the watershed
iv. To investigate the impacts of land use land cover change on soil erosion risk for the study watershed

1.4. Research Questions

Based on the stated objectives, the following questions have been used to guide the research process and finally answered from the findings of the study.

- What is the historical LULC change during 1987 to 2018 in the study area?
- What are the impacts of LULC change on soil erosion potential within the watershed during 1987 to 2018?
- What is the mean annual rate of soil loss in the study area?
- Which micro-watersheds are more prone to soil erosion?

1.5 Scope of the Study

This study is, actually a watershed level study and thus focuses mainly on investigate the impacts of land use land cover change on soil erosion potential and identification of the most soil erosion vulnerable micro-watersheds from the watershed. Thus, RUSLE model was used by integrating with geographic information system (GIS). To investigate the effect of LULC on soil erosion, estimation of potential soil loss rate of the watershed. The LULC of the study area was mapped by using Image classification concept and applied for identify the long term trend of land use land cover changes spatially.

1.6. Significance of the Study

The overall purpose of the study is to assess the impacts of LULC change on soil erosions and the vulnerability of the micro-watersheds for soil erosion by water. The result of this study will be used as an input data for land use study in the study area and development plan as well as decision making. Provide detail information on land use land cover dynamics, rate of soil loss in the study area, to fill a knowledge gap on the impacts of LULC change on soil erosion.

In general, the study will have significant contribution in mitigating the negative impacts of LULCC on soil loss and justifying erosion problem of the study area on time and in a cost effective way. The planning and interventions will be in line with addressed the problems of LULC change on natural resources and the identified erosion vulnerable micro-watersheds. The land use land cover dynamics and soil erosion potential map on the watershed bases was developed by integrating remote sensing and GIS application. It provides information on areas that are more prone to soil erosion based on the estimated value of soil loss and it provides the information on the LULC change based on the statistical value from supervised classification and its negative impacts on soil erosion. It is important for development of integrated watershed and Natural resource management as the database of degraded area and erosion risk of the micro-watersheds will be identified.

1.7. Limitations of the Study

The study had some limitations of its own and attempts have been made to optimize some of them. Getting the High resolution image for 1987 was difficult and it is assumed that all parameters within each cell (30m x 30m) are uniform. Moreover, to maximize the representativeness of the result of the soil erosion rate map relatively dense metrological stations were required to spatially represent rainfall over the study area, but only one station was available within the watershed. Thus, in the study additional sex rainfall data were taken from the stations nearby. Finance and time were also identified as real constraints in assessing the study area fully and buying appropriate imageries.

1.8. Structure of the study

The thesis is organized in five chapters. In chapter one, introductory part includes background of the study, statement of the problem, objective, research question, scope, limitation and significance of the study. Chapter two provides a review of existing literature related to this study. In chapter three, the methodology which includes a description of the study area, the materials, methods and techniques of data collection are described. It also gives an overview of the stages gone through the study. In chapter four, the results and discussion of the study are presented.in this section the total extent or composition of individual LULC classes and their dynamics over a span of three decades is presented, factors of the RUSEL model and the predicted soil loss rates by RUSLE models. Moreover, analyses the impacts of land use change on the soil erosion and hence on the soil loss rate in the study areas were also presented in chapter four. Lastly the discussion of obtained results is presented. In chapter five, the conclusions drawn from the study and recommendations are discussed and finding that need treatments has been forwarded for decision-makers.

CHAPTER - II

2. LITERATURE REVIEW

2.1. Land Use Land Cover Change

This research was designed to analyses the impact of land use/land cover change on soil erosion risk by water on vulnerable micro-watersheds.

The meanings of Land use and land cover are different According to (Coffey, 2013). Land cover is defined as "the observed biophysical cover on the earth's Surface" Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and artificial structures.

Land use as the arrangements, activities and inputs that people under-take on a certain land cover type" refers to the purpose the land serves, for example, recreation, wildlife habitat or agriculture; it does not describe the surface cover on the ground. That difference is the intentional role of people to adapt the natural land cover to their benefit. In general land cover types refers to the vegetation of the area.

Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal and conversion to non-agricultural use.

Most of the world‘s natural land cover change has been activated by human activities (Mottet *et al*., 2006), resulting in ecosystem degradation and biodiversity loss worldwide (Green *et al*., 2005). An estimated 4.7million km2 of grassland areas and 6 million km2 of forest/woodland have been converted to cropland worldwide since 1850 (Lambin *et al., 2003)*

Land use and land cover change (LULCC) also known as land change is a general term for the human modification of Earth's top surface. Though humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of LULC Change are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales. (Ellis, 2007). These changes encompass the greatest environmental concerns of human populations today, including climate change and soils erosion. Land use/land cover changes and land degradation are interrelated because usually the changes are associated with deforestation, biodiversity loss and land degradation.

LULC changes are driven by a combination of proximate and underlying drivers such as economic, demographic, biophysical and institutional factors. Agricultural land expansion, increased surface runoff production and soil erosion are major environmental.

2.2. Land use land cover change and it's Impacts on soil erosion

Changes in land use and land cover are important drivers of soil Erosion at global, regional and local scales. Perhaps the oldest of these is land clearing for agriculture and the harvest of trees and other biomass. Vegetation removal leaves soils vulnerable to massive increases in soil erosion by wind and water, especially on steep terrain. This not only degrades soil fertility over time, it also reducing the suitability of land for future agricultural use. Vegetation reduces soil erosion by protecting the soil against the action of falling raindrops, increasing the degree of infiltration of water into the soil, reducing the speed of the surface runoff, binding the soil mechanically, maintaining the roughness of the soil surface, and improving the physical; chemical and biological properties of the soil (Alejandero, 2007). However, the factor that significantly affects the soil displacement by rain is land cover or vegetation cover. The reduction of vegetation cover can increase soil erosion. This relationship is a reason why vegetation cover and land use have been widely included in soil erosion studies (Del Mar et al., 1998) the category and description of these land cover classes are presented in table 2.1

Land use and land cover changes affect many natural processes such as soil erosion, sediment production, flood, and physical and chemical properties of the soil (Martínez, 2000). the main effects of Land cover type and land use change on these processes in the watershed is that it can affect the soil erosion of the basins.

Change in land use exacerbates risks of soil erosion as intense harvesting and overgrazing cause the soil to be more vulnerable to the erosive forces of rainfall and wind. The areas covered with permanent vegetation are associate Land use change, the physical change in land cover caused by human activities, is a common phenomenon associated with population growth, market development, technical and institutional innovation. Changes in land use can have various consequences on economic growth and natural resources, such as soil and water pollution (Ellis & Erle et al., 2007). Changes in land use and land cover are among the most important processes for the understanding of the speed, magnitude and spatial reach of changes of the earth's surface and immediate sub-surface as a result of human impact (Meyer, 1994). Land use change is the conversion of land use due to human intervention for various purposes, such as for agriculture, settlement, transportation, infrastructure and manufacturing, parks, recreation uses, mining and fishery (Meyer, 1994). Primarily through deforestation and replacement of natural vegetation with cropland and pastures around 24 percent of global land has already suffered from declines in health and productivity over the past quarter of a century due to unsustainable land use, UNEP.

In most developing countries, population growth has been a dominant cause of land use and land cover change than other forces (Meyer, 1994). There is a significant statistical correlation between population growth and land cover conversion in most of African, Asian and Latin American countries (Meyer, 1994).The rapid increasing population pressure of Ethiopia brought significant change by increasing agricultural production.

Due to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grasslands in different region of the country, cultivated lands showed continuously increasing trend at the expense of forest and grasslands over the last three decades (Gete, 2000). LULC changes and socioeconomic dynamics have a strong relationship; as population increases the need for cultivated land, grazing land, fuel wood; settlement areas also increase to meet the growing demand for food and energy, and livestock population (Solomon, 1994).

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times it 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:

i. Detecting the changes that have occurred
ii. Identifying the magnitude 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.

2.3. Land Use Land Cover Changes in Ethiopia and its impact

Ethiopia historically passed significant dynamics in land use/land cover since long ago to date most of land use/land cover change in Ethiopia is in the form of changing forest and shrub lands to cultivation (Amare, 2013; Shimeles, 2012; Gete and Hurni, 2001), while (Kebrom, et al., 2000) reported increases in the size of barren land areas and settlements at the expense of shrub lands grass land and forests. The original 65% of total forest coverage of the country was reduced to 16% in 1950s, 2.7% in 1990 and 2.2% in 2000 with deforestation rate of 150,000 ha per year (Ethiopian Forestry Action Plan report) or 62,000 ha per year (World Bank report, 2003). In the Ethiopian highlands, favorable agro-climatic conditions have attracted early human settlers to occupy all agriculturally suitable areas over the past several centuries (Hurni, 1988). Accordingly, agriculture gradually expanded from gently sloping land into steeper slopes in the highlands as well as the flat swampy plains of the plateau with the subsequent clearing of forests and other vegetation.

Land use/land cover changes and land degradation are highly interrelated because usually the changes are associated with deforestation, biodiversity loss and land degradation. The significant change in land use/land cover changes in highland parts of the country resulted in the soil degradation, mainly in the form of soil erosion. Some Research shows that soil erosion is greatest on cultivated lands where almost half of the loss of soil comes from, even though they cover only 13 percent of the country (Hurni, 1993). The removal of vegetation cover and associated expansion of the cultivation system in the Ethiopian highlands are the major causes of triggered soil erosion processes (Mekuria, et al., 2005). Soil erosion has become a threat to sustainable agricultural production and water quality it's one of the physical processes of land degradation widely spread in the highlands of Ethiopia (Hurni 1988). It causes irreversible damage to the natural resource base in the present day of Ethiopia (Hurni 1990). Research in Ethiopia indicated that 57% and 28% of the area are moderately and severely affected by soil erosion (Lambin and Geist 2006).

Most of land use/land cover change in Ethiopia is in the form of changing forest, shrub and grass lands to cultivation (Belay, 2002). Removal of vegetation cover means exposing the land to soil erosion because process accelerates removal of soil particles and increased sheet, rill and gully erosions by reducing the protection of soil cover. This resulted in the soil degradation, mainly in the form of soil erosion, to be in worse sate. The estimate in mid 1980s by FAO, indicated as about half of the highlands' land area of Ethiopia was "significantly eroded" and over one-fourth was "seriously eroded" and over two million hectares of farm lands had reached the "point of no return" in the sense that they are unlikely to sustain economic crop production in the future. The Research has shown that Gojam area has undergone dramatic land use and land cover changes, with the result that almost all land units have been converted to cultivated land (Gete Z (2000). The result of Soil Conservation Research Project on 100ha soil loss monitoring catchment in Gojam showed annual soil loss from cultivated lands ranges from 130 to170 t/ha/yr (Huffnagel, 1961).

2.4. Accuracy assessment

In land use land cover classification it is important to check the compatibility of the produced classification with what actually exists in reality. And it is one of the major parts of the classification process. The accuracy assessment involves the production of references or facts from the field that evaluate the produced classification. It may be produced from maps, aerial photos or visits to the field with help from the GPS system and may be represented by points or areas (Congalton, 1991).

2.5. Watershed and soil erosion

Changes in land cover alter the water yield and discharge for watersheds at all spatial scales. The canopy and root systems of vegetation affect a range of processes in the hydrologic cycle such as interception, percolation, surface retention, transpiration, and consequently surface and subsurface runoff and stream flow (Chang, 2003).

However, Rapid runoff, downstream flooding, soil erosion, and sedimentation are clear examples of local impacts of land cover change. With transformation from undisturbed to extensive agricultural expansion, examples of these local impacts include cropland expansion these increase runoff, downstream flooding, and streambank erosion in the study watershed. Removal of vegetation cover means exposing the land to soil erosion because process accelerates removal of soil particles and increased sheet, rill and gully erosions by reducing the protection of soil cover.

2.6. Land degradation

Land degradation is defined as a decline in the productive capacity of the land in relation to actual or possible land uses thus it is a problem to those who use the land (Berry, 2003 cited in Kumela 2007). There are three categories of land degradation which are: - I) Physical land degradation such as water and wind erosion, crusting and sealing, compaction, water logging and reduced infiltration, II) Chemical land degradation which includes acidification, salinization, nutrient depletion, pollution and III) Biological land degradation such as soil organic matter decline, biomass burning and depletion of vegetation cover and soil fauna (FAO, 2001). Land degradation, on the other hand, is a biophysical process driven by socioeconomic and political causes. High population density is not necessarily related to land degradation but what people do to the land determines the extent and magnitude of degradation. Causes of land degradation are the agents that determine the rate of degradation. These are biophysical (land use and land management, including deforestation and tillage methods), socioeconomic (e.g. land tenure, marketing, institutional support, income and human health), and political (e.g. incentives, political stability) forces that influence the effectiveness of processes and factors of land degradation. However, environmental degradation from human pressure and land use has become a major problem worldwide but the effects are felt more in the developing countries than in the developed countries because of the high population growth rate and the associated rapid depletion of natural resources.

2.7. Soil Erosion

The process of Soil erosion by water starts from detachment of soil particles by raindrop impact then transportation by the force of flowing water and when the flowing water losses its energy deposition will occur (Foster and Meyer, 1977;Wischmeier and Smith, 1978). Depending on the stage of progress in the erosion cycle and the position in the landscape, there are various forms of soil erosion by water. Splash, sheet, rill and gullies are the major ones (Mitiku, et al., 2006). Rain splash Erosion occurs when water falling directly on to the ground during rainstorms or intercepted by the canopy and make contact with the ground. Thus it weakens the natural soil aggregates and breaks them down (Morgan, et al., 1995). Water that cannot infiltrate in the soil will be changed in to runoff (overland flow). If the runoff does not concentrate, sheet erosion will occur. Thus it uniformly moves the productive topsoil particles equipped by rain-splashdown slope (Mitiku, et al., 2006). Rill erosion is a concentrated runoff resulted from intensive rainstorms produces more observable features of linear erosion often on steep slopes and in depressions. This feature forms channels up to 50 cm deep (Nyssen et al., 2006).

2.7.1. Mechanisms and Processes of Soil Erosion

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, et al., 2005). The principle of soil conservation is, therefore; to limit the detachment and transportation of soil particles by erosive agents. (Brown et al., 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, et al., 1996).

2.7.2. Factors of erosion

Generally there are five primary Factors that affected soil erosion. These are Climatic factor, Soil, topography, land use and agricultural support practice. These factors are dependent on each other, as geology affects topography, which can influence climate and the like. Human disturbances and natural disturbances dramatically increase erosion (Costick, 1996).

2.7.2. 1. Climatic Factors

When raindrops act upon the soil particles Soil erosion will occurs. By the detaching power of raindrops striking the soil surface and through the contribution of rain to runoff soil erosion is highly affected by rainfall. Precipitation, temperature, wind, humidity, and solar radiation are Climatic attributes that affect erosion. Rainfall erosivity is a property of rainfall that can quantify the potential capacity of rain to cause erosion in a given circumstances. It measures the combined effect of rainfall and its associated runoff. This energy is responsible for breakdown of the soil aggregates, splashing them and subsequently carrying them with runoff and on impact (Saavedra, et al., 2005).

2.7.2.2. Soil Factors

Due to a function of a range of soil properties such as soil texture, structure, soil moisture, roughness, organic matter content and chemical and biological characteristics, soils are different in their resistance to erosion (Vrieling, et al., 2007).The susceptibility of soil to erosion agents is known as soil erodibility (Lal, 2001).Those soil erodibility factor refers the effect of soil on erosion through the resistance of soil to both detachment and transport (Morgan, et al., 1995). In general, soils having faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion (Saavedra, et al., 2005). In addition as greater force is required to move, larger particles are more resistant to transportation and the erodibility of soil with particle size less than 0.06 are low due to cohesiveness properties. Therefore silt and fine sand are the particles that are less resistant to erosion (Petter, et al., 1992). In this study soil Erodibility Factor (K) will be quantified by considered soil color. The value of K ranges from 0 to 1 (Hellden, et al., 1987).

2.7.2.3. Topographic Factors

The effect of topography on erosion is complex. The local slope gradient (S) influences flow velocity and thus the rate of erosion. Slope length (L) describes the distance between the origin and termination of inter-rill processes (Renard et al., 1997). Increase in slope steepness and slope length will increase erosion as a result of respective increases in velocity and volume of surface runoff (Doere, et al., 2005).For erosion studies to calculate LS- factor few researchers have applied DEM successfully which is derived from satellite data. In this study DEM-30 will be used to derive LS-factor. Moreover, The LS factor accounts for the effect of topography on erosion in RUSLE. The slope length factor (L) represents the effect of slope length on erosion, and the slope steepness factor (S) also, reflects the influence of slope gradient on soil erosion. In this study, the slope map was extracted from DEM data by using the terrain features analysis tool in the software of ArcGIS (version 9.2).We used the L (slope length) factor from (McCool et al. 1987).): The application of S is limited to slopes below 18 % because it is the upper bound considered in USLE

2.7.2.4. Cover(C) factor

The ratio of soil loss from land under certain type of cover to the corresponding land with no cover is known as C-factor (Wischmeier and Smith, et al., 1978). Land use classification is often used to map vegetation types that differ in their effectiveness to protect the soil.) Landover is defined as "the observed biophysical cover on the earth's Surface." And Land use as "the arrangements, activities and inputs that people under-take on a certain land cover type". That difference is the intentional role of people to adapt the natural land cover to their benefit. In general land cover types refers to the vegetation the area.

Vegetation reduces soil erosion by: protecting the soil against the action of falling raindrops, increasing the degree of infiltration of water into the soil, reducing the speed of the surface runoff, binding the soil mechanically, maintaining the roughness of the soil surface, and improving the physical; chemical and biological properties of the soil (DeAsis and Omasa, 2007). The category and description of these land cover classes are presented in table 2.1.

Table 2.1: Description and area of land cover categories

No	Land cover category	General description
1	Forest land	An area made of a main layer of natural trees with a cover from 10 to 100 %.
2	Shrub land	An area with a main layer of natural shrubs covering from 10 to 100 %.
3	Farm/Crop land	Areas currently under crops (rain-fed or irrigated crops). This class includes small inter-field cover types (e.g. hedges, grass strips, small windbreaks, etc.)
4	Bare land	Areas with degraded lands bare ground or inundation areas
5	Built-ups	Area any type of artificial surfaces areas under residential or industrial places
6	Water body	Areas with any type of inland water body persistence of 12 months/year including natural lakes, wetlands, rivers and manmade small dams
7	Grazing Land	Area with a main layer of natural herbaceous vegetation with a cover from 10 to 100%.

Source: (FAO, 2011)

After classification, a qualitative ranking of vegetation types is made, or C-factors are assigned from reported values in different literature described in table 2.2.

Table 2.2 cropping and land-cover C-values used in different studies

No.	LULC type	C factor value	References
1	Forest	0.02	Hurni (1988)
2	Grassland	0.01	Eweg and van Lammeren (1996)
3	Farm land	0.17	Hurni (1988)
4	Shrub	0.02	CGIP,1996
5	Bare land	0.6	BCEOM (1998)
6	Water body	0.0	Hurni (1988)
7	Urban	0.05	Hurni (1988)

Source: Hurni (1988), Hellden (1987)

2.7.2.5. Conservation Practice Factor

Soil which is covered by crop plants, mulches or residues would be protected from wind and water erosion. Those infiltrations of water and organic matter would be enhanced. Minimum tillage, cover cropping, managed grazing, contour planting, strip cropping, crop rotation, control structures and diversions are some of the practices that maintain soil cover and protect soils from water erosion. These practices principally affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff (Renard and Foster, et al., 1983). Especially in agricultural areas, conservation practices such as contouring, strip cropping, or terracing, reduce soil losses. For instance, in areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. The effectiveness of such practices is often analyzed with a support practice factor (P-factor) which is defined as the ratio of soil loss with the practice applied and up and down slope cultivation (Wischmeier and Smith, 1978; Renard et al., 1997).

P-values have been assigned to land use classes using literature values and ranges from 0 to 1 (Kaltenrieder et al., 2007).

Table 2.3 Conservation Practice P-values used in different studies

Land use type	**Slope (%)**	**P-factor**
Agricultural land	0-5	0.1
	5-10	0.12
	10-20	0.14
	20-30	0.19
	30-50	0.25
	50-100	0.33
Other Land	All	1.00

Source: Wischmeier and Smith, 1978

2.6. Watershed

A watershed is a surface area from which runoff which is resulting from rainfall is collected and drained through a common outlet. Most of the time the term is similar with a drainage basin or catchment area Hydrologically, it is an area from which the runoff drains through a particular point in the drainage system. It is made up of the natural resources in a basin, especially water, soil, and vegetative factors. Socioeconomically a watershed includes people, their farming system and interactions with land resources, cropping strategies, social and economic activities and cultural aspects (MoARD, et al., 2005).

2.7. Micro-Watersheds vulnerability

All parts of the micro-watershed cannot be eroded at the same extent because of their differences in environmental attributes across landscapes (Tamene and Vlec, 2007; Tripathi et al., 2003). Those it is very important to identify the most erosion vulnerable micro-watershed and give priority for soil and water conservation activities based on that it is possible to implement effective and efficient of watershed management programs. It is important to consider various factors to identify the most erosion vulnerable area because in the watershed there is an integration of different variables such as precipitation, runoff, erosion and sediment discharge as they relate to input and output in an open hydrological system (Deore et al., 2005).

2.8. Hydrologic model

To predict and evaluate soil erosion problem models which are the simplification of reality have effectively been developed and employed. According to soil erosion modeling is the process of describing soil particle detachment, transport and deposition mathematically on land surfaces. The reasons for soil erosion modeling are used because they are used as a tool: (1) to predict and assess soil loss for conservation planning, project planning, soil erosion inventories, and for regulation. (2) To predict where and when erosion is occurring and hence helping the conservation planner target efforts to reduce erosion. (3) For understanding erosion processes and their interaction and for setting research priorities (Lal et al., 1994). According to (Petter et al., 1992) the objective of soil erosion models is either predictability or explanatory.

Several models were developed for the assessment of soil loss and numerous are in the process of development and some of which are CREAMS, WEPP, SLEMSA, EUROSEM, GUESS, USLE, RUSLE, RMMF and MUSLE etc. In general, the models are categorized into three: namely conceptual, empirical and physically based models (Saavedra, 2005).

Conceptual models include only a general description of catchment processes, without including the details occurring in the complex process of interactions (Renschler et al., 1996). This allows these models to provide an indication of the qualitative and quantitative effects of land use changes, without requiring large amount of spatially and temporally distributed input data (Merritt et al. 2003).it reflect the hypotheses about the process governing system behavior. It plays an intermediary role between empirical and physical based models (Beck, et al., 1987).

Physically based models include the laws of conservation of mass and energy, where energy can change form but total energy remains the same (Petter, et al., 1992). They are based on the understanding of the physics of erosion processes. Examples of these models are SWAT, WEPP, CREAMS, ANSWERS, EUROSEM, and AGNPS etc.

An empirical model refers to a simplified representation of a system or phenomenon which is based on experience or experimentation. Examples of these models are SLEMSA, MUSLE, USLE, RUSLE etc. The computational and data requirements for such models are usually less than for conceptual and physically based models (Lietal et al., 1996). By considering its ease of implementation, reliance on easily accessible data, universal applicability, comprehensiveness in terms of the factors and erosion processes included, the ability to take account of changes in land use and conservation practice and its relatively accurate results in this study RUSLE was chosen.

2.8.1. Revised Universal Soil Loss Equation (RUSLE)

The Revised Universal Soil Loss Equation (RUSLE) is an empirical based model which has the ability to predict the long term average annual rate of soil erosion on a field slope caused by rainfall pattern, soil type, topography, crop system and management practices (Renard et al., 1997). In GIS environment, it can predict erosion potential on a cell-by-cell basis, which is successful in attempting to identify the spatial pattern of soil loss present within a large watershed area (Shi et al., 2003). From this GIS can be used to isolate and query these locations to identify the role of individual variables in contributing to the observed erosion potential value (Saavedra, 2005). The Universal Soil Loss Equation (USLE) was first developed in the 1960s by Wischmeier and Smith of the United States Department of Agriculture as a field scale model (Wall *et al.*, 2002). It was later revised in 1997 in an effort to better estimate the values of the various parameters predicting soil losses and planning control practices in agricultural watersheds by the effective integration of the GIS-based procedures to estimate the factor values in a grid cell basis in the USLE (Renard *et al.*, 1997).

The disadvantage of RUSLE is that it does not estimate sediment deposition and gully erosion. RUSLE estimates the average annual soil loss from: A = R.K.LS.C.P

Where A is the amount of soil erosion (t ha-1yr-1) which is eroded within unit area during the corresponding period of rainfall; R is a rainfall erosivity factor; K is a soil erodibility factor; LS is a surface characteristic factor (slope-length and steepness factor, L is the slope length while S is the slope gradient); C is a cover management factor; P is support practice factor (Wischmeier and Smith, et al., 1978).

2.9. Application of GIS and Remote Sensing for Mapping Soil Erosion Risk area

The potential utility of Remote Sensing and GIS techniques for quantitative assessment of soil erosion vulnerable area (Saha et al., 1991; Mongkoisawat et al., 1994) remote sensing and GIS techniques becomes an effective analytical tool that makes the watershed management relatively simpler because of its improvement from time to time. Although, The use of remote sensing and geographical information system (GIS) techniques makes soil erosion estimation and its spatial distribution feasible with reasonable costs infective and better accuracy in larger areas (Millward and Mersey et al., 1999; Wang et al., 2003)

2.9.1. Remote sensing

Remote sensing technology is power full tool which used to the comparison of different LULC in terms of change. Remote sensing technique lays on its capability to deliver spatially consistent data set that cover a wide range of spatial extent with both high and detailed spatio-temporal resolution, including historical time series data (Herold et al., 2005). Since 1972, the Landsat satellites have provided repetitive, synoptic, global coverage of high-resolution multispectral imagery. Their long history and reliability have made them a popular source for documenting changes in land cover and use over time (Turner et al., 2003).

Remote sensing becomes valuable in planning and development of watershed management, because satellites imagery provides a fast and economic way to analyze large watersheds by their advantage in synoptic and repetitive coverage (Jain and Goel, et al., 2002). It is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. "For the assessment of erosion vulnerable area remote sensing becomes very important in detecting erosion features and obtaining erosion model input data (Petter, et al., 1992; Vrieling, et al., 2006). With appropriate use of multispectral data, it is possible to differentiate different ground features from each other and prepare a thematic map depicting land use/land cover. Now a day's different study utilize Satellite imagery for the characterization of watershed and management aims (Saxena et al., 2000).

2.9.2. Geographic Information Systems

Geographic Information Systems are databases that have a spatial component for the storage and processing of the data. So they have the potential to store and create maps. It has also the potential for performing multiple analyses or evaluations of scenarios such as model simulations (Maidment and Djokic, et al., 2000). There are a number of strengths that a GIS technology has a number of advantages in watershed management studies by allowing improved database organization and storage. Obtaining different variables which is important for watershed studies has been difficult to do from paper maps and aerial photographs as it subjects to errors related to manual operations and it is proved to be time-consuming. In addition to this, the capabilities of modern GIS for modeling and visualization, offer fundamentally new tools to understand the processes and dynamics that shape the physical, biological and chemical environment of watersheds (Jain and Goel, et al., 2002). Mapping soil erosion using GIS can easily identify areas that are at potential risk of extensive soil erosion and provide information on the estimated value of land use land cover dynamics and it is impacts on soil loss at various locations in the watershed (Shi et al., 2003). The use of remote sensing and geographic information system (GIS) techniques with RUSLE model makes estimating soil erosion and mapping its spatial distribution.

CHAPTER - III

3. METHODOLOGY

3. 1. Introduction

This chapter presents the available data, the overall methods, techniques, approaches and materials that have been used to achieve the research objectives. It mainly explains the data sources and types, methods of field data collection, reference data were used to identification of driving forces of LULCC, image classification technique employed, and accuracy assessment, and list of software packages used in the research.

3.1.1 Study area description

The study was carried out in Chercher watershed, located in Western Harerge zone, Oromia Regional State. Chercher watershed is situated at about 372 km North of Addis Ababa, the capital city of Ethiopia and 40 km south east away from Chiro town, the capital center of the Zone. Which is geographically located between 08^{o} 20’ 00’’ to 09^{o} 00’ 00’’N and 40^{o} 40’ 00’’ to 41^{o} 10’ 00’’ E covering a total area of 1562.63 km^{2} shows in figure (Fig.3.1).

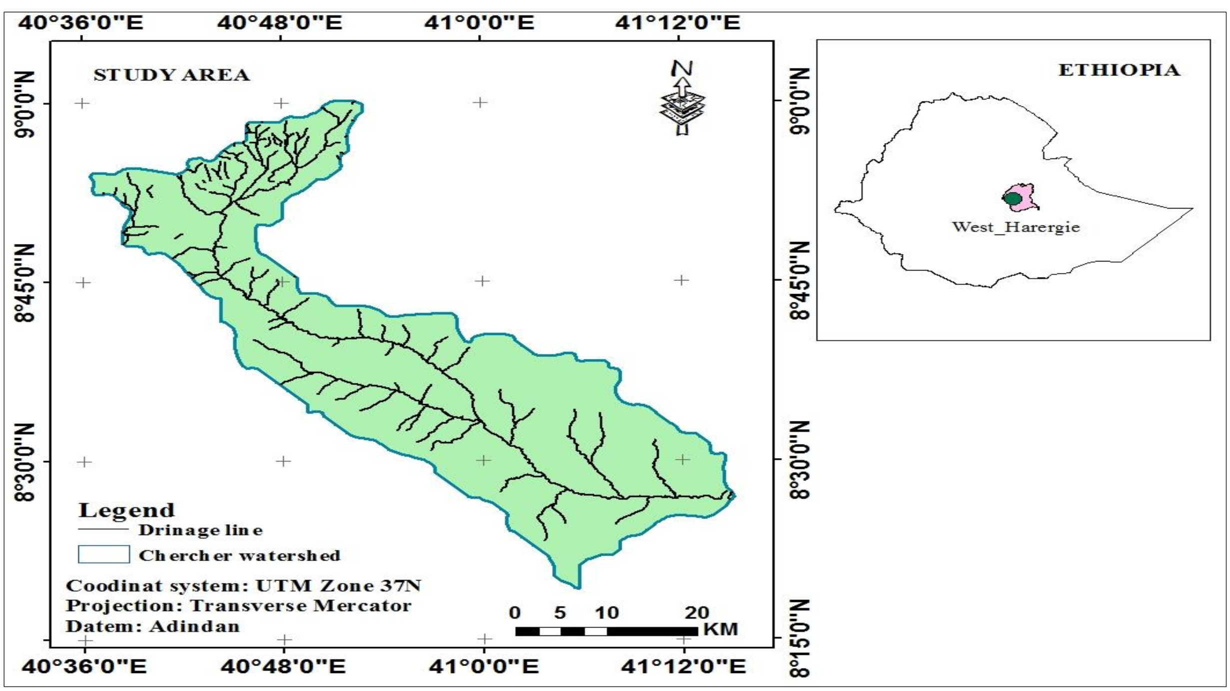

Figure 3.1: Locational Map of the study area

3.1.2. Climate

The watershed has a bimodal rainfall pattern with, a very erratic nature. The average annual rainfall and evapotranspiration (ETo) are 979.6 mm and 1099.3 mm, respectively. The aridity index of the watershed is 0.88. The watershed has Woynadega (mid altitude) agro climatic zone (Tewolde, 1989). From analysis of rainfall, the beginning of the growing period is in March and the rain ends in November. Onset of main rainy season 'kiremt' is on half of June and offset of the rainy season is in October. The shorter rainy season "belg" is from February to May.

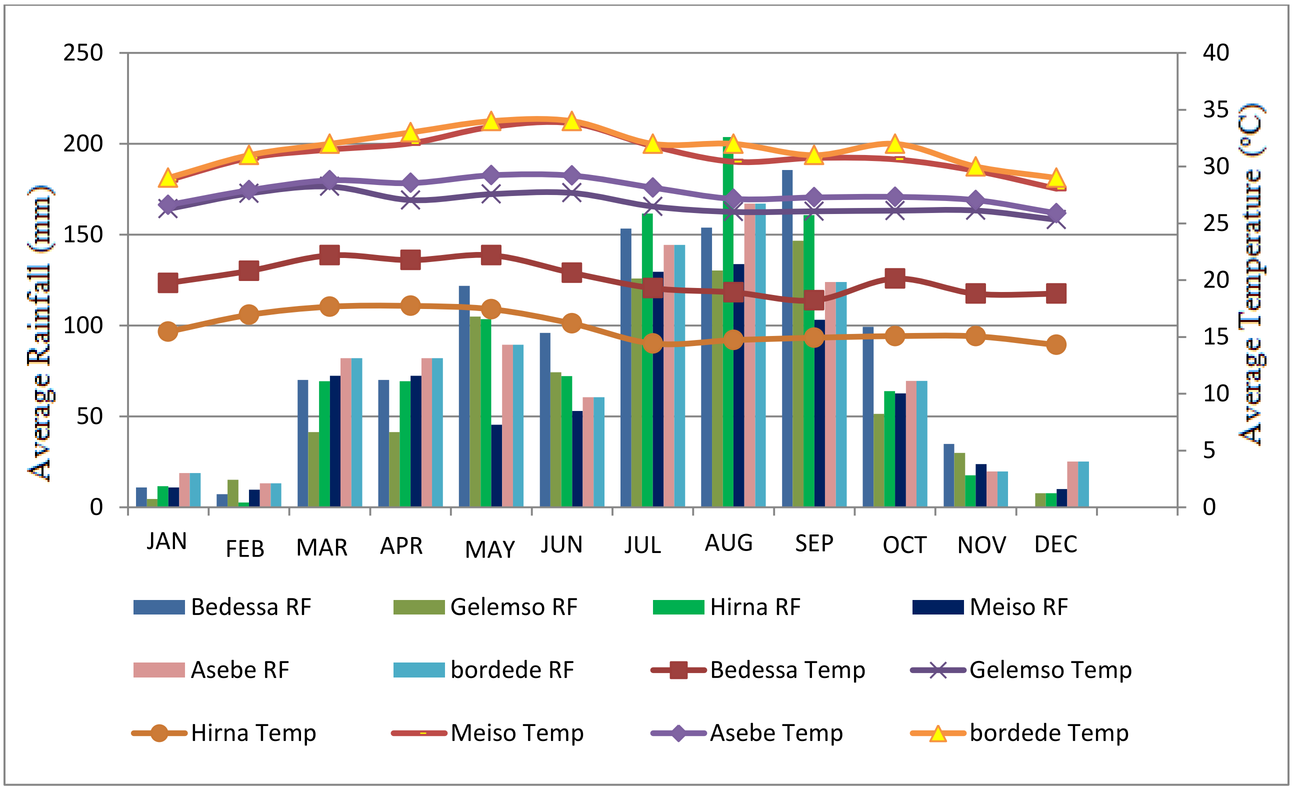

Figure 3.2: Average Monthly Rainfall and Temperature of Six Stations (1997 to 2018) source MOA

3.1.3. Topography

The physiographical feature of the area is characterized by Arsi-Bale massifs, plateaus, plains and valleys. The topographic features of the watershed include; hills, valleys, gentle, slopes and plains. The watershed is surrounded by hills in the north and gentle dipping slopes in the west and east and plain in downstream. The drainage density is higher on the upper hilly and gentle lands and lower on the flat lands. The elevation of the watershed is between 822 and 2904 meters.

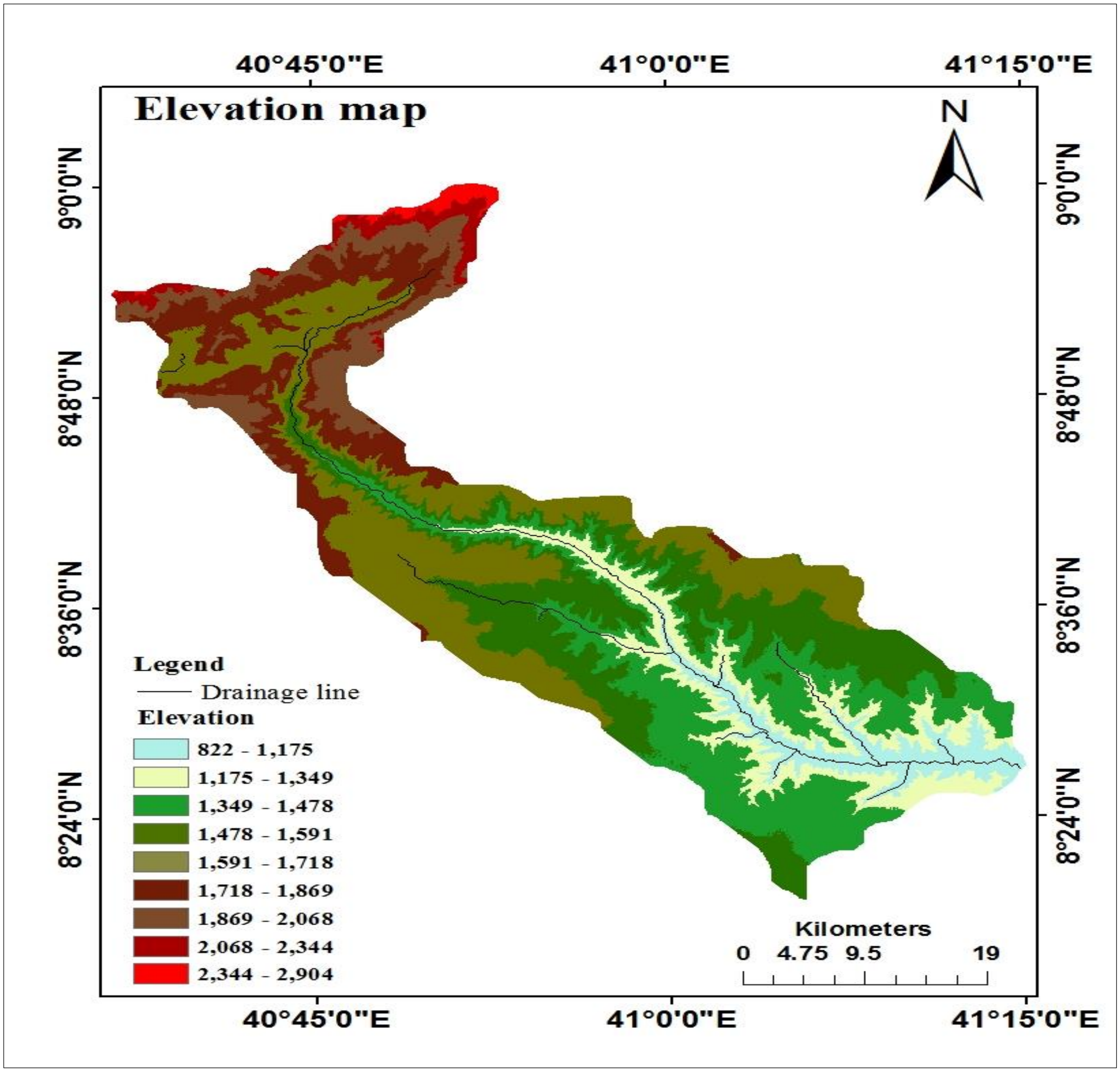

Figure 3.3: Elevation of the study area

3.1.4. Soils and Geology

Most parts of the watershed are highly degraded due to long history of land use change, topographic features and soil lose. The vertical rock formations in the watershed are from bottom to the top: Pre Cambrian basement complex, Mesozoic sediments (Adigrat sandstones, Antalo limestone's, and upper sandstone), and Cenozoic trappean lavas (Mohr, et al., 1971). The trappean lavas are composed predominantly of alkaline olivine basalts, tuffs, rhyolites, and phyroclastic fragments all belonging to what is generally described as the Ashangi Groups (Merla et al., 1979).

3.1.5. Land Use

The land use system in the watershed is a mixed farming one. The major land use types are farm land, open forest land, open bush land and grass land (Oromia land use plane, 2010)**.** The farmers use oxen drawn implements and traditional hand tools called 'Akafa' and 'dongora' to cultivate their land. Cereal/legume crops such as maize, sorghum, barley, chickpea, field pea, soybean, teff and haricot bean are growing in the area. Fruit trees like guava, mango, banana, avocado and papaya are also growing in the area.

Vegetable crops such as sweet potato, potato, cabbage, onion, carrot, beetroot, and swischard are being cultivated by the local farmers. Commercial crops growing in the area include; khat (Catha edulus) and coffee (Coffea arabica). Natural and plantation trees like Eucalyptus camaldulensis and Acacia spp. are widely growing around homesteads, along boundaries, paths and roads. The farmers use these trees for shade or beauty, live fences, firewood, and house construction.

3.1.6. Socioeconomic conditions

The livelihood of the dwellers in the watershed mainly depends on agriculture. Cattle rearing and annual crop production are very important in the area. Traditionally having more cattle is needed for selling for household use. Cut and carrying system with field tethering of animals is exercised in the area. Fattening cattle for sale in accordance to market demand for meat and source of income is well exercised in the area.

However, the recurrent drought has threatened the management of cattle and consequently most of the people in the area have fewer numbers of oxen for plowing. Food crops and commercial crops are also growing in the area.

The major food crops of the Chercher watershed are maize and sorghum with other annual crops. Commercial crops include Arabica coffee and Khat. Currently, high exaltation of the local farmers towards chat production reduced their focus for food crops. Even though, the farmers sow other crops between chat in rows, they give high worth for chat production owing to high value earns. This is because; chat is the main cash crop in the area. Today chat is the source for export revenue even at the country level and amphetamine-like stimulant which is consumed inside Ethiopia and in adjacent countries, and considered as a drug of abuse that can lead to mild to moderate psychological dependence (CSA, 2007). Small scale fruit trees growing around homestead and on farmland boundaries are also used as source of income.

3.2. Data Sources and Methods of Collection

3.2.1. Satellite Data

Cloud free satellite images of three different years 1987 Landsat 5 Thematic Mapper (TM), 2001 Landsat 7 (ETM+) and 2018 Landsat 8 OLI_TIRS used for analysis in this study were provided by USGS was downloaded and Spot satellite image from Ethiopian Mapping Agency for supervised land use land cover classification. 30m*30m resolution ASTER DEM was downloaded from USGS and used for watershed and micro-watershed delineation, the slope length and steepness factor were estimated. Additionally random sample of land use area polygons are generated from Google earth for the verification of classified map.

3.2.2. Field Data

The field data collection was made to collect the necessary reference data of land use/land cover (LULC) classes. A total of 557 ground reference data were collected from the field stratified proportional to each land use/ land cover class to support image classification and accuracy assessment. Handheld Global Positioning System (GPS) was used to collect all required field data.

3.2.3 Ancillary Data

Monthly rainfall and temperature data of nearby stations from 1997-2018 were accessed from the National Meteorological Agency. Mean annual rainfall data was generated from the monthly rainfall data of 20 years and well adopted for the analysis. For this study a soil data of the major soil groups of Oromia Region as per FAO soil group were obtained from Ethiopian Ministry of Water Resources and Energy (MWRE). The soil polygon feature map obtained by clipping the FAO soil map of Oromia Region with the study watershed in the GIS environment. In addition, to analyses the LULC factors with (Slope and Soil type) for soil Erosion protection support practices in the study area informal interview with the natural resource experts and development agents who work near the study area was undertaken. Reviewing of different relevant published and unpublished literatures of the specific study area and related studies of different areas in general have been undertaken almost throughout the course of the research period. Necessary data including socio-economic, demographic, vegetation, physiographic, soil, hydrologic and farming systems have been extracted from secondary data sources including woreda Administration, Secondary Data used for this study are indicated below in table: 3.1

Table 3.1: Source, description and purpose of the data used in the study

NO	Types of data	Source	Description	Purpose
1	DEM	USGS(United States Geological Survey)	SRTM 30*30m special resolution	For Watershed delineation and slope length (L) and slope steepness(S) generation
2	Landsat 5 TM _1987 7 ETM+_2001 8 OLI_TIRS_2018	USGS (United States Geological Survey)	30m*30m special resolution	For LULC classification and To extract Cover (C) factor
3	Digital Soil map	Ministry Of Agriculture (MoA)	vector format soil map of the (MoA) and converted into raster grids (30m*30m)	To extract soil Erodibility Factor (K)
4	Monthly Rainfall data	National Meteorological Agency, Ethiopia	20 years RF data from stations near the study area	To extract the R-map from mean monthly RF data
5	Google earth Image	Google Earth,	Digital Raster	Ancillary data for classification

3.2.4. Materials and Tools

For the success of this research the data-processing tools included ArcGIS 9.3, ERDAS Imagine 2015, RUSLE model and MS Excel was used. GIS and RS analysis could help to analyze land degradation mainly soil erosion in cost effective, fast and accurate way. Those software and tools with their purpose are indicated below in table: 3.2.

Table 3.2: Software and tools used for the study

No.	Software's & tools	Purpose
1	ERDAS Imagine	Land use/land cover classification
2	ArcGIS10.3	vectorization, area calculation and analyzing, displaying Spatial data
3	Arc Hydro extension	Watershed, Micro and sub watersheds delineation
4	RUSLE model	to predict the long term average annual soil loss

3.2.5 .Research Design

The proposed research was conducted in three phases: pre fieldwork, fieldwork and post field work phases. The first phase is a preparation phase which consists of research proposal development, including problem definition, formulation of research objectives and associated research questions, defining methods, identifying required data types, clearly defining data collection methods and preparing (field) work plans. The second phase was information and data gathering phase (field Work phase). In this phase, important data required to carrying out the research including primary and secondary data were collected during fieldwork. In the end, the collected data were processed, analyzed and the finding were presented (post fieldwork phase) so as to meet the predefined objectives of the research.

3.3. Methods of data analysis

3.3.1 GIS data base construction

ArcGIS10.3 was used for the generation of R, K, LS, and C layers, generation of potential location integration of layers and reclassification of derived datasets. Watershed, Micro and sub watersheds delineation was performed using Arc hydro extension with in ArcGIS10.3. ERDAS IMAGENE 15 Software was used for Extraction of information on LULC condition and quantified the changes over the study period from the classified image. For digital image processing including preprocessing of satellite image data, masking the image with the watershed boundary enhancement, visual interpretation. All derived maps will be projected into WGS1984 Zone 37N and held in grids of 30-m cell size.

3.3.1.1 Micro-watershed Delineation

The watershed under study was delineated by automatic delineation option using Arc swat Extension with in Arc GIS 10.3.1 for the delineation of the watershed, From SRTM 30m*30m resolution DEM, Fill, Flow direction and flow accumulation were generated respectively. As shown in figure: 3.3, 25 micro-watersheds were delineated by increasing the threshold value in the stream definition. Thus, provided is easy for the analysis and to compare the micro-watersheds each other. The area of the micro-watersheds ranges from 7.1 km^2 to 361km^2.

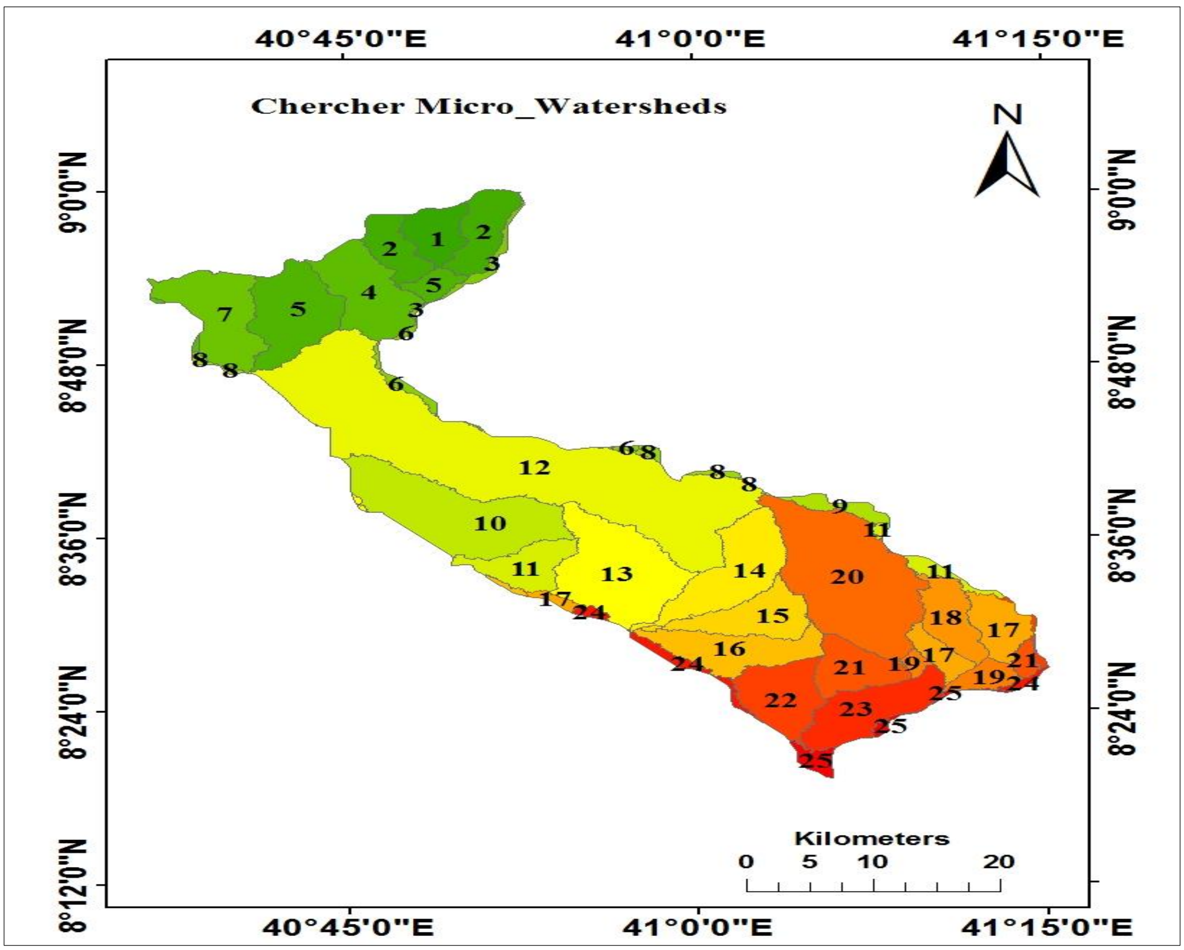

Figure 3.4: Chercher micro-watersheds

3.3.1.2 Image Classification

3.3.1.2.1. Satellite Images Preprocessing

Before LULC classification and change detection analyses, one should preprocess the twist out of shape and deteriorate images to ensure the results of adequate quality with a more correct and true to the fact representation of the real ground truth. In the context of the current study, this involved removing or diminishing any unpleasant image characteristics that occurred during the acquisition process (Lillesand, 1999; Mather et al., 2011). This was applied to all raw Landsat image data on board TM, ETM+ and OLI sensors. The Landsat images were preprocessed using the ERDAS IMAGENE version 2015. The first step involved the re-projection of the Landsat images into World Geodetic System (WGS 84) spheroid, a spatial reference system of the Universal Transverse Mercator (UTM) with Datum Zone 37 N. The preprocessing includes a series of sequential operations. This includes an atmospheric and radiometric correction to diminish the effects of clouds and the sun elevation angle of satellite images taken during different periods and from different sensors. Geometric correction accurately links the Landsat imagery with a ground truth data and other ancillary data sets, and masking operations (Song, 2001; Papadavid et al., 2011). Then, layer stacking single-band images were combined to get multi-band composite images (Cheruto et al., 2016). Additionally, image enhancement operations, including contrast adjustment, edge enhancement and color composite were employed to enhance the performance of image data. Since the entire scene of TM, ETM+ and OLI images respectively covers area are not the same (Earth Explorer, 20018). The area of interest (AOI) that covers the study area (1562.63 km^2) the area of interest (AOI) has been identified using the subset tool available in ERDAS IMAGINE 2015 software version 10.

From the downloaded three multi-temporal images (Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OLI_TIRS) by subtracting the two bands (the panchromatic band and the thermal band) the rest bands was combined by layer stack in ERDAS imagine 2015 software. Then combined bands of the image data will be classified. Next to this; the land use/land cover classes to be considered in the image classification process was identified. For this purpose, the training distinctive signatures were collected for each land use/land cover class from satellite images support by sampled field collected reference data, and knowledge of natural resource experts and people of the locality about the earlier state of land cover in the watershed. The study used a supervised maximum likelihood image classification procedure to classify satellite images to generate thematic LULC maps of the study area based on known features on the ground. This study has also used maximum likelihood classification algorithm as a parametric classifier that can train quickly with a capability to handle huge datasets. In fact, this method constitutes a historically dominant approach to RS-based automated LC derivation (Gao, 2004) and has become popular and widespread in RS because of its robustness.

This done by using the different temporal images were cross-referenced with ground truth, Google Earth maps and other ancillary data to make the classification as accurate as possible. The FAO 2011 land use/land cover classification system was used to define the land use/ land cover classes. For this study supervised land use and land cover classification was undertaken by ERDAS Imagine 15 software using the maximum likelihood image classification methods. Based on the satellite images, and training points, the land use land cover classes analyzed for changes were Grazing Lands, Shrubs, Bare, Cultivated land, Forests and Settlements and Water body (Table 2.1).

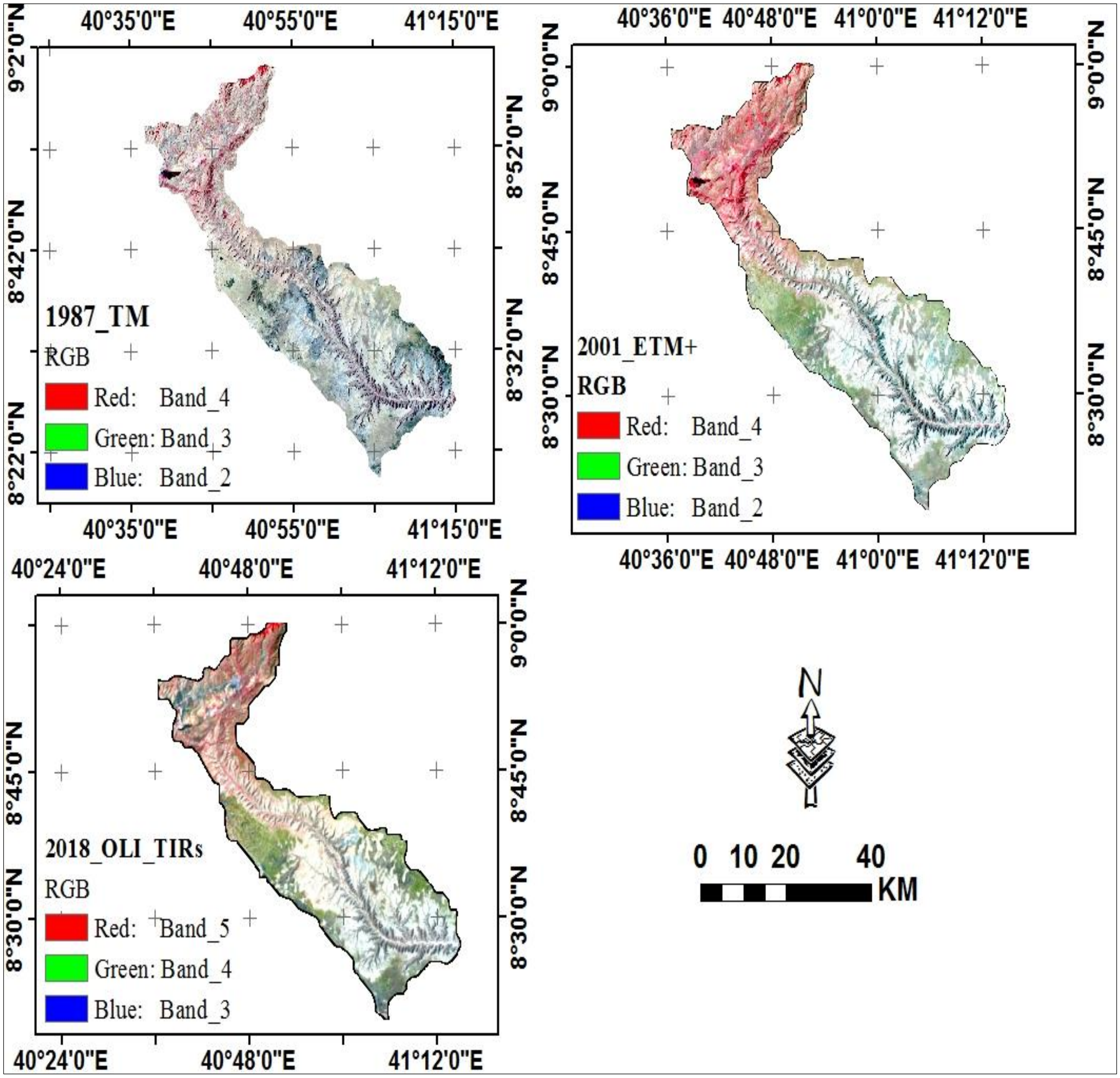

Figure 3.5: Satellite images of the study watersheds in 1987, 2000 and 2018

Table 3.3: Satellite Data acquisition information

Date Acquisition	Satellite	Resolution (m)	Path /row	Band combination
02-Feb-1987	Landsat 5, TM	30	167/054	1.2.3.4.5.6.7
23-Jan-2001	Landsat 7, ETM+	30	187/054	1.2.3.4.5.6.7
07-Feb-2018	Landsat 8, OLI_TIRS	30	167/054	1.2.3.4.5.6.7

Accuracy assessment performed to validate and compare the classified image with geographical data that are assumed to be true. The accuracy assessment of the LULC maps has been undertaken by comparing the Google earth image and field data collected by GPS with the classified images.

3.3.1.3. Land Use Land Cover Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different time (Singh, 1989). Change detection is a complex phenomenon which includes different method and procedures such as clearly identifying the specific change detection problem, image preprocessing and variables and algorithm selection for the computations. A variety of digital change detection techniques has been developed in the past three decades. Basically, the different algorithms can be grouped into the following categories: algebra (differencing, rationing, and regression), change vector analysis, transformation (e.g. principal component analysis, multivariate alteration detection, Chi-square transformation), classification (post-classification comparison, unsupervised change detection, expectation-maximization algorithm) and hybrid methods. To ensure an accurate change analysis, preprocessing of images from the three different satellites was carried out. Such as geometric correction and, radiometric corrections were applied. In order to avoid a seasonal variation in vegetation pattern and distribution throughout a year, the selection of images acquired data were made as much as possible in the same annual season of the acquired years. The classified image used for extraction of information on LULC condition and quantification of the changes over the study period by using both Remote sensing data and field survey were applied.

From this the land cover conditions of the three different periods (1987, 2001 and 2018) was compared and change can be detected by post classification comparison method then quantifying and evaluate the land use/land cover changes rate and structural change of the study area was evaluated. Following this, supervised land use land cover classification has been carried out and the changes in the land use land cover within this period were also determined using intersection tools in GIS software. Finally, Maps have been generated to indicate the variability of the vegetation in different years and to view the statistics result of each land use land cover dynamics.

3.3.1.4. Soil Erosion Assessment using RUSEL model

In this study, the mean annual soil erosion on Chercher watershed was calculated using the Universal Soil Loss Equation (USLE) because of its operating simplicity, convenient inputting availability, extensive applicability and simplicity in order to map the soil erosion potential areas and to estimate the amount of potential annual rate of soil erosion. All map layers were generated in a raster GIS environment. Generally, the RUSLE uses the simple equation:

A = **R x K x LS x C x P** --- (3.1)

Where: - A is the computed spatial average soil loss rate (t/ha /year),
R is the rainfall-runoff erosivity factor [MJ mm/ (ha h year-1)],
K is the soil erodibility factor [t ha h/ (ha MJ mm)],
L is the slope length factor,
S is the slope steepness factor,
C is the cover management factor, and
P is the conservation support practice factor.
The factors L, S, C, and P are all dimensionless.

3.3.1.5. Impact of LULC Change on Soil Erosion potential

In order to evaluate the impact of LULC change on the soil erosion potential of the Chercher watershed, the RUSLE model was run for 1987 and 2018 separately. During each model run, all parameters required for the model remains constant, except for the distribution of land cover types (C factors) and erosion management practice (P factors), directly depends on land use land cover which are changed according to the LULC of the respective year. Since the C factor in the RUSLE model directly depends on land use land cover, the change of land use type had a significant influence on soil erosion potential.

In order to evaluate the impact of land use/land cover change to the soil erosion estimation of the Chercher watershed, this study propose to proceed in four main steps (Figure 4.20):

1) Step 1: Calculation of the Normalized Difference Vegetation Index (NDVI).
2) Step 2: Estimation of the Land use Land Cover (LULC) changes as calculated by the difference and level of the NDVI images.
3) Step 3: Calculation of the RUSLE C factor (linked with NDVI values).
4) Step 4: Temporal difference of the C factor, highlighting significant changes in land cover with potential impact on the soil erosion potential.

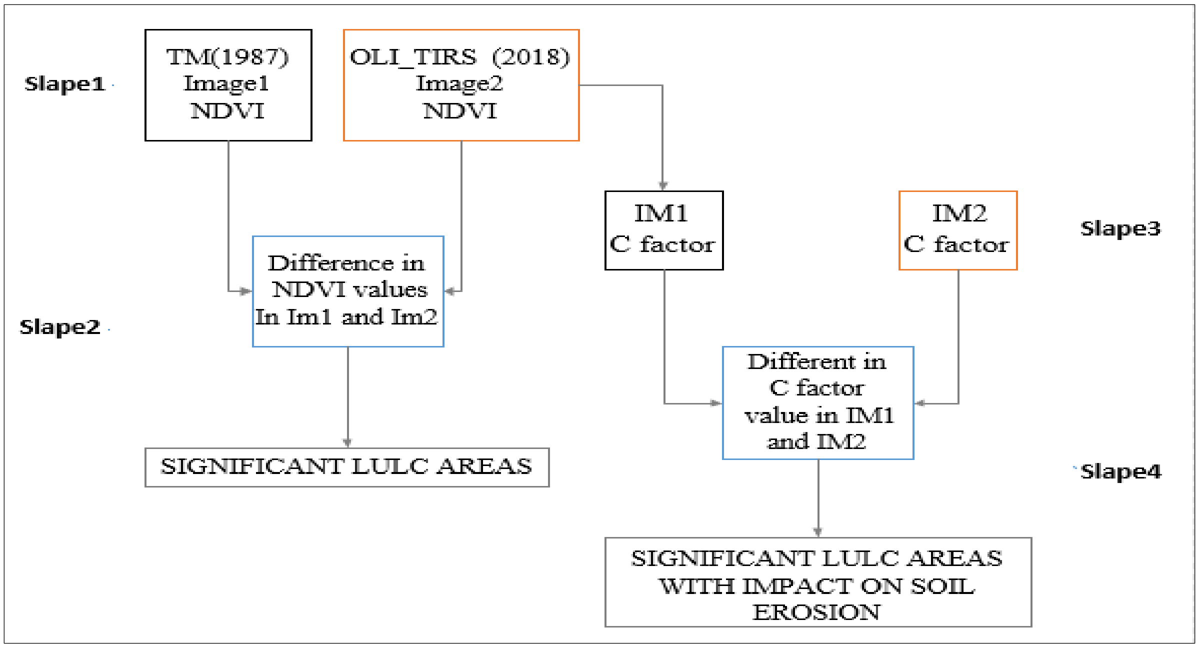

Figure 3.6: Methodology proposed for estimation of significant land change areas with possible impact on soil erosion

However, for a given climatic conditions the potential soil erosion from a particular Land Use Land Cover depends on the redistribution of individual area of LULC categories on the slope of the terrain and associated soil properties. Thus in the present study, special emphases were given for the different associations of LULC with terrain and soil to explore and reveal the underlying mechanism for changed erosion pattern of the study site.

In order to achieve the objectives of the study, a Research framework was formulated. The main theme was broken into concepts and then broken down into constructs and furthermore in to variables the frameworks are presented in Figure 3.7.

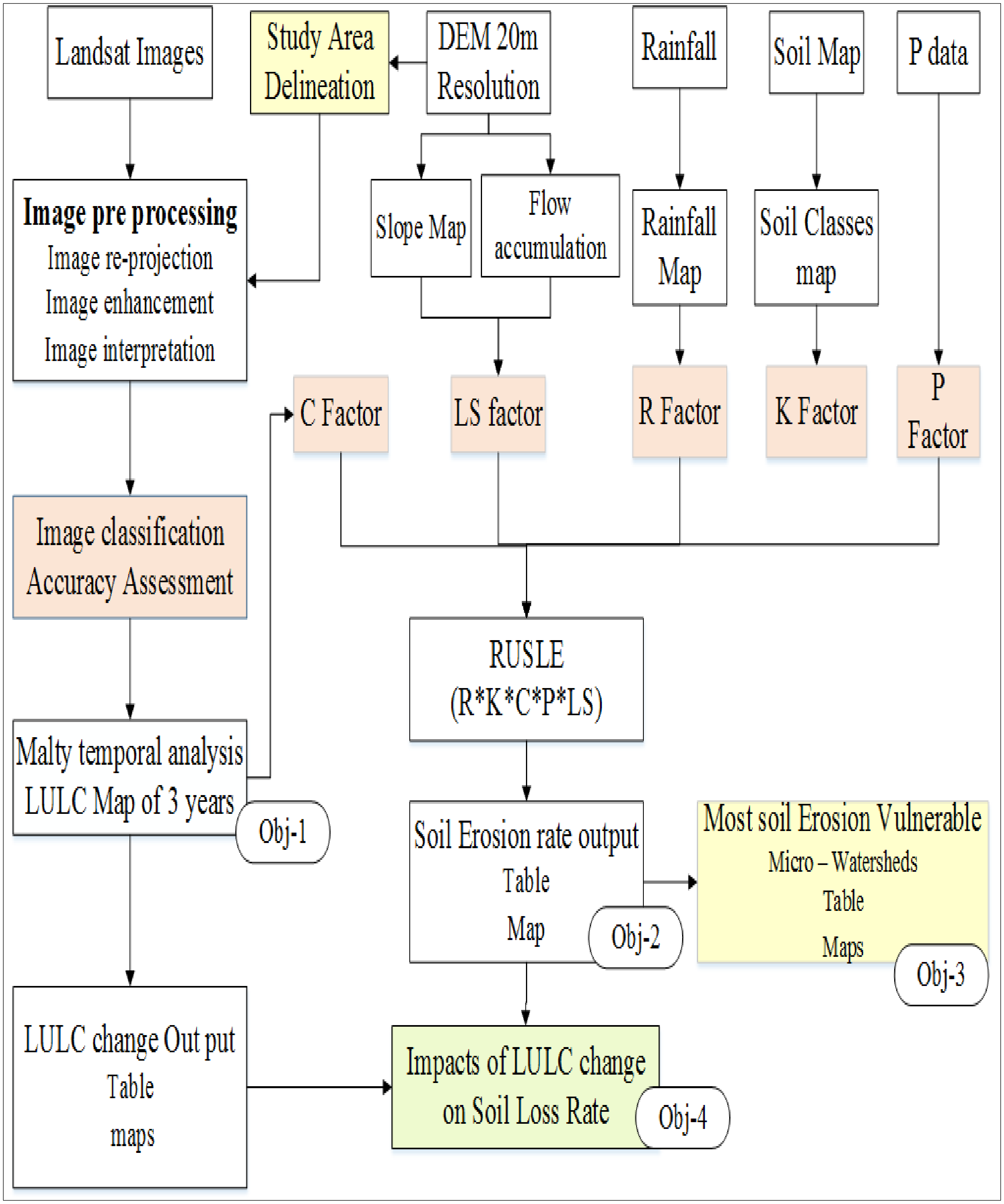

Figure 3.7: Flow chart of the overall methodology

CHAPTER - IV

4. DATA ANALYSIS, RESULT AND DISCUSSION

Introduction

This chapter presents the data analysis, result and discussion. The data analyses includes, performed multi-temporal land use land cover change analysis, dynamic soil erosion by applying RUSLE model, identification of vulnerable micro-watersheds on the basis of soil loss rate and assessment the effect of LULC change on soil loss rate of the study watershed.

4.1. Land Use/Land covers change Analysis

After collecting the entire relevant primary and secondary data, the next task is process and analyzing the data, as discussed earlier this research was applies remote sensing techniques to quantify LULCC processes and patterns. Remote sensing image classification is a relevant method that can provide information on the extent and rate of (Hai &Yamaguchi, 2008; Herold et al., 2003). Continuing the remote sensing technique for interpreting the three years satellite images, the land use land cover types of the study watershed was classified (Figure 4.1) however, the use of satellite image conceives geometric and radiometric error therefore when an image is utilized it is necessary to conduct radiometric correction to remove image noise and data acquisition error because image noise will affect the change detection capability. The entire preprocessing step was executed by using ERDAS IMAGINE 2015.

4.1.1: Land Use/Land covers change and Dynamics

Classification results of the preprocessed Landsat images for 1987, 2001, and 2018 are presented in Figure 4.1 and the statistics for the three different years of land cover are shown in Table 4.1 Seven land use and land cover types identified. From these, the largest portion of the study area is covered by two land uses Cultivation (53.22%) and bare (20.07%) while settlement occupied a very small portion of the entire watershed area in 2018. As it is shown from table 4.2 and 4.3, the various image preprocessing techniques along with the supervised maximum likelihood classification techniques enabled us to obtain an overall classification accuracy 84.17% and 91.51% for the LULC maps of2001 and 2018 thus the result is within the accepted accuracy (> 80%).

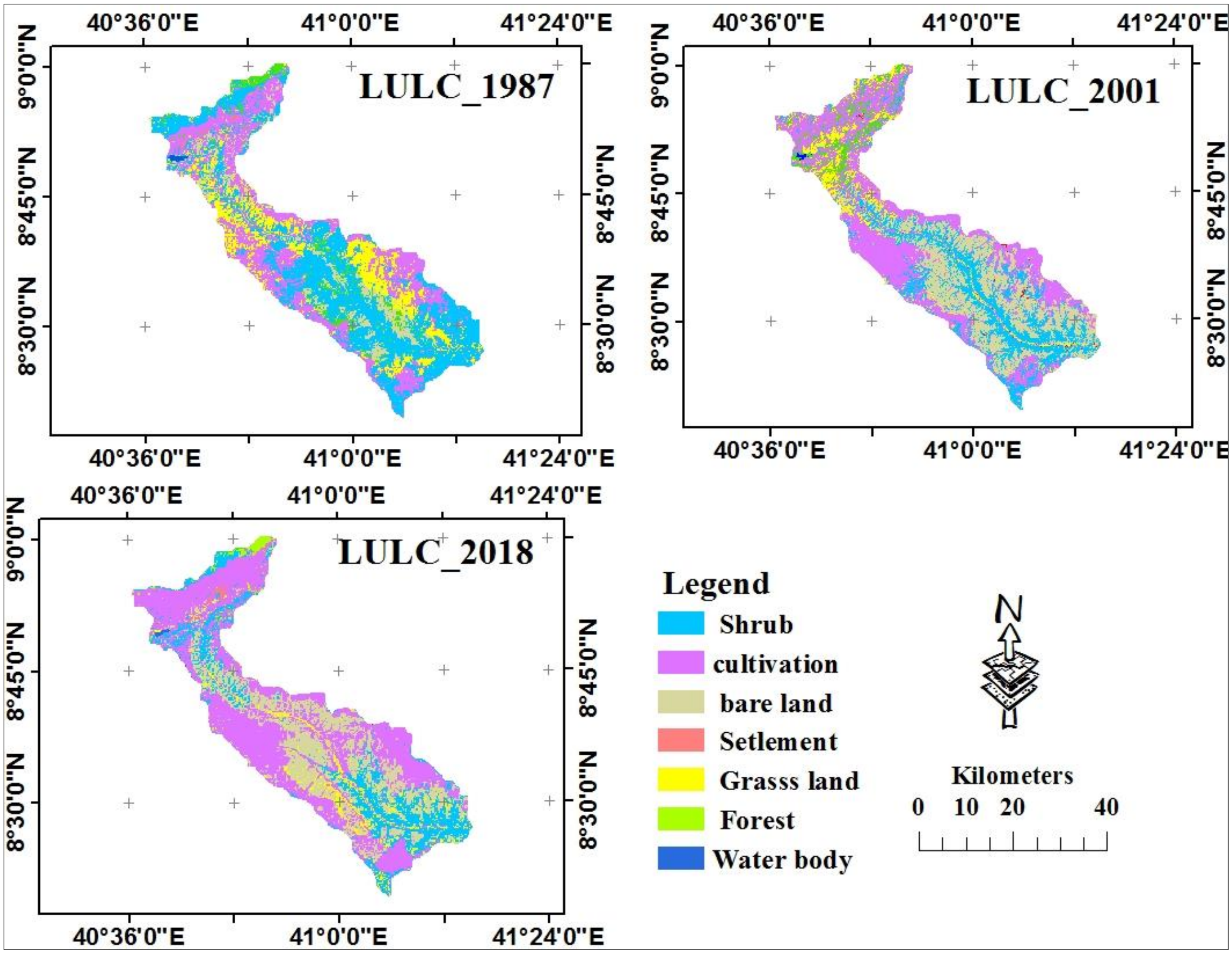

Figure.4.1: Land use land covers maps of 1987, 2001 and 2018

Table 4.1: Area and proportion of LULC in 1987, 2001 and 2018

LULC type	1987		2001		2018	
	Area(km^2)	Proportion (%)	Area(km^2	Proportion (%)	Area(km^2)	Proportion (%)
Forest	87.68	5.61 (%)	69.1623	4.42 (%)	32.609	2.08 (%)
Water body	3.67	0.23(%)	3.5019	0.22 (%)	2.3418	0.14 (%)
Settlement	3.748	0.24 (%)	6.7007	0.42 (%)	7.9389	0.50 (%)
Grass land	181.93	11.64(%)	128.483	8.22 (%)	84.1644	5.38 (%)
Shrub land	582.76	37.23(%)	411.343	26.32(%)	290.188	18.56 (%)
Barren land	236.74	15.15(%)	293.182	18.76(%)	313.761	20.07 (%)
Cultivation	465.93	29.82(%)	650.265	41.61(%)	831.776	53.22 (%)
Total	1562.63	100 (%)	1562.63	100 (%)	1562.63	100 (%)

Table 4.2: Accuracy assessment of the supervised LULC classification (2001)

Class Name	Reference Totals	Classified Totals	Correct Number	Producers Accuracy (%)	Users Accuracy (%)
Forest	20	27	17	85.00%	62.96%
Settlement	7	9	7	100.00%	77.78%
Water body	7	7	7	100.00%	100.00%
Barren Land	59	52	47	79.66%	90.38%
Cultivation	71	78	66	92.96%	84.62%
Grass land	22	28	20	90.91%	71.43%
Shrub land	71	58	54	76.06%	93.10%
Totals	259	259	218		
Overall Classification Accuracy = 84.17%			Overall Kappa Statistics = 0.8000		

Table 4.3: Accuracy assessment of the supervised LULC classification (2018)

Class Name	Reference Totals	Classified Totals	Correct Number	Producers Accuracy (%)	Users Accuracy (%)
Forest	12	9	9	75.00%	100.00%
Settlement	15	19	15	100.00%	78.95%
Water body	6	6	6	100.00%	100.00%
Barren Land	161	162	147	91.30%	90.74%
Cultivation	230	231	219	95.22%	94.81%
Grass land	33	40	31	93.94%	77.50%
Shrub land	117	110	101	86.32	91.82%
Totals	557	557	510		
Overall Classification Accuracy = 91.51%			Overall Kappa Statistics = 0.8818		

Investigation of the satellite derived thematic maps and field survey revealed a varying degree of changes in the composition of LULC categories in the study watershed over a span of 31 years. The total extent or composition of individual LULC class and their gain/loss is presented in Table 4.4. As shown in Table 4.1 above, the cultivated and bare lands remain the two dominant land use classes during the study period and together occupy about 73% of the total catchment area in 2018. The forest land was reduced to 62.60 km^2 (2.08%) in 2018 compared to 87.68 km^2 (5.61%) in 1987. Estimated shrub land cover in 1987 was about 582.76 km^2 (37.29 %), about 411.343 km^2 (26.32 %) in 2001, and about 290.188 km^2 (18.56 %) in 2018 this result show the shrub land was reduced to 18.56 % in 2018 from 37.29 % in 1987.wher as the cultivated land was increased to 831.776 km^2 (53.22%) in 2018 compared to 465.935km^2 (29.82%) in 1987.

The reduction of the forest and Shrub land during the past 31years is approximately 52.63% and 52.01% compared to the original area in 1987 and the increment of the cultivated land during the same period is approximately 76 %. There is not only a decrease in aerial extent of the forest and shrub land but it also became more fragmented during the study period. The possible reason for the reduction in forest and shrub land might be due to the expansion of agricultural land (Alemayehu, et al., 2011) as a consequence of rapid population growth (Hurni, et al., 1993).

Additionally, grazing land covers have been drastically reduced, which could be another cause for the increment in agriculture land cover and due to overgrazing. Human settlements occupy a relatively small portion (<1%) of the watershed. Town of Badesa is the only urban area and is the largest contiguous area under settlement category, while other settlements were mainly small, dispersed village communities. However, prevailing human-dominated activities in the study area led to a large increase in settlement cover (including built-up land) during the last 31 years.

The area under the settlement category underwent a drastic increase from 0.23% in the 1987 to 0.5% in 2018, which is approximately a 111% increase in aerial extent for settlement category in a full extent of 31 years. It is interesting to observe emerging human settlement areas in the recent year (2018) that occupies relatively small portion (<1%) of the watershed. The rural developing centers at the (Tefe, Boke and Bedesa) in the watershed are the largest contiguous areas under settlement category, while other settlements were mainly small, dispersed village communities and very difficult to easily detect from the satellite images.

Table 4.4: Extent of LULCC (Area in KM^2) during 1987–2018

Extent of LULCC (Area in KM^2) during 1987–2018				Extent of change in (%)
LULC Type	1987-2001	2001-2018	1987-2018	(1987_2018)
Forest	-18.52	-36.55	-55.07	-52.55(%)
Water body	-0.17	-1.16	-1.33	-9.05(%)
Settlement	2.95	1.24	4.190	111.77(%)
Grass land	-53.44	-44.31	-97.76	-53.74(%)
Cultivation	184.33	181.51	365.84	77.19(%)
Shrub land	-171.41	-121.15	-292.57	-51.93(%)
Barren land	56.44	20.57	77.021	36.31(%)

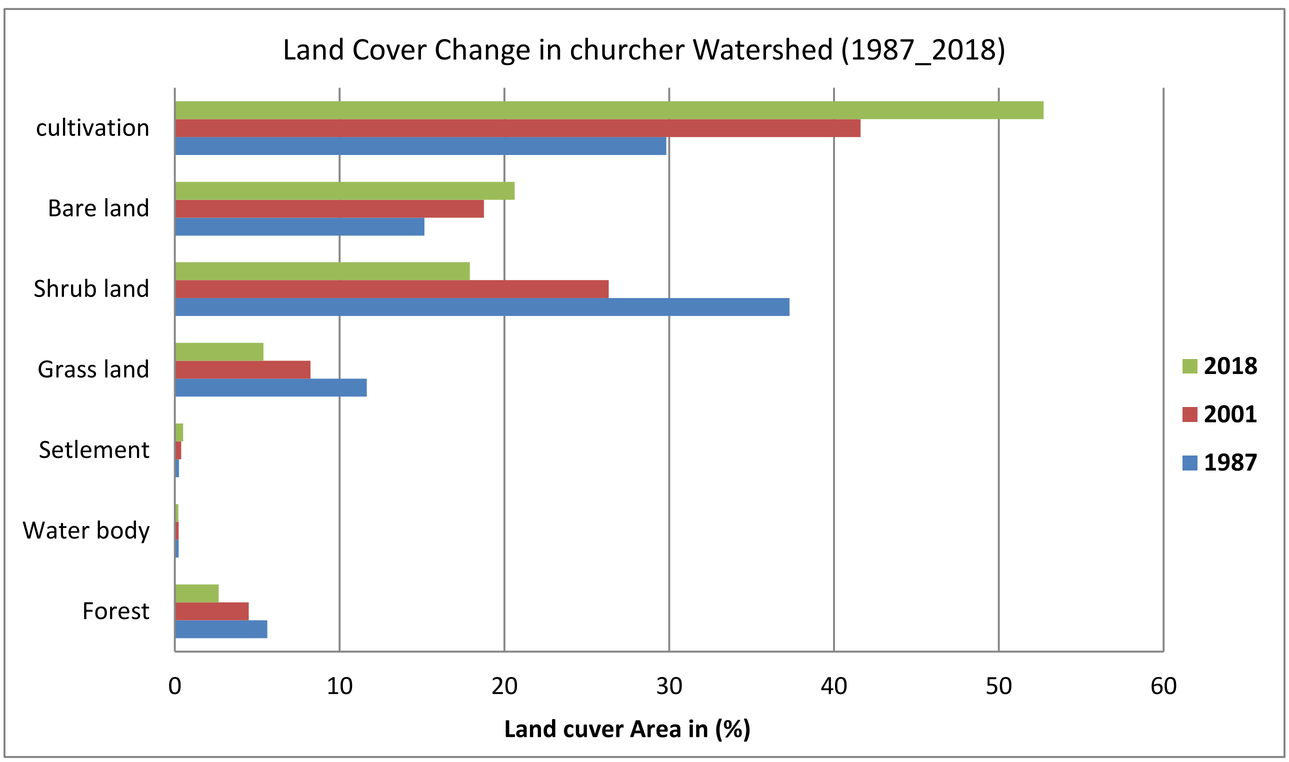

Figure.4.2: the magnitude of LULC changes during 1987-2018 in percent

The following bar graph illustrates size of each land use land cover classes during 1987, 2001 and 2018. During the periods 1987-2001& 2001-2018, a progressive increase in size of the land cover classes is observed for settlement, cultivated land and bare land. But the progressive decrease is observed for grass land, forest and shrub lands. Cultivated lands and bare land are created pressure on other land covers.

4.1.2: Analysis the accuracy assessment of image classification

Accuracy assessment is an important part of studying image classification and thus LULCC detection in order to assessed and estimate the changes of land cover accurately. Accuracy assessment of land use land cover classification is important to check the compatibility of the produced classification with what actually exists in reality. This gives information to user how reliable the information of the result of image classification compared to ground data. However, it reveals the extent of correspondence between what is on the reality and the classification land use/land cover results. It is important to be able to derive accuracy for individual classification if the resulting data are to be useful in change detection analysis (Owojori, et al., 2005)

The accuracy assessment was conducted by production of references or ground data of land use as from the field as the references. The ground data were collected from maps, aerial photos or visits to the field with help from the GPS system and a part of them was from Google Earth image for 1987 and 2001 image classification. Apart of the data was used as guides for determining training sample. The data used for training sample were separated from data used for accuracy assessment.

The Accuracy assessment of image classification on Landsat image 2018 show that the overall accuracy up to 91.51% and kappa coefficient 0.88%. It means that 88% of image classification agreed with the reference data. Producer accuracy and user accuracy represents the probability of reference data that is correctly classified and the user accuracy reflect the probability of classified sample truly represents the ground reality.

4.1.3 LULC Change dynamics between 1987 and 2018

Changes in land cover driven by land use can be categorized into two types: modification and conversion land use change detection evaluation of study area was determined by analyzing the LULC maps of the two years in ArcGIS 10.3 by overlaying and intersecting the 1987 and 2018 supervised classified images. The trend and magnitude of change of each land use/ land cover during the period 1987-2018 is shown in figure: 4.3 and the change detection statistics presented by

Table 4.5. 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 Rowe and the final state classes in the columns. This is required for a complete accounting of the distribution of pixels that changed classes. For each initial state class (each rows), the table indicates how these pixels were classified in the final state image. The Class Total column indicates the total number of pixels in each initial state class, and the Class Total rows indicate the total number of pixels in each final state class. The Class Changes columns indicate the total number of initial state pixels that changed classes. The Image Difference row is the difference in the possible reason for increasing in bare land might be degradation of shrub and grass land due to soil erosion and nutrient depletion because of the lack of required soil conservation measures.

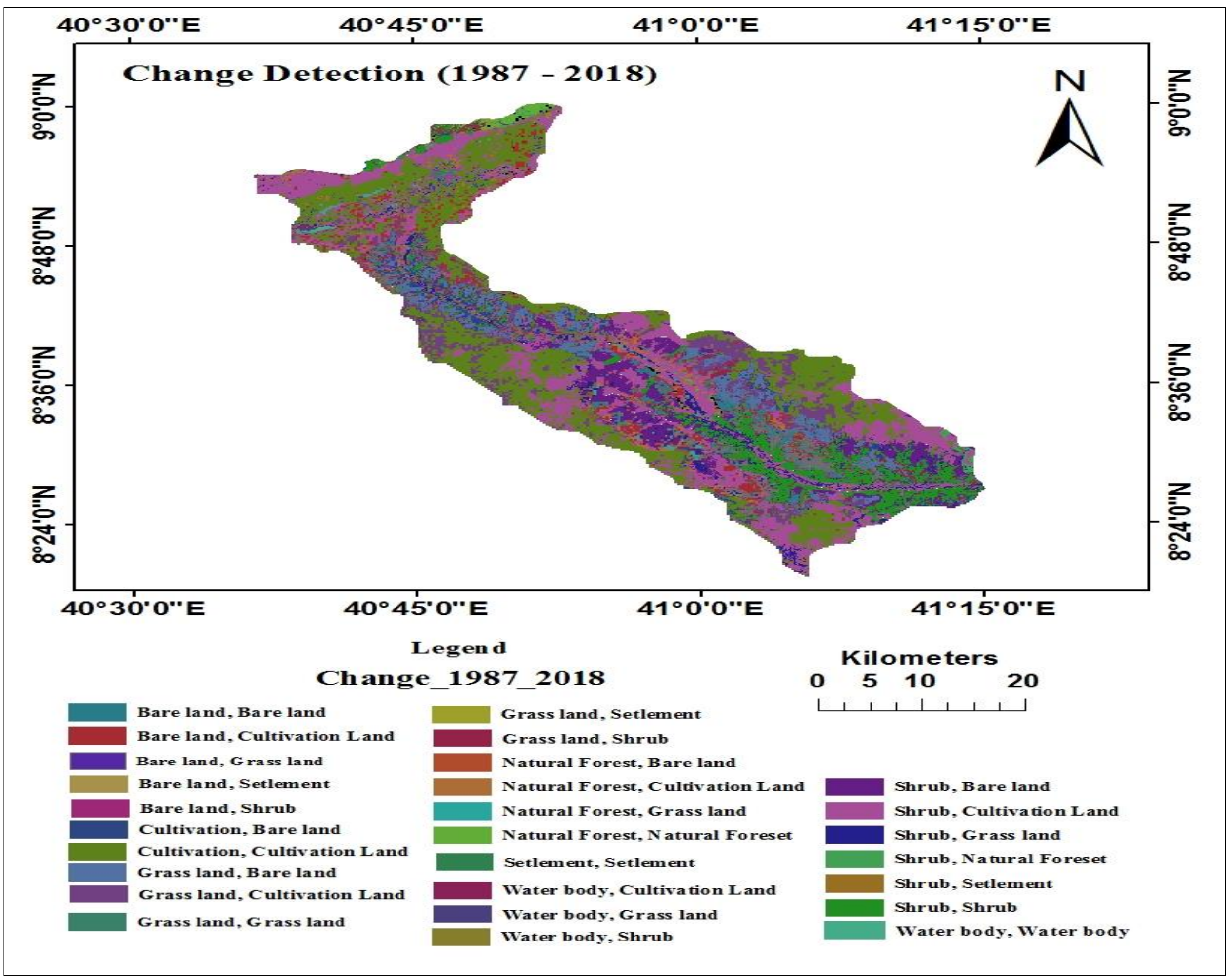

Figure.4.3: Map of land use change magnitude between 1987 to 2018 Chercher watersheds

Table 4.5 Land use land covers change statistics in (km^2) during the period 1987-2018

		Final stage (2018)								
	LU/LC	Grass land	Cultivated land	Bare land	Shrub	Forest	Settlement	Water body	Class Total	Change difference
Initial stage (1987)	Grass land	**33.58**	42.3	91.9	12.18	2.5	0.32	0.05	182.21	149.25
	Cultivation	10	**362.89**	78.06	9.88	3.9	0.9	0.02	465.93	102.76
	Bare land	6.05	145.3	**52.25**	28.9	2.92	0.98	0.3	236.7	184.45
	Shrub	29.94	240.78	76.92	**225.28**	8.95	0.86	0.03	582.76	357.48
	Forest	3.69	39.37	13.98	14.07	**15.08**	1.38	0.01	87.58	72.50
	Settlement	0.02	0.23	0	0	0	**3.52**	0	3.77	0.25
	Water body	0.88	0.9	0	0	0	0	**1.9**	3.68	1.78
	Class Total	84.16	831.77	313.11	290.31	33.35	7.96	2.31		
	Image Difference	-97.76	365.84	77.02	-292.57	-55.07	4.19	-1.33		

Total number of equivalently classed pixels in the two images computed by subtracting the Initial State Class totals (1987) from the final State class totals (2018) An Image Difference that is positive indicates that the class size increased and a negative indicates decrease in class size.

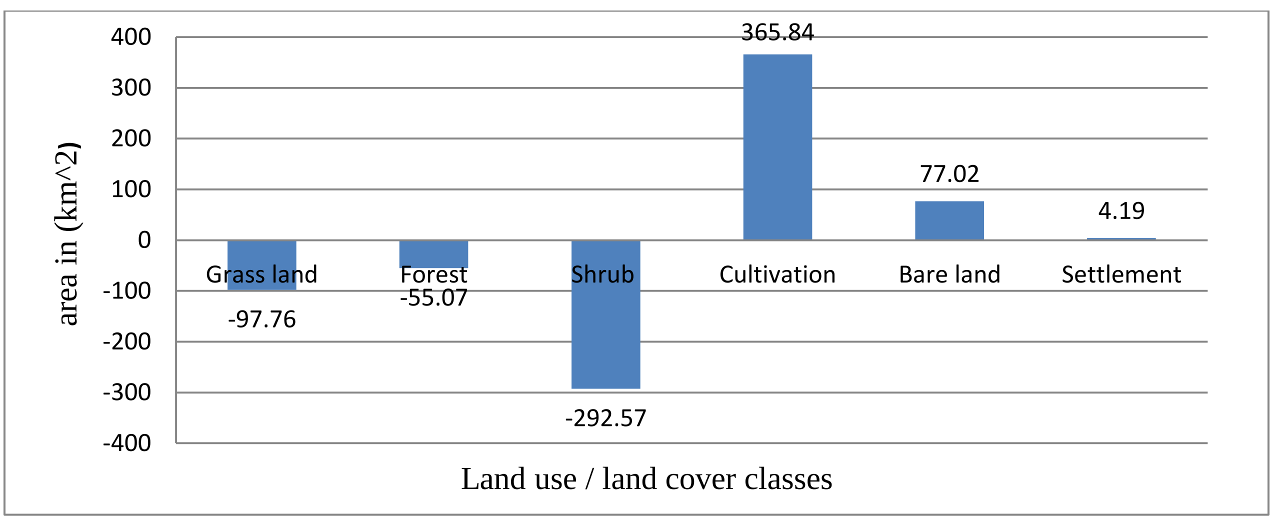

Figure 4.4: The magnitude of LULC changes during 1987-2018 in km^2

Figure.4.4 shows that land covers land uses of settlement, cultivated land, bare land were increasing while grass land, shrub land and water body were decreasing during the period 1987-2018. The cultivated land increased with the highest magnitude while Shrub and forest land decreased with the highest magnitude in the same period. In Table 4.4, unchanged areas are shown in diagonal cells. In general Rows describe at what expense the new cover classes are established. Let us consider the contribution of bare land, grass land, water body, forest and shrub land to cultivated land by the following graph.

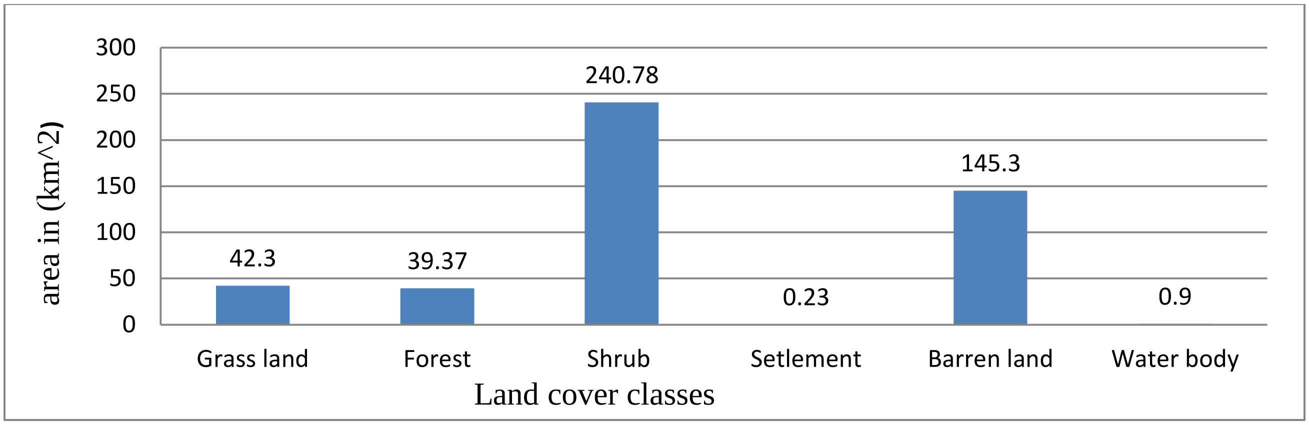

Figure.4.5: Area of different land covers in km^2 converted to cultivated land during the Period 1987-2018.

In 2018 cultivation land increased to 831.77 km^2 on the expense of other land covers /land use shrub and bare land contributed much more than any other land covers for cultivation land. When we consider bare land, it was 236 km^2 in 1987, but it increased to 313.11km^2 in 2018. The land covers which contributed for the increment of bare cover were grass land, Shrub land, and cultivated land and Forest lands. From table 4.4 it can be considered that there is no contribution of water body and settlement to bare land.

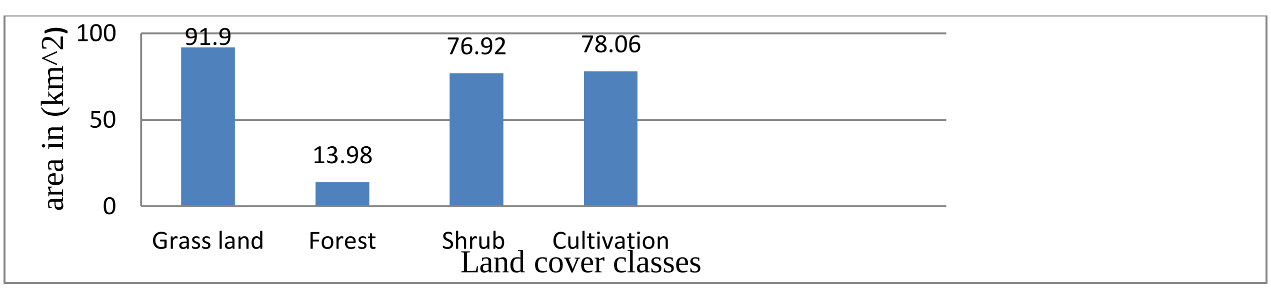

Figure.4.6: contributions of other land cover classes for increase of bare land.

In 1987, shrub land was 357.48 km^2 but it decreased to 290 km^2 in 2018 because of its conversion to grass land, cultivated land, and bare land.

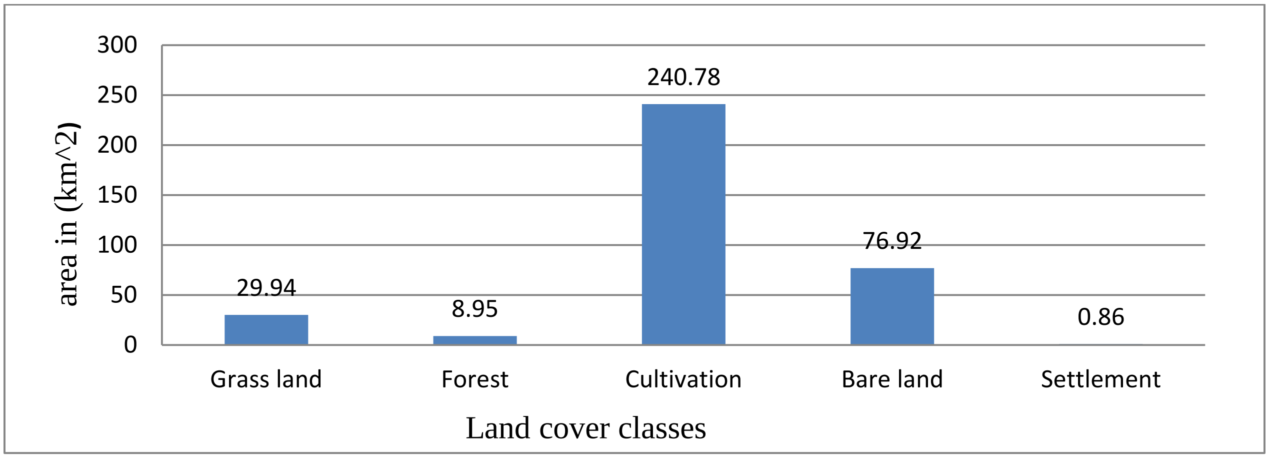

Figure.4.7: Area of land cover/land use converted from shrub land to other land covers during 1987-2018.

4.1.4: Factors of RUSLE model

To run the RUSEL model in GIS environment, first rainfall raster layer, soil, slope, Digital Elevation Model (DEM), and also layers of land-cover were created. Each of the involved factors was calculated in separate units in the study watershed level. To identify the spatial pattern of potential soil erosion in the study area, all the considered erosion factors (R, K, LS, C and P) was surveyed and calculated depending on the recommendations of (Hurni et al., 1985) to Ethiopian context and other related studies.

4.1.4.1. Cover (C) factor

The crop management factor represents the ratio of soil loss under a given crop to that of the bare soil (Morgan, 1994). In this research, the land use land cover is the variable to show its potential impact on soil erosion. The land use land covers of the two years (1987 and 2018) were used to determine the c-value. After changing the coverage to grid, a corresponding C-value was given to each land use classes (Table 4.6). Then, Rasterization and Reclassification method in ArcGIS10.1 were used in order to make suitable for model input and thematic map generation. The value of C-factor as shown in figure: 4.8 ranges from 0 – 0.6 which is estimated from different literatures listed in Table 4.6. Thus, based on C-factor the large value shows more vulnerable land use to erosion on the other hand the lower value shows less vulnerable land use for erosion. From the result bare lands have a large value of C-factor which is highly vulnerable to erosion. Next to bare land Cultivation are more vulnerable than the others. Grass lands, shrubs and forest having the C-factor value 0.05, 0.03 and 0.01 respectively are less vulnerable to erosion.

Table 4.6: Cropping and land-cover C-values

Land Cover Type	**Land Cover Factor**	**Land Cover** Type	**Land Cover Factor**
Dense forest	0.01	Dense grass	0.01
Other forest	0.01 – 0.05	Degraded grass	0.05
Bad land hard	0.05	Fallow hard	0.05
Bad land soft	0.04	Fallow ploughed	0.60
Sorghum, maize	0.10	Ethiopian teff	0.25
Cereals, pulses	0.15		

Source: Hurni (1985), Hellden (1987)

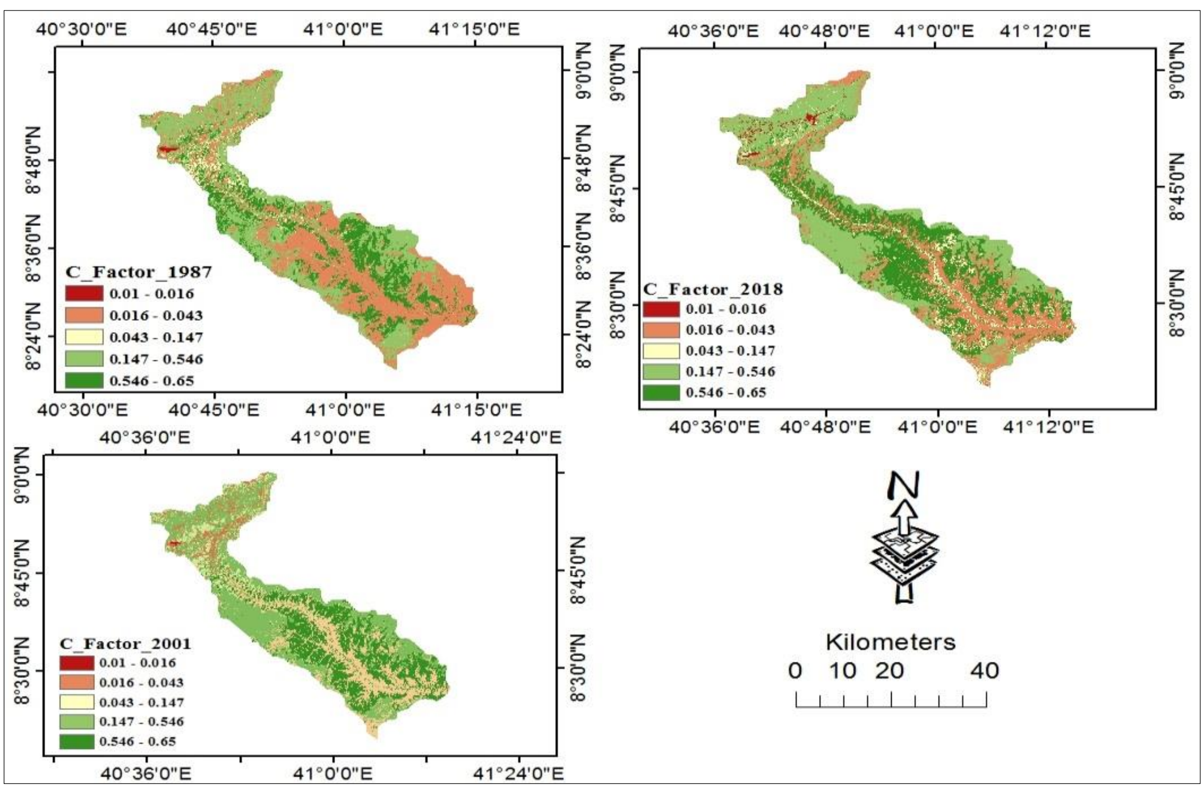

Figure 4.8: The cover factor (C) in 1987 and 2018

4.1.4.2. Rainfall Erosivity (R)

The erosivity factor R was calculated according to the equation given by (Hurni et al., 1985) which is derived from a spatial regression analysis (Hellden, et al., 1987) for Ethiopian conditions. It was based on the available mean annual rainfall data.

R = (0.55*MAP) -24.7 --- (4.1)

Where MAP is the mean annual Precipitation in mm

In this study, historic rainfall data of 20 years (1998-2018) was collected from seven reengages stations (Bedesa, Hirna, Chiro, Asebot, Meiso, Gelemso and Arbabordede) shown in Table: 4.7.

A rainfall map was generated from the average rainfall data of the five stations by using IDW interpolation technique in Arc GIS 10.3 the R-value was calculated from the rainfall map using raster calculator function of ArcGIS. Based on this the rainfall of the study watershed which is ranges from 896 mm - 1111mm has been plotted.

Table 4.7: Average annual Rainfall (mm) of seven stations

Rain gage station	Average annual RF (mm)	Rain gage station	Average annual RF (mm)
Bedesa	1111.04	Meiso	912.12
Asebe	928.8	Bordede	896.05
Hirna	1057.56	Asebot	796.52
Gelemso	966.3		

(Source: National Meteorological Agency)

As it is shown in figure: 4.10, the value of R-factor ranges from 495.5– 616. From this result the higher value which is 616.265 found in the upper part of the watershed shows high rainfall erosivity. Thus based on R-factor value it is more vulnerable to erosion. The lower value of R-factor in the lower part of the study area which is 496 indicates less vulnerable to erosion.

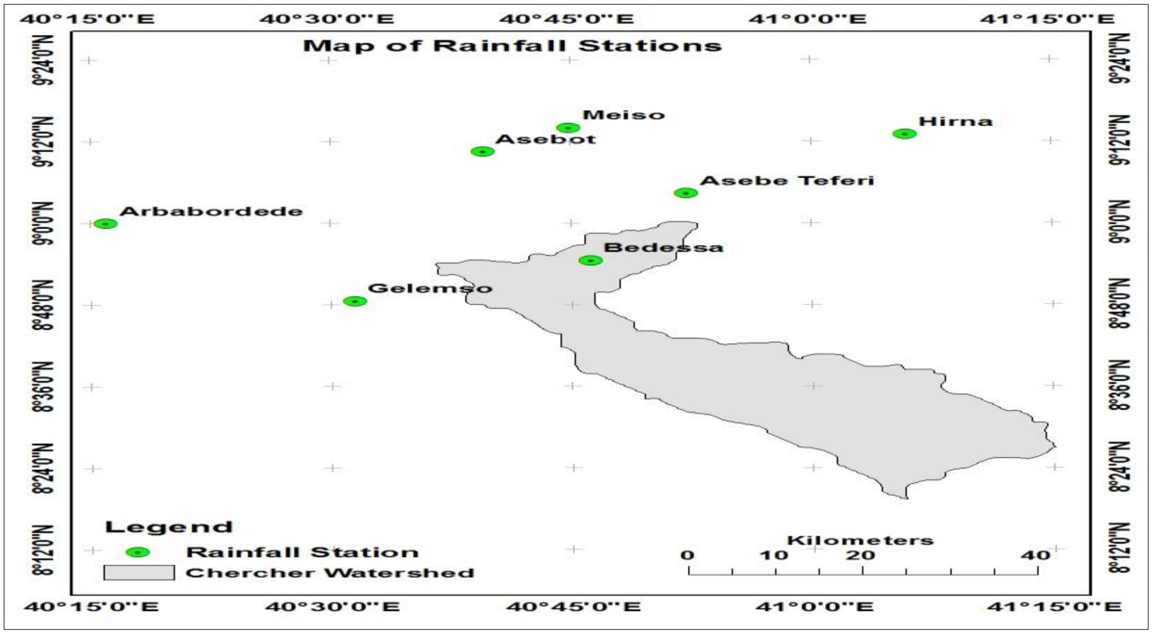

Fig 4.9: Location of the Rainfall station in and around Chercher watershed

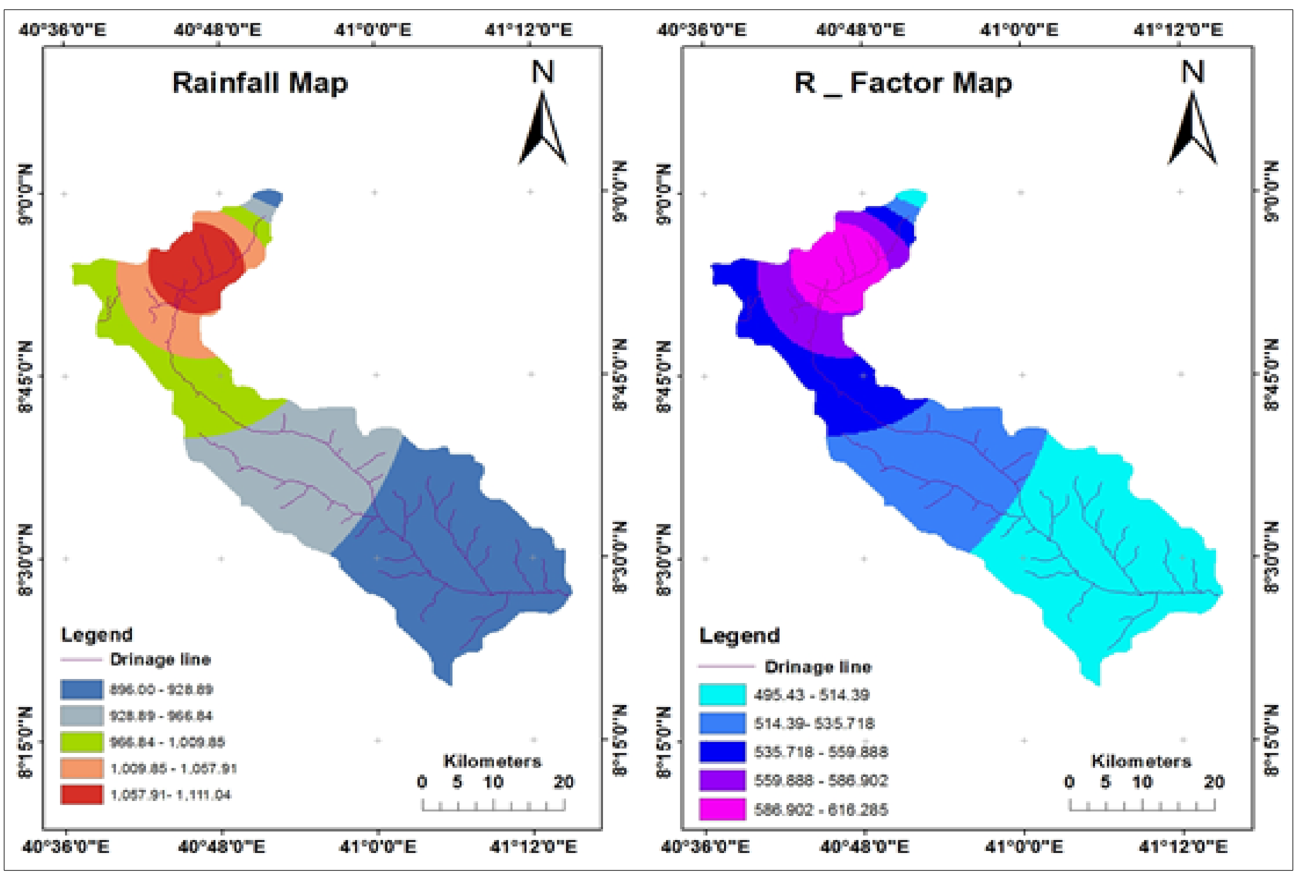

Figure 4.10: Rainfall and R_ factor map of Chercher watershed

4.1.4.3. Soil Erodibility Factor (K) Index

The soil erodibility (K-factor) refers to the liability of the soil to "suffer" erosion due to the forces causing detachment and transport of soil particles (Hellden, et al., 1987). Soil erodibility varies with soil texture, aggregate stability, structural strength, infiltration capacity and organic matter and chemical content of the soil (Morgan, 1995). Soil erodibility factor, K value is become with which a soil can be eroded. In the RUSLE model the 'K' factor is determined from the soil erodibility detailed information from values of percent of silt and very fine sand; percent of organic matter content; topsoil structure grade; and permeability grade.

For Ethiopian condition an attempt was made to classify the soil types of the study area based on their color by referring the FAO soil database.

Table 4.8: Soil Erodibility factor (Modified from Hellden, 1987)

Soil color	Black	Brown	Red	Yellow	Grey	White
K factor	0.15	0.2	0.25	0.3	0.35	0.40

In this study the vector format soil map of the FAO (1996) classification was clipped by the study area and converted into raster grids. After assigning values for each soil types the soil map was reclassified with a grid map using adopted K values shown in table: 4.8 (Kaltenrieder, et al., 2007). From figure: 4.11 the largest portion of the study area covered by Eutric cambisols (89.2%), Vertic luvisols (4.89%), Leptosols (4.5%) types of soil. And 1.7% of the study area is covered by other soil types**.**

The value of k-factor in the study area ranges from 0.15 to 0.28. The high k-factor value is shown in Calcaric flubisols major soil type which is found the middle and lower parts of the watershed and the largest portion of low value is shown in the upper side of the watershed which is Liptosoil. From the result, the high k-factor value indicates more vulnerable soil type to soil erosion and the smaller value shows less vulnerable soil type to erosion.

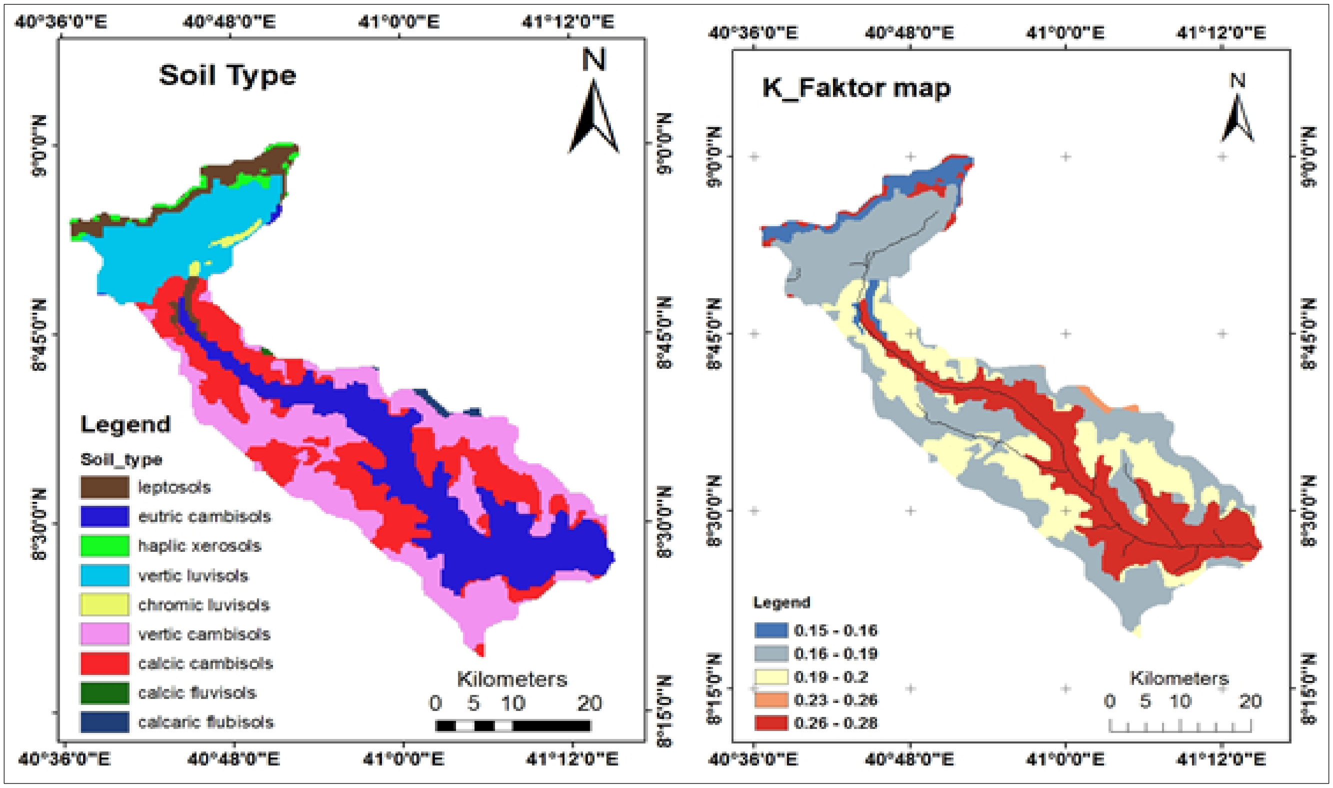

Figure 4.11: Soil type and K factor map of Chercher watershed

4.1.4.4. Topographic (LS) factors

In using RUSLE, the effects of topography on soil erosion are estimated by the slope length (L) and slope steepness (S). It has been demonstrated that increases in slope length and slope steepness can produce higher overland flow velocities and correspondingly higher erosion (Haan et al., 1994).The upslope drainage area for each cell in a Digital Elevation Model (DEM) was calculated with multiple flow algorithms. Multiple flow algorithms can divide flow between several output cells (Desmet & Govers, et al., 1996). The LS-factor was derived from slope and flow accumulation. Slope was generated from DEM using ArcGIS 10.3. To generate flow accumulation which is the unit contributing area first, any spurious single-cell sinks within the DEM was filled to produce a depression less DEM. In this process, individual sink elevations will be flattened. Then by using filled DEM the flow directions of each DEM cell was calculated. From flow directions Flow accumulation was determined. The slope length and slope steepness (LS-factor layer) can be used in a (single index which expresses the ratio of soil loss as defined by (Wischmeier and Smith et al., 1978) Slope Length (L) is given by the following expression

L= (λ/22.13)^{m}, m=F/1+F $$F = \frac{\text{Sin}\beta/0.0896}{3(\text{Sin}\beta)0.8 + 0.56}$$

…………………………………….. (4.2)

Where λ=slope length (m), m=the dimensionless exponential exponent that depends on slope steepness and β is slope angle.

L = (pow([Flowacc]+900,([m]+1))-pow([Flowacc],[m] + 1))/(pow(30,[m] + 2) *pow(22.13,[m]))

Slope Steepness (S)

Using Con toolset in Arc GIS10.1, the value of S was determined by the following expression:

S =Con (tan ([slope] x 0.01745) < 0.09, (10.8 x sin ([slope] x 0.01745) + 0.03), (16.8 x sin ([slope] x 0.01745) - 0.5) -- (4.3)

After determining the L and S for each grid cell, the LS factor was then determined by multiplying the L and S values in ArcGIS 10.3 and a map of the LS factor was produced (Figure 4.13). The value of LS ranges from 0.02 to 18.85.

Then equation (3) and (4) is used in raster calculator as:

LS=pow(flow accumulation*cell resolution/22.13,0.6)*pow(sin(slope*0.01745)/0.09,1.3)-----(4.4)

From the result of LS-factor, the value ranges from 0.02 –18.85. As it is shown in figure: 4.12 based on the mean and standard deviation the LS-factor was classified into five classes four micro-watersheds (MW-1, MW-2, MW -19 & MW-21) are in very high class of LS-factor (MW-3, MW-7, MW-12, MW-15, MW-17& MW-18) covering the class of high LS-factor. Thus, in the base of LS-factor these two classes are more vulnerable to soil erosion.

Table 4.9: LS-factor classes and their distribution in the watershed

No	LS-factor class	LS-class range	Micro watersheds	No. of micro watersheds	Area (km^2)	% total
1	Very low	0.62 - 1.18	6,9,10,11,25	5	189.51	12.13
2	Low	1.18 - 2.06	8,13,20,23,24	5	334.66	21.42
3	moderate	2.06 - 2.79	4,5,14,16,22	5	319.38	20.44
4	High	2.79 - 3.70	3,7,12,15,17,18	6	35.62	36.05
5	Very high	3.70 - 4.72	1,2,19,21	4	155.51	9.95
Total				25	1562.6	100

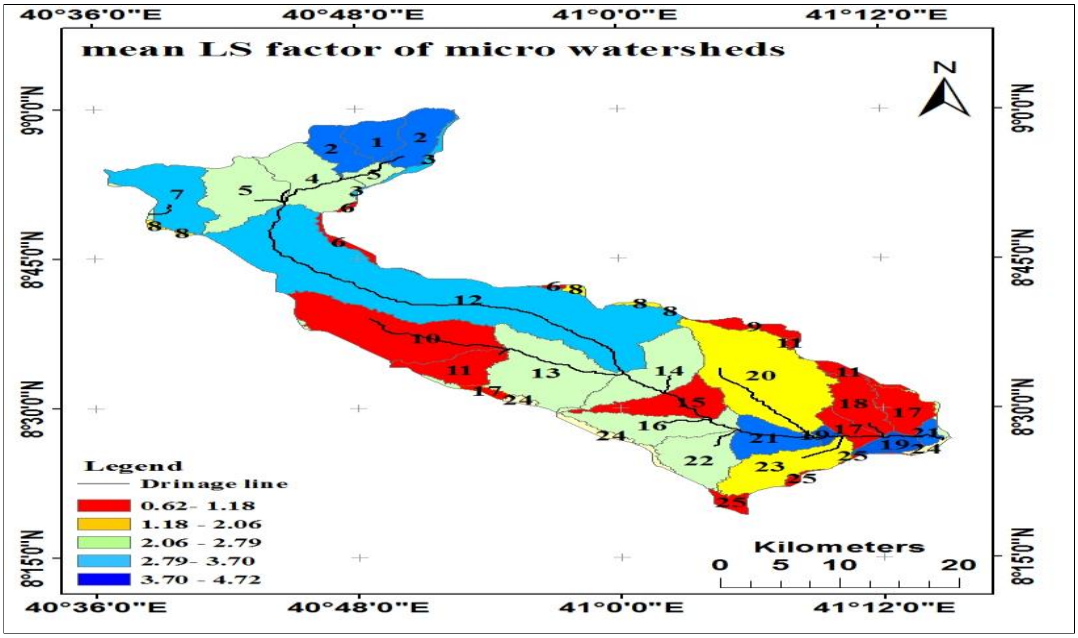

Figure 4.12: mean LS factor of the micro watersheds

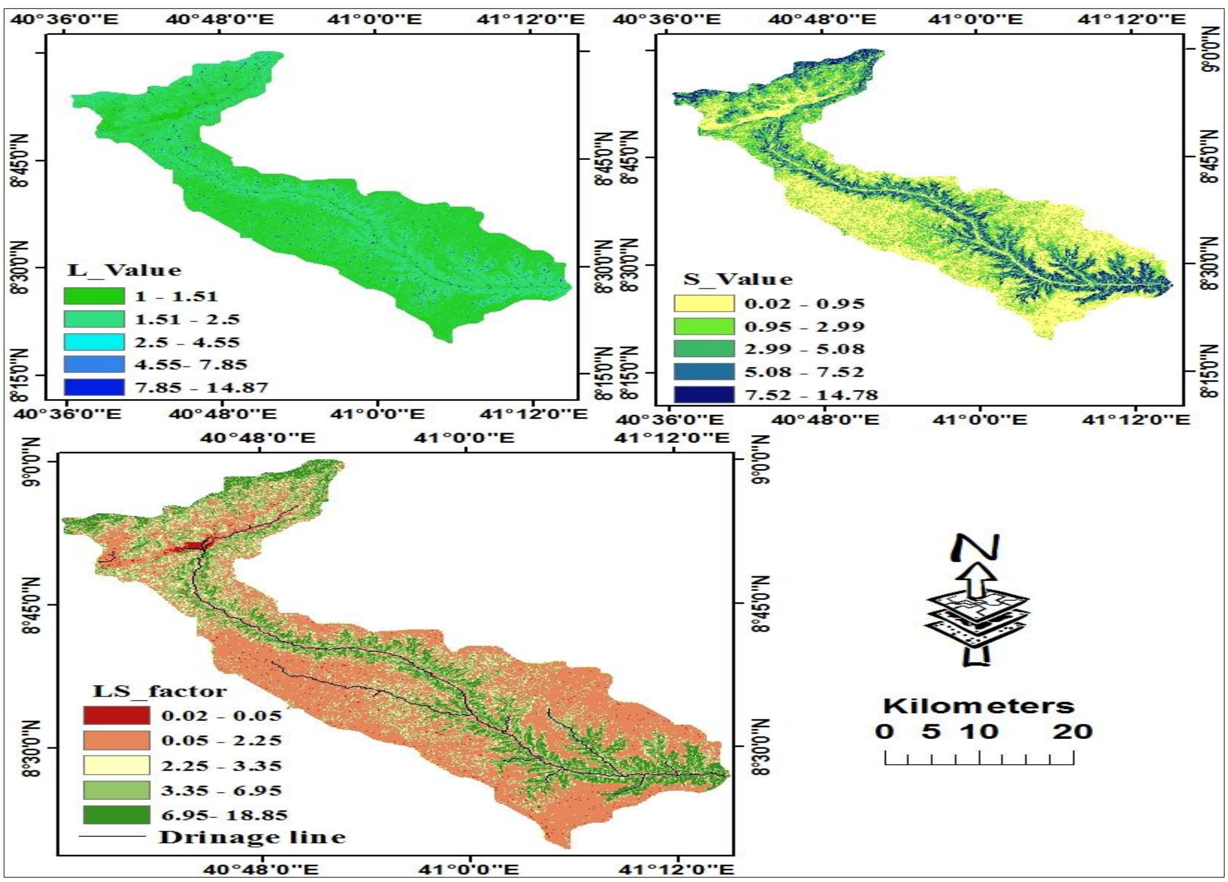

Figure 4.13: LS factor map of the study area

4.1.4.5. Conservation practice (P) factor

The management practice factor P indicates the effect of conservation practices on soil erosion, where in the land which has adequate conservation interventions. Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff (Renard and Foster, 1983). Values for this factor was assigned considering local management practices and based on values suggested in (Hurni et al., 1985). Hurni put parameters for different land management practices on cultivated land though these are more suited to small-scale mapping than regional or basin-wide erosion hazard assessment since areas with different land management practices such as contour ploughing cannot be mapped out at this scale. Especially in agricultural areas, conservation practices such as contouring, strip cropping, or terracing, reduce soil losses. For instance, in areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. The effectiveness of such practices is often analyzed with a support practice factor (P-factor) which is defined as the ratio of soil loss with the practice applied and up- and down slope cultivation (Wischmeier and Smith, 1978; Renard et al., 1997). These management activities highly depend on the slope of the area (Wischmeier and Smith, et al., 1978) and the slope classes of the study watershed is shown in Figure 4.14. P-values have been assigned to land use classes by delineating the land in to two major land uses, agricultural land and other land. The agricultural land sub-divided in to fore classes based on the slope percent (Table 4.10). As data were lacking on permanent management factors and most soil conservation support practices being utilized in the study area are not functional due to lack of regular maintenance, in this study has therefore used these parameters for land support practice mapping. As a result the classified LULC map has been changed in to vector format and the corresponding p values were assigned to be ranges from 0.11 to 1 to each land use/land cover classes and the p factor map was produced (figure 4.15).

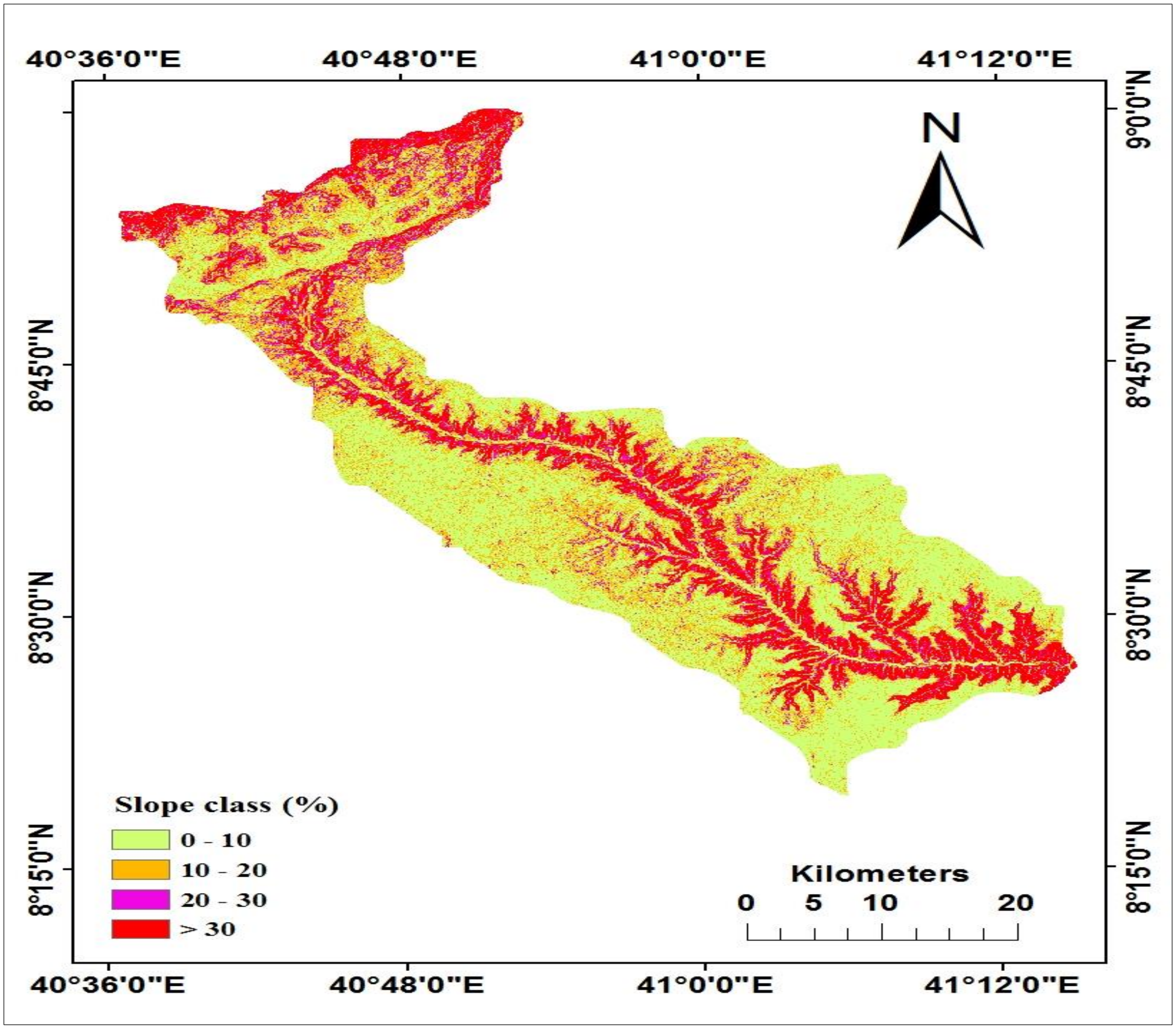

Figure 4.14: Slope classes of the study watershed

Table 4.10: Values of Erosion Control Practices (P-value) for the two Land use categories

Land use type	Slope (%)	P-factor
Agricultural land	0-5	0.1
	5-10	0.12
	10-20	0.14
	20-30	0.19
	30-50	0.25
	50-100	0.35
Other Land	All	1.00

Source: Wischmeier and Smith, 1978

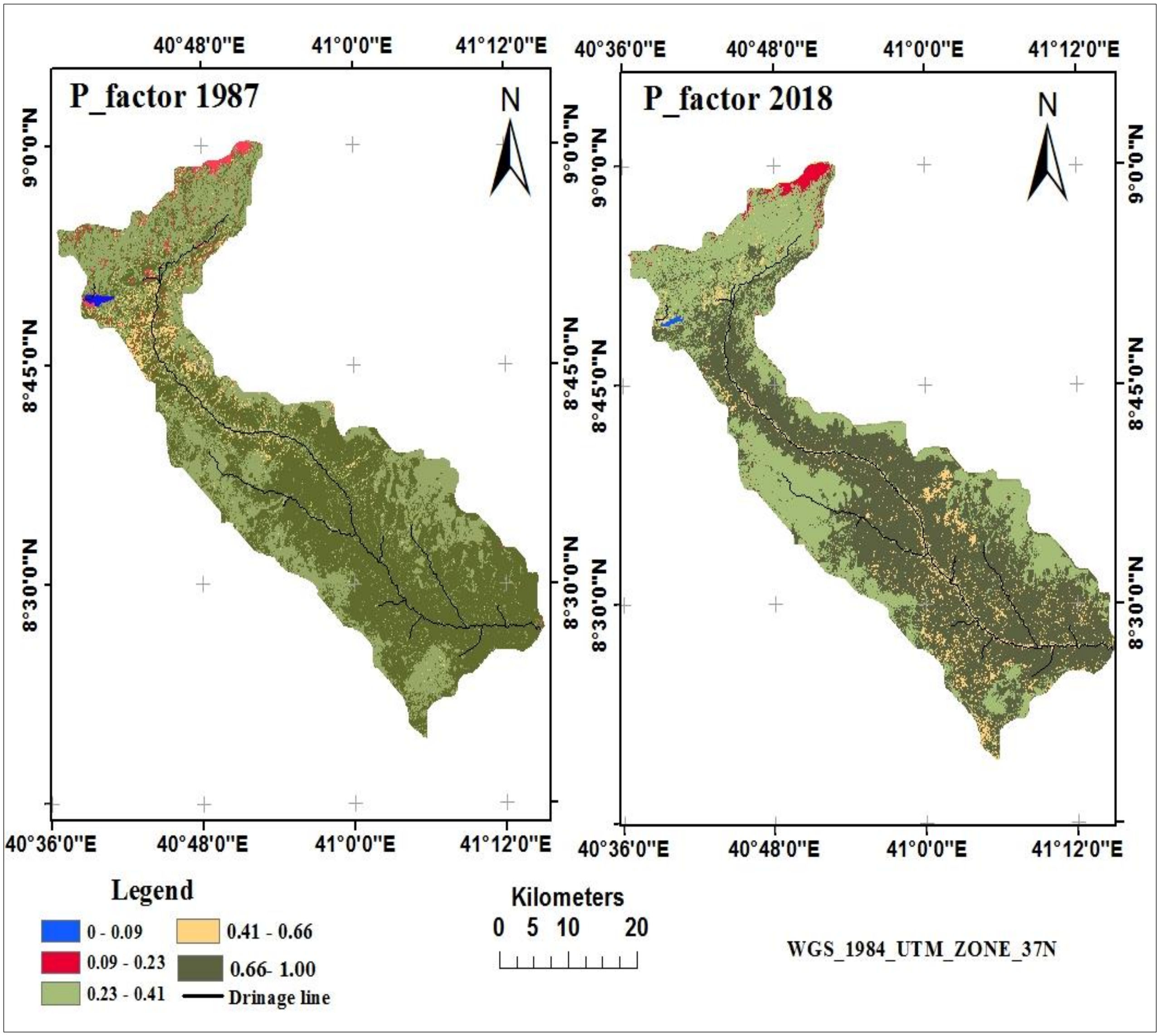

Figure 4.15: P-factor Maps of the study watershed in 1987 and 2018

4.1.4.6. Data Quality assessment

The validity assessment was done during the estimation of each factors of RUSLE so that a quality output could be obtained and in order to prevent introduction of wrong input through specific type of factor estimation which may lead to wrong output and conclusion. The attempts made to increase quality of output in generation of each factors is elaborated as follows.

R factor: The rainfall stations which are within the altitudinal range to the study area are used. Those stations which have high range of mean rainfall were rejected.

K factor: Since the erodibility of the soil is affected by soil type, texture and organic matter content, an attempt was made to include these parameters

LS factor: DEM of 30 m resolution was used instead of 90 m which results better output. In addition the result obtained by the equation (4.4) was cross checked with by the output obtained by equation (4.3) and (4.2) and found almost the same result.

C factor: The supervised classification of LULC was done with higher overall accuracy

P factor: collection of primary data for soil conservation practices using informal interview of Natural resource experts and Development Agents who work in the study are.

In an attempt to validate the soil loss estimated by the RUSLE models their values were compared to the recorded value from the field runoff plots. Although, it could not be acceptable to compare exact figures it can be expected that tendencies should be comparable. It should however be noted that the soil loss recorded from the field small trays doesn't normally represent the hole area field conditions.

The RUSLE has been used widely all over the world either in the same or modified forms (Tiwari et al., 2000), (Hurni et al., 1985) also used this model to assess soil erosion in Ethiopia. He even modified some factors of the USLE for the Ethiopian conditions. Three of the most significant modifications include R (rainfall erosivity index), C (land cover) and P (management factors) factors. This was a valuable input to the erosion and soil conservation research in Ethiopia since the 1980's.

The study was conducted at the experimental field of Alemaya University, Ethiopia, during the 2002 rainfall season. The geographical location of the site is 08°56'N and 40°52'E these location included in these study watershed. The mean annual rainfall for the last 22 years was 845mm. Dominant crops in the area include sorghum, maize, and wheat. Chat (Catha edulis) is also commonly grown in the area. The experimental plots were constructed on cultivated lands with slope gradients of about 8 -10% before the onset of the rainfall season. Runoff plots of 10m long * 2m wide were bordered by corrugated iron sheets which were inserted into the soil to a depth of 20 cm leaving 25 cm above the soil surface to prevent lateral flows from the plots to the adjacent area. The layout of the runoff plots is shown in Fig.4.16 A.

A. Experimental setup of the runoff plots

B. Runoff collectors

Fig. 4.16: Illustrations of (A) experimental layout of the runoff plots and (B) accessories for runoff collection

Runoff and sediment loss were collected in a barrel that was buried in the ground at a distance of about one meter from the lower end of each erosion plot. Each erosion plot was connected to a barrel through a hose of iron sheet. A cubic can having a diameter of 20 cm. was hanged in the barrel to collect runoff and sediments of small volumes (Fig. 4.16 B). Run off in excess of the cans were collected in the barrel. The top of the barrel was closed securely to prevent entrance of direct rainfall and any other sediment to make sure that whatever is collected in the barrel comes only from the erosion plots.

Runoff was measured from the runoff-collection cans and barrels after each rainfall event. A rainfall in this study refers to that event which initiated runoff at least on the control plots. After thoroughly mixing the contents of the runoff collectors, a known volume of the effluent was oven dried to determine the weight of sediment. The runoff collecting cans and barrels were emptied and cleaned after each measurement to make them ready for the rainfall event.

Comparison of measured and estimated soil losses under mulching treatments the total soil loss that was recorded from the field runoff plots during the study year was compared with the soil loss values predicted by using the RUSLE models and are presented in Fig. 4.17.

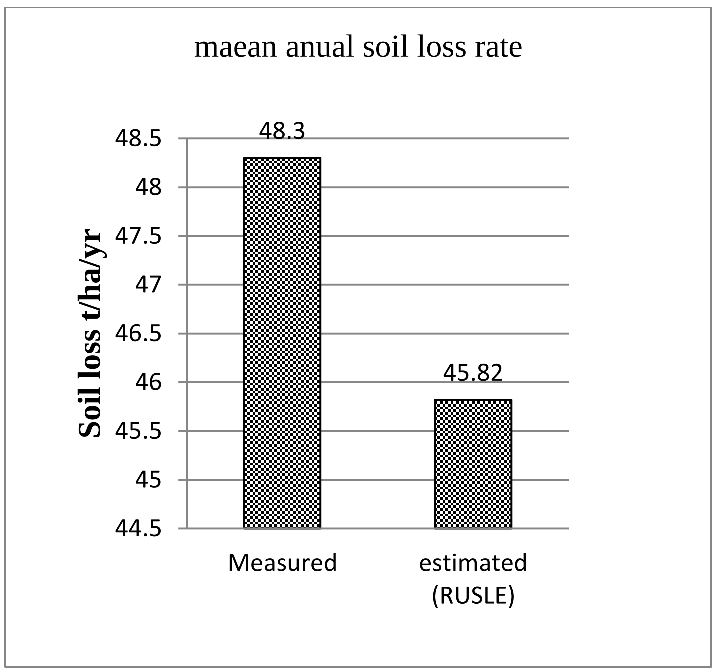

Fig. 4.17: Measured and estimated (by using the USLE models) soil loss (t ha^{-1} yr-^{1}).

The results indicated that the soil loss values that were estimated by using the RUSLE were lower than the measured values. These values are however closer to the measured values. Comparison of measured and estimated soil losses from mulched plots on Almay University revealed that the RUSLE provided more realistic estimates that are closer to the measured values with greater sensitivity to changes in surface cover. The methods and results described in this study provided that valuable for understanding the relationship between soil erosion risk and LULC classes and useful for managing and planning land use that will avoid land degradation.

4.2. Geographic and statistical analyses

After providing required information layers of the model and preparing them as raster maps with pixel size of 30 meters, the map of annual soil erosion potential was extracted. All the four RUSLE parameters temporally remain constant and the values of crop management (C-factor) and support practice (P-factor), which are dependent to each other, change both spatially and temporally. Through integrating ArcGIS10.3 software, the revised universal soil loss equation (RUSLE) was employed to estimate the average annual soil loss potential in Chercher watershed for 1987and 2018. Besides, the zonal statistic tool has been used to calculate the amount of the soil loss potential and to analyses the impacts of each LULC classify on the potential level of the soil loss in Chercher watershed.

4.2.1. Soil Erosion Rate Estimates

The annual soil loss rate of the study area was determined by multiplying the respective RUSLE factor (erosivity (R), erodibility (K), topographic (LS), cover management (C) and conservation support practice (P) factor) values interactively in ArcGIS 10.3 and the result (output) layer was generated which gives the rate of soil loss by erosion at a pixel level in a raster format Using Equation;

$$A = R * K * L.S * C * P.$$

As shown in figure: 4.18 below, the result shows that the potential annual soil loss of Chercher watersheds ranges from 2.54 and 233 ton/ha/year in (1987) and from 4.28 and 189 ton/ha/year in (2018) respectively. The mean annual soil loss rate of the whole study area is 32.91 in (1987) and 45.83 ton/ha/year in (2018); which is much greater than the tolerable level 2-16 ton/ha/year (Hurni, 1983). The annual soil loss of the highlands of Ethiopia ranges from 1248 – 23400 million ton per year from78 millions of hectare of pasture, ranges and cultivated fields throughout Ethiopia. This is equivalent to 16 to 300t/ha/yr (FAO, 1984). The result of this study falls within the ranges of the findings of FAO. Chercher becomes one of the watersheds that contribute a large amount of soil loss in Shebelle basin. Figures 4.18 also show that the areas with high soil erosion potential were mostly located along the foothill regions in the southern part and portions of the central watershed during both years. The maps of soil loss for the years (1987) and (2018) are presented in Figure 4.18

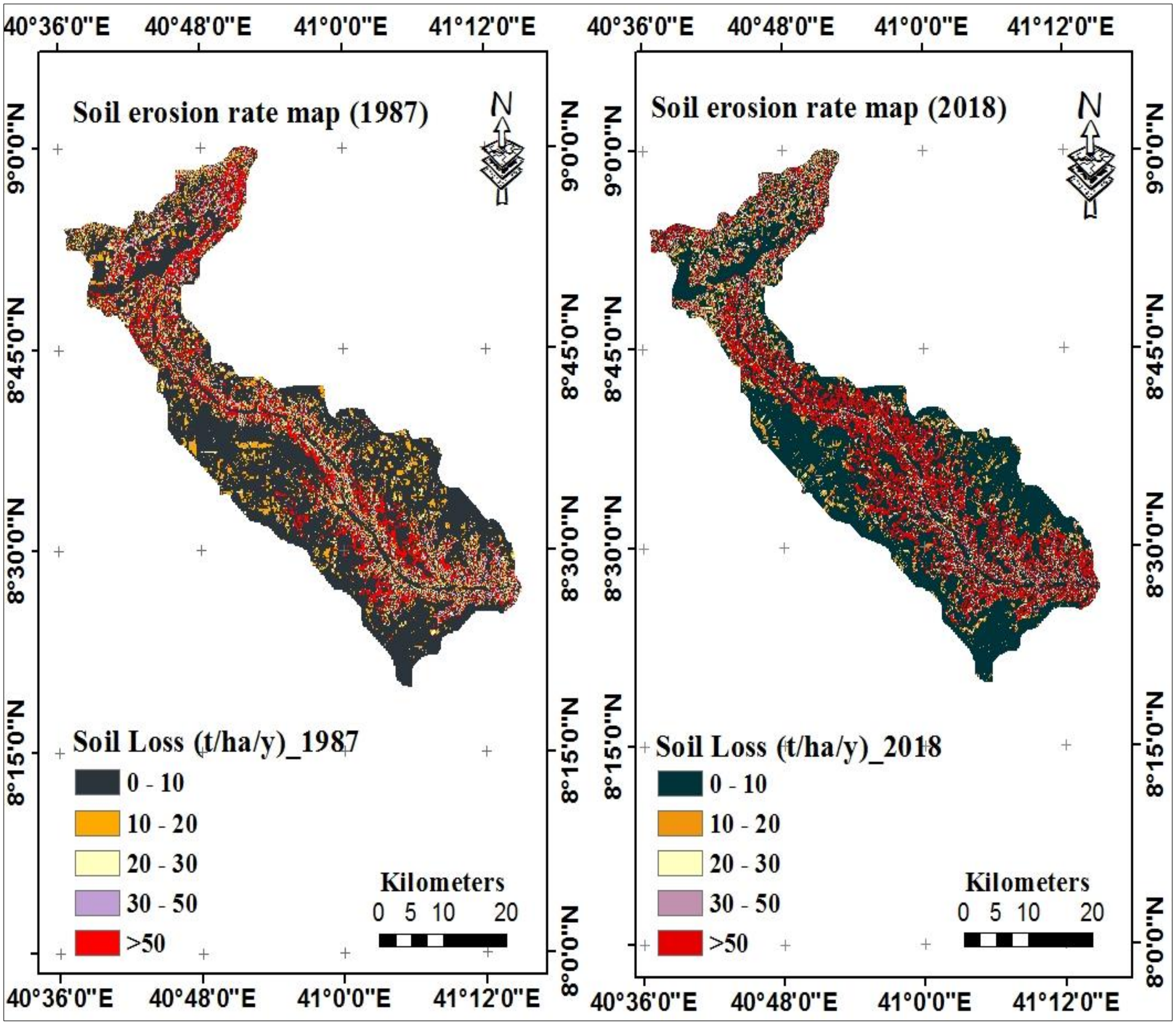

Figure 4.18: Annual Soil Loss Maps of the Chercher Watershed

4.2.2. Erosion vulnerable micro-watersheds Based on Potential Soil Loss rate

The total watershed was sub-divided into 25 major sub-watersheds (Figure 4.19) in order to identify the vulnerable micro-watersheds intermesh of soil erosion within the watershed. The ranks of Sub watersheds have been given on the basis of mean soil loss t/ha/year. Some micro-watersheds may get highly vulnerable to soil erosion due to various reasons. One of the major reasons for this is the intensity of land degradation (Trimphati, et al., 2003). According to the result, there has been observed very high soil loss in the upstream mountainous and in the hilly parts of the study watershed (Table 4.11). In this study, identification of vulnerable micro-watersheds on the basis of soil loss rate was done. Thus, the mean soil loss rate of the micro-watersheds area listed in below in table: 4.11.

Table 4.11: Classification of micro-watersheds based on soil loss

Erosion Risk Class	**Mean soil loss (t/ ha/yr)**	**Micro watersheds**	**No. of MWs**	**Area (km2)**	**% total**
Low	4.28– 8.53	9,10,25	3	137.66	8.81
Moderate	8.53– 30.47	1,2,3,4,5,6,7,8,11	9	358.18	22.92
High	30.47 – 51.7	16,17,20,22,23,24	6	388.44	24.86
Very high	51.07– 189	12,13,14,15,18,19,21	7	678.33	43.41
Total				1562.63	100

As it is shown in table: 4.10, the value of micro-watershed wise soil loss rate are classified in to four classes which are named as Low, moderate, high and Very high. Thus the very high and high shows relatively more vulnerable low and moderate show less vulnerability to soil erosion.

Out of the 25 ranked sub-watersheds, sub-watersheds 12, 13, 14, 15, 18, 19 and 21 Show in table 4.9 above the annual average soil loss rate (51.07– 189 t/ha/yr) respectively of the entire watershed due to high contribution from C and P factors. As shown in figure: 4.19, out of the 25 micro-watersheds, Seven micro-watersheds (MW 12,13,14,15,18,19 and 21) covering 43.41% of the watershed shows very high soil loss rate it may be due to high contribution of land use change and slope factors. These very high values found in the south west upper, part of the watersheds.

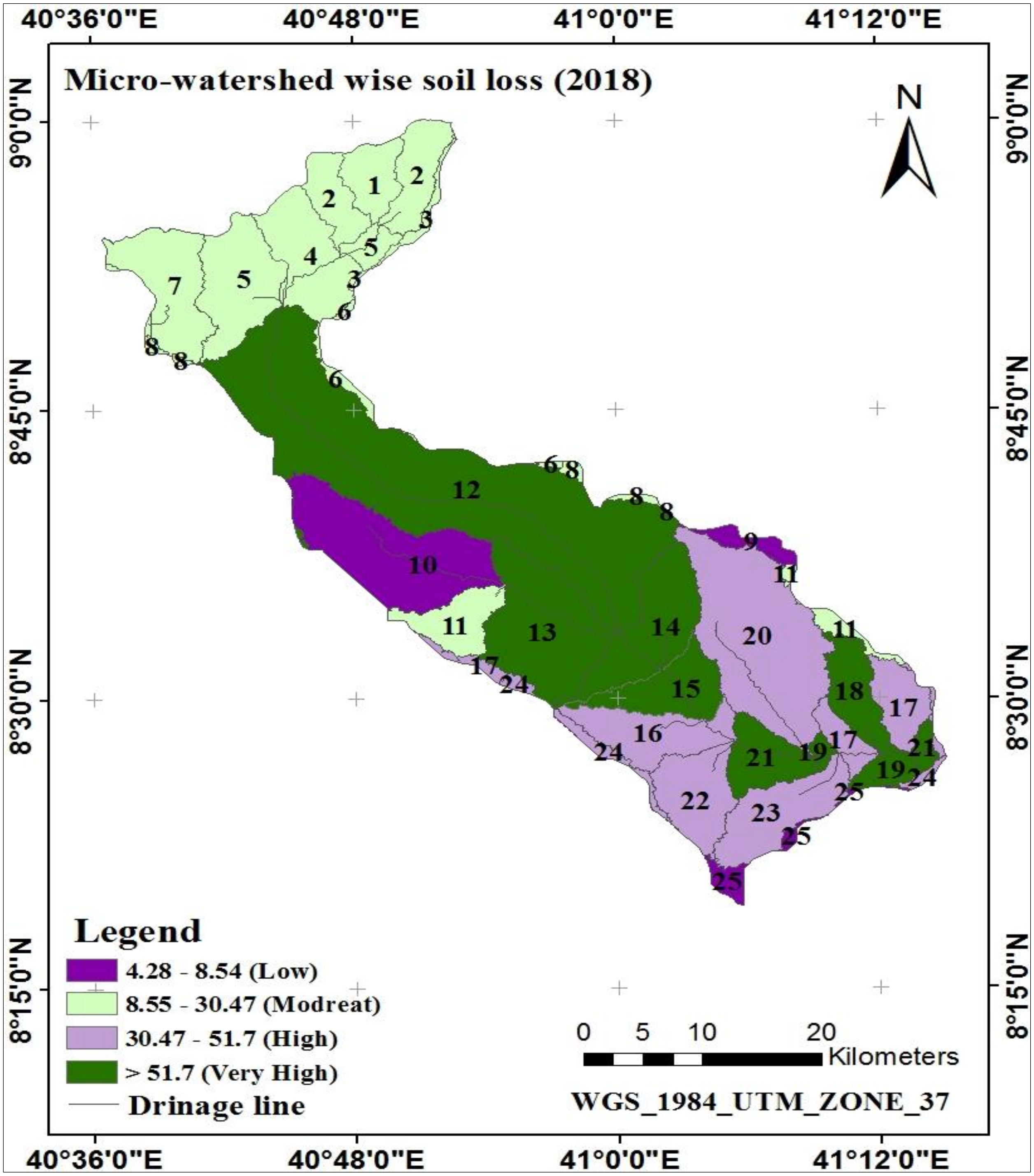

Figure 4.19: Micro-watershed wise soil loss rate map

In the moderate soil erosion rate class there are Nine MWs (MW-1, 2, 3, 4, 5, 6, 7, 8 & 11) and it covers 22.92 % of the study area. Sex micro-watersheds (24.86%) of the watershed fall in the high soil erosion rate class which includes (MW -16, 17, 20, 22, 23 & 24). About 8.81% of the watershed (MW-9, 10 & 25) are found in the low erosion rate class which is below the annual average soil loss of the entire watersheds (45.83ton/ha/year). The micro-watershed under this class is not immediate area of action plan. Based on the annual soil losses, erosion vulnerable micro-watersheds are identified and ranked in ascending order. The micro –watershed that comes first is more erosion vulnerable micro-watershed. Thus priority is given for developing the management plan to reduce the soil and nutrient losses. Based on this MW-12, 13, 14, 15, 18, 19 & 21with mean soil loss between 51.7 and 189t/ha/yr are the most erosion vulnerable micro-watershed and immediate attention can minimize the soil loss rate. Thus it is recommended to adopt the management measures in this erosion class to reduce the soil losses.

4.2.3. Soil erosion potential and Land use Land cover relative to Slope Category

Slope steepness is one of the criteria for the estimation of (R) erosivity potential. Runoff and erosion potential will increases as the slope steepens increase. Based on FAO, 2001 Slopes within the watershed vary from 0% to 180 %, with a mean slope 17%. To explore the effect of slope on soil erosion from a particular LULC, the slope map of the catchment was categorized into four distinct slope categories, shown on Figure 4.21. where Steep slope (>30%), which occurred in the North boundary and central parts of North to South of the watershed; high slope (20–30%), in the central and Northern part, Moderate slope (10–20) in the top center of Norther and East to west; and relatively flat area (0–10%), in the western and east to south region of the watershed.

Figure 4.20: Show that the increased Cultivation land during the study period took place in moderately slope (10–20%) and Steep slope (> 30%) areas of the watershed. The percentage of Cultivation under Low slope (0-10%) of the watershed decreased. the distribution of bare land show much variation under Low slope (0-10%) and Moderate slope (10-20). The percentage of Bare land under High slope (20 -30%) and Steep slope of the watershed decreased in the study duration, table (4.12) shows that distribution of the shrub land area increase on the steep and moderate slope (>30%) in 2018 but the redaction of shrub land at low and moderate slope is High on the conversation of shrub land to agricultural and bare land. However, the percentage distributions of forest area in steep slope as well as High slope (20–30%) increased in 2018 owing to afforestation activities in the top mountain, while in the flat region; it decreased owing to

conversion of forestland to agricultural and bare land the increased human settlement and other built-up land during the study period took place in moderately slope (10–20%) and flat (0–10%) areas of the watershed. the percentage of settlement under steep slope (>30%) of the watershed decreased. the percentage distributions of grass land area decreased in all slope except steep slope the reduction of grass land area is due to conversion in to agricultural and built-up land. The temporal distribution pattern of LULC with respect to slope steepness is presented in Fig. 4.22.

Table 4.12: LULC area distribution in percent relative to slope category

	Grass (%)		Cultivation(%)		Forest (%)		Shrub (%)		Bare (%)		Settlement(%)		Water (%)	
Slope	1987	2018	1987	2018	1987	2018	1987	2018	1987	2018	1987	2018	1987	2018
0 -10%	46.4	42.8	61.8	58.6	40.7	14.4	45.0	34.5	38.3	43.4	47.3	55.3	81.9	77.1
10–20%	34.4	27.9	26.7	27.3	29.8	26.8	29.0	26.6	34.9	35.9	37.6	32.5	17.5	18.0
20 - 30%	12.3	11.6	7.7	9.2	16.7	30.4	14.7	20.1	17.2	13.5	12.0	8.3	0.6	1.1
> 30%	7.0	7.7	3.8	5.0	12.8	28.4	11.3	18.8	9.5	7.3	3.1	3.9	0.0	0.1

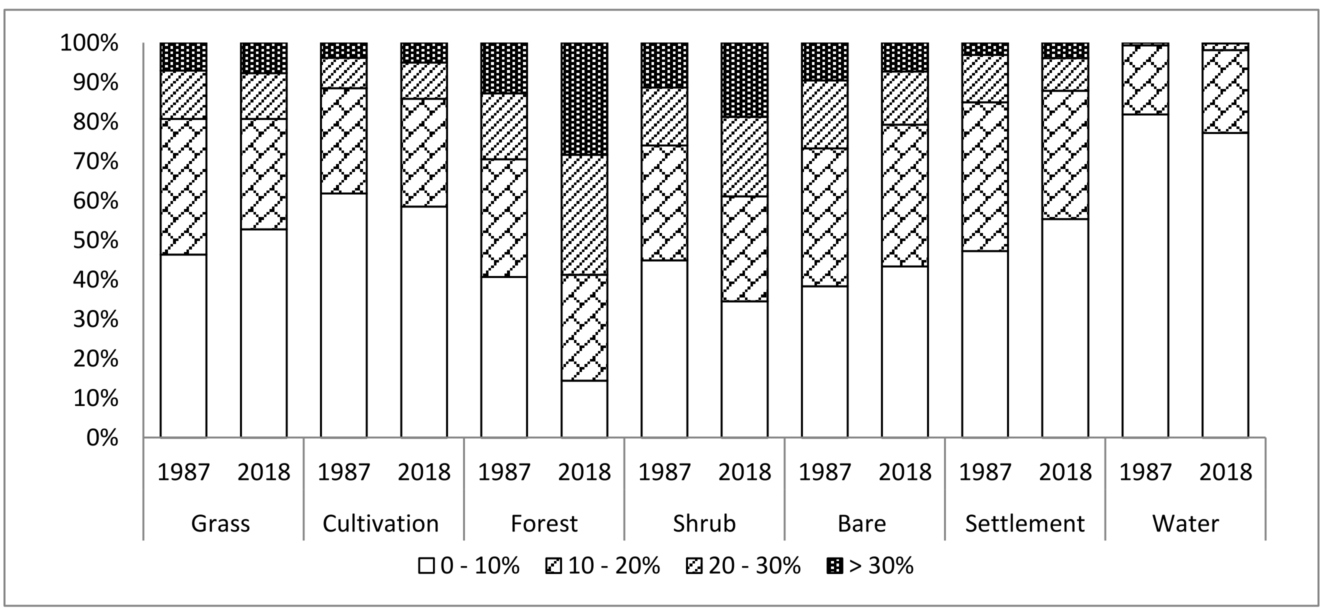

Figure.4.20: LULC distribution relative to slope category

4.2.4. Soil erosion potential and Land use Land cover relative to Soil Category

Soil Erodibility refers susceptibility of soil to erosion. To explore the change in spatial association of different LULC with soil it was reclassified into three categories Fig.4.21. low (0.15–0.185), medium (0.185–0.22), and high (0.22–0.28); Based on their K factor value Soil types having low K factor are less vulnerable to soil erosion and those soils having high K value highly vulnerable to soil erosion. Figure.4.21. show that the distribution of Bare and croplands followed a similar trend during the study period. Figure 4.21 shows that the association of both the LULC categories with medium and high-erodibility soil was higher in 2018 compared to in 1987, which is of very serious in terms of the soil erosion potential of the watershed. In the case of forest, its area were more distributed in low and medium soil erodibility in 2018 compared to 1987,thise indicating best management practices are implemented in the watershed. The distribution of Settlements and grass land covered also increased in high and moderate erodibility in 2018 compared to 1987 Concern in terms of the soil erosion potential of the watershed the distribution of Cultivation land also increased in high- and Moderate-erodibility soil needs to proper management practices taken by the soil conservation institute. The association with forest medium erodibility soil was decreased and Low erodibility soil increased over the same period. In the case of bare land, its area were more distributed in soil of high and medium erodibility in 2018 compared to 1987, indicating needs of best management practices implemented in the watershed. However the distribution of shrub cover also increased in high- and low-erodibility soil owing to proper management practices its association with medium-erodibility soil was decreased over the same period in 2018. .

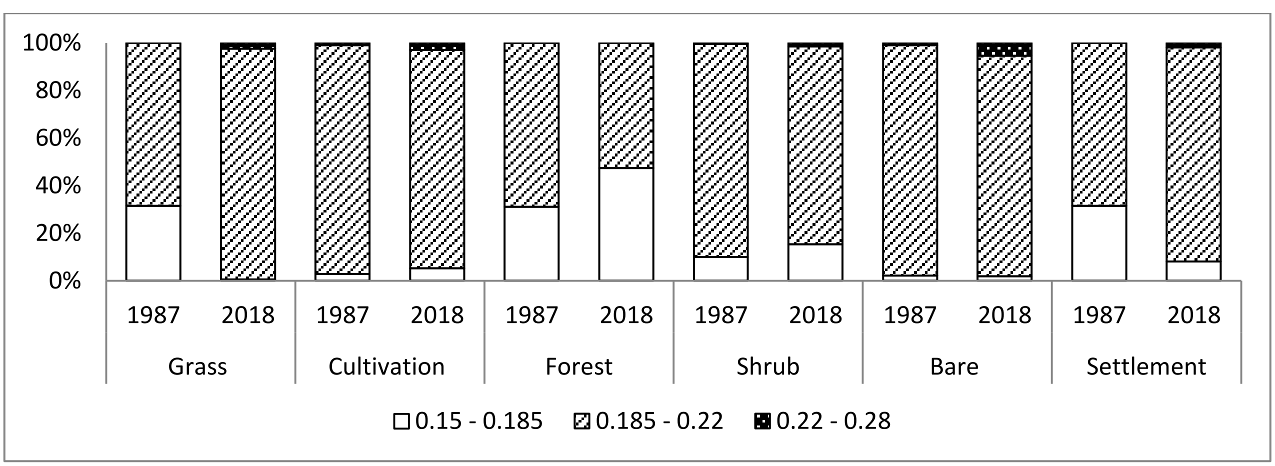

Figure.4.21: LULC distribution relative to soil erodibility category in 1987 and 2018 respectively

The changed association of different LULC categories with slope and soil category ultimately affected the net soil erosion from the different LULC categories as well as the watershed as a whole in the study area.

Table 4.13: Mean slope and erosion intensity for different LULC classes in (1987 and 2018)

Land use/cover	Mean slope 1987 (%)	Mean slope 2018 (%)	Mean Soil erosion 1987 (t $ha^{-1}yr^{-1}$)	Mean Soil erosion 2018 (t ha^{-1} yr^{-1})
Grass land	16.51	15.14	5.291	4.146
Cultivation	11.73	15.53	27.264	38.193
Bare	18.33	16.68	56.468	72.613
Shrub	21.26	27.76	13.719	18.027
Forest	23.94	40.44	9.535	12.144
Settlement	12.51	12.51	14.711	10.697

For this purpose, we calculated the mean soil erosion potential of different land use category. Figure.4.22. shows the mean soil erosion potential and the mean slope of different land use categories for 1987 and 2018. The pattern of mean soil erosion potential in 1987 was in the order of Bare > Crop > Settlement >Shrub >Forest > Grass, but in 2018, it was changed to Bare > crop >Shrub > Forest > Settlement > Grass. Table 4.13 shows the mean soil erosion potential for settlement and Grass land category decreased, while the same increased for croplands, bare land, shrub land and forest lands. The increased mean soil erosion potential of forest lands and Shrub land was due to the loss of forest and shrub in flat areas and replace by bare and cultivation land the same time increasing deforestation in steep mountainous slopes of the watershed.

The mean slope of croplands slowly changed in high slope area during the study period. Thus, the increase in the soil erosion potential of croplands was due to its more occurrences in high erodible soil in 2018 compared to 1987. Thus, the increase in the soil erosion potential of bare lands was high due to its more occurrences in high Slope of the watershed and high erodible soil in 2018 compared to 1987. The reduction in the mean erosion potential of settlement and Grass land is due to the decrease in mean slope in 20118 compared to 1987. However, the mean erosion potential for the whole watershed increased from 32.912 t ha^{-1} $year^{-1}$ in 1987 to 45.83 t ha^{-1} $year^{-1}$ in 2018, which was due to Negative effects of different land transitions.

However, the main reason for this increase in the soil erosion potential of the watershed over the studied period could be attributed to high reduction of forest and shrub land areas and substituted predominantly by cultivation practice and declining trend on the grazing lands and replaced by bare and cultivation land in higher slopes and more erodible soil. Mean erosion (ton $ha^{-1}yr^{-1}$)

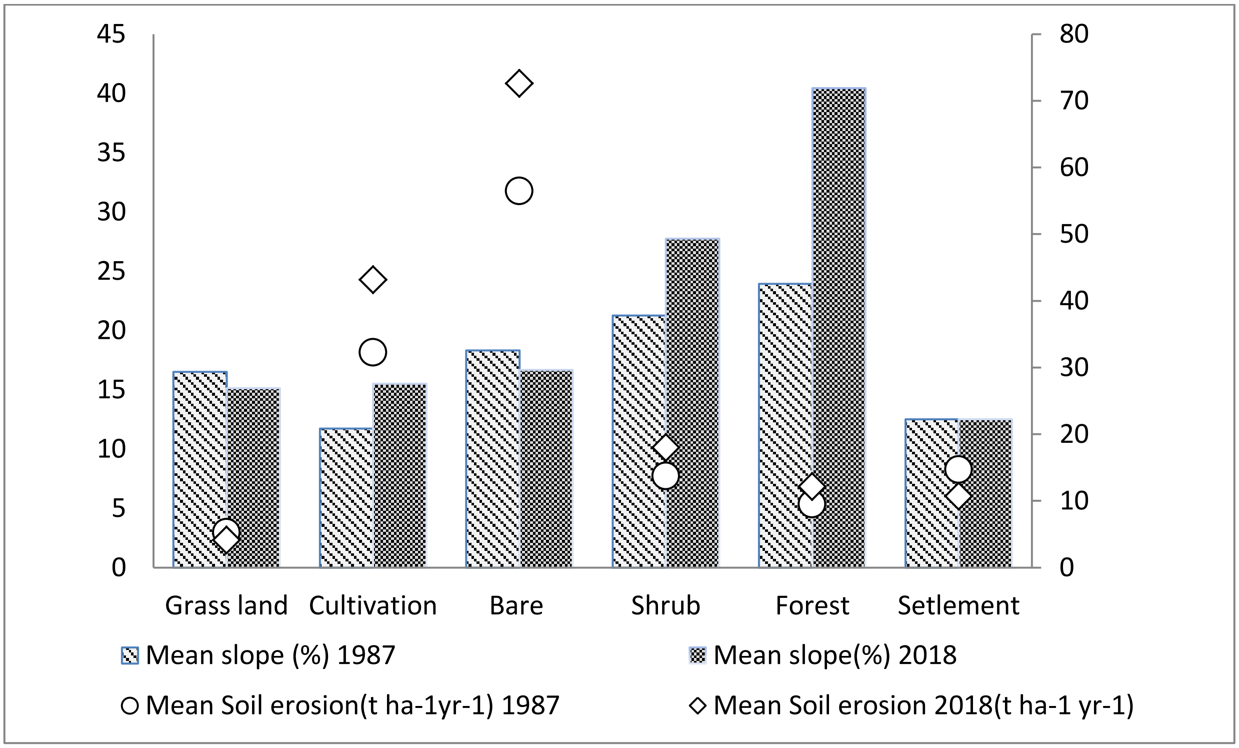

Figure.4.22: Mean slope and erosion intensity for different Land use land cover Classes.

4.2.5. Changes in Soil Erosion potential at Watershed Scale

The magnitude of change in the soil erosion potential and their spatial distribution was represent in Fig 4.23 shows that changes were strongest in Northern mountainous and central sub mountainous regions with high topographic potential during the studied period due to increasing human activities in the steep slope area of the watershed. The relatively flat areas of the western and eastern parts of watershed also had some unchanged where the erosion potential had undergone a great degree of changes. This can be attributed to phenomena such as increased agricultural practices in high erosion-prone soil and to the disappearance of forest and shrub Cavour from that area. This is attributed to the watershed due to increasing human activities. The relatively flat areas of the western and eastern parts of watershed also had some unchanged where the erosion potential had undergone a great degree of changes. This can be attributed to phenomena such as increased agricultural practices in high erosion-prone soil and to the disappearance of forest and shrub Cavour from that area.

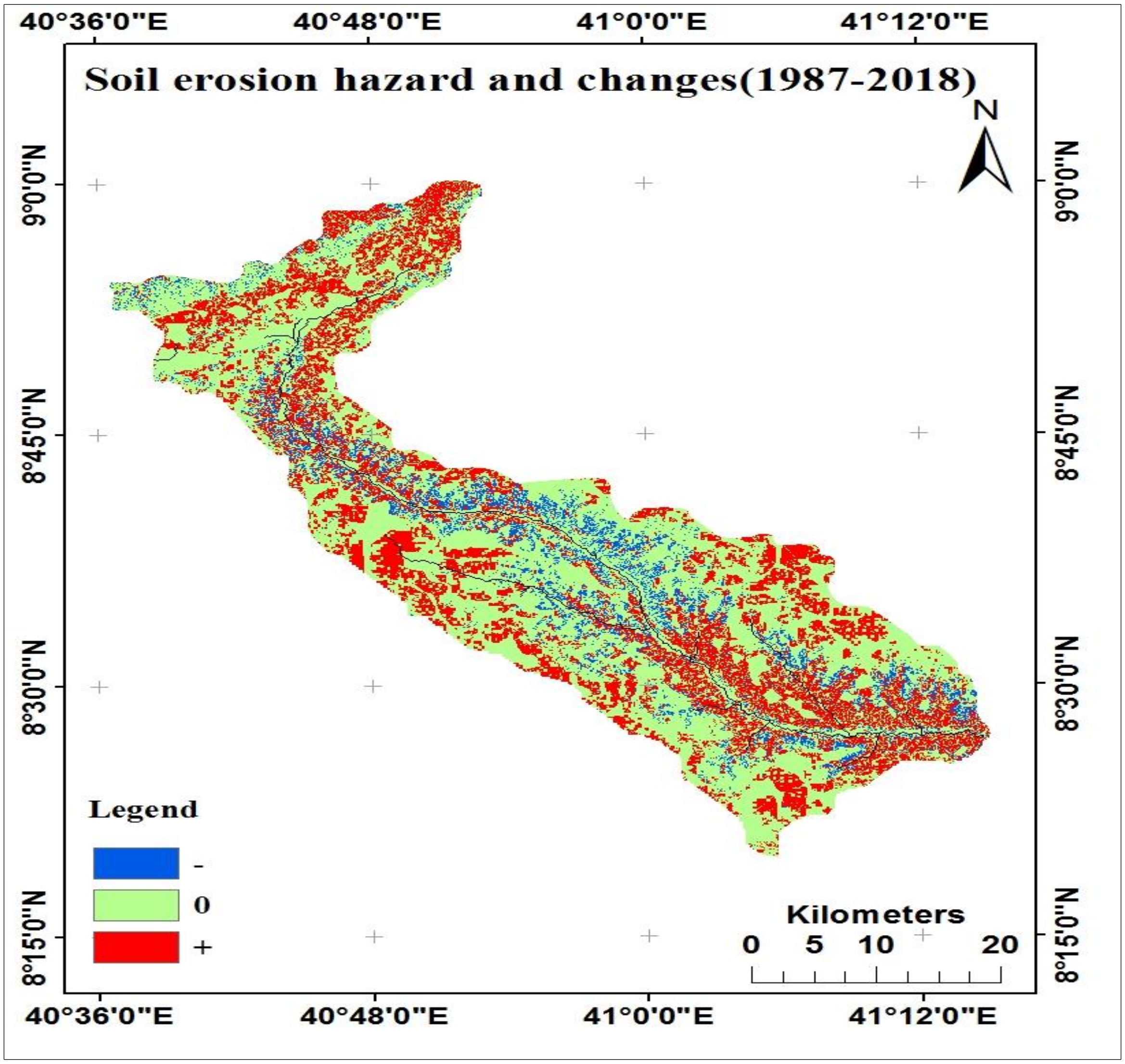

Figure 4.23: Spatial distribution of change in soil erosion potential

Land use changes such as increasing of agricultural activity in vulnerable areas and deforestation were the most dangerous changes, as these make the land more prone to soil erosion. The change mapped further reveals that the soil erosion potential of 225.86 km^2 (14.44%) and 225.85 km^2 (14.44%) of the total watershed area decreased and increased, respectively, while the remaining

71.2% of the watershed witnessed no change. The areas with mainly increase of soil erosion are located in the North and south western parts of the study area (red hues), are characterized by high slope. While the areas with decreased soil erosion are located in the Central parts (blue hues) are characterized by low slope. The other part shows no major change between the two years, and characterized with low rainfall, moderate slope and poor plant coverage.

4.2.6. Soil erosion changes per Each Land Cover

The overlaying of maps those showing the change in soil erosion potential and LULC transition further enabled us to reveal the cause and effect relationship between LULC dynamics and subsequent changes in the soil erosion potential of the watershed.

The results of the superimposition of the land use transitions map and the erosion change map are summarized in table 4.14.below.

Table 4.14: Different land use transition categories and corresponding change in mean erosion potential

1987	2018					
	Grass land	Cultivation	Bare land	Shrub	Forest	Settlement
Gras land	1.13	17.73	98.56	27.40	9.26	20.94
Cultivation	-3.01	2.29	36.14	-15.93	-18.06	-4.14
Bare land	-63.91	-39.78	26.01	-78.09	-79.27	-43.82
Shrub	-5.29	17.82	96.46	3.73	-0.696	14.66
Forest	-0.21	25.66	97.99	18.95	0.92	19.28
Settlement	-10.94	8.45	31.51	-1.96	-1.37	2.91

Table 4.14 demonstrates that most of the areas that experienced a high increase in erosion potential corresponded to the area where Grass lands were converted to bare lands the change in average erosion potential was 98.56 t ha^{-1} $year^{-1}$. The second most detrimental land transition in terms of the change in erosion potential was Forest to Bare lands, with a mean change in erosion potential of 97.99 t ha^{-1} $year^{-1}$. The thread most detrimental land transition in terms of the change in erosion potential was Shrub to Bare lands with a mean change in erosion potential of 96.46 t ha^{-1} $year^{-1}$

other land transitions that contributed to increased erosion potential of the watershed were in the order of Cultivation land to Bare land > Settlement to Bare land > Grass land to settlement > Forest land to Cultivation > Forest land to settlement > Shrub land to Cultivation > Grass land to Cultivation Land > Shrub land to Settlement land >Settlement to Cultivation land > Grass land to Shrub land. The positive land transitions that balanced the impact of negative transitions were in the order of Forest land to Grass land > Shrub to Forest >Settlement to Forest > settlement to Shrub land > Cultivation to Grass land > Cultivation to settlement land > Shrub to Grass land > Settlement to Grass land > Cultivation to Shrub land > Cultivation to Forest land > Bare to Cultivation land > Bare land to settlement land > Bare land to Grass land > Bare to Shrub land > Bare land to Forest land. From these results, it can be Show that any land transition to bare land and cropland would be detrimental, as it was the major source of Soil erosion. On the other hand, transition to Natural forest, Shrub and Grass land was the most effective Fence to prevent soil Erosion.

Since crop land and bare land together cover around 73% of the total area of the watershed, best agricultural practices and development of vegetative cover in bare lands would be more effective in reducing the soil erosion potential of the watershed.

From a management perspective, the erosion potential maps of both years were subsequently classified into four erosion potential categories such as low, medium, high, and very high as suggested by Hurni for Ethiopian context. The results of the difference of two maps (fig 4.24) are presented in Table 4.15.

Table 4.15: Different soil erosion potential categories and their area statistics in 1987 and 2018

Soil Erosion potential (t ha^{-1} ya^{-1})	1987		2018		Percent Change
	Area(km^2)	Area (%)	Area(km^2)	Area (%)	
Low (0 - 15)	309.74	19.82(%)	187.75	12.02(%)	-7.81(%)
Moderate (15 - 30)	412.20	26.38(%)	307.31	19.67(%)	-6.71(%)
High (30 - 50)	434.48	27.80(%)	454.51	29.09(%)	1.28(%)
Very High (> 50)	406.21	26.00(%)	613.05	39.23(%)	13.24(%)

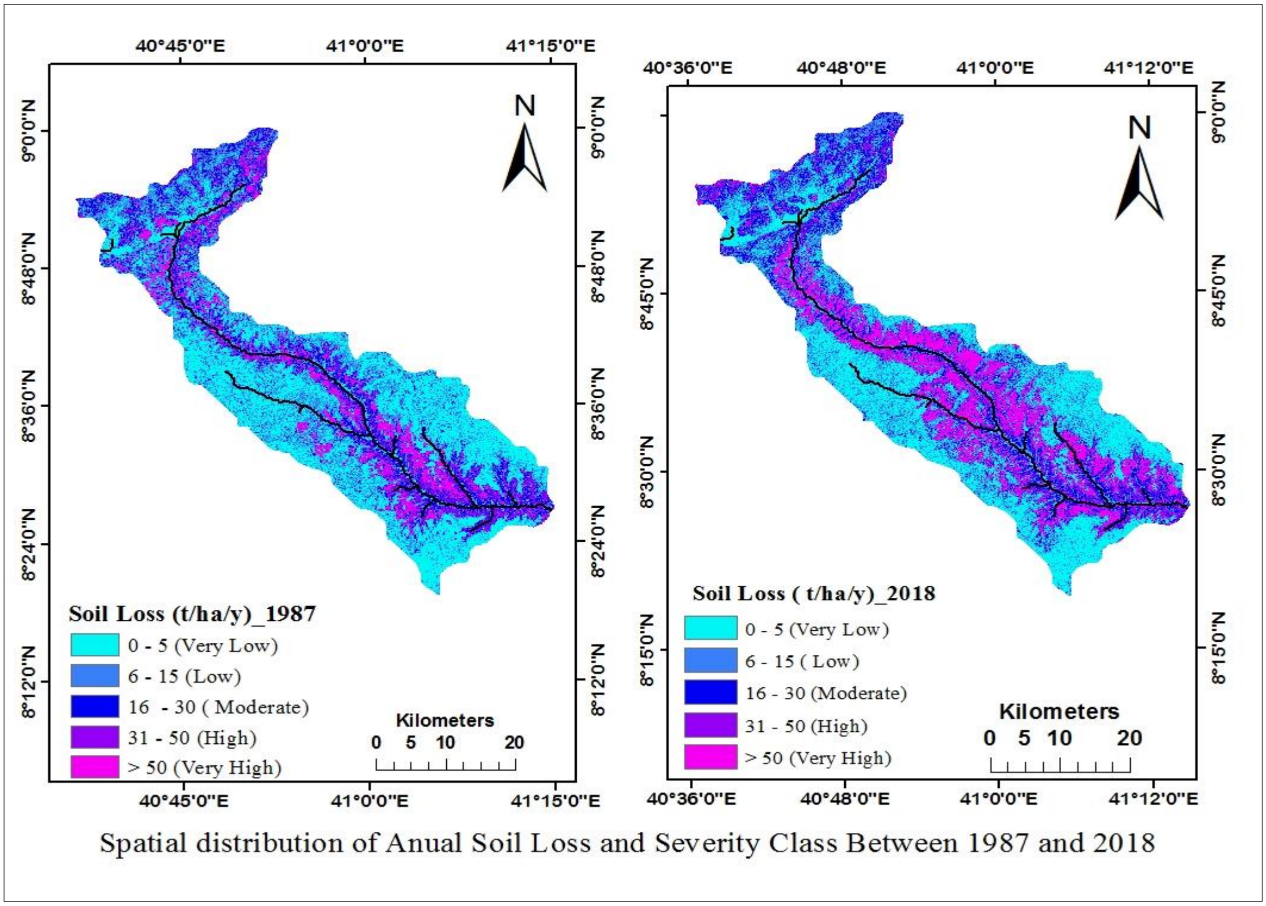

Figure.4.24: spatial distribution of annual soil loss and severity class in 1987 and 2018

Table 4.15 shows a clear pattern of changes characterized by gradual shifting of low erosion potential category to next higher erosion potential category.

However, the total areas of low erosion decreased from 19.82% in 1987 to 12.02 % in 2018 and the area of the moderate soil loss decreased from 26.38 % to 9.14%, whereas the percentage of high soil erosion over the same period increased to 29.09 % from 27.8 %. At the same time, the area under very high category is increased by 13.24%. The low and moderate erosion area showed the largest change decreasing by 226.88 km2 in the thirteen year period, while the area of the other erosion levels from high to Very high erosion show increasing trends, indicating the soil erosion level in whole province has become worse.

The soil erosion potential classes in 1987 and 2018 are compared in table 4.15 where the "low" and "moderate'' soil loss classes decreased and the "high" and "very high" soil loss classes increased in

2018. This could be interpreted due to the change in the land use land cover in the study area from shrub and forest land to agricultural land which reduced the shrub and grazing land in these areas and increasing the soil loss.

Through the field survey, large areas of the Cultivation activities in recent years have led to excessive deforestation and a substantial increase in barren land, thus causing serious soil and water loss which is a major issue of concern.

4.2.7. Impact of LULC Change on Soil Erosion potential on different land use type

This sub section was aimed to identify the susceptibility of land use types toward soil erosion. The susceptibility was detected from the largest proportional of high rate of soil erosion in a land use type. High rate of soil erosion means that the land use type is more detachable for sever reasons.

Table 4.16: Areas of different soil erosion intensity for different land use type (km^2)

Erosion levels	Grassland		Cultivation		Bare land		Shrub		Forest		Settlements	
	1987	2018	1987	2018	1987	2018	1987	2018	1987	2018	1987	2018
Low	214.10	67.62	351.75	702.62	7.51	20.84	414.15	86.88	52.00	20.37	1.78	4.39
Moderate	18.26	10.06	69.64	144.25	9.29	21.23	117.02	71.50	15.45	6.84	0.86	1.43
High	1.09	1.90	29.95	69.69	14.72	30.54	85.25	39.25	1.93	1.06	0.62	0.60
Very High	0.83	3.73	17.41	50.92	122.43	197.28	0.02	6.86	1.96	0.32	0.35	0.28

Table 4.16 shows that from 1987 to 2018, areas at different soil erosion levels changed as the areas of the land use changes. Bare land and Cultivation land show obvious increasing at all erosion levels due to the extensive increasing in land use areas. The erosion level of the forest land obviously show decreasing at all erosion level due to the extensive decreasing in land use areas by destruction of forest by human activities the grass land changed from low erosion level to High and Very High erosion levels, while the areas of Grass land in the low erosion level is highly decreasing. Shrub shows similar trend to Grass, but caused more soil erosion in High erosion level due to its areas have decreased and Distraction of the vegetation on the hilly sloppy mountains area

obviously in this period. The Settlements area increased in this period, it caused slight increasing in soil erosion at low erosion level.

4.3. Discussion

In Ethiopia, soil erosion is the most severe problem that affects agricultural productivity and negatively affects food security (Muluneh et al., 2017). However, According to the World Bank statistical estimate, land degradation cost to annual agricultural GDP ranges from 2% to 6.75%. To reduce the problem, the Ethiopian government adopted intensive soil and water conservation at the national level (FDRE, 2011). Nevertheless, the effectiveness of the government's efforts to deal with soil degradation needs up-to-date quantitative information on the extent of soil erosion, and its relationships with LULC change (Marartinez et al., 2000). This study assessed the magnitude of LULC change and impacts on soil erosion rate and identified the hotspot micro watershed for conservation.

Moreover the present study found that the mean annual soil loss of the watershed is 45.83t ha^{-1} y^{-1}, 32.91 t ha^{-1} y^{-1} in 2018 and 1987, respectively. Accordingly, the findings of this study are within the range of the early findings that estimated the annual soil loss rate in the highland areas of Ethiopia from 1248 to 23,400 million tons (FAO, 2001). But variations in annual soil loss rates were also reported in various parts of Ethiopia. Based on the assessment of soil erosion in the Holota watershed central Oromia, Ethiopia (Ayele el at., 2011). reported that the total annual soil loss accounted for 255,283 tons(Ayalew, 2015) estimated soil loss and sediment in the Zingin watershed of the Ethiopia highlands for conservation planning and reported a total annual soil loss potential accordingly shoes 57,750.15 tons. however, The estimated mean rate of annual soil loss in the study area is much greater than that of the maximum tolerable soil loss estimate at a national scale (18 t ha^{-1} y^{-1}) (Ayalew et al., 2015), and to the normal soil loss tolerances (from 5 t ha^{-1} y^{-1} to 11 t ha^{-1} y^{-1}) (Wischmeier et al., 1987). Although, higher than the findings of earlier researchers in other part of Ethiopia (Ayalew, 2015**)**. Conversely, the present studies results are lower than the findings across the Northwestern Ethiopia highland (Gete, 2000. Several previous studies suggested that vulnerability to a higher rate of water-increased the rate of soil erosion currently in eastern Ethiopia's highland is associated with the adverse effects of LULC changes, and unsustainable land management (Yacob, 2010; Mengistu et al., 2009). These events resulted in an accelerated increased the rate of soil loss and sediment accumulation in downstream areas. A complete drying up of Lake Hromaya in the East Hararghe Ethiopian highland over the recent years is one piece of compelling evidence that justifies the negative consequences of soil erosion, in combination with an unsustainable land use management practice (Setegn, 2009; Assen, et al., 2011).

The main reason for the change in soil erosion between the LULC types are due to the changes in land cover which are reflected by NDVI, and in turn changing the C factor values which effect strongly the soil erosion. This could be interpreted due to change caused by human activity and climate changes that occurred the last thirteen years. The man reason for the rising soil erosion rate in Chercher watershed is aggressive reduction of shrub and grass land and unmanageable cultivation practice expansions on the steep slope mountains area of the watershed. The declining of the forest and shrub areas can be considered one of the desertification consequences that existing in the study watershed. The increasing of cultivation land which is the land use change aspects in Chercher watershed were summarized and portrayed by the LULC change sub section, and showed that the area is dynamic and adversely changing.

It is clear in our study that with increasing "cultivation and bare land" areas and decreasing "shrub and forest" areas the erosion rate was increased in 2018. This is a clear indicator that the LULC change affects soil erosion rate. Many researchers found that the LULC affects soil erosion positively and negatively, among them (Aklile, 2014; Teshome et al., 2007) who studied the impact of LULC change on soil erosion in denki river,ethiopia.they and a case study in Gozamin Woreda, Amhara Region, North Central Ethiopia. They found that the soil erosion increased when the LULC are changed in some classes, for example the soil erosion risk increased when the land use changed from forest land in 1987 to cultivation in 2013. The mean soil loss estimated from each land use varies from one land use class to another based on the characteristics of each LULC class like the vegetation coverage and type, slope and management practices. In the study area, some land cover areas are increased and others are decreased.

The analysis of climate trends in his study showed that a land cover change, particularly deforestation, has become a global concern, with dynamic implication for human livelihood system. Natural land covers have been transformed to agricultural lands and urban areas to meet the increasing demands for food, water, consumption of goods and other public utilities Couse for the rising of soil erosion (Yacob, 2010; Teshomeet al., 2007). Based on the estimated rates of mean annual soil loss, erosion risk was grouped into five classes ranging from the very low to very high. In these study derived thematic maps to show the spatial distribution of erosion risk classes (Figure 4.26). The very low dominated major parts of the watershed area in 1987 and 2018 (Table 4.14) account for 67% and 58% of the total study area, respectively. The high and very high erosion risks have increased by 7.56% and 6.9% of the total study area, respectively. Moreover, the magnitude of soil loss rates across the Chercher Watershed marginally increased over the period between 1987 and 2016. The rising in soil loss rates is due to the LULC change existing on the watershed over the study years. This result implies that the local communities within the study area is not well recognized the environmental problems posed by LULC change and soil erosion by water. because of this, putting efforts into soil conservation practices in hot spot micro watersheds. Supporting the current study's findings (Amare and Kameswara, et al., 2011; Amare and Gebeyehu, et al., 2017), noted that a land cover change, particularly deforestation, has become a global concern, with dynamic implication for human livelihood system Natural land covers have been transformed to agricultural lands and urban areas to meet the increasing demands for food, water, consumption of goods and other public utilities Couse for the rising of soil erosion. The dramatic increase human population in our study area resulted in the conversion of natural vegetation, into cultivated and bare lands through change of land use of forest and natural shrub these aggravate the rate of soil erosion in the study area. The study show that land use/land cover changes towards cultivated on the loss of forest and shrub Land cover aggravate the rate of soil loss unless proper management is undertaken. (Belay T (2002)), Also reported that Most of land use/land cover change in Ethiopia is in the form of changing forest and shrub lands to cultivation. However, the overall effect of land cover change over the period 1987–2018 has affected the watershed slightly negatively by increasing soil erosion risks. The mean erosion potential for the whole watershed was increased slightly from 32 t ha−1 year−1 in 1989 to 45 t ha−1 year−1 in 2004.

The main reason for the increase in the soil erosion potential of the watershed over the study period is attributed to the reduction of forest and shrub, increase in bare land in higher slopes, and increased cultivation practice in higher slopes and more erosion-prone soil. The study results also showed that the transition of other LULC categories to bare land and cropland was most detrimental, while the forest, shrub and grass land was the most effective barrier to soil loss. Since cropland and bare land are the two dominant LULC categories, implementation of best agricultural practices and development of vegetative cover in barren land would be suggested for reducing soil erosion potential of the watershed. Although "Bare land and cultivation land" was one of the major covers of high and very high erosion in the study pared, and these land use was the dominant land use coverage area Proportion is (45%) in 1987 and (72%) in 2018. In 2018 and in the same area, the high and very high erosion hazard increased remarkably with declining of the "shrub and natural forest" areas. On the other hand the low and moderate erosion hazard decreased in the north part of the study area in 2018 due to the changes in LULC in these areas from bare land to shrub and cultivation land. Our study showed that the differences in soil losses between LULC classes and their contribution area in each soil erosion hazard in 1987 and 2018 years were notable. This gives a clear indication that changes in LULC in the study area affect considerably the soil erosion rate.

Although the possibility of getting larger variations of the mean erosion potential of different micro watersheds. Results also indicated that it is not only the composition but also the spatial position of LULC parcels with respect to terrain and associated soil properties are also equally important in soil erosion assessment Therefore, in conclusion there is geospatial variation in soil erosion potential distribution across the micro watershed area; identification of the hot spot area is the key factor for planning and implementing appropriate soil conservation.

Accordingly, this study provided the prioritized areas with a higher and increasing soil loss rate as soil conservation priority areas (Table 4.9). This can play a vital role in supporting decision makers and conservation planners to design proper soil conservation measures based on the potential levels of soil loss in the Chercher Watershed. The first, priority levels account for about (38.68% of the watershed area) needs urgent soil conservation measures. Most of the top five micro watersheds are spatially situated found in the south west upper part of the watersheds. Moreover, these districts are situated in the steep slope area with slope gradients greater than 30 meters and due to high contribution of land use change.

CHAPTER - V

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The major objective of this study was to assess the impact of land use land cover change on the soil erosion risk in Chercher watershed the parts of Wabeshebelle River basin. The study uses an empirically based erosion assessment model. Thus, RUSLE model integrated with satellite remote sensing and geographic information systems (GIS) has provided useful information for the assessment and decision-making about the vulnerability of micro-watersheds. In line with these the land use land cover of the study area are classified and characterized using maximum likelihood supervised classification.

This study confirms that there is a significant increase in cultivated and bare land conversely there was a significant decline in the density of forest, shrub and grasslands in the Chercher Watershed over thirty-year period Cultivation on marginal and steep-slope areas which shows a strong relation to population pressure on natural resources without sustainable land use system, has been found to be the root causes of land use and land cover dynamics and the problems associated to them. The cultivated land is expanding with the highest magnitude with an expense of other land use land cover classes. This shows that there is high degree of land use/land cover change in the study area.

The study also presented the impact of the long term land use/land cover change on the soil erosion risk, in marginal areas such as steep slopes of the study watershed between 1987 and 2018. The overall land use land cover change over the two study periods has affected the watershed negatively by increasing soil erosion risks.

From the result of RUSLE model in Arc GIS environment, the average annual soil loss of each micro-watersheds ranges from 4.28 to 122.17 t/ha/year. The mean soil erosion rate for the study catchment was increased from 32.4t/ha/yr in 1987 to 45.41t/ha/yr in 2018 which is very large to degrade the area.

Five micro-watersheds that cover (38.68%) of the area shows very high erosion rate and they are in the North to south central part of the study area within steep dissected to mountainous terrain and hilly terrain slope classes which is due to high contribution from land cover factor. Five micro-watersheds (35.91%) fall in a high erosion rate. The very high and high value may be due to high contribution of land cover change on marginal and steep-slope areas in the south eastern part of the study area. Seven micro-watersheds covering 14.57% of the watershed are in the moderate class. Only 10.85% of the study area that includes eight micro-watersheds is under the low class which shows relatively less vulnerable to soil erosion.

Indeed, as all parameters required for the model, except for the distribution of land cover types, remained constant between 1987 and 2018, increases in erosion rates can only be attributed to changes in land cover.

The study have found that as land use changes from forest cover to bare and agricultural use, erosion and sediment runoff increase. For instance, it was shown that the greatest land use change between 1987 and 2018 for the chercher watershed consisted in the conversion from forest and shrub to bare land and agricultural use. These areas were also home to the greatest erosion and sediment runoff. As predicted by scientific theory, the results therefore show that bare and agricultural intensification is increasing rates of erosion due to the protective topsoil layer being washed away, rendering land more vulnerable to the impact of raindrops.

The result also shows that the most damaged zones in the scope of soil erosion are located in the mountain area. It is due to the fact that the determinants of soil erosion are mostly located in this area. In terms of the land use, for example, the forest and shrub was exponentially converted to the farming or bare lands are the main causes for the increasing of mean soil loss in 2018. The intense rainfall and steep topography and low vegetation cover coupled with cultivation on steep sloop without inadequate conservation practices also contributed for the high rate of soil loss in the Chercher watershed. Results of the analysis on the rate of soil loss from each land use land cover in the study watershed also show that the transition of other LULC categories to bare and crop land was the most severe, while the forest and shrub lands were the most effective barrier to soil loss.

5.2. Recommendations

This study focuses on the identification of the long term LULC changes and its impacts on soil erosion. Based on the soil loss rate value, the most erosion vulnerable micro-watersheds should have been prioritized for conservation activities Based on the results of this study recommendation ware suggested as following.

- The assessed land cover and soil loss dynamics may support decision-makers and planners to take relevant forest and soil conservation priority steps and thereby reduce the soil loss and land degradation issue of the study watershed.
- Moreover, it is essential to increase the awareness of local society on optimum use of natural resources and appropriate conservation practicing. Providing a systematic training system could lead to a positive revision on the farming trend.
- LULC management in a sustainable way must be implemented as soon as possible giving priority to sever erosion micro watersheds. Otherwise it will not take longer to face sever land degradation and consequently productivity loss which may cause the local, food insecurity.
- Since cultivated and bare lands are the most dominant LULC classes, implementation of best agricultural practices, diverting the runoff entering the gully by constructing cutoff drains and check dams are recommended to more erosion prone sub-watersheds for reducing soil erosion risk of the watershed.
- Application of the empirical RUSEL model in ArcGIS environment for estimating the soil loss rates, assess the impact of LULC change on the spatial change of soil erosion potential and prioritization of soil conservation in the Chercher Watershed can be applied to other similar watersheds. Further studies need to be done in order to assess the conservation measures required for different stages of erosion vulnerable micro-watershed under different factors and figure out how soil loss possibly affects soil quality.

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APPENDICES

Appendix 1: Mean monthly Rainfall data of Six Stations (1997 – 20118)

Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bedessa	10.94	7.14	70.00	136.72	121.91	95.97	153.43	153.84	185.67	99.37	34.86	14.48
Gelemso	4.60	15.20	41.40	41.50	105.00	74.30	125.90	130.30	146.63	51.47	29.87	7.82
Hirna	11.61	2.57	69.33	92.08	103.46	72.18	161.68	203.81	160.81	63.87	17.59	7.75
Meiso	10.86	9.67	72.41	96.79	45.47	52.96	129.52	133.82	103.26	62.64	23.72	10.04
Asebe	18.86	13.24	82.05	103.00	89.43	60.63	144.36	167.04	124.00	69.48	19.72	25.11
bordede	12.00	9.97	51.61	91.61	49.94	35.89	121.93	110.42	118.21	36.05	13.65	21.58

Source: Ethiopia Metrology Agency

Appendix 2: Mean monthly temperature of five stations (1997 – 20118)

Stations	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bedessa	19.75	20.81	22.18	21.76	22.19	20.64	19.29	18.92	18.22	20.13	18.80	18.80
Gelemso	26.27	27.63	28.24	27.05	27.57	27.68	26.48	26.01	26.06	26.12	26.13	25.32
Hirna	15.46	16.94	17.66	17.73	17.44	16.18	14.42	14.72	14.93	15.07	15.05	14.29
Meiso	28.81	30.75	31.49	32.04	33.49	33.82	31.80	30.42	30.76	30.63	29.62	28.04
Asebe	26.61	27.91	28.79	28.54	29.23	29.20	28.14	27.15	27.28	27.33	27.04	25.89

Source: Ethiopia Metrology Agency

Appendix 6: Micro watershed wise potential soil loss rate

Rank	Micro-watershed	Area(km2)	Mean soil loss (t/ha/yr.)
1	19	19.92	188.30
2	21	43.19	108.62
3	12	361.19	103.97
4	13	102.14	84.90
5	14	70.89	79.61
6	18	35.62	71.00
7	15	45.38	67.82
8	24	13.59	45.63
9	17	59.64	51.70
10	20	155.69	41.63
11	16	50.96	41.16
12	23	56.73	30.80

13	22	51.85	30.63
14	2	64.09	24.24
15	8	7.17	23.67
16	3	7.85	23.64
17	1	28.36	23.57
18	5	72.01	18.95
19	7	61.88	18.88
20	11	44.25	17.96
21	4	63.77	17.85
22	6	8.81	16.04
23	10	115.05	7.55
24	9	12.11	4.31
25	25	10.50	4.28

Appendix 7: some images of the Land use/Land cover in the study area