ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Civil Engineering and Architecture

Department of Geomatics Engineering

MSc in Geodesy and Geomatics Engineering

Soil Erosion Risk Assessment in Nashe Dam Reservoir Using Remote Sensing, GIS and RUSLE Model Techniques.

A Thesis Submitted to school of graduate studies of Adama Science and Technology University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geodesy and Geomatics Engineering

By

Ayana Abera Beyene

June, 2016

Adama, Ethiopia

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Advisor: Hasan Raja Naqvi (PHD)

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CANDIDATES' DECLARATION

I the under signed, declare that the thesis entitled "**Soil Erosion Risk Assessment in Nashe Dam Reservoir Using Remote Sensing, GIS and RUSLE Model techniques''** has been carried out by me under the supervision of Dr. Hasan Raja Naqvi, Department of Geodesy and Geomatics Engineering, Adama Science and Technology University, Adama during the year 2016-2016/17 as a part of Master of Science program in Geodesy and Geomatics Engineering.

I further declare that this work has not been submitted to any other University or Academic institution for the award of any degree or diploma and that all sources of material used for the thesis have been duly acknowledged.

Ayana Abera Beyene __________________________ ________________________

Candidate Signature Date

CERTIFICATE

This is to certify that the thesis entitled **"Soil Erosion Risk Assessment in Nashe Dam Reservoir Using Remote Sensing, GIS and RUSLE Model techniques"** is a work carried out by under my guidance and supervision. The Thesis work is done by *Ayana Abera* for the partial fulfillment of the award of the Degree of Master of Science in Geodesy and Geomatics Engineering, Adama Science and Technology University, Adama, Ethiopia.

Dr. Hasan Raja Naqvi _____________________ _____________________

Advisor Signature Date

APPROVAL

This thesis has been submitted in partial fulfillment for the requirements of the award degree in Master of Science in Geodesy and Geomatics Engineering at Adama Science and Technology University.

This thesis has been approved by examining board on the date shown below:

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School of Civil Engineering and Architecture	Signature	Date

DEDICATION

This thesis manuscript is dedicated to my family who paved the way towards education and nursing me with affection and love in success of my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my work and that all sources of materials used for the thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree at the Adama Science and Technology University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Name: Ayana Abera **Signature: ______________**

Place: Adama Science and Technology University, Adama

Date of Submission: ________________

BIOGRAPHICAL SKETCH

The author was born on August 05, 1980 in Horro District, Horro-Guduru Wollega zone, Oromia National Regional State. He attended his elementary school at Wendo primary School, his junior secondary education at Shambu model school, Horro District, at Shambu town and his secondary school at Shambu Senior and secondary school, Horro guduru Wollega Zone. After completing his secondary school education, he joined Wollega University in September 2008 and graduated with Degree in Surveying Technology in June 2010.

After graduation, he was employed by the Ministry of Education for higher institute teaching at Mizan Tepi University. Later on the author joined Wollega University in August 2012 for teaching and October 2014, he joined the Adama Science and Technology University to pursue his MSc studies in Geodesy and Geomatics Engineering.

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Finally, I would like to express my gratitude to all my families for their encouragements and support. Especially, my appreciation goes to my wife Bokeshe File, my son Nanbon Ayana and my families.

ABSTRACT

Soil degradation is wide spread and serious throughout the Ethiopian Highlands. It is also a major watershed problem in many developing countries causing significant loss of soil fertility, loss of productivity and environmental degradation. This research has, therefore, been carried out to evaluate the soil erosion risk and quantify the major land use land cover changes over the past 20 years (1996-2016) in the Nashe watershed.

The research integrates the Revised Universal Soil Loss Equation (RUSLE) with a Geographic Information System (GIS) and Remote Sensing (RS) to quantify the potential soil erosion risk and land use land cover changes. Rainfall data, soil data, Elevation data and satellite image were used as input data sets to generate RUSLE factor values. Raster calculator was used to interactively calculate potential soil loss and prepare soil erosion risk map. For the land use land cover change calculation two satellite images (Landsat TM 1996 and Landsat ETM+2016) has been utilized. As a result the potential soil erosion risk and land use land cover map of 1996 and 2016 of the study area was generated.

The result showed that the potential annual soil loss of the watershed ranges from 0.00 to 243..065ton/ha/yr. and the mean annual soil loss rate is 45.7ton/ha/yr. Concerning the land use land cover change Grass land decline from (8.85%) to (6.85.4%), open forest changes from (47.10%) to (22.75 %) and settlement land changes from (4.42%) to (7.59%). On the contrary farm land changes from (27.18%) to (45.55%), bare lands increase from (5.40%) to (5.55%) and water body changes from (7.06%) to (12.10 %).

Key Words: *Nashe Dam, Soil erosion risk, Watershed, RUSLE, GIS*

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LISTS OF ABBREVATIONS AND ACRONOMYS

ASTER	Advanced Space Born Thematic Emission and Reflection Radiometer
ASTU	Adama Science and Technology University
AOI	Area of Interest
CPS	Country Program Strategy
CGS	Council of Graduate Studies
CGGC	China Gezhouba Group Corporation
DGS	Departmental Graduate Studies
DEM	Digital Elevation Model
ETM+	Enhanced Thematic Mapper Plus
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agricultural Organization
GIS	Geographic Information system
GPS	Global Positioning System
HGWZAO	Horro-Guduru Wollega Zone Agriculture Office
IDW	Inverse Distance Weighted
MSc	Master of Science
MSL	Mean Sea Level
NMA	National Meteorological Agency
MoA	Ministry of Agriculture

RUSLE	Revised Universal soil Loss Equation
SRTM	Shuttle Radar Topographic Mission
SCRP	Soil conservation Research Project
SGC	School Graduate Studies
SWC	Soil and Water Conservation
SAR	Stereoscopic Optical and Microwave Remote Sensing
TM	Thematic Mapper
t/ha/yr	ton per hectare per year
UNEP	United Nation Environmental Program
USLE	Universal soil loss Equation
USDA-ARS	United State Department of Agriculture - Agricultural Research Service
UTM	Universal Traverse Mercator
WGS	World Geodetic Survey

CHAPTER ONE

INTRODUCTION

1.1 Background

Soil degradation by accelerated water and wind-induced erosion is a serious problem and will remain so during the 21st century, especially in developing countries of tropics and subtropics (Lal, 2001). Of all the processes leading to land degradation, erosion by water accounts for 56% of the total degraded land surface of the world (Oldeman et al., 1990).

The amount of river-borne soil carried into the oceans had increased from 9.9 billion tons a year before the introduction of agriculture, grazing and related activities, to the present rate of 26.5 billion tons a year (Judson, (1965)

Hydrologists estimated that one-fourth of the soil lost through erosion in a watershed actually makes it to the ocean as sediment (FAO/UNEP, 197). The remaining three-fourths are deposited on foothill slopes, in reservoirs, in river plains and other low-lying areas or in the river-bed itself, which often causes channel shifts. In an overview of global erosion and sedimentation (Pimental, (1995) stated that more than 50% of the world's pastureland and about 80% of agricultural land suffer from significant erosion.

Most studies in Ethiopia indicated that sheet and rill erosion by water and burning of cow dung and crop residue are the major components of land degradation that affects on-site land productivity (Hurni,1993,Zeleke & Hurni, 2001)). According to Fournier (1962) cited in (Hurni, 1985), the degradation and loss of soil resulting from soil erosion was estimated to be about 20 tons per hectare which means about 1mm of soil depth per year across the country. (Hurni, 1989), indicated that Ethiopia loses about 1.9 billion metric tons of fertile soil from the highlands every year and the degradation of land through soil erosion is increasing at a high rate. The Ethiopian Highlands Reclamation Study (FAO, 1986) soil erosion had been forecasted to cost the country 1.9 billion USD between 1985 and 2010.

The off-site effects of erosion such as reservoir sedimentation and water resources pollution are usually more costly and severe than the on-site effects on land resources (Phillips, 1989) Therefore, proper management of on-site effect of soil erosion could reduce the risks and negative impacts of downstream water resources due to water erosion. Severe soil erosion is occurring in most of the world's agricultural regions, and the problem is growing as more marginal land is brought into production and less crop residues are returned to the soil for protection and improvements. In the world 80% of agricultural land suffers from moderate to severe erosion which induced loss of productivity. Because of this and population growth the global per capita food supply is currently declining. In many areas the on-site impacts of increased soil loss are frequently coupled with serious off-site impacts related to the increased mobilization of sediment and its delivery to rivers (Pimentel et al., 2006).

Worldwide degradation of agricultural land by erosion, salinization, and water logging is causing the irretrievable loss of an estimated 6 million hectares each year. Depletion of soils and water resources are a major hazard in the third world. As cited in Abey (2007),in Ethiopia land degradation in the form of soil erosion and declining fertility is serious challenge to agricultural productivity and economic growth (Mulugeta, 2004). Soil conservation is a significant socio-environmental issue that reflects the wellbeing of the people in every country in the world and also information on the factor leading to soil erosion can be used as a perspective for the development of appropriate land use plan. In order to predict and also prevent soil erosion it is necessary to assess the potential and also the actual risks of soil erosion. Many attempts have been made on the modeling of soil erosion. There are wide varieties of models available for assessing soil erosion risk. Erosion models can be classified in a number of ways. All methods could be divided as expert-based and model-based methods. One may make a subdivision based on the time scale for which a model can be used: some models are designed to predict long-term annual soil losses, while others predict single storm losses (event-based).Alternatively, a distinction can be made between lumped models that predict erosion at a single point, and spatially distributed models. Another useful division is the one between empirical and physically-based models. The choice for a particular model largely depends on the purpose for which it is intended and the available data, time and money (Ivan and Stanimir, 2010).

As mentioned in (Wischmeier and Smith, 1978), Revised Universal Soil loss Equation (RUSLE) is one of the empirical models that enable planners to predict the average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern, and topography. When these predicted losses are compared with given soil loss tolerance, they provide specific guidelines for effective erosion control within specified limits.

Thus, remote sensing (RS) and GIS have resulted in great progress in the research of soil erosion and soil and water conservation since the end of 1980s. Estimation of soil erosion and its spatial distribution using RS and GIS techniques were performed with reasonable costs and better accuracy in larger areas to face up to land degradation and environmental deterioration (Ozcan, 2008). Generating accurate environmental risk maps in GIS environment is very important to locate the areas with high environmental risks and to develop adequate risk prevention techniques (Lal, 1995). While Remote Sensing (RS) has proved to be a useful, inexpensive and effective tool in soil erosion risk mapping. Remote Sensing can provide the data necessary for erosion modeling within a GIS (Leh, 2011). In this study; an integrated Remote Sensing-GIS and Revised Universal Soil Loss Equation (RUSLE) has been used to assess the annual soil loss risk.

1.2 Statement of the problem

Soil erosion is broadly considered the most serious form of soil degradation which affects a large proportion of the earth’s population (Ivan and Stanimir, 2010) and (Biggelaar et al., 2004). Since the last century, soil erosion accelerated by human activities has become a serious environmental problem. It has a manifold environmental impact by negatively affecting water supply, reservoir storage capacity, agricultural productivity, and freshwater ecology of the region (Sharma et al., 2011). It has also been recognized to be the major non-point pollution source in many areas, which causes a large amount of damage every year. Each year, 75 billion metric tons of soil is removed from the land by wind and water erosion, with most coming from agricultural land (Pimental et al., 1995).

This is posing a significant threat to world's food production capacity and global food security (Biggelaar et al., 2004).This is not the only case; when agricultural land is degraded and abandoned, more forests are cut and converted to agricultural production. Over the last few decades, the deforestation and degradation of forests has proceeded at an alarming rate, as cited in (Efrem et al., 2009). (FAO, 2005), reported that, globally, deforestation from 1990–2005 was about 13 million hectares each year, and there was no significant decrease in the trend over time. Most of this deforestation occurred in Africa, Asia and South America. Deforestation rates in East Africa, including Ethiopia, were the second highest in Africa: 0.94% between 1990–2000 and 0.97% between 2000–2005.

Erosion by water and wind adversely affects soil quality and productivity by reducing infiltration rates, water holding capacity, nutrients, organic matter, soil biota, and soil depth (Begum, and Pereira,2008 and pimental et al., 1995). It also causes, gully development, sedimentation and reduced water reservoir capacity and damage to buildings and infrastructure especially reservoirs. Sediment delivery to river channels is probably the most problematic off-site consequence of soil erosion. Ethiopia is one of the developing countries which have got the worst land degradation problems (IUCN, 1994) and soil erosion is a major factor causing severe land degradation, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population .Rapid population growth, cultivation on steep slopes, clearing of vegetation and overgrazing are the main factors that accelerate soil erosion in the country. Such unsustainable and exploitative land use practices due to an increasing demand for food, fiber and fodder by the growing human and livestock populations are responsible for accelerated soil erosion in many parts of Ethiopia. Abate (2011) mentioned that, these practices reduce the protective plant cover, thereby exposing the soil surface to the destructive impact of high intensity rainfall (Aregay and Chadokar, 1993). Soil degradation is wide spread and serious throughout the Ethiopian Highlands (Abate, 2011,Bayouand Van Ierland, 1999 and Shiferaw & Holden, 1996), which contain more than 90% of the population including about 93% of the cultivated land, around 75% of the country's livestock and accounts over 90% of the country's economic activity (Solomon *et al*., 2013).The average soil removal in the country is about 2 billion t/yr^{-1} (FAO, 1986).The highest rate of soil loss occurs from cultivated fields, which is estimated at $42tha^{-1}yr^{-1}$on average and causes an average annual reduction in soil depth of 4mm (Hurni, 1993)

It is also a major watershed problem in many developing countries causing significant loss of soil fertility, loss of productivity and environmental degradation (Awulachew &Tenaw, 2008). As dams are one of the most important infrastructure investments in a country in which providing essential services such as drinking water, irrigation water, hydroelectric power, fisheries, wildlife, recreation, and other environmental benefits.

The *Amerti-Neshe* hydropower dam constructed over the *Nashe* River had a long history. Its survey dated back to 1950's during the era of Imperial Haile Silase regime. A man of the study area called Ato Bekela Merga (age 65) witnessed that during the era of Imperial Haile Silase regime, Government made discussion over the issue of the dam with local land lords of the area on a meeting held at Nekemte town. Later, based on the consensus made, a crew of higher officials together with some foreigners came to the area and marked on the ground where the dam was to be constructed over the *Nashe* river and driven a stake in to the ground marked with flag to delineate the reservoir boundary. Before the dam was built, the people living in the area that is now inundated were not taken into consideration: they were neither resettled nor financially compensated. Assefa (1994) mentions that the then Ethiopian Electric Light and Power Authority attempted to compensate only the landlords who officially owned most of the land and whose settlement area and trees were submerged, but the majority of farmers were not considered. It is not exactly known how many households were displaced from their dwellings. Some people possibly migrated to areas outside the Nashe watershed to make a living, while others stayed within the watershed. A survey among 120 households in Nashe revealed that 14% had to relocate in the watershed as a result of the dam construction. The majority of these households had resettled themselves in the hilly areas of the watershed, owning 23% less land and 24% fewer livestock units. Others probably left the area and moved to towns or started farming in neighboring watersheds. The migration of households towards the higher and steeper parts of the watershed may have further aggravated the soil erosion problems which are a serious problem in the Ethiopian highland areas, threatening the agricultural sector (Hurni, 1983) and causing increased sedimentation of reservoirs and lakes. Unfortunately, there is very little reliable information on the spatial dynamics of the land use types, the factors driving land use changes, and the implications of these changes on soil degradation. Such information is, however, very important for planning watershed-based development projects such as soil and water conservation (SWC) programs.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of the study is to assess the extent of soil erosion risk on Nashe Dam watershed and to investigate the land use changes.

1.3.2 Specific Objectives

- To estimate the average annual soil loss from the watershed.
- To analyze and quantify the land use land cover change over the past twenty years (1996-2016).
- To determine the relationship of Erosion and Elevation in connection to its susceptibility to erosion.

1.4 Significance of the study

The problem of environmental deterioration has become one of the most serious problems confronting mankind. Sustainable land use manners can be the solution for this. Soil erosion is one of the major non-point pollution sources in many watersheds (Wang and Cui, 2005).Therefore, assessing the extent of soil erosion risk of the study watershed and forwarding possible amelioration measures will help the future soil conservation and watershed management efforts. The people’s lives around the dam and the woreda can be for most beneficiary of the outcome of the project. In addition, utility service delivering organization and institutions concerned with planning, managing, and conservation of land can share the output, as it evaluates the impact of their program on the well-being of land and will suggest some key issues for further redesign. The investigation will provides information on soil erosion risk at a woreda level that could be used by the pertinent decision makers to act upon the current land use policy for in reducing soil erosion risk occurred on the dam.

1.5 The scope of the study

The scope of the study limited to cover surrounding villages around the dam and the work will be concentrated on mapping, analyzing and assessing the soil erosion risk in Nashe dam watershed with the application of Revised Universal Soil Loss Equation (RUSLE) and Using GIS and RS Techniques.

1.6 Thesis Structure

This thesis report comprises six chapters, which provides a background of the study. They describes the theories methodologies and analysis pertaining to the application of the remote sensing and GIS in Soil erosion Risk assessment. The report discusses in detail the application of these technologies on land classification and soil erosion modeling. The chapters of the report is as follows:

Chapter 1 provides an introduction to the study, including background and the research aim, in addition to a description of how the thesis is presented. This chapter also describes areas, where remote sensing and GIS would be needed in order to support the establishment of an effective and sustainable watershed management.

Chapter 2 describes Different Literature Reviews

Chapter 3 Describes the physical characteristics of the study area in detail. The location, Climate, Geological features, DEM and metadata of Landsat images and other attributes are explained together with maps and photographs and

Chapter 4 provides an analysis of land cover land use of the Nashe watershed area. This chapter discusses some of the methods and techniques of remote sensing and the analysis presented in this chapter includes a determination of the area for each land cover class and their distribution based on slope and elevation.

Chapter 5 Presents a GIS based modeling of the soil erosion risk, in the Nashe watershed. This chapter discusses the basic factors that contribute to erosion and it provides some explanation on their effects based on the results of the previous studies. The procedure used in the preparation of factor maps, rainfall. Soil, slope steepness, slope length and vegetation coverage are describe in detail.

Chapter 6 Summarizes the conclusion of the each chapter and it provides recommendations for the improvements of the study and further research. Conclusions on the preparation of the data, methodology and results are enumerated. Recommendations for the implementation of the methods and results of the study are also provided

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil Erosion and its extent

Soil erosion was defined earlier by (Bennett, (1939), as the vastly accelerated process of soil removal brought about by human interferences with the normal equilibrium between soil building and soil removal. (Mitchell and Bubnezer, (1980), also defined soil erosion and soil loss in the following way: “Soil erosion is the gross amount of soil moved by drop detachment or runoff and Soil loss is the soil moved off a particular slope or field”.

Soil erosion is one of the most serious environmental problems in the world today, as it threatens agricultural and natural environment (Vrieling, 2006). As sources cited by (Deore, (2005), study on global soil loss has indicated that soil loss rate in the United States is 16 t/ha/yr; in Europe it ranges between 10 – 20 t/ha/yr, while in Asia, Africa and South America between 20 and 40 tons/ha/yr.

As mentioned by Hawando (1995), the recorded annual soil erosion in Ethiopia ranges from 16- 300 tons/ha/yr depending mainly on the slope, land cover, and rainfall intensities. According to the Ethiopian highland reclamation study (FAO, 1984), in mid1980’s 27 million ha or almost 50% of the highland area was significantly eroded, 14 million ha seriously eroded and over 2 million ha beyond reclamation.

In general, Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced. The Ethiopian Highland Reclamation Study (FAO, 1986) estimated that water erosion moves nearly 9 billion tons of fertile soil from highlands annually.

2.2 Soil Erosion Types

Soil erosion is the removal of soil from the earth’s surface by erosive agents such as water and wind. Water erosion involves the detachment, transport and deposition of soil particles by the erosive forces (Renard et al., 1997). Any soil condition which encourages surface run-off brings with it the risk of soil wash and erosion. If the water flow is significant or concentrated, then shallow channels (rills) may be formed which can become deeper gullies. Soil erosion by water occurs in various forms (e.g., splash, sheet, rill, gullies) depending on the stage of progress in the erosion cycle and the position in the landscape. Some of the types of erosion are discussed below:

2.2.1 Rain Splash Erosion

Rain splash Erosion is the result of water falling directly on to the ground during rainstorms or when it is intercepted by the canopy and finds its way through the ground (Morgan, 1995). Some of the water infiltrates into the soil, while some water stays on the surface saturating it and weakening natural soil aggregates so that the impact of subsequent raindrops breaks them down.

2.2.2 Sheet Erosion

Sheet erosion occurs as a shallow 'sheet' of water flowing over the ground surface, resulting in the removal of a uniform layer of soil from the soil surface. Although often difficult to recognize, sheet erosion is responsible for extensive soil loss in both cultivated and non-cultivated environments. Raindrops detach the soil particles, and the detached sediment can reduce the infiltration rate by sealing the soil pores. The eroding and transporting ability of overland flow depends on the rainfall intensity, infiltration rate, slope steepness, soil properties, and vegetative cover (Fangmeier et al., 2006).

2.2.3 Rill Erosion

Rill erosion is the detachment and transport of soil by concentrated flow of water. Rills are eroded channels that are small enough to be removed by normal tillage operations. Rill erosion is the predominant form of surface erosion. Rill initiated at a critical distance down slope where surface runoff concentrates and becomes channeled. These channels are called rills when they are small enough to not interfere with field machinery operations. The water in a rill has sufficient depth for turbulence to develop in it and therefore entrain large particles (Morgan, 1995).

2.2.4 Gully Erosion

Gully erosion produces channels larger than rills. These ephemeral channels carry water during and immediately after rains. Gullies are distinguished from rills in that gullies cannot be obliterated by tillage. The amount of sediment from gully erosion is usually less than from upland areas, but the nuisance from having fields or developed areas divided by large gullies is often a greater problem (Fangmeier et al., 2006).

The rate of gully erosion depends primarily on the runoff-producing characteristics of the watershed, the drainage area, soil characteristics, the slope in the channel, and the alignment, size, and shape of the gully (Bradford et al., 1973).

2.3 Impact of Soil Erosion by Water

The problem of soil erosion has been a problem ever since land was first cultivated. The consequence of soil erosion occurs both on- site and off-site. In Ethiopia, the on-site impacts of soil erosion are most frequently studied, typically by estimating the productivity losses as economic cost of soil erosion. Less well known and documented are the off-site costs of soil erosion (Eyasu, 2003).

On site effects are those that are happens at the site where erosion occurs. Such effect is particularly important on agricultural land where the distribution of soil with in a field , the loss of soil from a field , the breakdown of soil structure, the decline in organic matter and nutrient, a reduction of cultivable soil depth and a decline in soil fertility happens. Erosion also reduces available soil moisture, resulting in more drought prone conditions. The net effect is loss of productivity which at first restrict what can be grown and results in increased expenditure on fertilizer to maintain yields, but latter threatens food production and leads ultimately , to land abandonments (Santra, 2001). In Ethiopia, the EHRS estimated an on-site productivity loss of 60 million Ethiopian Birr in 1986 due to soil erosion (FAO 1986; Sutcliff, 1993).

An off-site effect are those which occurs when runoff and sediments from one field, watershed or waterway enters to another. These downstream effects reduce the capacity of river and drainage ditches, enhance the hazard of flooding, blocking irrigation canals and shorten the design life of reservoirs. Many hydro-electric and irrigation projects have been ruined as a result of erosion (Santra, 2001).

2.4 Factors Affecting Soil Erosion by Water

The major factors affecting soil erosion are climate, soil properties, vegetation characteristics, and topography. These factors are not totally independent, as geology affects topography, which can influence climate and the like. Human disturbances, such as tillage and construction, and natural disturbances, such as severe weather or fire, dramatically increase erosion. Of these, the vegetation and some disturbances, and, to a lesser extent, the soil and topography can be managed to reduce erosion (Fangmeier et al., 2006).

2.4.1 Climatic Factors

Climatic attributes affecting erosion are precipitation, temperature, wind, humidity, and solar radiation. Soil erosion occurs when raindrops act upon the soil particles. Soil loss is closely related to rainfall partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to runoff. Potential ability of rain to cause erosion is known as erosivity (R) factor (Renard et al., (1997). Raindrops while falling acquire kinetic energy and on impact, the kinetic energy is used up in detaching the soil particles. Energy is required to break the soil aggregates, splashing them and subsequently carrying them with runoff (Saavedra, 2005).

2.4.2 Soil Factors

Physical properties of soil affect the infiltration capacity and the extent to which particles can be detached and transported. In general, soil detachability increases as the size of the soil particles or aggregates increase, and soil transportability increases with a decrease in the particle or aggregate size. That is, clay particles are more difficult to detach than sand, but clay is more easily transported. The properties that influence erosion include soil structure, texture, organic matter, water content, clay mineralogy, and density, as well as chemical and biological characteristics of the soil (Fangmeier et al., 2006). The susceptibility of soil to erosion agents is generally referred to as soil erodibility (Renard et al., 1997).

Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Soils high in clay have low K values, because they are resistant to detachment. Coarse textured soils, such as sandy soils also have low k values, because of low transportability even though these soils are easily detachable. Medium textured soils, such as silty loam soils, have a moderate k values, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having high silt content are the most erodible of all soils as they cause a decrease in infiltration (Saavedra, 2005).

2.4.3 Topographic Factors

Topographic features that influence erosion is slope length and steepness, shape (including concave, uniform, or convex) and size and shape of the watershed. The slope factors (LS) refer to topographic and/or relief factor. Erosion would normally be expected to increase with increase in slope steepness and slope length as a result of respective increases in velocity and volume of surface runoff (Deore, 2005). Steeper terrain slopes cause higher runoff velocities, more splashes downhill and faster flow and therefore contributes greater soil erosion. Erosion only doubled for a steepness change from 2-20% and the erosion rate tends to level off (Remortel, 2001). A slight increase in detachment rate probably occurs as the raindrops strike at a greater angle, but this effect should not cause a major change in total splash detachment.

2.4.4 Ground Cover Factor

Vegetation cover is one of the most crucial factors in reducing soil erosion. 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 (De Asis and Omasa, 2007).

Differences in erosion rates are commonly related to land use in areas where soil, climate, and topography are similar, For example, in Malaysia, the rate of soil erosion increased from 0.24 ton/ha/yr under natural forest to 4.9 ton/ha/yr in areas of mature coffee, to 7.32 ton/ha/yr in areas with cultivated vegetable crops (Lal, 1990). In Puerto Rico, soil erosion in coffee plantations without ground cover was ten times greater than from adjacent areas of coffee with natural ground cover (Smith and Abruna, 1955 as cited in Lopez *et al*., 1998).

To account for the effect of vegetation in erosion assessments, a cover and management factor (C-factor) has often been used. The C-factor is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding clean-tilled continuous fallow (Wischmeier and Smith,17978; Renard et al. , 1997).

2.4.5 Conservation Practice Factor

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

2.4.6 Soil Erosion Models

A wide variety of models are available for assessing soil erosion risk. Erosion models can be classified in a number of ways. One may make a subdivision based on the time scale for which a model can be used: some models are designed to predict long-term annual soil losses, while others predict single storm losses (event-based). Field studies for prediction and assessment of soil erosion are expensive, time-consuming and need to be collected over many years. Though providing detailed understanding of the erosion processes, field studies have limitations because of complexity of interactions and the difficulty of generalizing from the results. Soil erosion models can simulate erosion processes in the watershed and may be able to take into account many of the complex interactions that affect rates of erosion. The choice for a particular model largely depends on the purpose for which it is intended and the available data, time and money (Lal, 2001).

Erosion models allow users to ascertain temporal trends, examine spatial variations, identify critical processes and explore the possible impacts of remedial measures and the relative effectiveness of implementations strategies for erosion and sedimentation controls (Baigorria & Romero, 2007). Modeling in soil erosion is the process of mathematically describing soil particle detachment, transport and deposition on land surfaces. The objective of soil erosion models is either predictability or explanatory (Petter, 1992). In general, the models fall into three main categories: conceptual, empirical and physically based models.

Conceptual models play an intermediary role between empirical and physical based models. Whilst they tend to be aggregated, they still reflect the hypotheses about the process governing system behavior. This is the main feature that distinguishes conceptual model from empirical models (Beck, 1987). According to (Renschler, 1996), conceptual models tend to include a general description of catchment processes, without including the specific details of process interactions, which would require detailed catchment information. 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).

Physically based models are models based on the knowledge of the fundamental erosion processes; and incorporate the law of conservation of mass and energy (Bennett, 1974).

In theory, the parameters used in physical-based models are measurable and so are known (Merritt et al., 2003). In practice, the large number of parameters involved and the heterogeneity of important characteristics, particularly in catchments, means that these parameters must often be calibrated against observed data (Beck, 1987). Examples of physically based models are the Water Erosion Prediction Project (WEPP) and the Soil and Water Assessment Tool (SWAT).

Empirical models are generally the simplest of the three model types. They are based primarily on defining important factors through field observation, measurement, experimentation and statistical techniques relating erosion factors to soil loss (Petter, 1992). Empirical models are frequently used in preference to more complex models as they can be implemented in a situation with limited data and parameters input (Merritt et al., 2003). They are particularly useful as a first step in identifying the sources of sediments. The Universal Soil Loss Equation (USLE) and its revised version RUSLE are two of the empirical models that have been most widely used and generally accepted by the natural resources community because they are relatively easy to use (Saavedra, 2005).

2.5 Revised Universal Soil Loss Equation (RUSLE) Model

The first attempt to develop a soil loss equation for areas such as hill slopes and fields was that of (Zingg, 1940), who related erosion to slope steepness and slope length. Further developments led to the addition of a climatic factor based on the maximum 30-minute rainfall total with a two year return period (Musgrave, 1947), a crop factor, to take account of the protection effectiveness of different crops (Wischemeier and Smith, 1958), a conservation factor and a soil erodibility factor. Changing the climatic factor to the rainfall erosivity index (R) ultimately yielded the USLE (Wischmeier & Smith, 1978).

The Revised Universal Soil Loss Equation (RUSLE) is an empirically based model that has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practices (Renard et al., 1997). It retains the factors of the USLE by including improved means of computing soil erosion factors. The RUSLE model in GIS environment can predict erosion potential on a cell-by-cell basis, which is effective when attempting to identify the spatial pattern of soil loss present within a large watershed area (Shi et al., 2003). GIS can then 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). In spite of this advantage, RUSLE does not estimate sediment deposition and gully erosion. RUSLE computes average annual erosion as a function of six factors (Renard et al., 1997):

$$\mathbf{A = R * K * L * S * C * P}$$

Where: A = **estimated average annual soil loss**: unit are expressed in tones/hectares/years

R = **rainfall erosivity factor**: the erosive power of rainfall, expressed in MJ mm/t/ha/yr

K = **soil erodibility factor**; soil resistance against erosive force expressed with t ha M/J/h/mm

L = **slope length factor**; the ration of soil loss from the field slope length to the soil loss from a 22.1m length, under identical condition.

S = slope steepness factor; the ratio of soil loss from the field slope gradient to soil from a 9%slope, under otherwise identical condition.

C = cover management factor; the ratio of soil loss from an area with specified cover and management to soil loss from an identical area with no vegetative cover.

P = conservation practice factor; the ratio of soil loss with support practice, such as contouring, strip cropping or tracing to soil loss with a straight row farming up and down the slope.

2.6 The use of GIS and Remote Sensing in Soil Erosion Modeling

Several studies showed the potential utility of RS and GIS techniques for quantitatively assessing erosional soil loss (Saha et al., 1991); (Mongkolsawat et al., 1994).The advancement in the remote sensing and GIS technology provide an effective analytical tool in the modeling of soil erosion. Soil erosion is spatial phenomena, thus geo-information techniques play an important role in erosion modeling (Yazidhi, 2003). The potential utility of remotely sensed data in the form of aerial photographs and satellite sensors data has been well recognized in mapping and assessing landscape attributes controlling soil erosion, such as physiography, soils, land use/land cover, relief, soil erosion pattern (Pande et al., 1992).

In a GIS environment, it is possible to link data generated from remote sensing with their spatial location (Beck, 1987). In general the use of geo-information techniques offer the following advantages in erosion modeling: fast and cost effective estimates, possibilities to investigate larger areas, greater possibilities of continuous monitoring of these areas and possibilities to refine the soil erosion model depending on the required output scale i.e. rough global to more precise local scale. According to (Yazidhi, 2003), the use of digital elevation models and GIS offers possibilities to estimate topographical parameters that are useful in soil erosion modeling.

2.6.1 Remote Sensing

The basic fundamentals in remote sensing are the properties of electromagnetic radiation and their interaction with matter. Remote sensing has opened a new era in the planning and development of watershed management, as satellites imagery provides a fast and economic way to analyze large watersheds by virtue of their synoptic and repetitive coverage (Jain & Goel, 2002). Thus, by using multispectral data appropriately, different ground features can be differentiated from each other and a thematic map depicting land use/land cover can be prepared. Satellite imagery has been well utilized in different studies for watershed characterization and management aims (Saxena et al., 2000) and for measuring qualitative and quantitative terrestrial land-cover changes (Lu et al., 2004) in a watershed.

For soil erosion assessment in a watershed, remote sensing has been used for both detecting erosion features and obtaining erosion model input data (Petter, 1992). Remote Sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Multi-temporal satellite images provide valuable information related to seasonal land use dynamics. DEM (Digital Elevation Model) one of the vital inputs required for soil erosion modeling can be created by analysis of stereoscopic optical and microwave (SAR) remote sensing data (Pande et al., 1992).

2.6.2 Geographic Information System (GIS)

Soil loss by erosion is most frequently assessed by USLE (Spanner, 1982), first demonstrated the potential of GIS for erosional soil loss assessment using USLE. GIS is characterized by its capability to integrate layers of spatially oriented information. The number and type of applications and analysis that can be performed by GIS in a watershed are as large and diverse as the available geographic datasets (Deore, 2005)

GIS has been widely used in characterization and assessment studies which require a watershed based approach (Khan et al., 2001). In addition, the modeling and visualization capabilities of modern GIS, offer fundamentally new tools to understand the processes and dynamics that shape the physical, biological and chemical environment of watersheds (Jain and Goel, 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 soil loss at various locations in the watershed (Shi et al., 2003). Remote sensing and GIS techniques were utilized in the present study to identity priority areas for conservation measures on the basis of erosion risk map.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Geographical Location

The study area is conducted at Abay Choman District of Horro Guduru Wollega zone, Oromia regional state, Ethiopia. The study area is located at about 310km west of Addis Ababa (the capital city of the country). The study area is located between 09°29’30“N to 09°46’00“N and 37°08’15“E to 37°16’45“E and at an altitude of approximately 2296 m.a.sl geographical coordinates. The area has one long rainy season extending from March to Mid-October (Olana, 2006). According to the 2010/11 annual report of Abay choman district the monthly annual rainfall ranges from 1000-2400mm. Nashe dam is constructed on the Nashe River in the village of EGU ABAY that is located in Abbay choman woreda. This dam is constructed for hydropower and irrigation purposes.

The *Amerti-Neshe* hydropower dam was constructed on the *Neshe* River which is one of the major river of the Finchia valley basin situated along the common border of Horro and Abay-Chomen districts of Horro Guduru Wollega Zone. There are many tributary rivers flowing into the *Neshe* River amongst which *Aseti, Babbo, Nugulo, Chige, Nebas, Defas,* and *Torben* are the major ones.

The *Finchaa-Amerti-Neshe* Multipurpose Project was constructed by Ethiopian Electric Power Corporation (EEPCO) by the contractor named China Gezhouba Group Corporation (CGGC) with the total outlay of more than 2.63 billion birr out of which 85% was covered by loan of Export Import Bank of China and the 15% with Ethiopian government (FANMHO Report, 2011). The reservoir occupied an area of 2920 hectares of land and has a total storage volume of 4.48 * 108m3. The project was constructed to generate hydroelectric power of 97 MW from two units. After generating the intended electric power, the water will irrigate more than 6000 hectares of land for sugar cane downstream in the Fincha valley, and also 0.75 hectares of farmland for each household affected by the dam when they resettle. Dam construction was the major component of the project, whose construction was started in 2008 and completed in January, 2010 and the reservoir started to accumulate water that is necessary to generate electric power (FANMHO Report, 2011).

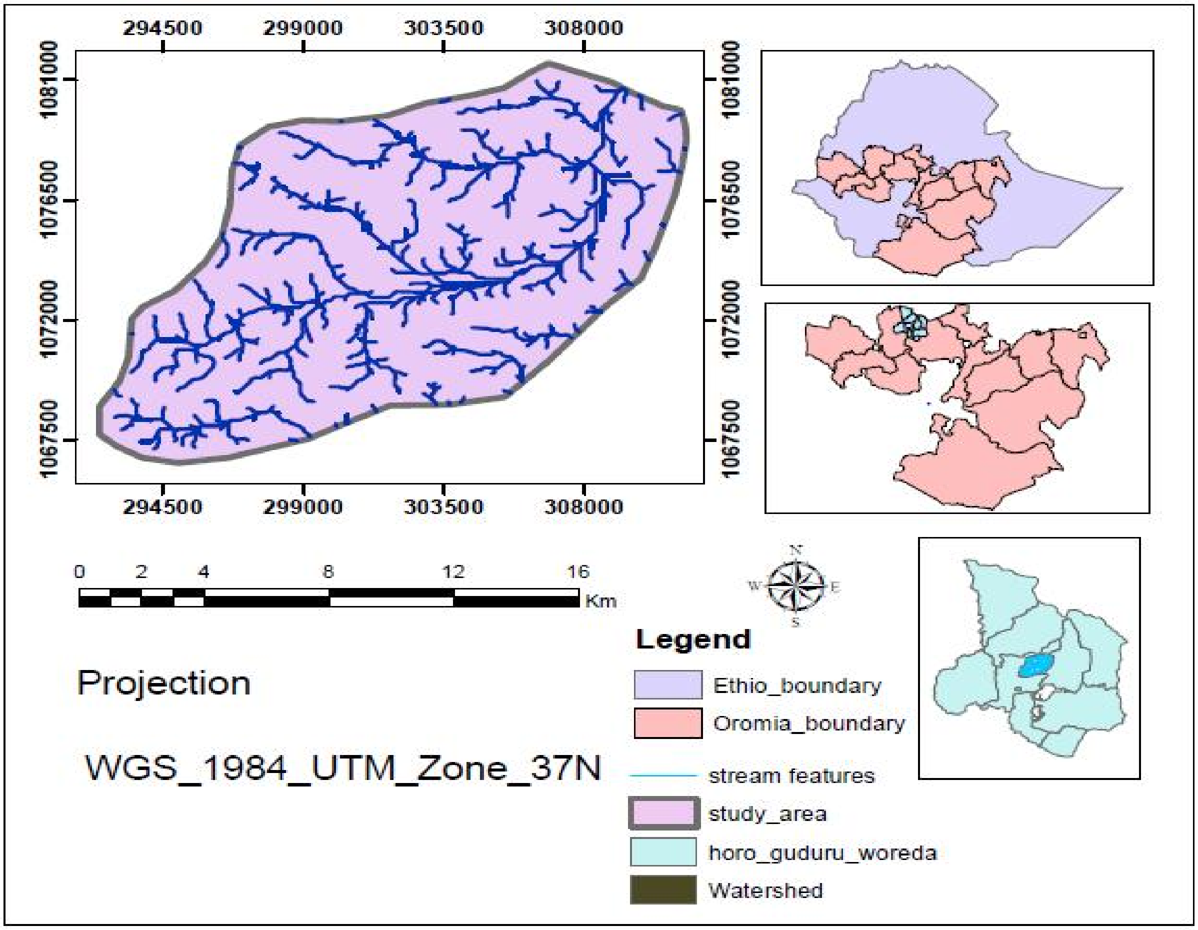

Figure 3.1 Location of Study area

3.1.2 Topography, altitude and climate

The two districts have more or less similar topography and agro ecological factors as they have common boundaries to a large extent. Plain land to plateau, hills, and deep Fincha valley systems are common topographic features of the two districts. The altitude rises from 1500- 2300 m.s.l. for Horro district, and 1400-2250 m.s.l. for the Abay-Chomen district. Climatically *dega* (high land), *weinadega* (mid-high land) and *kola* (low land) respectively accounts for 43%, 56% and 1% of the total land mass of Horro district. Whereas, *Waina dega* (mid-high land) and kola (low land) accounts for 43% and 57% respectively for the Abay- Chomen district. *Oda Bulluk* which is culturally most respected area among Oromo people of the Zone and annually celebrated on *Erecha* is found in Horro district.

Agro-ecologically, *dega* (high land), *weinadega* (mid-high land) and *kola* (low land) respectively accounts for 43%, 56% and 1% of the total land mass of Horro district. Whereas, *Wainadega* (mid-high land) and *kola* (low land) accounts for 43% and 57% respectively for the Abay-Chomen district. Both districts have similar rainy season, summer starts mostly from mid-May and ends of early September. Horro district receives annual average rain fall ranging from 1850mm to 1900mm, while Abay-Chomen district receives from 1400mm to 1500mm (ZoFED, 2010).

3.1.3 Soil Data

According to FAO (1986) soil classification major soil types of the area are six types of soils in the catchment. These soils are Vertisols, Leptosol, Luvisol and Cambisol. Vertisol is the predominant soil type which, is found in almost all parts of the watershed.

Vertisols are soils having, after the upper 20 cm have been mixed, 30 percent or more clay in all horizons to a depth of at least 50 cm. Vertisols have A (B) C-profiles; the Ahorizon comprises both the surface mulch (crust) and the underlying structured horizon that changes only gradually with depth. Dry Vertisols have a very hard consistence; wet Vertisols are very plastic and sticky.

Luvisols characterized a marked textural differentiation within the soil profile, with the surface horizon being depleted of clay and with accumulation of clay in a subsurface 'Argic' horizon. Luvisols have typically a brown to dark brown surface horizon over a reddish brown to strong brown or red argic subsurface horizon and exist on hilly part of the study area.

Cambisols are soils with initial stage of soil formation or weakly developed soils relating to their parent material and exist in all part of the watershed. Leptisols have continuous hard rock within 25 cm from the soil surface; or a mollic horizon with a thickness between 10 and 25 cm directly overlying material.

Leptosols are very shallow soils over hard rock material but also deeper soils that are extremely gravelly or stony. They are found particularly in hilly to mountainous area in Nashe Reservoir watershed (Figure 3.5).

3.1.4 Land use and land cover

The land use and land cover of the catchment area is classified under six major classes. The land use and land cover types that were mapped in the catchment area are: Forests (Dense and open), Water body, Grass land and Farm land (Agricultural lands). The forest both open and dense occupied mostly by Eucalyptus plantation (mature and young) which covers 22.75% of the total watersheds.

For Nashe Dam watershed, the relevant maps were created using ArcGIS 10.1 and ERDAS Imagine 2014 software tools. Satellite imagery, DEM, Soil and Rainfall of the study area was used as primary data source. The rainfall distribution map was prepared from Ethiopian rainfall data. The land use/land cover map was extracted from LANDSAT (Satellite imagery) satellite image using ERDAS Imagine 2014 software and the data was classified using GIS software. The slope map and Elevation map was extracted from DEM of the study area using GIS spatial analyst tool. The study was conducted using **Revised Universal Soil Loss Equation (RUSLE)** model for soil loss methods. A personal geo-database was created in Arc Catalog and dataset was created for the Study area with the spatial reference of WGS_1984_UTM_Zone_37N to arrange, store and to have the same projection of coordinate. In addition to these personal geo-database is to protect the data from lost and easy access in the GIS tool. The thematic maps of Rainfall map, Slope map, Elevation map, land use land cover map, and soil map were prepared using Raster calculation Method in ArcGIS software by multiplying all the parameters. The data layers have been integrated in GIS spatial analyst by Overlaying Analysis using Raster calculator or multiplying all causative factor using Raster calculator to obtain the soil erosion map.

The overall methodology involved the use of the RUSLE in a GIS environment, with factors obtained from meteorological stations, soil surveys, topographic maps, satellite images, digital elevation model and results of other relevant studies. Individual GIS layers were built for each factor in the RUSLE and combined by cell-grid modeling procedures in ArcGIS to predict soil loss in a spatial domain (Eastman, 1999). The expected soil loss potential (erosion hazard) expressed as tone per hectare per year for the study area was determined using the RUSLE model in a GIS environment. The Universal Soil Loss Equation (USLE) developed by (Wischmeier and Smith, 1978) is the most frequently used empirical soil erosion model worldwide. More recently, (Renard et al., 1996) has modified the USLE into a Revised Universal Soil Loss Equation (RUSLE) by introducing improved means of computing the soil erosion factors.

The USLE has been used widely all over the world either in the same or modified forms. (Hurni, 1985), also used this model to assess soil erosion in Ethiopia. He even modified some factors of the USLE for Ethiopian conditions. Three of the most significant modifications include R (rainfall erosivity index), C (land cover) and P (management) factors. This was a valuable input to this research and other erosion research in Ethiopia since the 1980’s. However, the available information in this regard is still generalization of the realities in different localities and doesn’t show specific conditions. Therefore, there is a need to conduct a detailed and extensive assessment of erosion hazard by considering the various site specific erosion factors into considerations. The control factors of soil erosion, namely: climate, soils, vegetation cover, topography and management are combined in the empirical Revised Universal Soil Loss Equation (Renard et al., 1996). The model estimates sheet and rill erosion as a function of six major factors:

$$A= R * K * LS * C * P \ldots\ldots (1)$$

Where A is the average annual soil loss due to water erosion (t $ha^{-1} y^{-1}$), R is the rainfall and runoff erosivity factor, K is the soil erodibility factor, LS is the slope length and slope steepness factor, C is the crop management or land cover factor and P is the erosion control practice factor.

To identify the spatial pattern of potential soil erosion in the study area, all the considered erosion factors (R, K, LS, C and P) had been surveyed and calculated depending on the recommendations of (Hurni, 1985) ,to Ethiopian context and other related studies. RUSLE doesn’t estimate deposition, sediment yield at a downstream location and ephemeral gully erosion and doesn’t represent fundamental erosion processes and interactions. It is however, found to adequately represent the first order effect of the factors that affect sheet and rill erosion. Individual GIS files were built for each factor in the RUSLE and combined by cell-grid modeling procedures in GIS software to predict soil loss in a spatial domain. The flow chart of erosion risk mapping is presented in Figure 4.6

3.2 Methods of land use land cover change detection

Multi-temporal (1996 and 2016) satellite imageries of the study area have been imported to ERDAS 2014 image processing software. Image pre-processing, enhancement, classification were applied on the raw image. The classified images have been used in the extraction of information on land cover condition and quantification of changes over the last two decades using multi temporal GIS analysis. The land cover conditions of the two different periods (1996 and 2016) have been compared and change has been detected and quantified by post classification comparison method.

3.2.1 Image processing

Landsat image of (1996) and (2016) was used for this study. For each of them digital image processing operations such as image restoration, geo-referencing, image enhancement and image classification (unsupervised and supervised) have been done using ERDAS Imagine 2014 image processing software. Area of interest is delineated using ERDAS IMAGIN 2014 software and study area is digitized using Arc GIS 10.1 software from topographic map of scale 1:50,000 after the topographic map is geo-referenced or projected to Datum: UTM/WGS 1984, 37N. Then, subset was prepared for the imageries based on area of interest (AOI).

3.2.2 Image classification

Image classification is necessary to convert image data to thematic data. According to (Lillesand & Kiefer , 1994), the overall objective of image classification procedures is to automatically categorize all pixels in an image into land use land cover classes. Notice that data are transformed into information. Multispectral classification is one of the most often used methods of information extraction (Jensen, 1996)). In classifying the images, both unsupervised and supervised image classifications techniques were applied. The unsupervised was done before field work. Supervised classification requires a prior knowledge of the scene area in order to provide the software with unique training classes. It is up to the user to define the original pixels that contain similar spectral classes representing certain land cover classes. Correspondingly, representative points believed to represent the various land cover classes were marked using GARMIN GPS during the field visit. These points were used to sample representative signatures for various land cover types identified during the field visit. Following this, supervised land use and land cover classification has been carried out using ERDAS Imagine software from 2016 Land sat Satellite image. The maximum likelihood image Classification was utilized for the supervised classification. By having applied the techniques of image classification, land use and land cover types have been classified so as to use the classified images as inputs for generating crop management (C) factor and support practice (P) factor of the Revised Universal Soil Loss Equation. With the help of visual interpretation elements and the different reflection characteristics of the features in the satellite image of 2016, the study area has been classified into six land use and land cover classes, namely, farm land, bare lands, settlements, grass land, Water body, and forest lands.

3.2.3 Accuracy Assessment

Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. To assess the classification accuracy, confusion matrix was employed. The confusion/error matrix consists of rows and columns. The rows represent the classification values and the column represents facts from the field. The diagonal line of the error matrix represents the number of pixels that were correctly classified. The overall accuracy index is produced by dividing all the pixels correctly classified by the total number of pixels in the matrix. The producer accuracy index is produced by dividing the number of correctly classified pixels that belong to a class by the sum of the values of the column of the same class. The user accuracy index is produced by dividing the total number of correctly classified pixels that belong to a class by the sum of the values of the rows of the same class. By having this, in this study the overall classification accuracy is (5 + 4 + 12+ 4 + 29+ 16) / 80 which is equal to 0.875 or 87.5 percent (Table 3-1)

Table 3:1 Error matrix showing classification accuracy of the true land cover

Classified Data	Grass land	Bare lands	Forest land	Water bodies	Settlement	Agricultural lands	Row Total
Grass lands	5	0	0	0	0	0	5
Bare lands	0	4	1	0	0	0	5
Forest land	0	0	12	0	0	1	13
Water bodies	0	0	0	4	0	0	4
Settlement	0	0	3	0	29	4	36
Agriculture lands	1	0	0	0	0	16	17
Column Total	6	4	16	4	29	21	80

$$\text{Kappa coefficient} = \frac{(\boldsymbol{total * sum\ of\ correct}) - \boldsymbol{sum\ of\ tha\ all}\ (\boldsymbol{row\ total * column})}{\boldsymbol{total\ squared} - \boldsymbol{sum\ of\ the\ all}(\boldsymbol{row\ total * column\ total})}$$

The overall classification accuracy of 83.07 and overall Kappa statistics of 0.8307 was achieved, which is feasible for further application. The kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give percentage measure of classification accuracy. Kappa value is characterized in to three grouping: value greater than 0.8 represents strong agreement, 0.4 - 0.8 represents moderate agreement and that of less than 0.4 is considered as poor agreement (Congalton, 1991), as cited in (Israel, 2011). The reasons for the errors may include the similarity of reflectance of settlement, grazing land and cultivated areas. In addition, the fast land use land cover dynamic nature of the area may also introduce the classification error.

3.2.4 Land use and Land cover Data

The Landsat images of (1996) and (2016) which have a Path168 and Row 054, acquired 21/1/1996 and 13/1/2016, from Ethiopian Mapping Agency (image month January during the dry season) was used to classify the current and twenty years back land use and land cover map of the study watershed. The image has 30 X 30 meter resolutions. Ground truth data of eighty (80) reference points were collected from the field to verify the classified image and to collect the necessary land use land cover data for training area delineation and accuracy assessment. Garmin GPS were also employed to collect Ground Control Points (GCPs). The ground truth data collection was similar season of image acquisition

3.2.5 The topographic map

Topographic map of scale (1:50,000) was taken from Ethiopia Mapping Agency to support the supervised classification and to assure the rectification of imageries. Description of the topographic map used for this study includes: scale 1:50,000, Series (ETH4), Sheet (0937C1) and Edition (2 EMA 1982). The map has better information about the topographic features of the watershed and the production of digitized data is based on this topographic map. This top sheet was used as a base map for georeferencing the input data and vector data generation. For the purpose of georeferencing all the routine steps of digital image processing was applied using ArcGIS software. During georeferencing, data integration and compatibility with the national reference system considered are: Projection UTM, Spheroid WGS 1984, Datum WGS 1984 and UTM Zone 37 North.

CHAPTER FOUR

DATA SOURCES AND METHODOLOGY

4.1 Data Sources

For this study various basic primary and secondary input data were collected from different sources. For the land use/land cover analysis purpose, Landsat satellite images, ASTER DEM, Topomap of the study area (1:50000) purchased from Ethiopian mapping agency, Soil map (shape file, 1:1,000,000) collected from Oromia water works design and supervision enterprise and rainfall from Metrological agency were used.

Software used	Purpose of the software	remark
ArcGIS	Used to delineate the watershed, Geo-database creation, georeferencing, topology creation, rasterization, reclassification and factor map development	ArcGIS 10.1
Erdas Imagine	Image pre-processing of the satellite image ,land use and cover creation and supper classification	Erdas 2014
Microsoft office	Used for thesis report writing and presentation	2013

Data type	Format	Data source	Purpose of the data
DEM	.img	ASTER GDEM	To generate slope, elevation
Satellite	.img	USGS.gov	To generate land use land cover
Rainfall data	Excel	National Metrological Agency	To develop rainfall map
Soil data	Raster format	Ministry of Agriculture	To develop the soil map for soil erosion risk

4.1.1 Precipitation (Rainfall) data

There is Nashe metrological station on the study watersheds as a result of this, ten stations were used which are near to the watershed. These ten stations were Fincha, Shambu, Alibo, Gida Ayana, Homi, Jarmet, Kombolcha, Gebete, Hareto and Kachisi. The monthly amounts of rainfall (28-30 Years) and average annual rainfall for these stations were collected from National Metrology Agency. The annual rain fall was interpolated from these eleven points observation in Arc GIS 10.1 by spatial analyst tool and the following rainfall map is produced (Fig 4.2).

Table 4:1Mean Annual Rainfall of the gauging stations

station	latitude	longitude	Mean annual
Shambu	9.5712	37.12117	1443
Alibo	9.88633	37.074	1215.79
Kombolcha	9.502333	37.47267	1252.22
Fincha	9.57	37.37033	1614.46
Gebete	9.38383	37.4092	1066.16
Hareto	9.35	37.12	1168.63
Homi	9.621333	37.24117	1524.78
Jarmet	9.8	37.01667	1242.8
Nashe	9.72333	37.26833	1508.97
Kachisi	9.583333	37.86	1625.87
Gida Ayana	9.86667	36.61667	1498.34

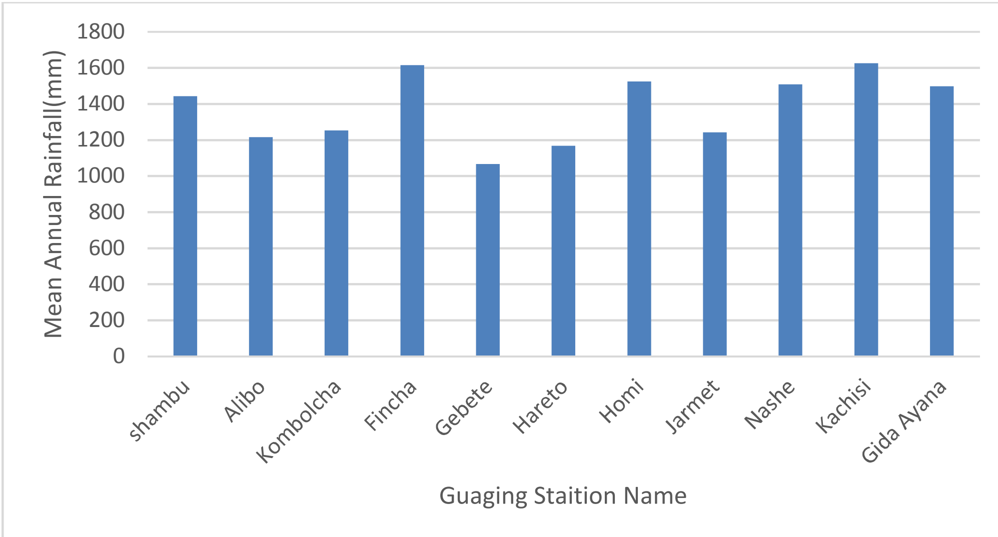

Figure 4.1 Mean Annual Rainfall of the Gauging Stations

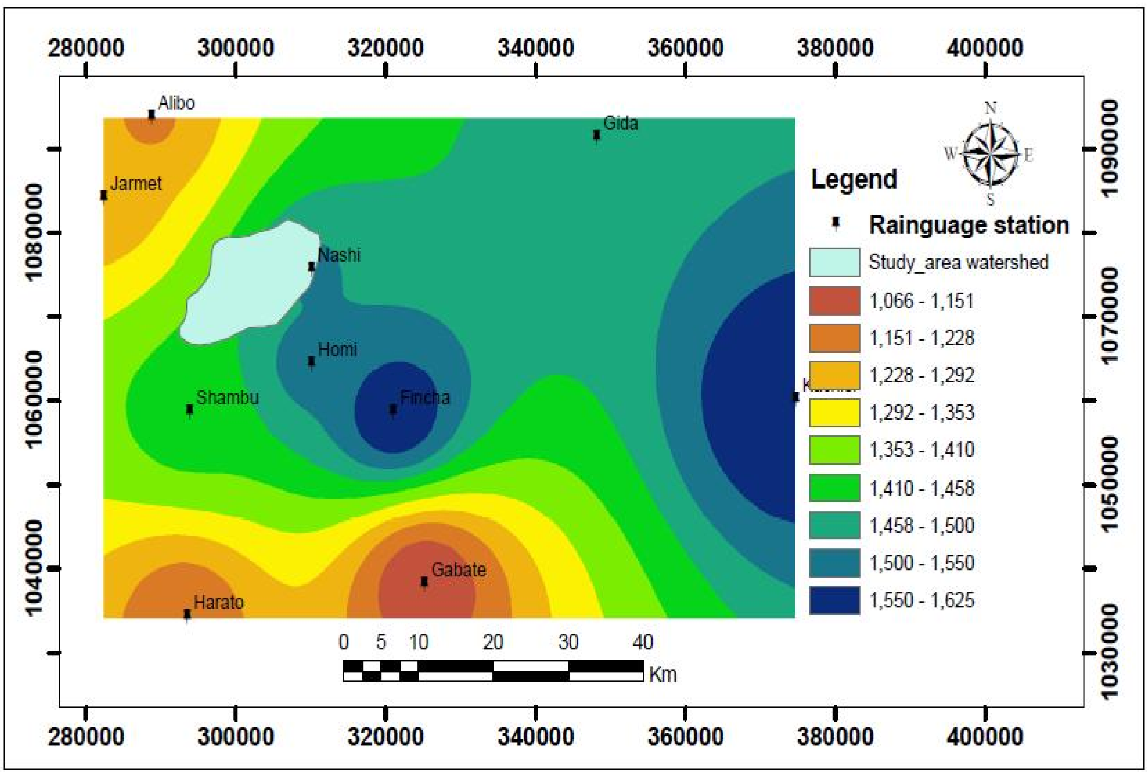

Figure 4.2Meteorological Station and Interpolation result map

4.1.2 Geology and Soil Types

According to the Ethiopian physiographic region division, the study area is situated in the upper Fincha part of the valley system and adjoining the plateau lands of the central high lands. The dominant landscapes of Nashe Dam watershed area are flat, gently undulating plains and mountainous which elevation range from 1907 to 2577 m.s l.

According to FAO (1986) soil classification major soil types of the area are six types of soils in the catchment. These soils are Vertisols, Leptosol, Luvisol and Cambisols. Vertisol is the predominant soil type (Figure 3.5) which, is found in almost all parts of the watershed.

Vertisols are soils having, after the upper 20 cm have been mixed, 30 percent or more clay in all horizons to a depth of at least 50 cm. Vertisols have A (B) C-profiles; the Ahorizon comprises both the surface mulch (crust) and the underlying structured horizon that changes only gradually with depth. Dry Vertisols have a very hard consistence; wet Vertisols are very plastic and sticky.

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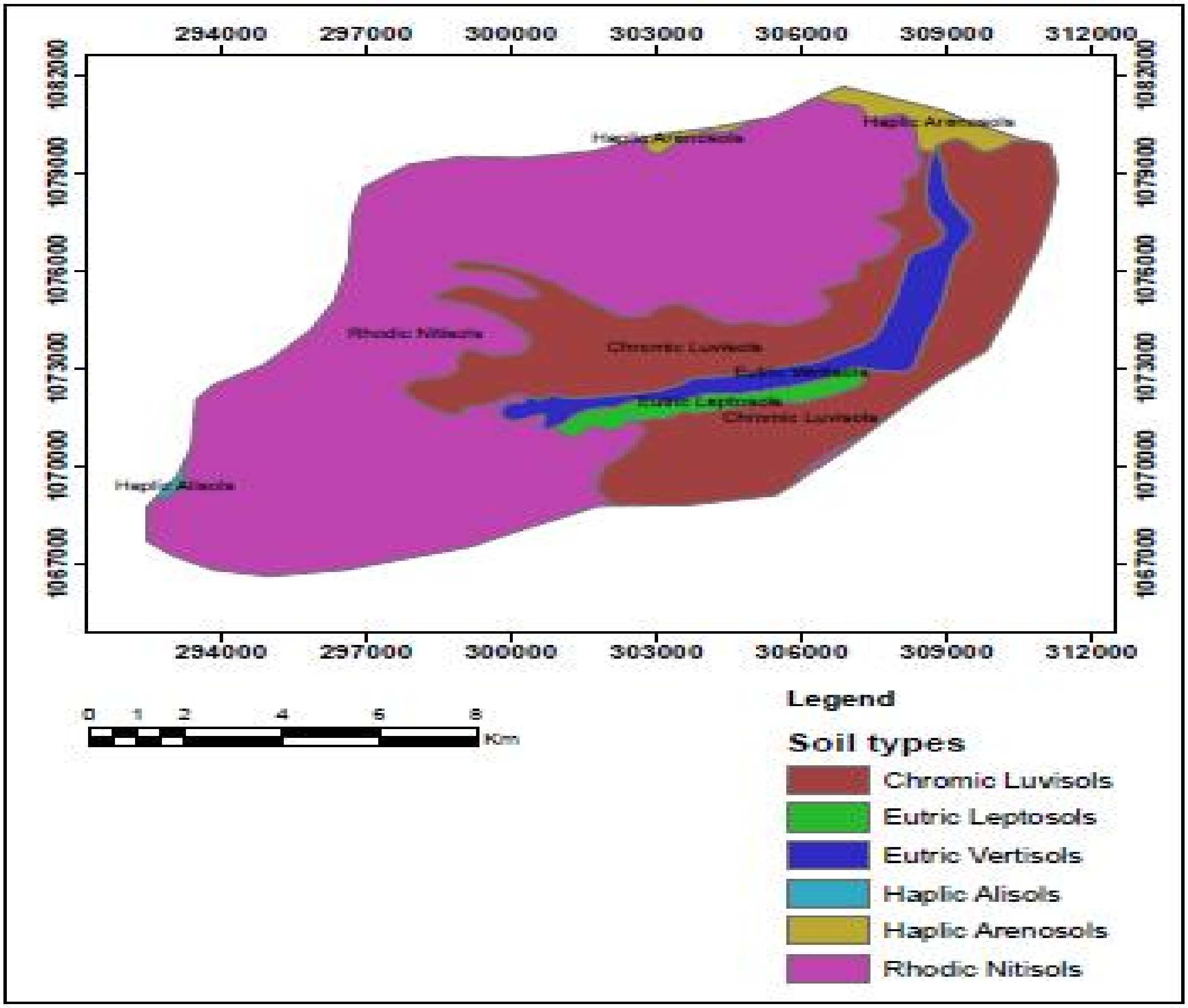

Figure 4.3 Soil types of the study area

4.1.3 The Digital Elevation Model (DEM)

Digital Elevation Models do play a fundamental role in mapping. The digital description of the three dimensional surface is important for several applications. The ASTER-DEM files may be used in terrain analysis, with the generation of graphics displaying slope, direction of slope (aspect), and terrain profiles between designated points. The DEM for this study is extracted from Global Land Cover Facility (www.landcover.org) with 30 meter resolution and used to develop topographic parameters such as slope gradient, slope length (slope map).

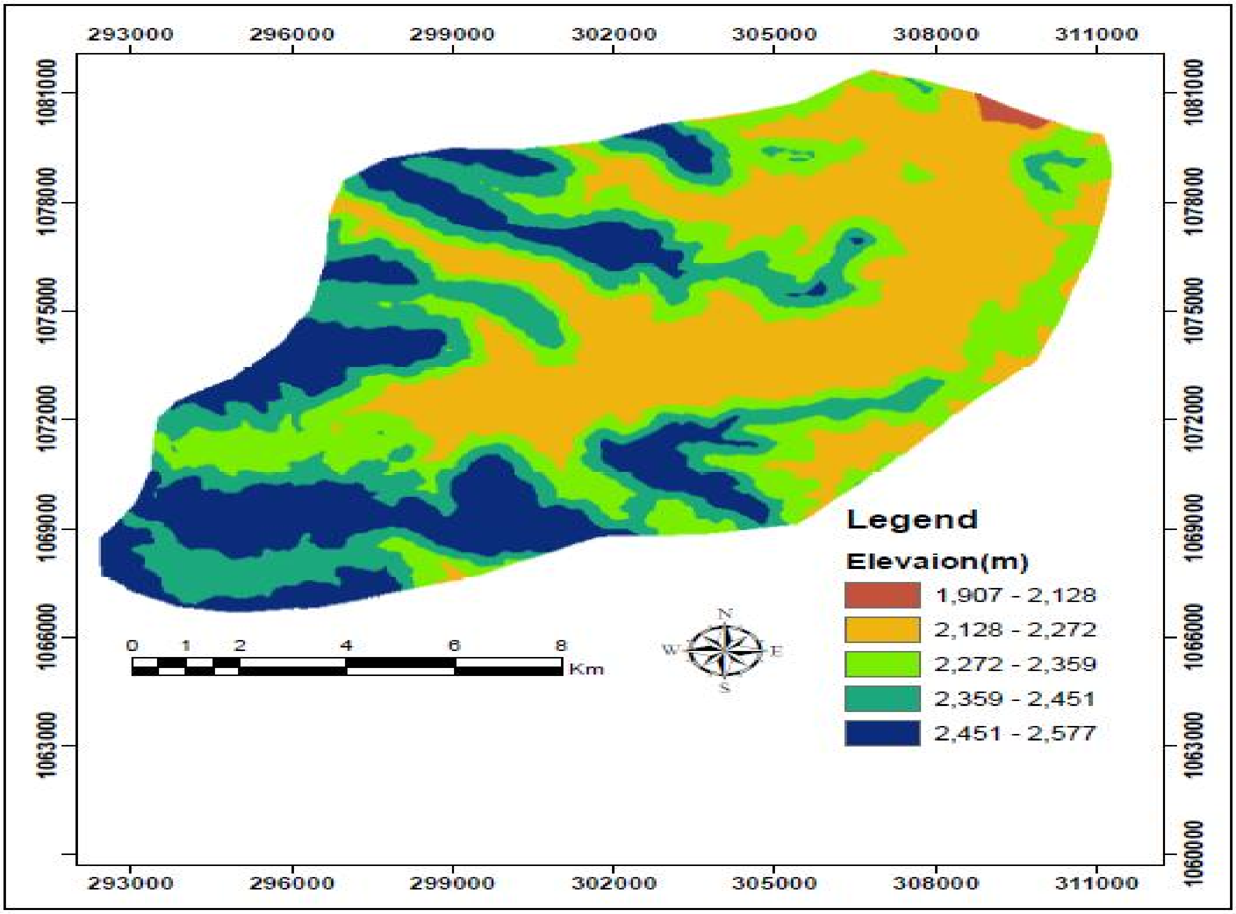

Figure 4.4Elevation of the study Area

4.1.4 Land use and Land cover Data

The Landsat of 1996 and 2016 satellite imagery have been collected from Ethiopian Mapping Agency which was used to classify the current and twenty years back land use and land cover map of the study watershed. The image has 30 X 30 meter resolutions. Ground truth data of Eighty (80) reference points were collected from the field to verify the classified image and to collect the necessary land use land cover data for training area delineation and accuracy assessment. Garmin GPS have employed to collect Ground Control Points (GCPs). The ground truth data collection was similar season of image acquisition.

Table 4:2General description of land cover categories of the study area

No	LULC classes	Description of land cover types
1	Water bodies	Area under manmade of Nashe reservoir
2	Settlement areas	These areas includes small rural residential places including trees in individual garden. Recently, this lands covers types dominantly found in all watershed plant.
3	Eucalyptus plantation	Areas covered with relatively tall and dense eucalyptus plantation trees that have open and closed canopy cover. Land areas that is covered with scattered woods lots areas which covered with mainly shrubs and other remnant small sized plant species.
4	Cultivated land	Areas of plant ploughed/prepared for growing various annual crops. This categories includes areas currently under crop, fallow and land under preparation for cultivation.
6	Bare lands	Areas of land within or around forest that have no vegetation cover, degraded lands, bare grounds areas. The category of land denotes areas that are without any vegetation cover at the time of satellite image acquisition.
7	Grazing lands	All areas of land used for open grading and as well as in some extent kept for grass production to make hay for livestock. It also includes grass dominated non woody species and rooted herbaceous plant.

4.1.5 The topographic map

Topographic map of scale (1:50,000) was taken from Ethiopia Mapping Agency to support the supervised classification and to assure the rectification of imageries. The map has better information about the topographic features of the watershed and the production of digitized data is based on this topographic map. This top sheet was used as a base map for georeferencing the input data and vector data generation. For the purpose of georeferencing all the routine steps of digital image processing was applied using ArcGIS software. During georeferencing, data integration and compatibility with the national reference system considered are: Projection UTM, Spheroid WGS 1984, Datum WGS 1984 and UTM Zone 37 North.

4.2 Research Methodology

The methodology that is used in this soil erosion risk assessment and mapping is the implementation of Revised Universal Soil Loss Equation (RUSLE) in a raster GIS environment (or grid-based approach) after some modifications in the calculation of specific factors. RUSLE is developed as an equation of the main factors controlling soil erosion, i.e., climate, soil characteristics, topography, land cover and land management practice. As cited in (Renard et al., 1991), (USDA-ARS, 1980), the form of the Revised Universal Soil Loss Equation (RUSLE) is expressed by the formula:

A= R x K x LS x C x P

Where: A = **estimated average annual soil loss**: is the mean annual soil loss caused by sheet and rill erosion; unit are expressed in tones/hectares/years

R = **rainfall erosivity factor**: the erosive power of rainfall, expressed in MJ mm/t/ha/yr

K = **soil erodibility factor**; soil resistance against erosive force expressed with ton ha M/J/h/mm

L = **slope length factor**; the ratio of soil loss from the field slope length to the soil loss from a 22.1m length, under identical condition.

S = **slope steepness factor**; the ratio of soil loss from the field slope gradient to soil from a 9%slope, under otherwise identical condition.

C = **cover management factor**; the ratio of soil loss from an area with specified cover and management to soil loss from an identical area with no vegetative cover (dimensionless, ranging between 0 and 1)

P = **conservation practice** factor; the ratio of soil loss with support practice, such as contouring, strip cropping or tracing to soil loss with a straight row farming up and down the slope(dimensionless, ranging between 0 and 1).

The unit of average annual soil loss (A) are based on the R and K factors. The R factor which represents the erosive power rainfall is considered as the main cause of soil erosion, whilst the erodibility or K factor represents the soil erodibility or the capability of a particular soil type soil resistance to erosive forces. The other USLE factors (L, S, C, and P) are considered as adjustment factor and they are dimensionless.

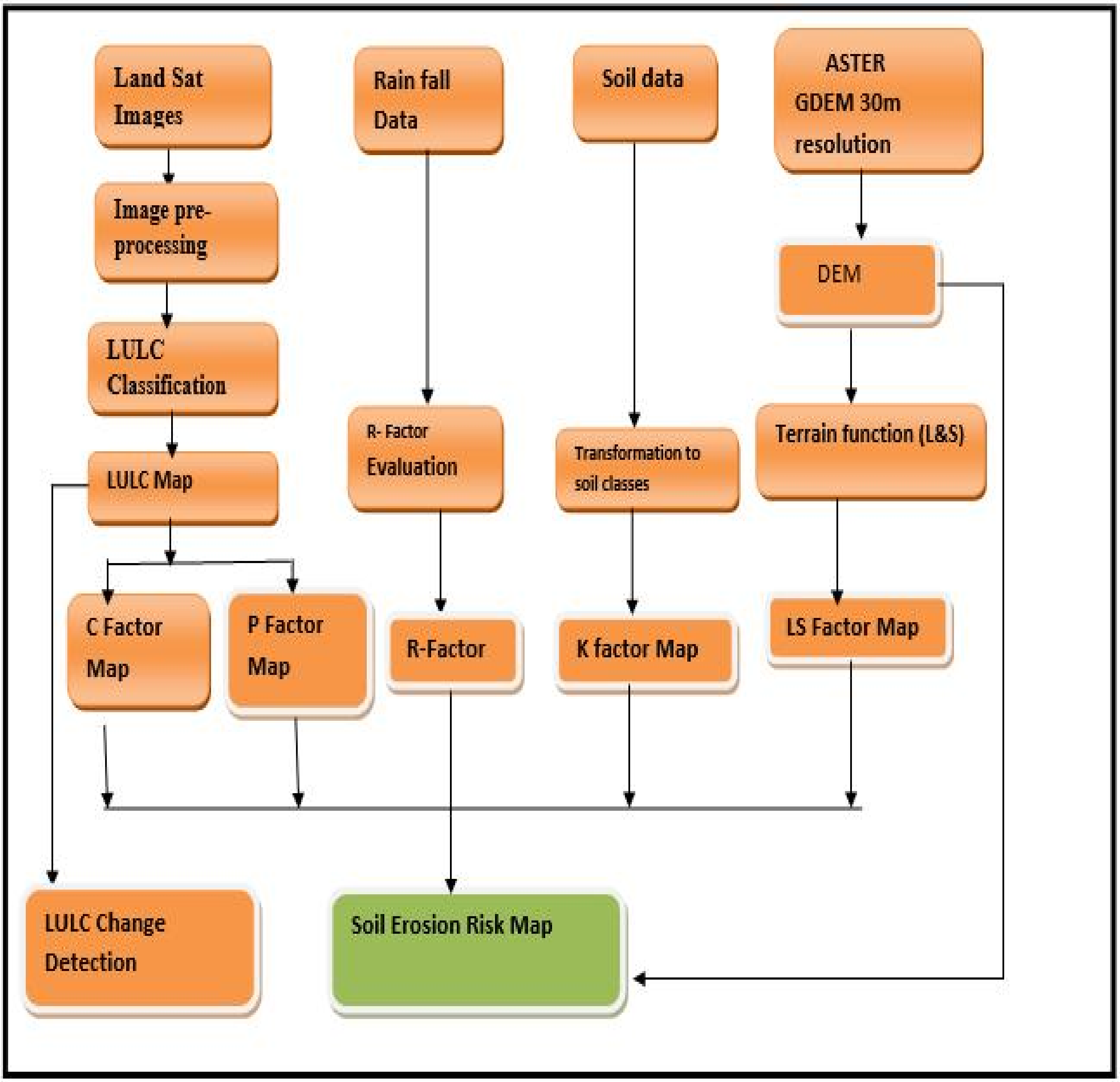

Figure 4.5 The Scheme of the Methodological steps

CHAPTER FIVE

RESULTS AND DISCUSIONS

5.1 RUSLE MODEL PARAMETERS

5.1.1 Rainfall Erosivity factor (R)

For the study area, the mean annual rainfall data of 11 stations (Alibo, Combolcha, Gebete, Kombolcha, Kachisi, Gida Ayana, Hareto, Homi, Jermet, Neshe and Shambu) over 20 years (1996 – 2016) was considered to calculate the R-factor (Table 5.1).

Rainfall erosivity (R) factor of the RUSLE was estimated from the rainfall data according to the equation given by Hurni (Hurni, 1985), derived from a spatial regression analysis (Hellden, 1987), for Ethiopian condition:

$R = -8.12 + 0.562 * P$--- (i)

Where R = rainfall erosivity factor, and P = mean annual rainfall of the Watershed Reservoir that was collected from National Meteorological Agency.

After the corresponding mean annual rainfall is assigned, the R value was calculated from the rainfall map using ‘Raster calculator‘ ‘tool in ‘ArcGIS‘ ‘software. The raster rainfall data of the study area is converted to erosivity map of the study area using the regression equation.

Owing to variation in mean annual precipitation amount within the study area, variations in rainfall erosivity were observed (Table 5.1). The values in Table 5.1 show that as the mean annual rainfall increases the rainfall erosivity also increases. Following this, the rainfall erosivity is high at the northeast of Neshe and Homi but low to the northwest towards Jermet. Similarly, the rainfall erosivity value estimated from the rainfall map using ArcGIS ranged from 591.06 to 905.62 MJmm/ha.h.yr (Figure 5.1), which is close to the erosivity values estimated using the mean annual rainfall. According to (Hudson, 1981), high rainfall may have high erosive power but the total erosivity is not directly proportional to the total amount of rainfall. Therefore, based on this the Northern part of the study area receives relatively higher rainfall that have high erosive power

Table 5:1 Rain Gauge Stations considered around the Study Area

Station Name	Average annual precipitation	R- factor(Erosivity)(MJmm/t/h/yr
Shambu	1443	802.85
Alibo	1215.79	675.15
Kombolcha	1252.22	695.63
Fincha	1614.46	899.21
Gebete	1066.16	591.06
Hareto	1168.63	648.65
Homi	1524.78	848.81
Jarmet	1242.8	690.33
Nashe	1508.97	839.92
Kachisi	1625.87	905.62
Gida Ayana	1498.34	833.95

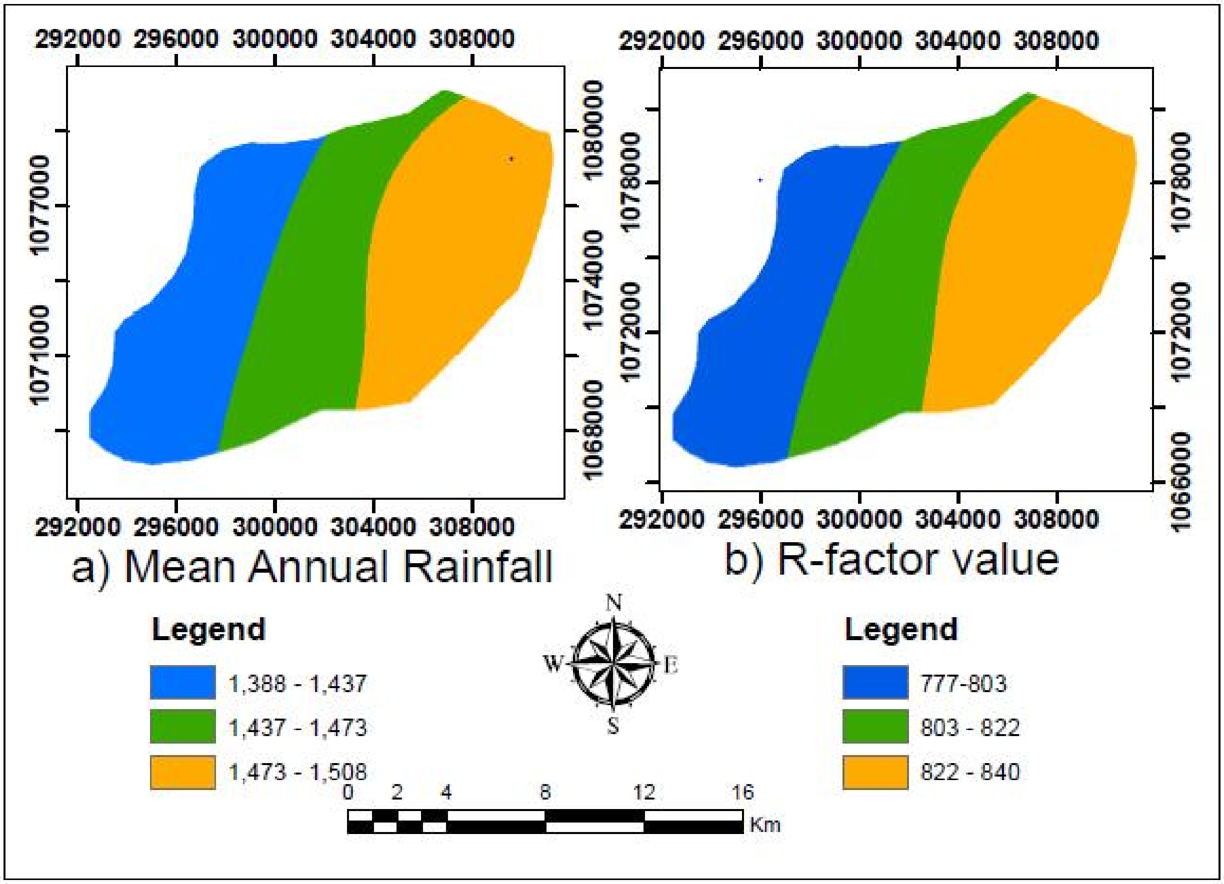

Figure 5.1 Spatial Variability of Rainfall Erosivity in the study area

5.1.2 Soil erodibility factor (K)

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. Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic matter and chemical content of the soil (Morgan, 1995). In the USLE model, (Hurni, 1985) estimated the K-factor values for soil types from the experiment conducted on some six research centers in Ethiopia. For determination of soil erodibility factor (K) Hurni based on soil color.

Black = 0.15

Brown = 0.20

Red = 0.25

Yellow = 0.30

The major soil types in the study area were extracted from the digital soil map data obtained from the MoA and RDE. IDW provides a versatile and simple tool which has sufficient accuracy when used to interpolate continuous surface from scatter point data sources (Lam, 1983).The resulting shape file was changed to grid file to raster with a cell size of 30 meters resolution.

Table 5:2 Soil types and there colors in Nashe Dam Watershed and their Erodibility factors

Soil type	Rhodic Nitisols	Chromic Luvisol	Eutric Vertisol	Eutric leptisols	Haplic Arenosols	Haplic Alisols
Soil color	Brown	Red	Yellow	Yellow	Black	Black
Erodibility(K-value)	0.2	0.25	0.3	0.3	0.15	0.15

From the digital soil map data Eutric Vertisols, Chromic Luvisols and Rhodic nitosols were recognized and obtained from MOA in the study area. These soil types were assigned with suitability values for further processing. Chromic Vertisols contain much exchangeable Aluminum and are notorious for inactivating fertilizer phosphate. Nitosols are the most fertile productive soils and have a potential under rain-fed agriculture. Nitosols are found in northern, Eastern, southern and Southwestern. It covers majority of the study area. Chromic Luvisol are found in northern, Central and southeastern corner of the study area.

As can be seen from (figure 5.2) the soil erodibility values of the study area ranged from 0.15 t/ha.yr, the lowest to 0.30 tons/hac/MJmm, the highest. The Erodibility values were found to be consistent in the northern central parts, western and southwestern parts of the study area. This indicates that the soils are highly vulnerable to erosion because they have low aggregate stability and low infiltration rate which may lead to high runoff soil loss, namely Rhodic Nitisols , Chromic Luvisols and Eutric Vertisols by comparing(figure 4.3 and 5.2) . The soils which area found in the northern, Eastern, southern and Southwestern parts of the study area have relatively low K-factor values (figure), that indicates resistance to erosion. Although the highest K-factor value of the study area K=0.25, is relatively low compared to the standard maximum value (K=1). Medium textured soils, such as silty loam soils have a moderate K values, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having high silt content (K=1) are the most erodible of all soils as they cause a decrease in filtration (Saavedra, 2005). Hence, soil loss in the study area is expected to be relatively low compared with areas that may have a K-value close to maximum.

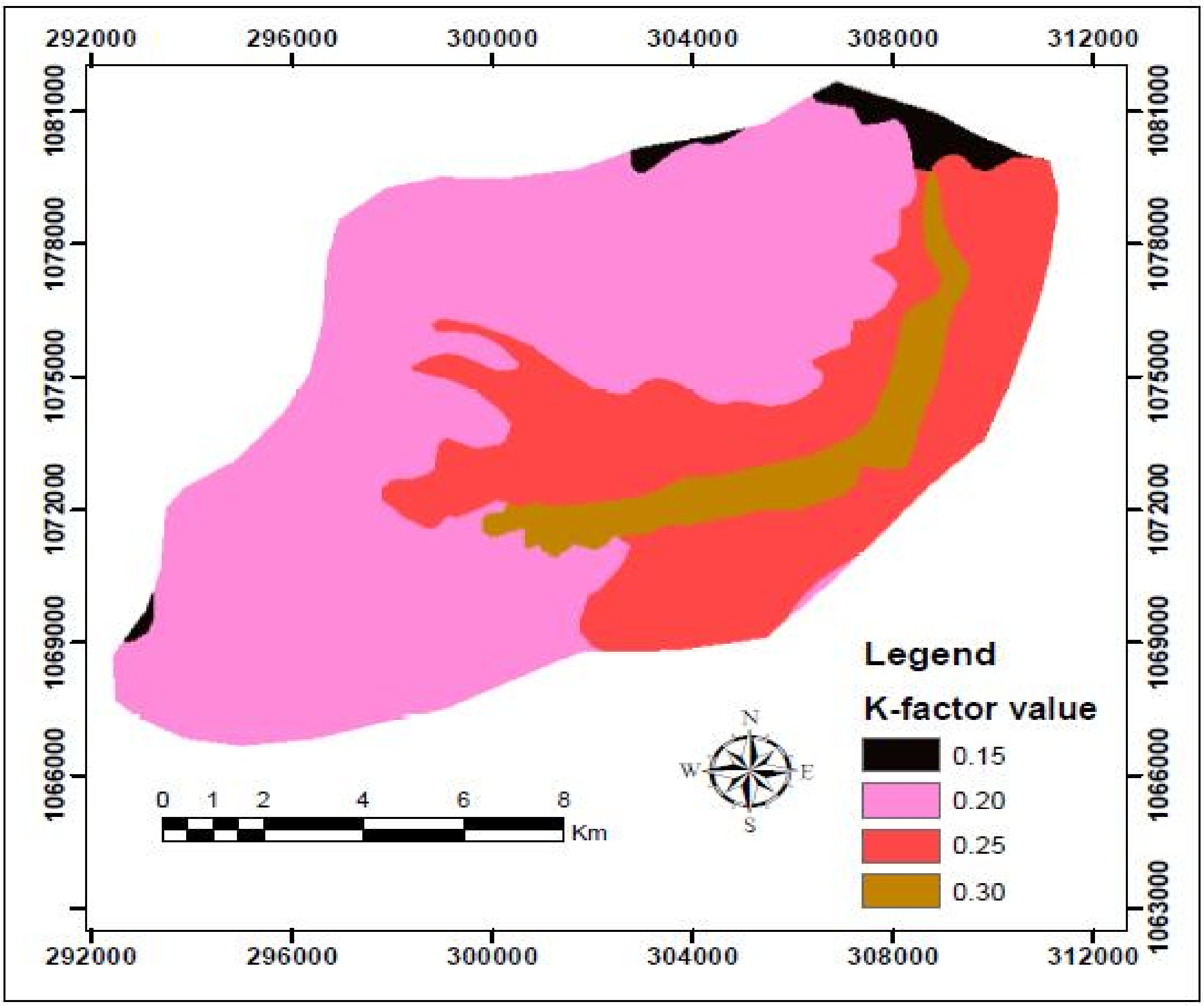

Figure 5.2 Map of the spatial Variability of the soil erodibility (K) factor of the study area

5.1.3 Slope length and steepness factors (LS)

Slope Length and Slope gradient (steepness) has been obtained from the ASTER- DEM of the study area. The elevation of the study area ranges from 1907 to 2577 meters above sea level (Figure 4.4). Low values of the elevation are found on the west corner, southwest central and northeastern part of the study area. High values of the elevation were also obtained in the northeastern corner and southwestern part of the study area. High slope length and slope steepness factor values were obtained in areas with steep and long slopes.

According to (Deore, 2005), erosion would normally be expected to increase in slope length and slope steepness factor as a result of respective increases in velocity and volume of surface runoff. Steeper slope causes higher runoff velocities, more splashes downhill and faster flow and therefore contributes greater soil erosion (Remortel, 2001). Based on these, since the study area is located in the midland and highlands (with altitude greater than 1500m m.s.l.) it may have a great contribution in soil loss by water erosion.

The effect of topography on erosion in RUSLE is accounted for the LS factor. Erosion increases as slope length increases, and is considered by the slope length factor (L). Slope length is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel (Wischmeier and Smith, 1978).

The slope steepness factor (S) reflects the influence of slope gradient on erosion. Both slope length and steepness substantially affects sheet and rill erosion estimated by RUSLE. In erosion prediction, the factors L and S are usually evaluated together. In this study, the slope gradient was determined from digital elevation model (DEM) of 30 meter resolution. The slope gradient determined for the study area is used for generating the LS factor as determined by Soil Conservation Research Project for Ethiopian condition.

Erosion is influenced both by the slope gradient and length of the slope, the potential erosion on uniform slopes increases as these parameters increase. The new RUSLE equation has major changes in way that LS values are calculated. The assumptions taken into consideration are as follows:

- The USLE assumed that runoff was uniform over the catchments and that some runoff was channeled into rills and gullies; rill erosion is a major component in the RUSLE.
- The USLE calculated the amount of runoff as the excess applied minus soil infiltration but did not consider that long rains would saturate the soil, infiltration would be slower and runoff, which causes erosion, would be greater.
- Sediment deposition at the bottom of concave slopes was not considered, USLE being applied only to those areas with net erosion.
  - The USLE was not designed to handle converging and diverging terrain; this has been rectified in the RUSLE.

Several methods of LS factor determination is developed with different GIS professionals at different time. These includes; using the formula:

LS = (flow accumulation * DEM cell resolution/22.13)0.6 * (sin (slope * 0.01745)/0.09)1.3 and LS = λ 0.3/22.1/22.1)*(S/9)1.3.

For this study calculating LS factor by using DEM after preparing the flow direction and flow length map of the following formula (Equation 3) was used.

LS = (λ 0.3/22.1) * (S/9)1.3 ……………….. Equation (3.3)

LS = (pow (flow length, 0.3)/22.1) * pow (slope/9, 1.3)

Where; λ = Flow length, S = Slope in percent

In raster calculator two steps was followed:

Determination of (λ0.3) * (S/9)1.3

Division of the result of step one by 22.1

The LS value is considered to have values between 0.02 - 48 for Ethiopian condition (Hurni, 1985) and the study area are ranging from 0 to 12.03.

The basic input for generating an LS factor grid in GIS is a DEM dataset of suitable scale that has been clipped to encompass the zone of interest, usually a topographically defined catchment or watershed. Therefore, for this study the slope gradient in percent (Figure 5.3) was determined from

ASTER digital elevation model (DEM) of 30 meter resolution. Slope gradient (%) used to generating LS factor combined with slope length (m) and slope steepness (S) produce LS factor as determined by Soil Conservation Research Project for Ethiopian condition.

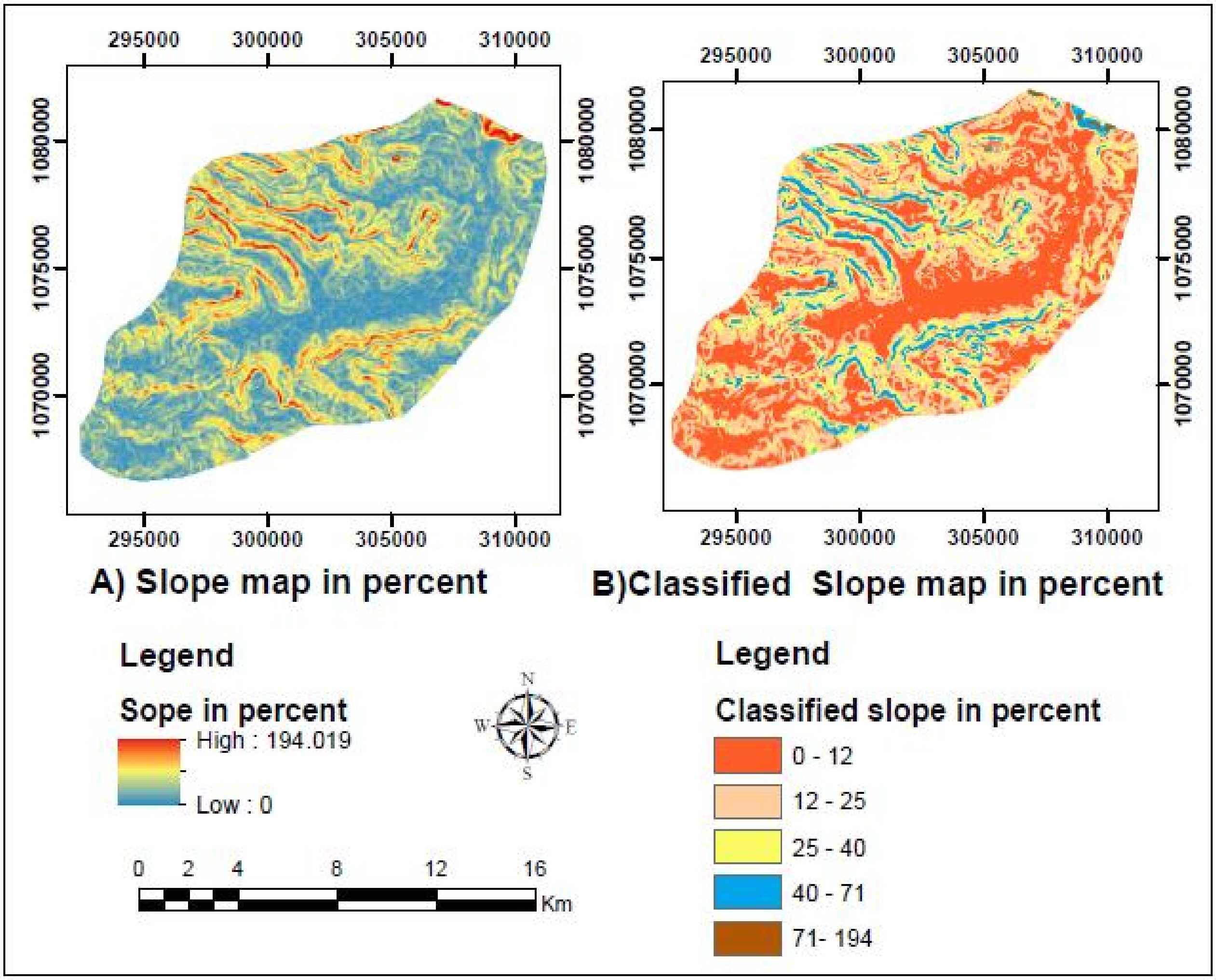

Figure 5.3Slope map of the study area

Thus, producing the LS factor map (Figure 5.3) based on the value assigned to each slope classes by SCRP for Ethiopian indicated as below (Table 5.3)

Table 5:3 LS factor value for each slope classes

Gradient in percent	<2	2-4	4-6	6-8	8-13	13-15	25-40	40-55	55-100	>100
LS factor value	0.19	0.38	0.66	1.14	1.9	3.8	6.08	7.98	10.45	19

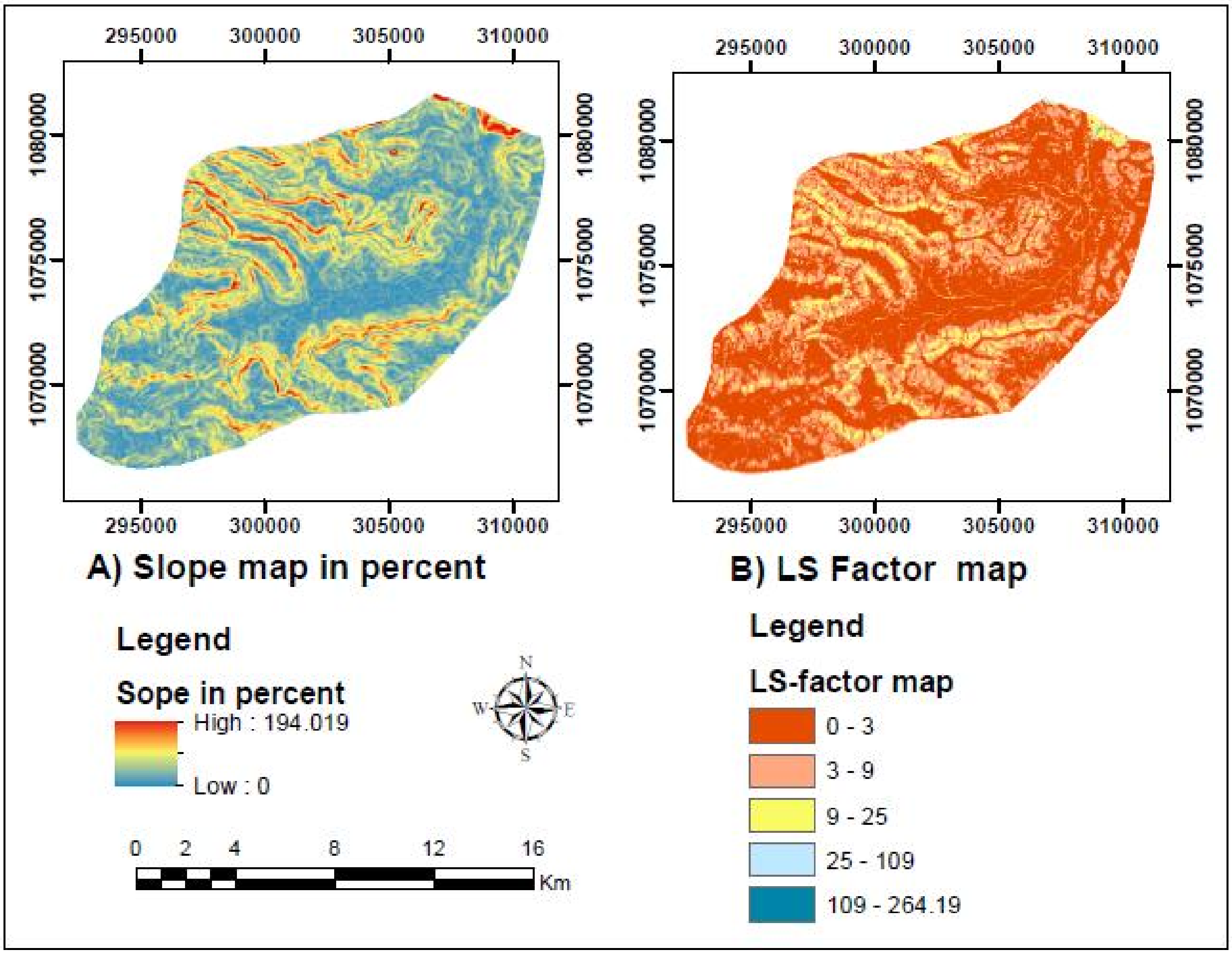

Figure 5.4 Slop Map and LS factor Value Map

5.1.4 Land use/land cover factor (C)

The C-factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow with the same rainfall (Wischmeier and Smith, 1978). The type of land cover (crop type) and tillage make the greatest difference in the amount of erosion that occurs in a given area. For this reason up-to-date and accurate land use/land cover map was used for analyzing the C-value Remotely sensed data was used to estimate the C-factor distribution based on land-cover classification results (Millward, 1999), assuming that the same land covers have the same C-factor values.

The land use/cover area was derived from a supervised of the study land cover classification of the Landsat image of 2016 and was verified with field observation to representative sites of the study area. After getting the classified image, it was changed in to vector format and the corresponding C-value was obtained from (Hurni, 1985) and C- factor map was produced.

Over the study area, it has been realized that in the study area maize *(Zea mays, L.), sorghum (sorghum bicolor, L.)),'teff' (Eragrostis teff, L.), 'neug'*, and others are the dominantly grown crops. Most of these crops are categorized under moderately cultivated land use/land cover. From the 2016 year's Landsat ETM+ image extract, C-factor values were assigned to each of the land use/land cover classes recognized over the study area (Table 3). In order to identify specific values for each land use/cover category, the image data was classified into five categories (figure5.4)

Table 5:4 Estimated cover management factor(C) Values for the study Area

LULC categories	Water body	Cultivated lands	Settlement	Grazing land	Forest/Eucalyptus plantation	Bare lands
Proposed C-value	-	0.18	0.05	0.05	0.02	0.05

As shown in Figure 5.5, the estimated Cover Management (C) factor of the study area shows that northeastern corner, Central and Northern corner parts were covered by grassland which has low C-factor values. Most parts of the lands in the area are intensively cultivated farmlands. It was exposed to erosion because the higher the C-factor, the higher the soil loss will be. Forest land is found in the west and northwestern corner and also in central part of the study area having low C-factor values, whereas the moist land is found in southwestern part.

In general, 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 (De Asis and Omasa, 2007). Therefore, soil cover in the form of crop plants, cover crops, mulches, or residues can protect soils from wind and water erosion, enhance water infiltration, and help maintain or increase organic matter (Bobe, 2004). Thus, they have low C-factor values that have low contributions to the soil loss.

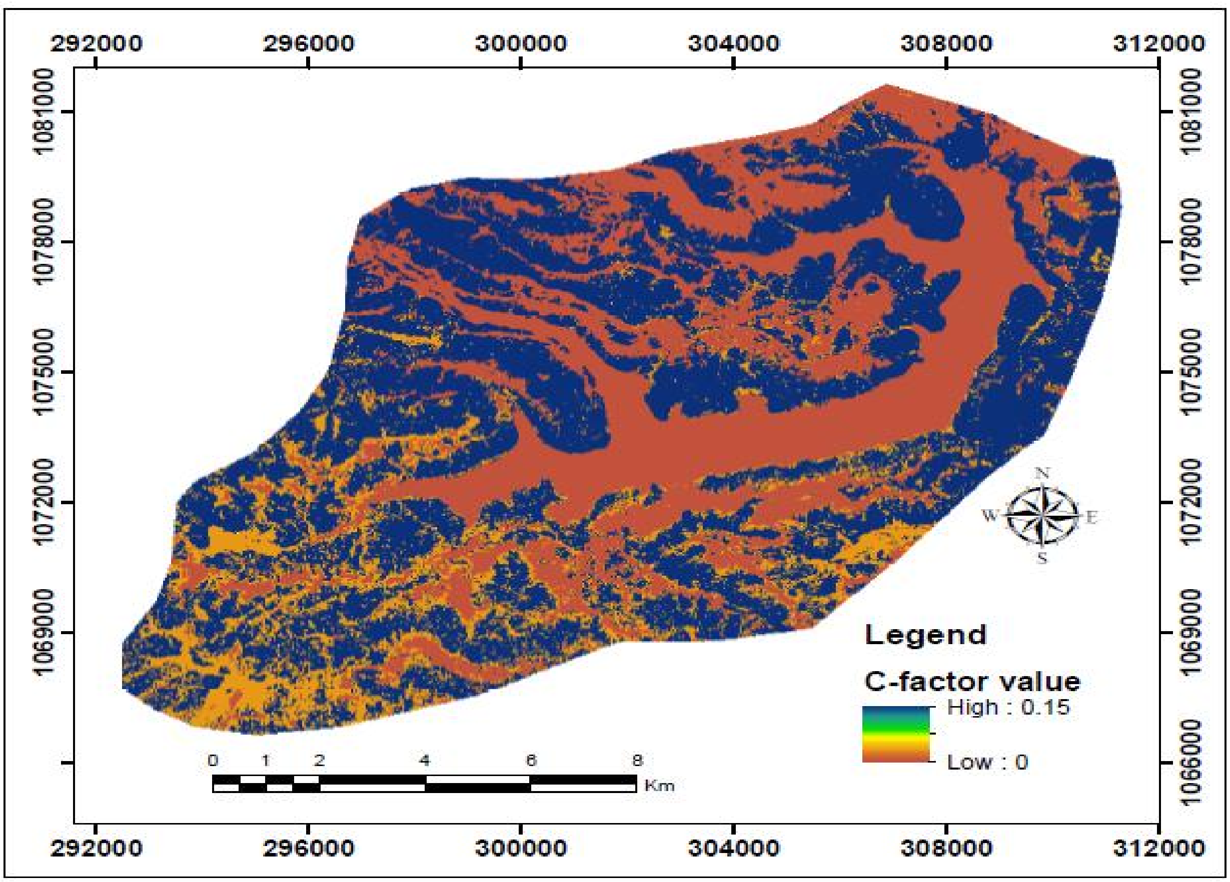

Figure 5.5 C-factor Values map of the study area

The C-factor values which represents the vegetation cover of the area vary from 0 to 1. The highest value of 1 was assigned to bare lands (Morgan, 2005) whilst the value 0 was designated to the water areas. The Forest cover was given the value of 0.005. In some studies (Breiby, 2006), the C-factor value varies from 0.001 to 0.010 depending on the type and condition of the forest.

The C-factor values (Figure 5.5), of the study area range from 0.001 to 0.15. The C-factor values were high in the intensively cultivated land. The low C- factor values were 0.001 that were found to northeastern corner, western corner, southwestern corner and southeastern part of the study area.

5.1.5 Management (support) practice factor (P)

From the 2016 Landsat image extracted, P-factor values were assigned to each of support practice (P) classes recognized over the study area (Table 5.5). In order to identify specific values for each management practice category, the image data was classified into two major categories (Figure 5.6). The P-factor values of the study area ranged from 0.7 to 0.9. The P-factor values were found to be low in the corner of northeastern, western, northwestern and southwestern part of the area but in most part of the midland and highland the P-factor values were high.

Table 5:5 Land Use /Land cover and the associated support practice (P) factor value of the study area

LULC categories	Water body	Cultivated lands	Settlement	Grazing land	Forest/Eucalyptus plantation	Bare lands
Proposed P-value	-	0.9	0.63	0.63	0.53	0.73

In general, as shown in Table 5.5 and Figure 5.6, the open land and cultivated land of the study area have relatively high P-values (P= 0.9), whereas the grassland, dense forest land and moist land have low P-values (P= 0.7). The estimation of the P-factor values for the study area was carried out taking into account the local management practices. Practices that maintain soil cover include minimum tillage, cover cropping, managed grazing, contour planting, strip cropping, crop rotation, control structures and diversions to protect soils from water erosion by decreasing the effective slope length along a field. Land use classification is often used to map vegetation types that differ in their effectiveness to protect the soil. The factor takes into account the use of farming techniques as contour plowing and terracing that tend to decrease soil erosion. It was observed that, in almost all the areas, farmers plough their farmlands in different directions with traditional ox drawn sub soiled ploughs that penetrate into and scratch the soil many times before broadcasting the seed. Over these areas where intensive and moderate cultivation was taking place, the prevention of erosion and runoff on crop fields across varied slopes has been recognized through construction of traditional furrows, waterways, some graded bunds and contour Ploughing.

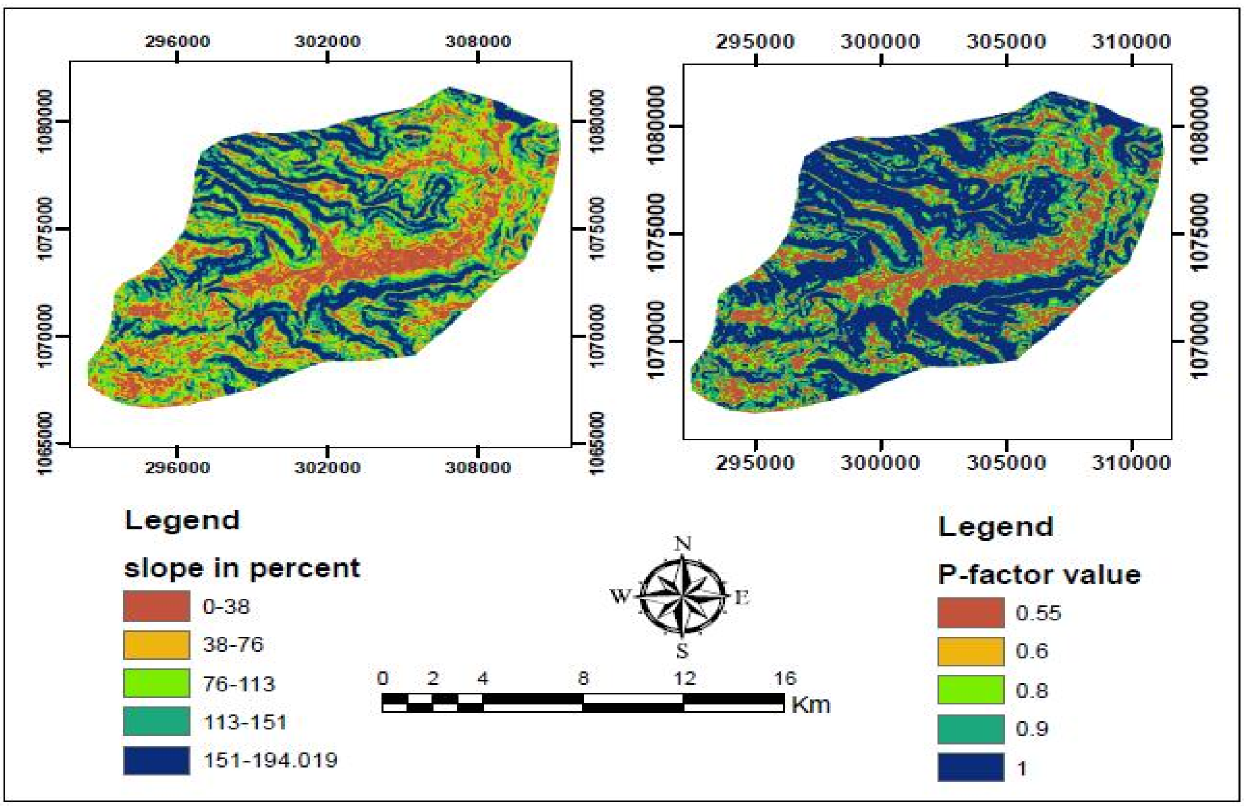

Figure 5.6 Variation of the Estimated P-factor values for the study area

5.2 Status of Soil Loss in the Study Area

The RUSLE model estimates the amount of annual soil loss as a function of the parameters. As can be seen from the statistics and map output of the cell to cell multiplied parameter layers, the study area has significant levels of annual soil loss as a function of: rainfall erosivity (R), soil erodability (K), slope gradient (S), slope length (L), cover management (C) and support practice (P) factors .that vary from 0.00 t/ha.yr, the lowest, to 243.065t/ha/yr, the highest.

This is the real indicator of the existence of risk of soil erosion in the area. In general, low potential soil losses were mostly found in the northeastern, western and southwestern parts of the study area, which is closely associated with the relatively less susceptibility of the soils of those areas to erosion (Figure 5.7), and low C-factor values. On the other hand, the estimated soil loss showed an increasing trend towards the central parts of the northeastern, southern and southwestern parts of the area, which might be attributed, among others, to the dominance of soils with high susceptibility to erosion. Accordingly, the results obtained clearly indicated that the north and the northeastern central parts of the District are highly susceptible to erosion and require immediate attention.

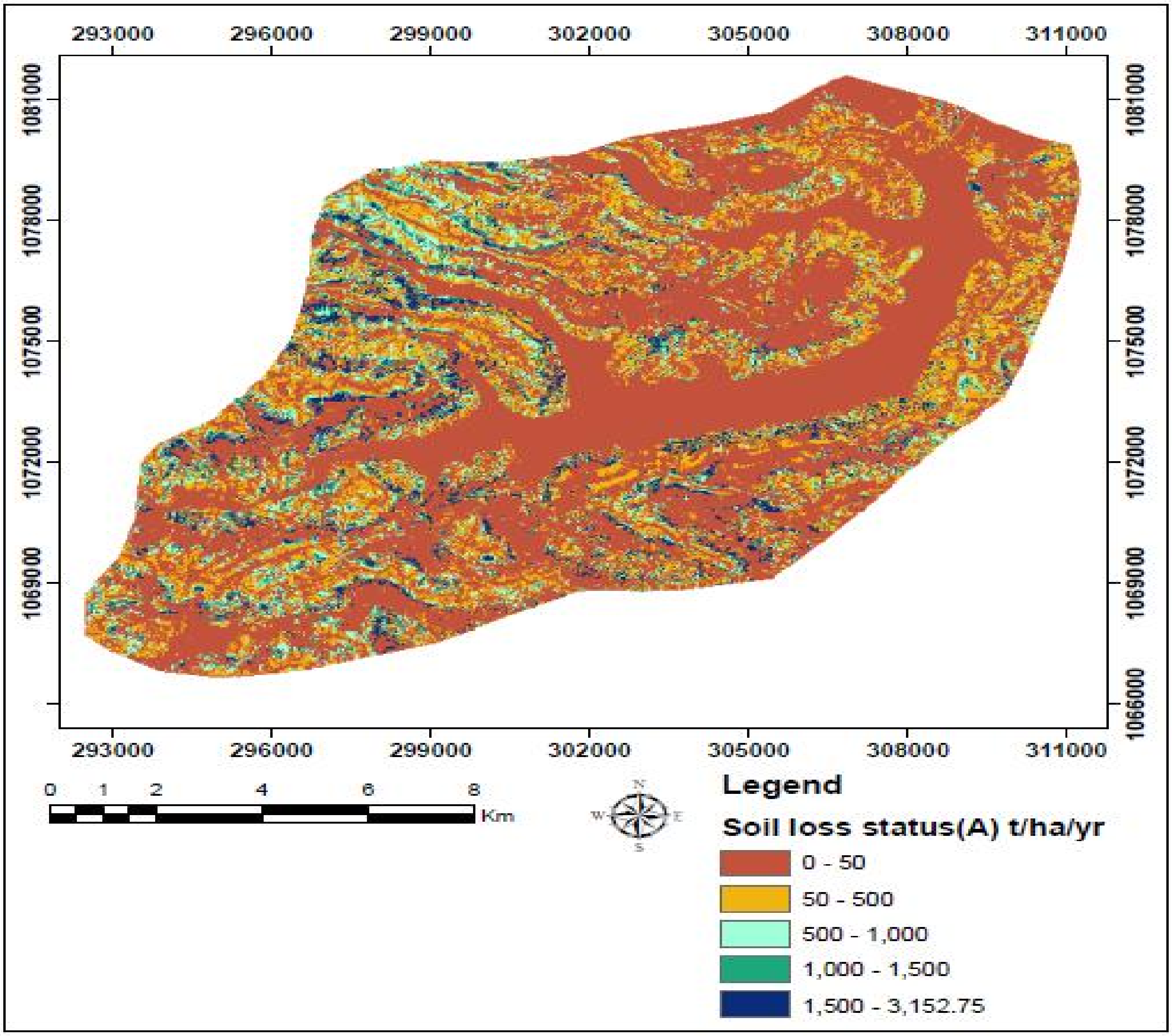

Figure 5.7 Status of soil loss

5.3 Land use land covers change

There are six major land use land cover classes have been identified including forest, settlement, bare land, water body, farm land and grass land. The land use land cover changes comparisons over the study years is below.

Table 5:6 Change of the land use land cover classes for two different years

No	Land use land cover	1996		2016	
		Area(Km^2)	%	Area(Km^2)	%
1	Water body	12.40	7.06	21.27	12.10
2	Forest land	82.79	47.10	39.99	22.75
3	Grass land	15.55	8.85	12.04	6.85
4	Settlement	7.77	4.42	13.34	7.59
5	Farm lands	47.76	27.18	80.06	45.55
6	Bare lands	9.48	5.40	9.05	5.15
Total		175.75	100	175.75	100

The LULC in the study watershed have undergone modifications and conversions over the study years (Figure 5.8). In 1996, forest land, grass land and farm land constituted a relatively large proportion about (47.10 %), (8.85 %) and (27.18) respectively. Besides, a relatively considerable amount of the area was covered by settlement 4.22%, bare land and water body are 12.46%.These conditions were considered as a baseline for change detection over the study period (Figure 5-8). After 20 years, forest and grass land have been declined to 22.75%, 6.85% respectively. In contrast there is large expansion on farm land which accounts (45.55%).Also settlement and water body increased to 7.55% and 12.10 % respectively (Figure 5-8).

During the study of these two different years as Figure 5-7 shows the area of farm land show enormous change, this may be caused by population growth. Different scholars suggested that soil erosion from cultivated land is high than other land use land covers. In general other land use land covers, bush and shrub land, open forest and grass land decline. Clearing vegetation is stretch all over the watershed area these changes occur as a result of farm land expansion and using the trees for different purpose such as for fuel and construction. Land cover is one of the components of RUSLE and over all the land use land cover change affects the soil erosion rate of the study area.

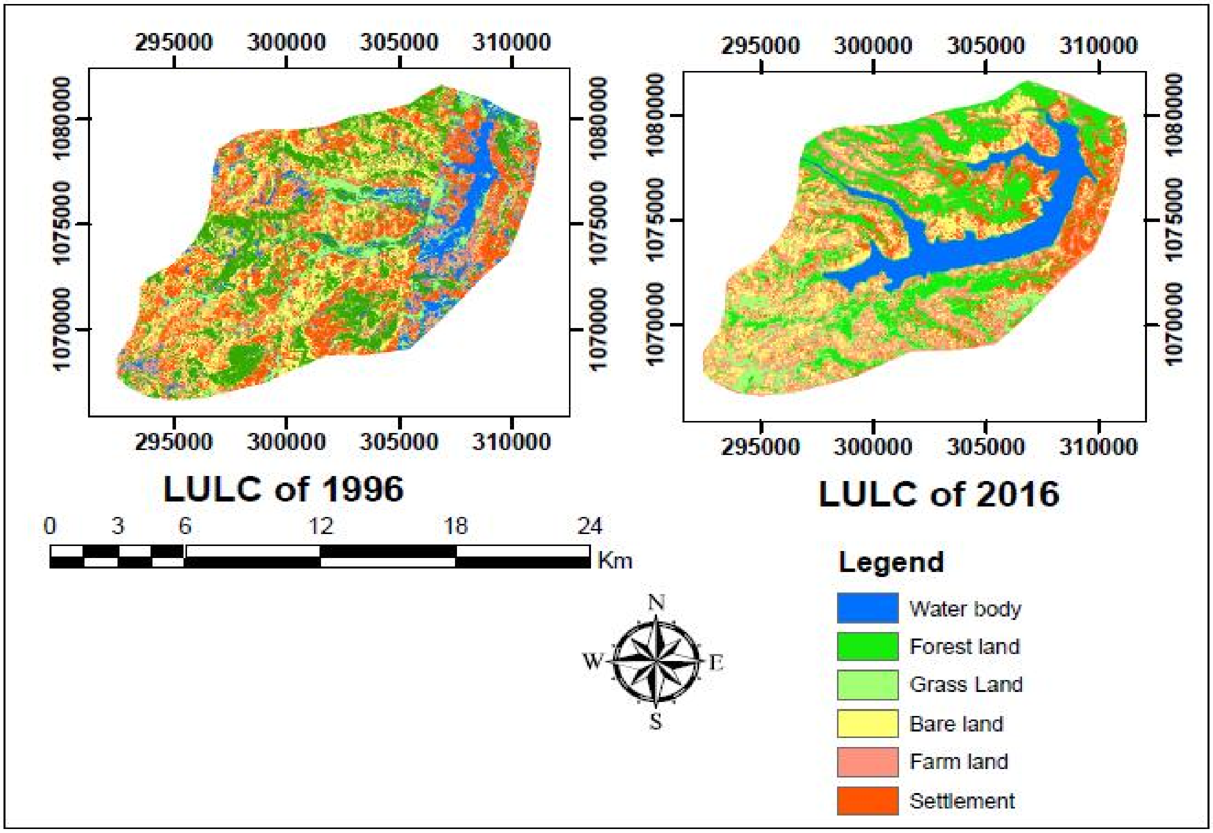

Figure 5.8 Land use land cover map for year1996 (a) and 2016(b)

5.4 Average erosion rates per Elevation classes

Erosion rates in different Elevation classes for the watershed areas were also determined. As shown in figure (Average erosion rates per elevation classes). Average erosion rates at watershed increases as slope increases. The average erosion rates are lowest in flat areas, which ranges from 5 to 24 ton/ha/yr and the highest rate is found in the very steep classes between 16 to 320 to/ha/yr. (table. Erosion rates per slope classes)

Proud (1999) reported that the average soil erosion losses for mountainous Elevation e in the southern part of the Philippines ranged from 218 to/ha/yr to 508 ton/ha/yr. This report also further noted that soil erosion rates in particular cultivated cassava plantation areas, significantly increased with increases in the slopes. It was reported that erosion rates for slopes between 1-15% varied from 3 ton/ha/yr to 221 ton/ha/yr. Soil erosion rates increased with an increase in slope steepness, as a result of faster water flow (Morgan, 2005)

Furthermore, erosion rates are expected to be higher as slope steepness rises and thus land disturbances should minimized or prevented.

Table 5:7 Average erosion rates per elevation classes

Elevation classes in (m)	Erosion rate (tone/ha/yr)
1900-2200	29.05
2200-2300	216.52
2300-2400	299.30
2400-2500	312.60
2500-2577	362.28

At the watershed, averages erosion rates shown an increasing pattern from flat to steep classes, the average erosion rates increases from flat to moderate classes. However, a drop in the average soil loss can be observed for the very steep classes at the northern area and for the high and very steep classes at the southern area. These drops in the average erosion rates for the southern and northern sites could be attributes to land cover. The land cover for the very steep areas at eastern and for the high and very steep areas at western sites are predominantly forest. This has mitigated the impact of the factors such as the LS factors which are usually higher on the steep areas.

In contrast, the extremely high erosion rates, at the high and very steep areas of the southern and northern sites could be ascribed to the presence of the bare lands which are likely to have a high potential risk of erosion. This disparity in the results illustrates the importance of the vegetation cover to protect the soil from excessive erosion.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Soil erosion is a serious problem in the highlands of Ethiopia and attempting different methods to evaluate soil loss at the watershed scale is necessary for planning of soil erosion protection and conservation measures, which are necessary for sustainable land use and development.

RUSLE is often used to estimate average annual soil loss from an area. RUSLE model in GIS environment is a relatively simple soil erosion assessment method. GIS is valuable tool for soil erosion risk estimation and prediction. With proper selection of digital elevation models, satellite imagery indices and appropriate methodology, very objective results can be achieved.

GIS-based soil erosion risk assessment, minimizes subjective errors of the traditional (classical) estimations, and maximizes the possibilities for different uses and spatial computation. To adopt the RUSLE, large sets of data starting from rainfall, soil, slope, crop, and land management are needed in detail. This paper attempts to evaluate soil losses and map the area susceptible to the soil erosion in Nashe dam reservoir by means of satellite images and Geographic information system tools. The average annual soil loss in the Nashe dam watershed area was computed by overlaying the five factor maps using RUSLE with Spatial Analyst extension. The average annual soil loss ranged from 0.01-300 t/ha/yr.

Land use land cover is one of the important factors that used to minimize soil erosion. Based on this having knowledge about changes occurs on land use land cover features is effective for soil and water conservation. In this area there are unsustainable land use land cover practices aggravated by continuous deforestation and soil erosion.

The finding of the land use land cover change over the last two decades showed that vegetation covers in different forms decline year after year, except dense forest area. Grass land decline from (30.81%) to (21.4%), open forest changes from (36.37%) to (16.66%) and bush and shrub land changes from (2.36%) to (1.25%).Quite the opposite areas which occupied by farm land, dense forest and water body increase to (53%), (4.62%) and (2.45%) respectively. Different causes contribute for these change but the most driving reasons are demand for additional land for farming, wood for fuel and construction and due to rapid growth of population.

6.2 RECOMMENDATION

The assessment of soil erosion risk using remote sensing and GIS techniques was conducted in Nashe dam reservoir Catchment, Abay choman District, Oromia region, western Ethiopia. The objective of the study was to investigate areas prone to high risk of water erosion and to map the spatial variability of erosion in the study area and the prioritization of conservation priority categories, which can be used for preparation of a conservation plan for management of the watershed. In particular, the assessment and mapping of soil erosion risk was set out to indicate evidence that accounts for a decline in soil fertility due to water erosion and this decline is related to socio-economic status of the farmer and the type of land use.

The analysis was carried out using RUSLE model which is an empirically based model that has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practice. The evaluation of soil loss estimation requires an understanding of the contribution of each of the parameters controlling the erosion process.

The spatial variability of rainfall erosivity in the study area estimated from rainfall data covering a period of nineteen years ranged from 801.6 MJmm/t/h/yr in the mid altitude to 982.3 MJmm/t/ha/yr in the highland. Erodibility values were generally low over the study area. It ranged in between 0.00 and 0.30 ton//ha/J/ha/mm in the north central parts, eastern and south western parts of the study area. Soils having high silt content (K= 1) are the most erodible of all soils as they cause a decrease in infiltration.

The result of map output of the cell to cell multiplied parameter layers show that the study area has significant levels of soil loss estimation that varies from about 0.00 to 243.065 t/ha/yr. This estimated soil loss for the study area is within the range of soil loss estimated for the Ethiopian highlands by the Soil Conservation Research Project which ranges from 0.00 to 300t/ha.yr.

When prioritizing for conservation intervention, so any strategy which will be used for soil conservation must focus upon the changes of the values of the factors that are taken into consideration in soil loss evaluation. In addition, the following points are forwarded as a recommendation:

Further studies should be done to determine what conservation structure will be required for each severity classes to break the situation.

Based on the result of the study, the study area which has high soil loss need immediate attention in their order of soil erosion potential.

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APPENDIX

Appendix 1: The Universal Soil Loss Equation (USLE) adapted for Ethiopia

A= R*K*L*S*C*P (t ha^{-1} yr^{-1})

1.R=Rainfall Erosivity											
Annual Rainfall	1443	1215	1252	1614	1066	1168	1524	1242	1508	1625	1498
Factor R	804	675	899	695	591	648	848	691	839	906	834
2.K=Soil erodibility factor											
Soil color	Black	Brown	Red	Yellow							
Factor K	0.15	0.2 0.	25 0	0.30							
3.L=Slope length											
Length(m)	5	10	20	40	80	160	240	320			
Factor L	0.5	0.7	1.0	1.4	1.9	2.7	3.2	3.8			
4.S= Slope gradient											
Slope (%)	5	10	15	20	30	40	50	60			
Factor	0.4	1.0	1.6	2.2	3.0	3.8	4.3	4.8			

5.C=land cover factor			
Dense forest	0.001	Dense grass	0.01
Other forests	0.01-0.05	Degraded grass	0.05
Bad land hard	0.05	fallow land	0.05
Bad land soft	0.04	Fallow land ploughed	0.6
Sorghum, maize	0.01	Ethiopian teff	0.25
Cereals, pulses	0.15	Continuous fallow	1.00
6.P=management factor		Ploughing on contour	0.9
Ploughing up and down	1.00	intercropping	0.8
Strip cropping	0.08	dense intercropping	0.7
Appling mulch	0.4	stone cover(40%)	0.8
Stone cover(80%)	0.5		

Source: Hurni (1985), Hellden (1987)

Appendix 2: P: Management factor which adapted from Bewket and Teferi, (2009) and Wischmeir and Smith (1978)

No	slope	Contouring	Terracing and contouring
1	1-2	0.6	0.1
2	3-5	0.5	0.1
3	6-8	0.5	0.1
4	9-12	0.6	0.12
5	13-16	0.7	0.14
6	17-20	0.8	0.16
7	>20	0.9	0.16

Appendix 3: Climatic Stations in Proximity to Dire Dam watershed

Name of station	Long	lat	Elev	Mean Monthly RainFall												Mean annual
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nev	Dec	
Alibo	37.07	9.88	2513	6.46	8.52	37.62	58.6	160.2	158.9	247.9	238.8	192.6	72.7	20.2	13.2	1216
Shambu	37.12	9.57	2460	11.4	19.9	45.44	72.11	136.9	229.3	312.3	275.7	205.7	85.8	29.4	18.9	1443
Kombolcha	37.47	9.50	2341	5.02	13.6	42.44	43.3	112	181	300.1	264	186.8	64.3	28.2	11.4	1252
Fincha	37.37	9.57	2248	8.32	8.16	44.94	66.55	150.2	272.1	361.4	345.	238	82.6	21.1	15.9	1614
Gebete	37.41	9.38	2287	19.2	10.3	44.65	44.5	92.29	199.5	254.2	211.7	119.3	43.6	15.1	11.9	1066
Hareto	37.12	9.35	2260	11.1	22.6	74.57	80.35	149.8	218.3	207.9	198.3	120.9	39.4	16.1	29.3	1169
Homi	37.24	9.62	2371	17.7	9.31	42.67	83.05	164.1	260.5	320.1	300.4	205.9	74.59	22.1	24.3	1525
Jarmete	37.0.1	9.8	2455	17.9	23.7	50.93	77.63	133.4	181.9	265.7	251.4	159.6	74.28	28.3	20.9	1286
Nashe	7.27	9.72	2060	5.56	9.01	38.7	63.46	182.1	238.1	324.3	301.5	206.3	106.5	23.7	9.74	1509
Kachii	37.86	9.58	2520	14.8	16.6	76.4	73.42	136.2	263.3	348.8	329.8	244.3	86.9	22.1	13.3	1626
Gida Ayana	36.61	9.86	1850	3.54	7.16	37.14	59.89	153.4	273.9	293.1	267.7	245.4	117.5	28.8	11	1498

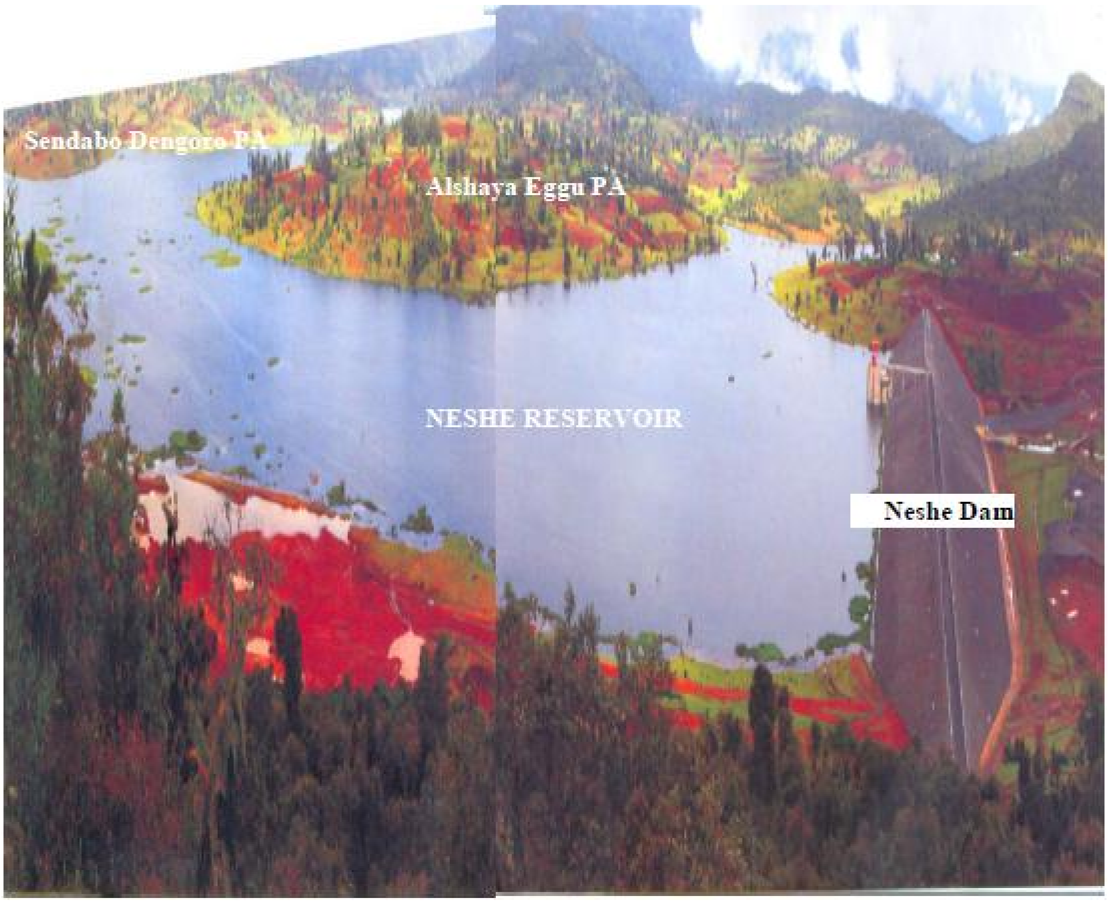
Appendix 4: GPS Points in the Watershed

No	LULC class code	Location		Elevation
		X	Y	
1	PF	303210	1072110	2461
2	PF	304320	1070460	2302
3	CL	305010	1081410	2484
4	PF	296700	1067790	2360
5	CL	306120	1077270	2368
6	PF	304470	1071810	2060
7	BL	296790	1071810	1980
8	CL	309150	1070400	2321
9	CL	301710	1068870	2410
10	CL	299370	1075470	2443
11	SE	306360	1065480	1943
12	WB	303300	1073070	2449
13	GL	296910	1072020	2527
14	PF	299370	1075080	2474
15	SE	302190	1071300	2367
16	BL	302190	1071300	2508
17	CL	307260	1075740	2455
18	PF	298290	1077900	2398
19	CL	303030	1079670	2459
20	PF	309000	1081890	2154
21	WB	300690	1071630	2369
22	CL	297510	1066980	2361
23	CL	304980	1069410	2463
24	CL	306630	1080630	2485
25	GL	297000	1070970	2432

26	CL	297660	1069920	2303
27	PF	310830	1081710	2561
28	CL	310860	1074660	2169
29	CL	298170	1066560	2489
30	PF	306750	1076580	2029
31	CL	307140	1067580	2418
32	CL	301260	1075620	2146
33	CL	301620	1078500	2435
34	CL	304560	1075110	2471
35	CL	305280	1079490	2518
36	PF	298110	1080690	2326
37	CL	300510	1068720	2491
38	CL	298230	106920	2310
39	PF	310020	1074450	2518
40	PF	306030	1079040	2446
41	WB	309030	1077630	2389
42	CL	310710	1067340	2436
43	CL	296370	1077060	2451
44	BL	303720	1074480	2522
45	CL	310920	1071840	2150
46	CL	293070	1076790	2380
47	CL	307440	1068930	2440
48	CL	295560	1067430	2512
49	WB	309180	1077000	2567
50	PF	295620	1073460	2312
51	PF	298110	1070010	2473
52	WB	306600	1073820	2551
53	PF	299220	1068060	2068

54	PF	306210	1070010	2367
55	CL	297150	1070640	2534
56	CL	300630	1072140	2481
57	CL	303990	1007220	2136
58	PF	307890	1081470	2503
59	CL	295200	1078050	2506
60	CL	298710	1080540	2544
61	CL	292800	1076970	2206
62	CL	299670	1080930	2489
63	CL	293340	1075620	2409
64	SE	302130	1068900	2501
65	PF	300150	1080960	2483
66	CL	299970	1069860	2375
67	CL	294900	1080990	2465
68	CL	297330	1078680	2249
69	PF	310200	1081710	2329
70	CL	293400	106640	2539
71	CL	299490	1070190	2533
72	PF	302490	1068930	2490
73	CL	301500	1066710	2507
74	CL	298320	1067640	2156
75	PF	299880	107880	2546
76	PF	298170	1078950	2407
77	CL	294390	1073370	2556
78	CL	298770	1081620	2380
79	PF	300810	1075380	2512
80	PF	298710	1070400	2563

Where, PF-Plantation forest CL-Cultivated land GL-grass land SET-Settlement WB-Water bodies BL-Bare land.



NASHE DAM FEASIBILITY