JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCE AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

SPATIAL ASSESSMENT OF SOIL EROSION RISK IN MENZ MAMA MIDIR DISTRICT, CENTRAL ETHIOPIA

BY: ABEBE DEMESSIE

A Thesis Submitted to the School of Graduate Studies of Jimma University, Department of Geography and Environmental Studies, in Partial Fulfillment of the Requirements the Degree of Master of Science in Geographic Information System and Remote Sensing

OCTOBER, 2017
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MAJOR ADVISOR
Dr .Eng. Fekadu Fuffa (PhD)

CO – ADVISOR
Ajay Babu (PhD)

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ABEBE DEMESSIE

APPROVED BY EXAMINING COMMITTEE:

Major Advisor:

Dr.Eng. Fekadu Fuffa ______________ ______________
Date Signature

Co – Advisor

Dr.Ajay Babu ______________ ______________
Date Signature

Internal Examiner:

Mr.Sintayehu Legesse ______________ ______________
Date Signature

External Examiner:

Dr.Biadglign Demissie ______________ ______________
Date Signature

Chairman of Degree Examining Board:

Mr.Sintayehu Teka ______________ ______________
Date Signature

OCTOBER, 2017

DECLARATION

I hereby declare that this thesis entitled “Spatial assessment of soil erosion risk in Menz Mama Midir District, central Ethiopia”, has been Carried out by me under the guidance and supervision of Dr .Eng. Fekadu Fuffa and Dr. Ajay Babu. The thesis is original and has not been submitted to any other University or Institution for the award of degree of diploma.

Researcher’s Name	Date	Signature

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Abstract

Soil erosion is one of the major agricultural problems in the highlands of Ethiopia. Identification of erosion areas on a regional scale can be very useful for appropriate soil and water conservation measures and can help reduce land degradation. The aims of this study were to assess soil erosion risk areas and to estimate annual soil loss rates of Menz Mama Midir District using Geographic Information System (GIS) and Remote Sensing (RS). In this study, annual soil loss rates are estimated using the Revised Universal Soil Loss Equation (RUSLE) Model that has been used all over the world. Rainfall data, soil data, and satellite image and Digital Elevation Model data were used as input data sets to generate RUSLE factor values. Five principal factors were used to calculate soil loss per year, such as rainfall erosivity (R), soil erodibility (K), slope length and slope steepness (LS), land use/cover factor (C) and Conservation practice or erosion control practice factor (P). Based on the analysis, the model final result shows that the current annual soil loss of the study area ranges from 0 to 23,790.1ton/ha/year with the mean annual value of 32.2 ton/ha/year from 65,101 hectare of land. These values were categorized into four priority classes depending on the calculated soil erosion amount to provide site specific *conservation interventions. According to the study result, areas which are classified as severe erosion class covers an area of* 18,759ha *which is about* 28.89*% of the total study area , high erosion risk class covers an area of* 8447ha (13.01%)*, moderate erosion risk class covers an area of* 5,809ha (8.94%) *and the remaining* 31,928ha (49.16%) *are under low erosion risk classes. A majority of the high erosion risk sites are on the banks of rivers and on the steep slope land of the study area. This is due mainly to the high steep slopes along the river banks and the practice of agricultural activities in this area. As a result, the areas that have high erosion risk should be conserved and requires effective soil conservation measures.*

KEY WORDS: Soil Erosion, RUSLE, Prioritization, Conservation

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Acronyms and Abbreviations

ASTER	Advanced Spaceborne Thermal Emission and Reflection
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agriculture Organization
GIS	Geographical Information System
GPS	Global Positioning System
NMA	National Meteorological Agency
OLI	Operational Land Imager
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
TIRS	Thermal Infrared Sensor
UNCCD	United Nations Convention to Compact Desertification
UNEP	United Nation Environmental Protection
USDA-ARS	United States Department Of Agriculture-Agricultural Research Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Soil is a fundamental natural resource of the world. It serves as a major link between climate and biogeochemical systems and supports biodiversity, and plays an important role in the ability of ecosystems to provide diverse services necessary for human well-being (Ademola and Paul, 2007). Healthy soils are essential prerequisite to meet various needs of food, biomass (energy), fiber, fodder, and other products, and to ensuring the provision of necessary ecosystem services in all regions of the world (FAO,2015). Therefore; it needs to be protected and enhanced. However, more than half (52%) of all fertile food producing soils globally are now classified as degraded, many of them severely degraded (UNCCD, 2015). Soil erosion is a major environmental problem that threatens world food production. The loss of soil from land surfaces reduces the productivity of all natural ecosystems as well as agricultural, forest, and pasture ecosystems (Lal and Stewart, 1990). The accelerated loss of topsoil through erosion from agricultural land was recognized as an important threat to the world's soil resource many decades ago (FAO, 2015). Worldwide, nearly 24 billion tons of fertile soil disappear/year, the most significant, nonrenewable resource (UNCCD, 2015).

Severe soil erosion is occurring in most of the world's agricultural regions .Soil erosion has on-site and off-site effects (Osman, 2014). On- site impact refers to the reduction in soil quality. The on-site effects include loss of soil, loss of organic matter and nutrients, damage to growing crops, reduction of rooting depth, reduction of water and nutrient storage capacity and later decline in soil fertility and productivity. The effects of on-site problems are very significant on agricultural land, where soil degradation can influence on crops yield. Runoff causes damage on the field (on-site damage) by leaving fertile topsoil and by reducing the available amount of water for plant growth. Off-site erosion is the consequences of down slope or downstream erosion. The off-site effects are damage of crops, siltation of reservoirs, eutrophication of ponds and lakes, pollution of water, etc. Also Off-site erosion impacts lead to contamination of drinking water, disruption of marine and ecosystems and many other problems. Off-site effects involves costs due to the consequences of sedimentation of dams that can reduced production on irrigated land, reduced energy and fish production, diminished aesthetic value for recreation areas. Several mechanisms are employed for the control of water erosion such as; no- tillage, minimum tillage, mulching, strip cropping, contour cropping, contour strip cropping, and terracing.

Soil erosion has direct negative effects on global agriculture. The impact of soil erosion is more serious in developing countries because of lack of capacity to cope with it and also to replace lost nutrients. Soil erosion is considered as the major driver of land degradation in the areas of rainfed agriculture of Ethiopia. At this moment several inappropriate agricultural practices here resulted in misuse and degradation of previously fertile land. In Ethiopia, the productivity of the agricultural sector of the economy, which supports about 85% of the employees, is being seriously affected by soil productivity loss due to erosion and unsustainable land management practices. Land degradation, especially soil erosion, soil nutrient depletion and soil moisture stress, is a major problem facing the areas already under cultivation, thus aggravating the situation is the seriousness of soil degradation and loss of soil fertility. Rapid population growth, cultivation on steep slopes, clearing of vegetation, and overgrazing are the main factors that accelerate soil erosion in Ethiopia. Due to surface topographic condition of most arable lands which concentrates in the highland, the problem of soil erosion is a serious one. Annually, Ethiopia losses over 1.5 billion tons of topsoil from the highlands to erosion which could have added about 1.5 million tons of grain to the country’s harvest (Ademola and Paul, 2007). This indicates that soil erosion is a very serious threat to food security of people and requires urgent management intervention.

Soil erosion is a complex process that depends on soil properties, ground slope, vegetation, and rainfall amount and intensity (Montgomery,2007). Predicting the location of high risk areas with the highest possible accuracy is extremely important for erosion prevention as it allows for identification of the proper location and type of erosion prevention measures needed (Mitasova et al., 1996). The USLE is the most widely known and used empirical soil loss model all over the world (Wischmeier and Smith, 1978).

Later in the 1980 USDA-ARS modified the model to the RUSLE which was an improved version of USLE incorporating new approaches and corrections of the USLE limitations to more accurately estimate soil loss. For example USLE does not estimate gully or stream channel erosion, it is also not been designed to operate at large scale but it is widely used, especially at regional and national level, because of its relative simplicity and robustness (Desmet and Govers, 1996). A Revised Universal Soil Loss Equation (RUSLE) followed the same formula as USLE, but got several improvements in the determining factors and a broader application to different situations, including forest lands, rangelands and disturbed areas compared to USLE (Trojacek and Kadlubiec, 2004).

RUSLE is a model that has the ability to estimated annual soil loss from a number of factors that have been measured for climates, soil types, topography and land use land cover types. There are several factors included in this model, such as rainfall erosivity (R), soil erodability (K), slope length and steepness factor (LS), land use land cover (C) and conservation practice (P) factors. These factors are combined in a number of formulas in RUSLE, which returns a single number, the Computed soil loss per unit area, equivalent to predicted erosion in ton /ha/year (Wischmeier and Smith, 1978).

Remote sensing and GIS have resulted in great progress in the research of soil erosion and soil and water conservation assessment 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 et al., 208). RUSLE is a computation method that may be used for site evaluation and planning purposes and also for assisting in the decision process of selecting erosion control measures. It provides an estimate of the severity of erosion and also numerical results that can validate the benefits of planned erosion control measures in the risky areas (Silleos, 1990).

Soils are considered as increasingly essential in global as well as in regional development issues such as food security, land degradation, and the provision of ecosystem services. Therefore, assessments on soil erosion risks are essential for formulation of effective soil conservation plans for sustainable development. This study aimed at integrating RUSLE model and GIS technique to provide valuable input for planning soil conservation strategies in the study area. Soil erosion susceptibility mapping is one of most important requirement for its planning management and conservation Therefore, identifying and targeting specific high-priority areas is important for the implementation of soil conservation and management practices of the study area. This benefits rural household to improve their agricultural productivity and contribute positively to the improvement of food security and economic growth in particular for the area and the country in general.

1.2. Statement of the Problem

Soil degradation is a major global problem, the effects of which may be felt most strongly in developing countries where large proportions of the population reap their livelihoods directly from the soil (Tully et al., 2015).Therefore, the sustainable use of the land resource constitutes the major constraint in agricultural growth in these countries. In the same way Soil erosion is one of the most serious environmental problems in most area of Ethiopia. Degradation of the resource mainly due to soil erosion and nutrient depletion has continued at alarming rate. Soil erosion reduces the general productivity of terrestrial ecosystems, increases water runoff by decreasing water infiltration and the water storage capacity of the soil (Pimentel and Burgess, 2013).

The agriculture sector is the main source income and livelihood of most Ethiopians community, where about 12 million smallholder farming households account for an estimated 95 percent of agricultural production and 85 percent of all employment (FAO, 2014). Where agriculture is the main engine of the economy and the livelihoods of the majority of the population depend on agriculture, since soil resource losses reduce food productive capacity of agricultural land by reducing the ability of the soil to store water and nutrients. Reduced production capacity of the land is a major cause of food insecurity in many parts of Eastern Africa; in Ethiopia, about two-thirds of the population is directly affected by soil degradation, an age old phenomenon which started with the spread of agriculture millennia ago, but was greatly accelerated in the past century (Hurni et al., 2015). The cultivation of steep mountain slopes in the Ethiopian high lands from the inception of agriculture 2,000-5,000 years ago until the present day resulted in extreme degradation due to soil erosion (Hurni, 1988). Loss of arable land due to soil erosion is a widespread phenomenon in the highlands, which account for about 45% of Ethiopia's total land area and about 66% of the total land area of Amhara Region (Lakew et al., 2000).

Soil erosion is among the major problems challenging farmers in Menz Mama Midir District. The study area is characterized by rugged topographic features with very negligible vegetation covers that can cause significant soil loss by soil erosion. The limiting vegetation covers on the study area affect soil erosion. Certain slopes are cultivated and can be cause to significant soil erosion when the slope becomes steeper. Land degradation from soil erosion and cultivation of steep and fragile lands has resulted in reduction of crop productivity in the area. Therefore, identifying and assessing of high risk areas for soil erosion, helps us to develop an intervention soil water conservation programs to enhance the soil productivity potential and to minimize soil erosion. Due to this reason mapping prone areas to erosion risks areas needs to know the severity of erosion extent in the study area. Despite the severity of erosion and its associated consequences in the study area, there have been few related studies of which none of them conducted using geospatial techniques to quantify erosion rates and the spatial dynamic of soil erosion at the study area. Early erosion researches focused on the physical causes and its associated consequences of erosion. Hence, the study proposed to assess the spatial extent and mapping soil erosion risk areas in Menz Mama Midir District.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of this study is to identify the spatial distribution of soil erosion risk area in Menz Mama Midir District using by using GIS and RS techniques.

1.3.2. Specific Objectives

The specific objectives of the study are:

- To estimate the annual average soil loss in the study area;
- To analyze the soil loss intensity and pattern in the study area; and
- To investigate the areas vulnerable to soil erosion and their future fates.

1.4. Research Questions

1. What is the mean annual rate of soil loss in Menz mama Midir District?
2. Which areas are the most vulnerable to soil erosion in Menz mama Midir District?
3. Which areas of the District as need to be given highest priority for conservation measures?

1.5. Significance of the Study

Identification and mapping soil erosion risk areas are important for formulation of effective soil conservation plans for agricultural productivity. As a result, by considering and evaluating controlling factors of erosion, the erosion risk map prepared for the District with the objective of identify the spatial distribution of soil erosion risk areas. Therefore, information on the extent, severity and geographic distribution of eroded lands will help for determining erosion control areas, starting regulation projects and making soil conservation measures for sustainable agriculture development.

1.6. Scope of the Study

Mapping soil erosion using RS and GIS can easily identify areas that are at risk of soil erosion areas and provide information on the estimated value of soil loss at various locations. The scope of this study is identifying and mapping soil erosion risk areas using GIS and RS technique in Menz Mama Midir District.

1.7. Limitation of the Study

To maximize the representativeness of the result of the soil erosion risk map relatively dense metrological stations were required to spatially represent rainfall over the study area, however only one station were available within the study area; as a result some distant rainfall stations found around the study area are all considered. Also lack of data of rainfall for many years for the stations area is another other problem.

1.8. Thesis Organization

The thesis is organized into five chapters. Chapter one contains introduction part which states background, statement of problems, research objectives, questions, Scope, significance of the study , limitation of the study and thesis organization. Chapter two reviews related literature. Methodological issues including the study area description were presented in chapter three. Chapter four deles about the results and discussions of the study. Finally Chapter five presents conclusion and recommendation of the study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Soil Erosion

Soil erosion is broadly defined as the accelerated removal of topsoil from the land surface through water, wind or tillage. It leads to loss in soil productivity due to physical loss of topsoil, reduction in rooting depth, removal of plant nutrient and loss of soil. Soil erosion is a natural phenomenon which occurs throughout the continental portion of the globe. The intensity of erosion is directly dependent on natural factors, but also on those which are under direct human influence. Soil is naturally removed by the action of water or wind but accelerated soil erosion is the result of mankind's unwise actions which leave the land vulnerable during times of erosive rainfall or windstorms. Deforestation and overexploitation of vegetation, mismanagement of agricultural land, overgrazing, indiscriminate use of agrochemicals and lack of soil conservation practices, and over extraction of ground water are some anthropogenic causes of soil degradation (Osman, 2014). Soil erosion is typically divided into two major categories; wind and water erosion. Water erosion on agricultural land occurs mainly when overland flow entrains soil particles detached by drop impact or runoff, often leading to clearly defined channels such as rills or gullies where as Wind erosion occurs when dry, loose, bare soil is subjected to strong winds (FAO, 2015). Wind erosion is common in semiarid areas where strong winds can easily mobilize soil particles, especially during dry spells. This dynamic physical aeolian process includes the detachment of particles from the soil, transport for varying distances depending on site, particle and wind characteristics, and consequent deposition in a new location, causing onsite and offsite effects (FAO, 2015). Soil erosion by water is the main type of soil degradation that occupying 56 percent of the world wide area affected by human induced soil degradation whereas the area affected by wind erosion occupies 28 percent of the degraded terrain mainly occurring in Asia and Africa (Tirkey et al., 2013) . In most of Ethiopia, soil erosion by water is a fundamental and one of the major causes of soil fertility problems (Tewodros and Belay, 2015).

2.2. Types of Water Erosion

Water erosion is caused by water that comes in rain and runs off the land as overland flow or stream flow (Osman, 2014). At the initial stage, soil particles are detached from aggregates by the impact of falling raindrops or flowing water, which is followed by transport of the detached particles by runoff water. According to (Osman, 2014), there are four types of water erosion recognized. These types of water erosion are; splash erosion, sheet erosion, rill erosion, and gully erosion. Therefore the removal of topsoil by water takes place in the following way.

Raindrop (Splash) Erosion

Rain splash erosion is the displacement of soil properties by the impact of falling rain drops. The amount of displaced particles depends on the rainfall and soil characteristics. Splash erosion is the beginning of other types of soil erosion, mainly sheet erosion. It is the first stage of the erosion process. At the start of a rain event, falling raindrops hit the soil aggregates, break them and detach soil particles. As a result splash erosion occurs when raindrops bite bare soil (Osman, 2014). .

Sheet Erosion

Sheet erosion is the removal of soil in thin layers by raindrop impact and shallow surface flow as a result of finest soil particles that contain most of the available nutrients and organic matter in the soil. Soil erosion is characterized by the down slope removal of soil particles within a thin sheet of water. Sheet erosion occurs when the entire surface of a field is gradually eroded in more or less uniform way. It removes the finest fertile topsoil with plenty of nutrients and organic matter. It is the most dangerous type of soil erosion because it is a gradual process and it is not immediately obvious that soil is being lost. Soils most vulnerable to sheet erosion are overgrazed and cultivated soils where there is little vegetation to protect and hold the soil (Osman, 2014).

Rill Erosion

Rill erosion can occur on steep land or on land that slopes more gently. Because there are always irregularities in a field, water finds hollows in which to settle and low-lying channels through which to run. As the soil from these channels is washed away, channels or miniature dongas are formed in the field. When the runoff moves down a slope, it cuts small paths or rills. In rill erosion, water flowing through these paths detaches more soil from their sides and bottoms. Rill erosion is common in bare agricultural land, particularly overgrazed land, and in freshly cultivated soil where the soil structure has been loosened. The rills can usually be removed with farm machinery. Rill erosion is often described as the intermediate stage between sheet erosion and gully erosion (Osman, 2014).

Gully Erosion

Gully usually occurs near the bottom of slopes and is caused by the removal of soil and soft rock as a result of concentrated runoff that forms a deep channel or gully. On steep land, there is often the danger of gullies forming. Water running downhill cuts a channel deep into the soil and where there is a sudden fall, a gully head forms at the lower end of the channel and gradually works its way back uphill. It deepens and widens the scar that the gully makes in the hillside. Gully erosion is related to stream bank erosion, in which fast flowing rivers and streams increasingly cut down their own banks (Osman, 2014).

2.3. Factors Affecting Soil Erosion

Erosion processes are affected by several factors. According to (Toy, et al., 2002) factors affecting soil erosion are soil texture, slope (length and steepness), vegetation and rainfall. The combination of these factors determines the amount of erosion that will occur as well as the amount of sediment that may be transported and deposited elsewhere.

Rainfall

Rainfall is one driving force for soil erosion. The raindrops which pound on the soil surface either infiltrate into the soil or leave the field as surface runoff. Runoff occurs when the precipitation rate exceeds the infiltration capacity of the soil, and then it collects and flows across the land surface (Toy et al., 2002).

Rainfall presents two parameters to consider; the rain intensity or how hard the rain falls and the length of time it rains. Generally, the amount of rain that falls and how quickly it falls determine show fast soils become awash and runoff begins. Soil erosion by rainfall is usually greatest during duration and high intensity thunderstorms. The amount of runoff can be increased if infiltration is reduced due to compactness of the soil. The ability of rain to cause erosion is defined as erosivity and it is a function of rainfall. 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 (Morgan, 1995).

Soil Factors

Soils with higher infiltration rates, higher levels of organic matter and enhanced soil structure have a greater resistance to erosion. Sand is the largest sized particle, followed by silt, with clay being the smallest sized soil particle. Of all the soil particles, silt sized particles erode most easily. Sand has large pore spaces that allow for greater infiltration water at a higher rate of infiltration. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Clay particles are compacted to each other becoming more difficult to dislodge and translocate. The susceptibility of soil to erosion agents is generally referred to as soil erodibility (Renard, *et al*., 1991).

Slope (Length and Steepness)

Soil erosion can occur at different rates depending on the slope of the land. The steeper the slope will be the greater the velocity of the water flowing across the surface of the land and its capacity to transport and erode soil. Moreover when increase the length of the slope and the erosive energy of the water increases.

Vegetation Cover

Vegetation cover destruction significantly affects soil erosion process. Soil erosion potential is increased when the soil has no or very little vegetation cover. Vegetation cover protects the soil from raindrop impact and splash by slow down the movement of surface runoff and allows excess surface water to infiltrate. Vegetation is the main factor to control erosion because of Vegetative cover acts as a barrier that protects the soil particles from raindrop impact.

2.4. Soil Erosion Models

Several erosion models have been developed in the past decades, utilizing different scientific methods and modeling approaches to predict the soil loss and to assess the soil erosion risk. Soil erosion models can be divided into three main groups: empirical models, conceptual models and physically-based models. These models are empirical (statistical/metric), conceptual (semi-empirical) and physical process based (deterministic) models have been designed for specific set of conditions of particular area.

2.4.1 Empirical Models

Empirical models are a simplified representation of natural processes based on empirical observations. They are based on observations of the environment and thus, are often of statistical relevance. The computational and data requirements for such models are usually less than for conceptual and physics-based models, often being capable of being supported by coarse measurements. Empirical models are frequently utilized for modeling complex processes and, in the context of erosion and soil erosion, particularly useful for identifying the sources of sediments. The computational and data requirements for such models are usually less than for conceptual and physics-based models, often being capable of being supported by coarse measurements. (Merritt et al., 2003). The commonly used empirical erosion models include: the Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE) and the Soil Loss Estimation Model for South Africa (SLEMSA).

2.4.2 Physically Based Models

Physically based models represent natural processes by describing each individual physical process of the system and combining them into a complex model. Physical equations hereby describe natural processes, such as stream flow or sediment transport.
This complex approach requires high resolution spatial and temporal input data. Physically based models are therefore often developed for specific applications, and are typically not intended for universal utilization (Merritt et al., 2003). According to Morgan (1995) these models are developed to predict the spatial distribution of runoff and sediment over the land surface during the individual storms in addition to total runoff and soil loss. The common physically based models used in water quality erosion studies include Water Erosion Prediction Project (WEPP), Areal Non-point Source Watershed Environment Response Simulation (ANSWERS) and European Soil Erosion Model (EUROSEM).

2.4.3 Conceptual Models

Conceptual models are a mixture of empirical and physically based models and they take into account the physical processes governing erosion by water through empirical relationships among the involved variables (Terranova et al., 2009). The main feature that distinguishes the conceptual models from the empirical models is that the conceptual models, whilst they tend to be aggregated, they still reflect the hypothesis about the processes governing the system behavior. These models usually incorporate general descriptions of catchment processes without specifying process interactions that would require very detailed catchment information (Merritt et al., 2003). Therefore Conceptual models provide an indication of quantitative and qualitative processes within a watershed. Discrete Dynamic Models and Agricultural Catchment Research Unit (ACRU) are among the Conceptual based soil erosion model.

2.5. Revised Universal Soil Loss Equation Model

The USLE was developed initially as a tool to assist soil conservationists in farm planning by W. H. Wischmeier, D. D. Smith, and others with the USDA-ARS Soil Conservation Service and Purdue University in the late 1950s. A conservationist used the USLE to estimate soil loss on specific slopes in specific fields. USLE was used to guide the conservationist and farmer in choosing a practice or practices that would control erosion adequately while meeting the needs and wishes of the farmer to erosion control practices to specific sites (Renard et al ,1991). Although the USLE is a powerful tool that is widely used by soil conservationists in the United States and many foreign countries, research and experience since the 1970s have provided improved technology that is incorporated in the RUSLE. The main coefficients of this equation are including rainfall, soil erodibility, slope, vegetation, and cultivate method.

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., 1991). With the advent of remote sensing and GIS technologies their integration with the RUSLE method led to a more simpler, cost effective and efficient perception of erosion, and this integrated application was applied by many researchers in the whole world.

2.6. Soil Erosion Risk in Ethiopia

Soil degradation can be regarded as a direct result of the past agricultural practices in the Ethiopian highlands. Since soil erosion by water must be considered the most important of all degradation processes, the extent of the damage is taken here as the sole indicator of the present status of the soil recourses (Hurni, 1988).The reduced production capacity of the land is a major cause of food insecurity in many parts of Eastern Africa. In Ethiopia, about two-thirds of the population is directly affected by soil degradation.

According to (Hurni et al.,2015) the overall rain fed agricultural area of Ethiopia covers 600,000 km^2, or 54% of the country. In this predominantly highland and mountain area, yearly net erosion, soil erosion minus soil deposition is estimated at about 940 million tons, or an average of 18 tons per hectare. On cropland, which covers more than one-third of the rain fed agricultural area, both erosion and deposition rates can be much higher than average. Since the 1970s, much effort has been invested in soil and water conservation, not only on cropland but also in reforestation and area closure. To date, about 18% of the cropland can be considered as treated, while another 23% requires no treatment. Over the next five to ten years, sustainable land management measures must be taken on the remaining 59 % of cropland.

2.7. The Application of GIS and RS in Soil Erosion Analysis

There are many applications of GIS and Remote Sensing techniques in various fields, such as natural resource management and environmental studies. GIS became a very important factor in soil erosion studies and consequently in the development of appropriate soil conservation strategies. The application of GIS in soil erosion include land use data, topographical data, vegetation cover data, gully density data, rainfall data, water and soil conservation get them from satellite image or aerial photographs. With the development of GIS and Remote Sensing it is possible to set up Soil Erosion Assessment System for erosion monitoring, forecasting and rapid investigation. In terms of soil and water conservation, the objective of GIS application is to capture soil erosion data, set up database and model for soil erosion evaluation and management (Shougang et al., 2014). 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. Digital Elevation Model (DEM) is one of the vital inputs required for soil erosion modeling that can be created by analysis of stereoscopic optical and microwave remote sensing data (Pande et al., 1992). DEM is a digital representation of terrain as a raster (a grid of squares) of the earth's surface that stores Earth’s elevation information and of making such information available to applications programs such as GIS.

CHAPTER THREE

3. METHODOLOGY

3.1. Description of the Study Area

Menz Mama Midir is one of the Districts in Amhara regional state of Ethiopia. It is located at the eastern edge of the Ethiopian highlands in the north shewa administrative zone. The capital of the District Molale town is located at about some 254 km north east of Addis Ababa, the capital city of Ethiopia. Geographically it is located at 9°57'19" to 10'14'37" North latitude and 39°20'45" to 39°51'15' East longitude. Its altitudinal location ranges between1575 and 3425m above mean sea level. The total area of this District is 65,101 hectare.

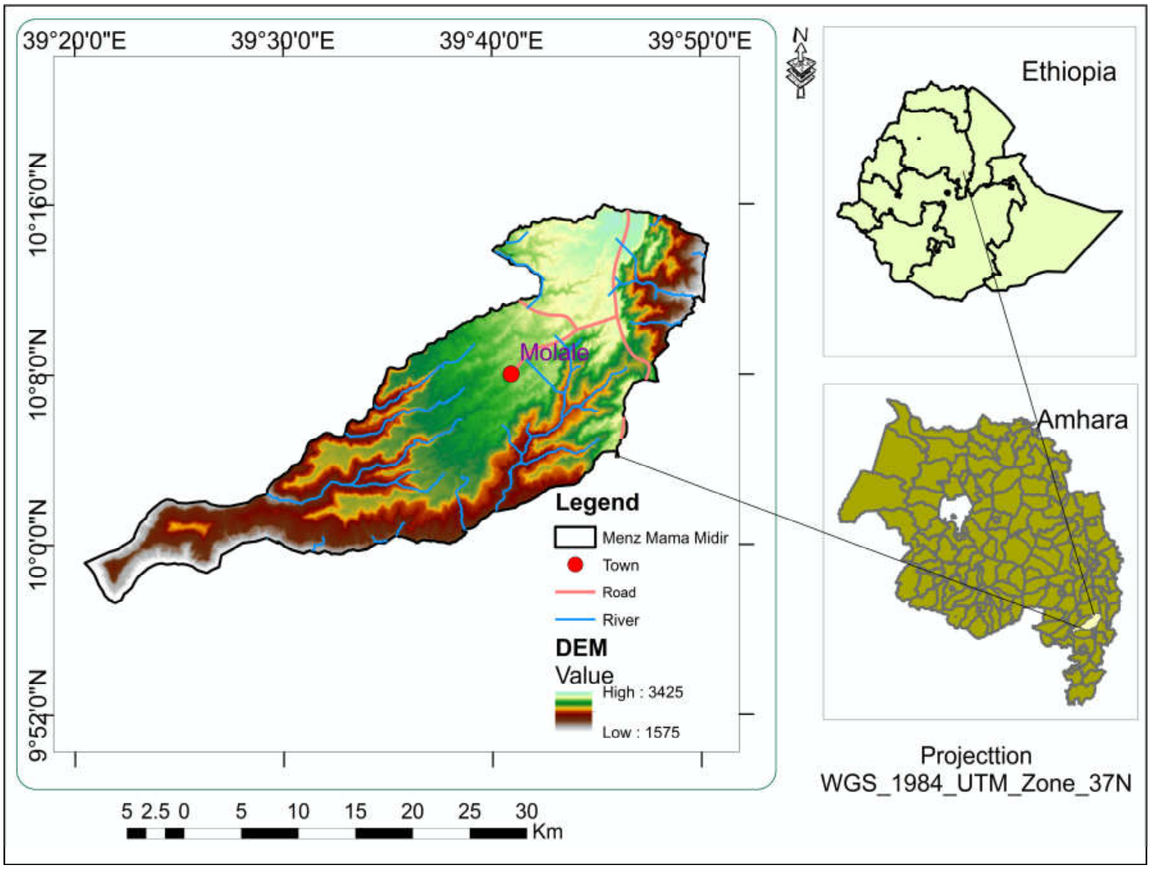

Figure 1: Map of the study area

Population

Based on the 2007 national census conducted by the central Statistical agency of Ethiopia this District has a total population of 85,129, of whom 42,102 are men and 43,027 women.

Climate

Based on Agro-ecological zones of Ethiopia, divided according to altitudinal zones Menz Mama Midir District has *Dega (*1500 to 2300 m.a.s.l*) and Woinadega (*2300 to3200 m.a.s.l) agro climatic zones. The altitude of the District ranges from 1575 to 3425m above mean sea level. The agro climatic conditions are favorable for different agricultural activities.

Agriculture

Agriculture is the major economic activities for the community in the District under study. Mixed farming, which includes crop and livestock production, is practiced in the area. Crop production is rain fed, and planned around the *kremt* season which lasts from June to mid September. An erratic *belg* short rainy season occurs from February to April. In the District, more than three types of cereals are produced. The main livestock reared are cattle, sheep and goat, of which sheep is the dominant livestock type. The current agricultural policy is reflected in the ongoing agricultural extension package (Menz Mama Midir District bureau of Agriculture and Rural Development, 2017).

Topography

The topography of the district consists of 40% plain and undulating plateau, 50% hills and 10% steep slope and cliff. The current land use category of the District is classified into 1.82% forest, 8.56% Shrub land, 77.99% Agricultural land, 8.92% grass land , 1.37% wet land, 0.07%bare land, 1.27% urban built up area. Altitudinal of the study area ranges from 1575 and 3425m above mean sea level.

3.2. Materials

For the purpose of this Study different types of software and instruments were used. The main data used in this Study are rainfall data, soil map, DEM and land use land cover map of the study area. The soil map was extracted from FAO soil map of Ethiopia (FAO, 1998). Rainfall data from National Meteorological Agency of Ethiopia and DEM and land sat images for land use land cover classification was obtained from USGS website (**http://earthexplorer.usgs.gov**). ArcGIS 10.3, ERDAS imagine 2014 and GPS (Garmin GPS 64) tools were used for the analysis of spatial distribution of soil erosion risks for this study.

3.3. Estimating Soil Loss

The methodology that is used in this soil erosion risk assessment and mapping is the implementation of Revised Universal Soil Loss Equation (RUSLE) in ArcGIS environment after some modifications in the calculation of specific factors. RUSLE is developed as an equation of the main factors controlling soil erosion which are climate, soil characteristics, topography, land cover and land management practice (Renard et al., 1991). Mathematically the Revised Universal Soil Loss equation (RUSLE) is expressed by the formula as:

$$A = R * K * L * S * C * P \qquad (1)$$

Where, A is the average annual soil loss in tons per hectare per year; R is rainfall and runoff erosivity factor; K is soil erodibility factor; L is Length of slope factor; S is degree of slope factor; C is the land use cover factor; and P is conservation practice or erosion control practice factor.

To identify the spatial distribution of soil erosion risk in the study area, all the considered erosion factors; The rainfall erosivity (R), soil erodibility (K), slope length and gradient (LS), land cover (C) and conservation practices (P) factors were surveyed and calculated depending on the Ethiopian context and other related studies. In consequence all the maps were produced with the Projected Coordinate system: WGS_1984_UTM_Zone_37N and Units: Degree. Then the final result is multiplied within the raster calculator. The Procedures of RUSLE implementation in GIS environment are as shown in figure 2.

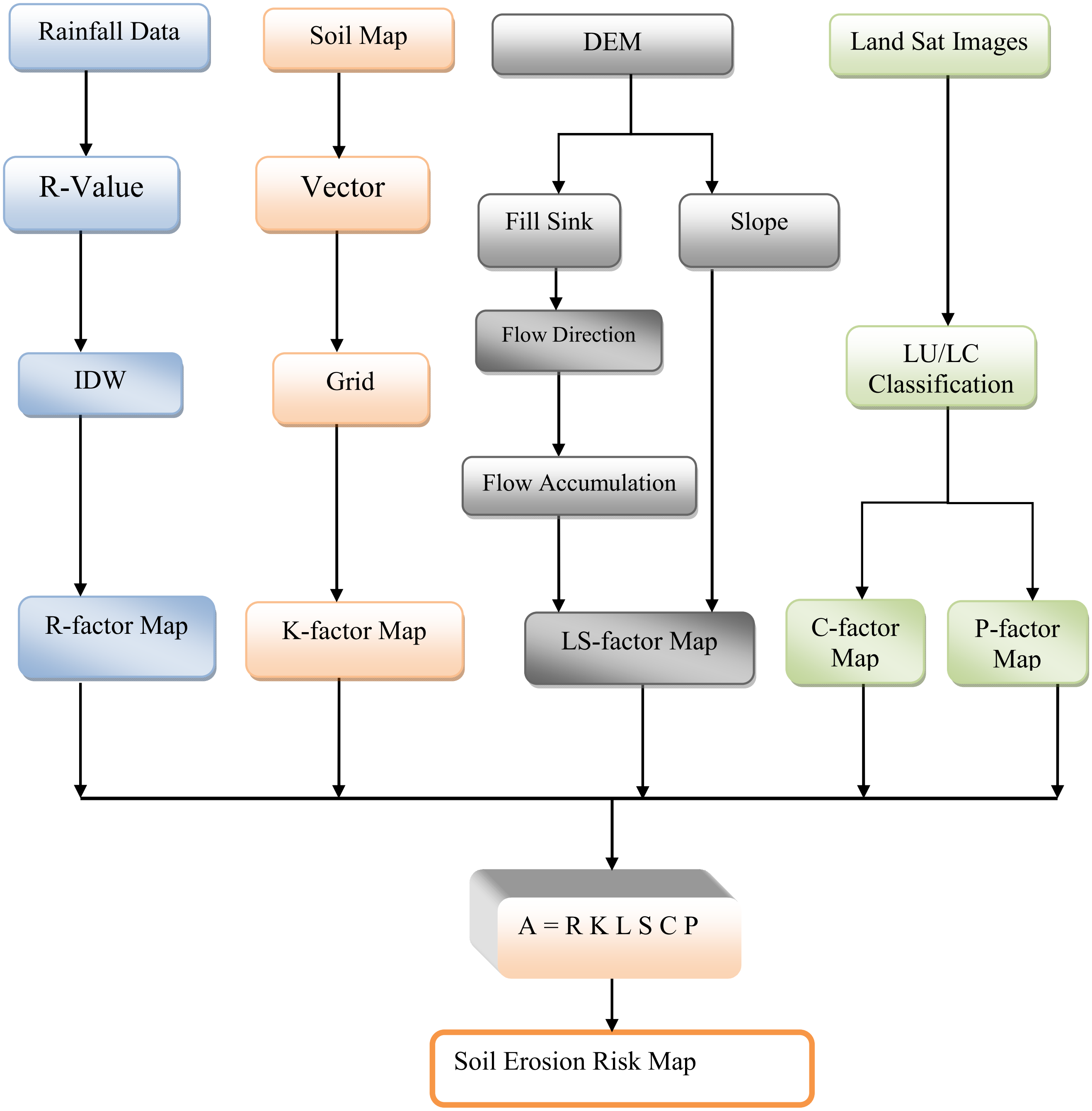

Figure 2: Flow chart of soil erosion risk mapping

3.4. Data Analysis

3.4.1 Rainfall Erosivity Factor (R)

Rainfall erosivity is defined as the product of kinetic energy of rain to cause erosion and given as composed of total storm kinetic energy (E) times the maximum 30-min intensity (I30) of the total energy of rainstorm and the annual erosivity will be estimated by summing rainfall erosivity of individual erosive storms of the year or season (Wischmeier and Smith 1978). Therefore Rainfall erosivity (R factor) is usually calculated calculated from the annual summation of rainfall energy (E) in every storm times its maximum 30 minute intensity (I30). However, such data is not available in most developing countries and in the study area , as a result Rainfall erosivity (R) factor of the RUSLE was estimated from the rainfall data based on the analysis of monthly rainfall data of different stations according to the equation developed by Hurni (1985), for Ethiopian condition:

$$R = -8.12 + (0.562 * p) \qquad (2)$$

Where R is rainfall erosivity and P is the mean annual rainfall value (mm)

The rainfall factor is a measure of the total annual erosive rainfall for a specific location, combined with the distribution of erosive rainfall throughout the year. To compute R factor, mean annual rainfall of covering the period 2010-2015 years were collected from five meteorological stations, one of them (Molale) was found within the District boundary, the remaining four (Mehalmeda, Seladngay, Jihur and Zemero) were taken from neighboring District. Despite the fact, there were missed (unrecorded) monthly rainfall data in these stations. Therefore, all missed data were filled by station average methods.

$$\mathrm{PX} = \frac{1}{\mathrm{N}} \sum {}_{\mathrm{i=1pi}}^{\mathrm{n}} \qquad (3)$$

Where; PX = the missing precipitation values for station X; n is the number of nearby stations; and P1, P2… Pn are precipitation values at the adjacent stations for the same period.

Then, after calculating average annual rainfall(2010 -2015) for each station, the R factor was computed using the formula (Hurni,1985) and converted in to raster surface with the cell size of 30 m to meet the spatial resolution of other maps used in the RUSLE model using IDW (Inverse Distance weighted) interpolation methods in ArcGIS tool. Inverse distance weighting is a commonly used deterministic interpolation method. It predicts cell values at unknown locations based on distance between unknown cell and from the known points.

3.4.2 Soil Erodibility Factor (K)

Soil erodibility refers to the liability of the soil to suffer erosion due to the forces causing detachment and transport of soil particles (Renard et al. 1997). Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute. Soil erodibility factor (K) in RUSLE accounts for the influence of soil properties on soil loss during storm events on upland areas. Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic matter and chemical content of the soil (Morgan, 1995).

The soil types of the study area were extracted from the available soil data of FAO soil map of Ethiopia (FAO, 1998) which are in vector format. Four types of soil classes were identified for the study area. These four soil classes are Cambisols, Leptosols, Regosols and Vertisols. Some soils are naturally more erodible than are other soils. The soil erodibility factor varies according to soil type. For this study, K value is assigned for each of the four soil types based on Hurni (1985) K factor values for different soil types (See Annex 2). After that, this shapefile of soil map were converted to the raster image format with a cell size of 30m resolution using the conversion tools. The raster map was then reclassified based on their erodibility value.

3.4.3. Slope Length and Steepness Factors (LS)

The L and S factors in RUSLE reflect the effect of topography on erosion. The topography (LS) comprises of two elements. The slope length or flow length (L) represents the effect of slope length on erosion and the slope gradient (S) is a slope steepness factor expressed as slope angle degree or percent. This is a very important factor in the overall erosion rate (Wischmeier and Smith, 1978).

To calculate the LS factor for the RUSLE equation, determination of the flow direction from the DEM is the first step then, calculate fallow accumulation and slope in degree (slope) required. Flow direction function defines which direction water would flow from each grid cells assuming the surface is impermeable. The flow direction function then serves as input for the flow accumulation. The flow accumulation function describes as the drainage network by calculating each cell's contribution to its neighboring cells. A depression less DEM which there are no sinks is required to perform the subsequent steps in finding the LS factor. Therefore simply using the Fill tool in ArcGIS can produce a sink free DEM. This is done to avoid the problem of discontinuous flow when water is catched in a cell, which is surrounded by cells with higher elevation. Then, the flow direction and flow accumulation should be calculated respectively. Finally, Slope in degree was generated from DEM to calculate LS factor values of the study area.

The DEM of ASTER with spatial resolution of 90m is derived from the United States Geological Survey (USGS) website by search of the study area via a dataset was used for generating LS factor maps of the study area. To meet the spatial resolution of all other factor maps the 90m spatial resolution of ASTER DEM was resembled in to 30m resolution using Resample (Data Management) tools in ArcGIS 10.3. Therefore; 30m spatial resolution DEM of ASTER was used to generate LS factor. Several methods of LS factor determination is developed with different GIS professionals at different time. Of which, the raster calculator tool calculates the LS factor using equation (5) in ArcGIS 10.3(Pelton *et al.*, 2014) is used for calculating LS factor after preparing the flow accumulation map and slope map by using Digital elevation model.

The L factor is the ratio of the actual horizontal slope length to the experimentally measured slope length of 22.1m. The S factor is the ratio of the actual slope to an experimental slope of 9%. The L and S factors are designed such that they are one when the actual slope length is 22.1 and the actual slope is 9%. 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.

$$LS = Power\left(flowacc * \frac{cell\ resolution}{22.1, 0.4}\right) * Power\left(\frac{\sin(slope * 0.017\,45)}{0.09, 1.4}\right) * 1.4 \tag{4}$$

Where, flowacc is flow accumulation raster; cell resolution is resolution of DEM in meters and slope is slope raster in degree.

3.4.4 Land Use Land Cover Factor (C)

The land use land cover factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith 1978). Remote sensing provides an effective way to show land cover as it produces a map like representation of the Earth's surface that is spatially continuous and highly consistent, as well as available at a range of spatial and temporal scales. Land sat 8 OLI_TIRS satellite image of 2017(Path 168 and Row 053) acquired on 2017/02/11 from USGS website (**http://earthexplorer.usgs.gov**) was used to classify the current land use and land cover map of the study area to determine the C factor values. The image has 30 meter resolutions. The detail of the satellite images is given in table 2.

Table 1: Source and data collection processing

Data set Attribute	Attribute value
Sensor Identifier	OLI_TIRS
Path	168
Raw	053
Date of acquisition	2017/02/11
Spatial Resolution	30m
Sun Elevation	52.51355123
Cloud Cover	0.03

When identifying land use or land cover for a given area of interest, two common approaches to classify each pixel in an image are supervised classification and unsupervised classification. Unsupervised classification is useful for scenes in which land cover is not well known or undefined. In unsupervised classification Computer algorithms group similar pixels into various spectral classes which the analyst must then identify and combine into information classes. In supervised classification, an analyst uses previously acquired knowledge of an area, or a priori knowledge, to locate specific areas, or training sites, which represent homogeneous samples of known land use and land cover types. Supervised classification groups the classes according to the judgment of the operator who decides not only the required number of classes but also which classes should be grouped together. For this study supervised classification methods using Maximum likelihood classifier with field observation were used to classify land use land cover factor in ERDAS IMAGINE 2014. Ground truth data is essential to performing accuracy assessment. For that reason Garmin GPS 64 also was employed to collect Ground Control Points with similar season of image acquisition to facilitate classification of the images. There are 101 ground truth data were used as a vital reference for supervised classification, accuracy assessment and validation of the result. Maximum Likelihood assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Each pixel is assigned to the class that has the highest probability. The land use and land cover of the study area is classified under seven major classes. These are forests, shrubs land, agricultural land, grass land, wet land urban built up area. To compute c factor values for the study area the result of land use land cover classification was converted to vector data as shapefile and shapefile of land use land cover were converted to the raster image files based on c factor vales with cell sizes of 30m.

3.4.5 Management (Support) Practice Factor (P)

The P factor compares the soil losses from up and down slope farming to losses that result from practices such as cross slope cultivation, contour farming and strip cropping. The P- factor gives the ratio between soil loss with a certain soil conservation practice to that with up-and down-slope ploughing (Wischmeier and Smith 1978). Soil erosion can be reduced by adjusting the flow pattern, grade, or direction of surface runoff and P also supports the C factor in land management system. For the study area Land sat 8

OLI_TIRS of 2017 satellite image was used to determine the P factor by land cover classification in to cultivated and non-cultivated lands. Then all the non-cultivated land use covers were merged using GIS application to be able to determine the support practice factor of the study area. After that the agricultural lands are classified into six slope categories and assigned P factor values from 0.1 - 0.33 depend on corresponding slope classes, while all non-agricultural lands are assigned a P factor value of 1.00 based on (Bewket and Teferi, 2009; Wischmeier and Smith, 1978). DEM of 30m resolution was used to generate slope map of the study area. Then the slope map was reclassified with the slope range and converted to a feature class. Finally the feature class was converted to raster (grid format) with cell sizes of 30m using P factor value field and a P factor map was obtained.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. RUSLE Model Parameters

Rainfall, soil type, topography (slope length and steepness), use/land cover and management Practice have been identified as model parameters for the study.

4.1.1. Rainfall Erosivity (R) Factor

The rain fall erosivity value was interpolated through annual rainfall data from nearby five meteorological stations. According to Erosivity value and using ArcGIS 10.3 IDW statistical Interpolation technique the raster value R factor was generated with the cell size of 30 m to meet the spatial resolution of other thematic maps used in the RUSLE model. Thus, the R-factor was calculated based on Equation.2 and Erosivity value calculated as shown in (Table 2).

Table 2: Average annual precipitation values (NMA, February 2017)

Stations	Latitude	Longitude	Elevation	Average Annual Precipitation (mm)	R factor
Mehalmeda	10.3146	39.66025	3084	384.6	208.02
Molale	10.12142	39.66139	3046	378.5	204.51
Seladngay	9.95	39.61667	2870	434.1	235.84
Jihur	10.03333	39.25	2700	335.3	180.31
Zemero	10.2167	39.45	2850	368.1	198.75

The result shows that the rainfall erosivity, as estimated from mean annual total rainfall of the respective stations, varied from 190.11 to 229.01. Therefore, based on these the southern part of the study area receives relatively higher rainfall that has high erosive power. As a result, the High rainfall may have high erosive power.

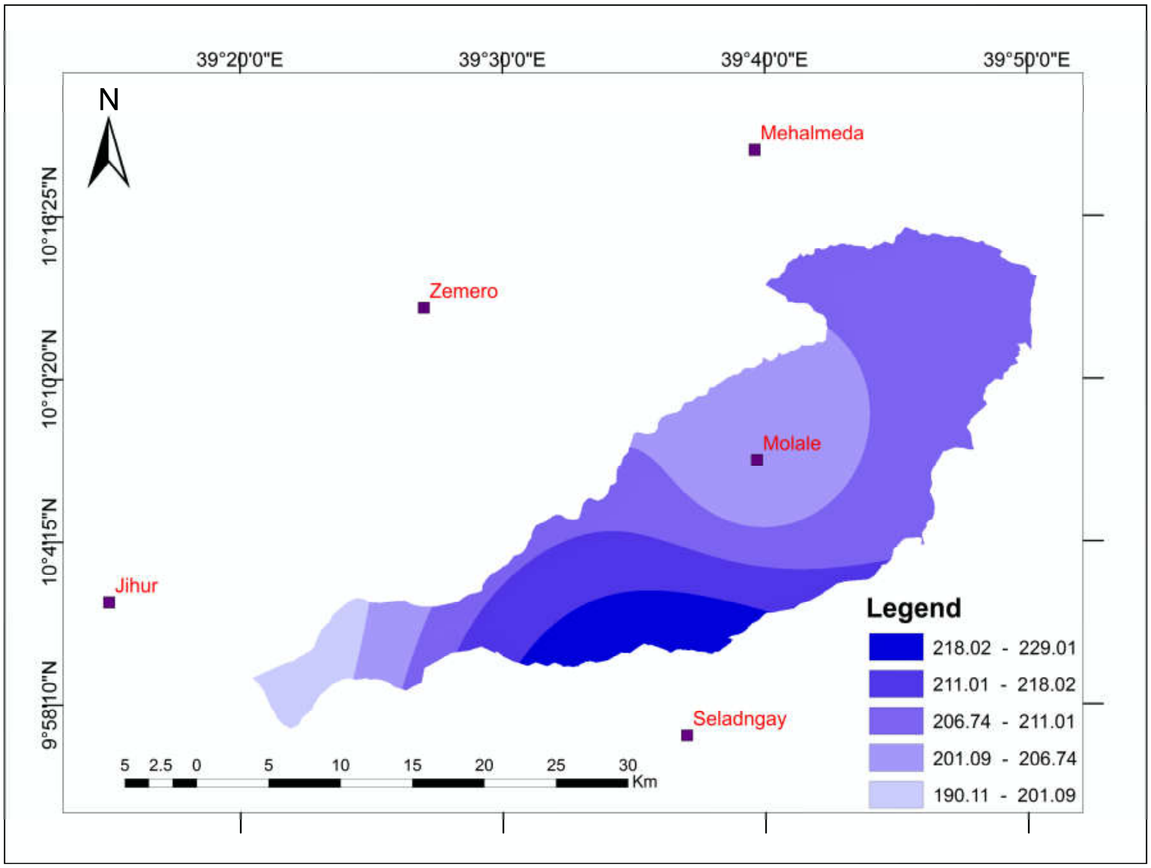

Figure 3: Meteorological Stations and Interpolation result (R factor map)

4.1.2. Soil Erodibility Factor (K)

The soil data used for this study were from the FAO digital soil map of Ethiopia. According to FAO digital soil map of Ethiopia, four soils are recognized in the study area which are; Cambisols, Leptosols, Regosols and Vertisols. The Soil erodibility factor of surface soils of each soil types computed using adopted K values by Hurni (1985).

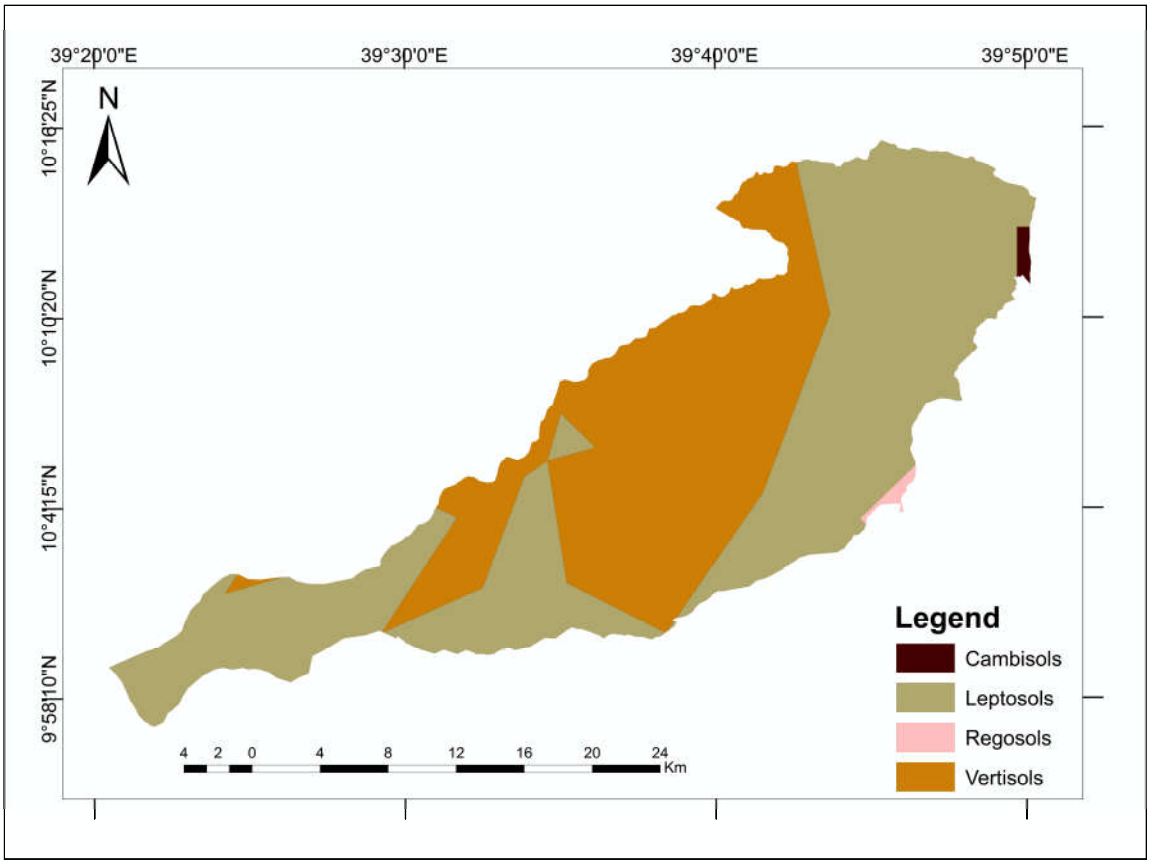

Figure 4:Soil type map of the study area

Table 3: Types and erodibility values of the study area (Adopted from Hurni 1985)

No.	Major Soil types	Erodibility factor (K) Value
1	Cambisols	0.15
2	Leptosols	0.25
3	Regosols	0.30
4	Vertisols	0.20

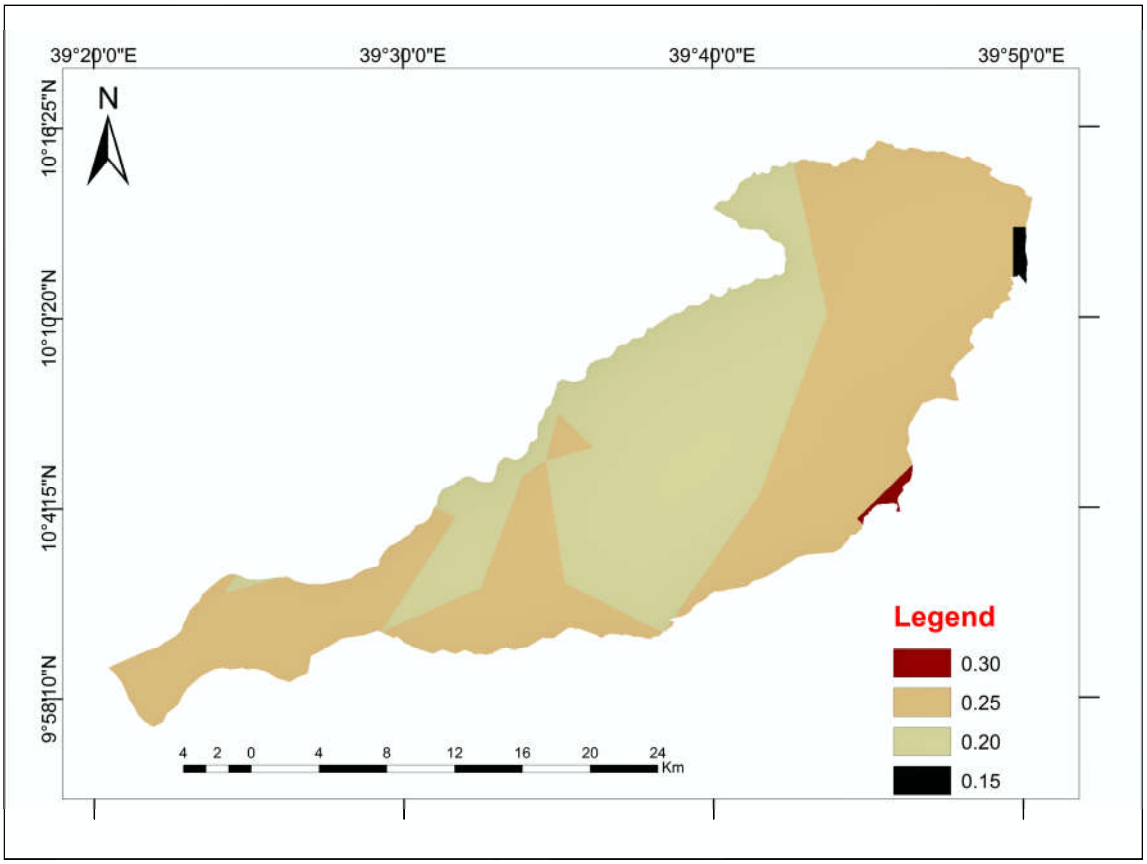

Figure 5: K factor map

The result shows that the soil erodibility values of the study area ranged from 0.15 the lowest, to 0.30 the highest. Higher value indicates more susceptibility while lower value indicates less susceptibility to erosion. The values indicate that Cambisols have lower erodibility value even it covers nominal amount of the stud area, while Vertisols, Leptosols and Regosols have moderate to high erodibility factor to erosion. Therefore, they have a more susceptible to erosion that affects soil loss. These is because of Cambisols have relatively good structure and chemical properties, and are not therefore greatly affected by degradation processes or high resilience to degradation and moderate sensitivity to detachability because of increasing clay with depth, they tend not to be greatly impacted by degradation. Whereas, Leptosols comprise very thin soils over continuous rock and soils that are extremely rich in coarse fragments that can be cause to erosion susceptibility. Regosols are characterized by very weakly developed mineral soils in unconsolidated materials and Vertisols are heavy clay soils with a high proportion of swelling clays. Clays usually active, cracking when dry and swelling when wet. The heavy soil texture and domination of expanding clay minerals result in a narrow soil moisture range between moisture stress and water excess; hence they are easily eroded by erosion.

4.1.3. Slope Length and Steepness Factors (LS)

Digital elevation models (DEM) with 30 meter resolution developed by USGS were used in analyzing the flow accumulation and slope gradient of the study area. The DEM showed that the elevation variation of the area ranges from 1575m to 3425 m**.** The elevation of the study area ranges from 1575 to 3425 meters above sea level. This shows the area has a huge topographical variation.

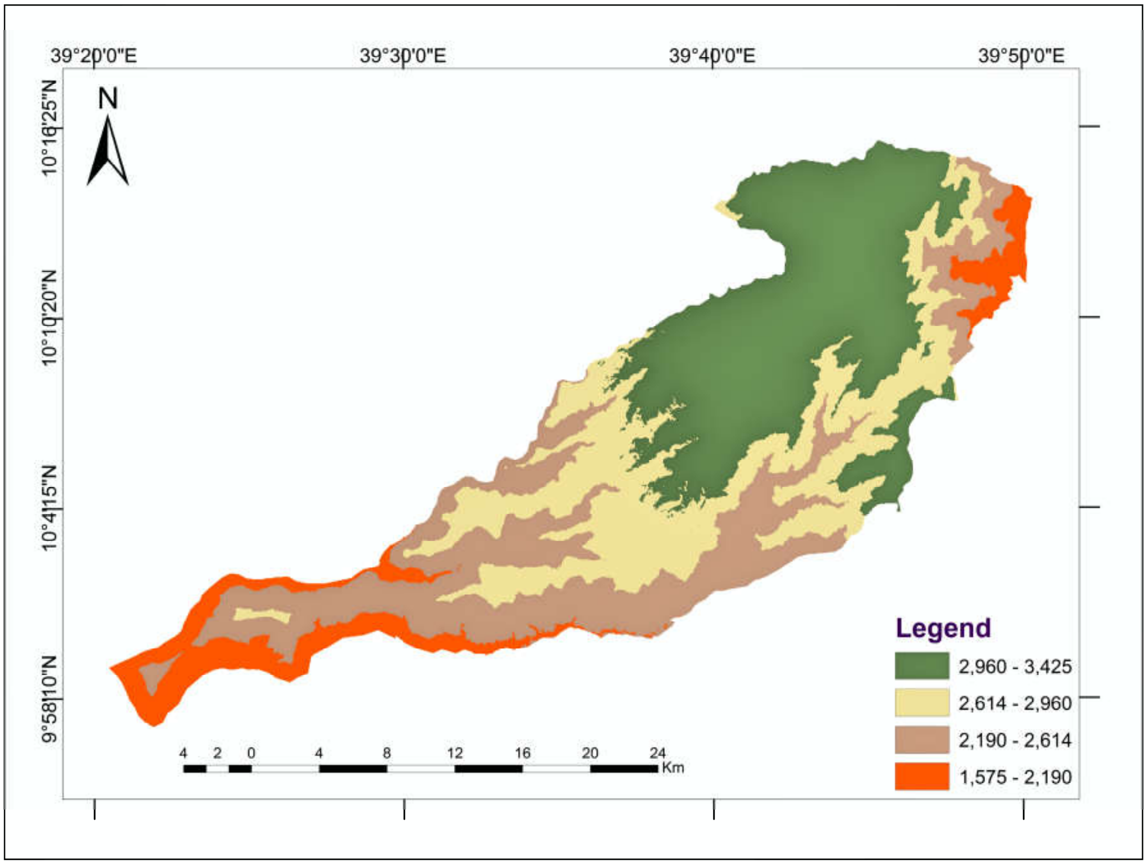

Figure 6: Digital Elevation Model

The slope degree value of the area was calculated in ArcGIS using Spatial Analyst tool. The slope varies from 0 to 69.72°. These show that the study area is characterized by rugged topographic features that can cause significant soil loss by soil erosion.

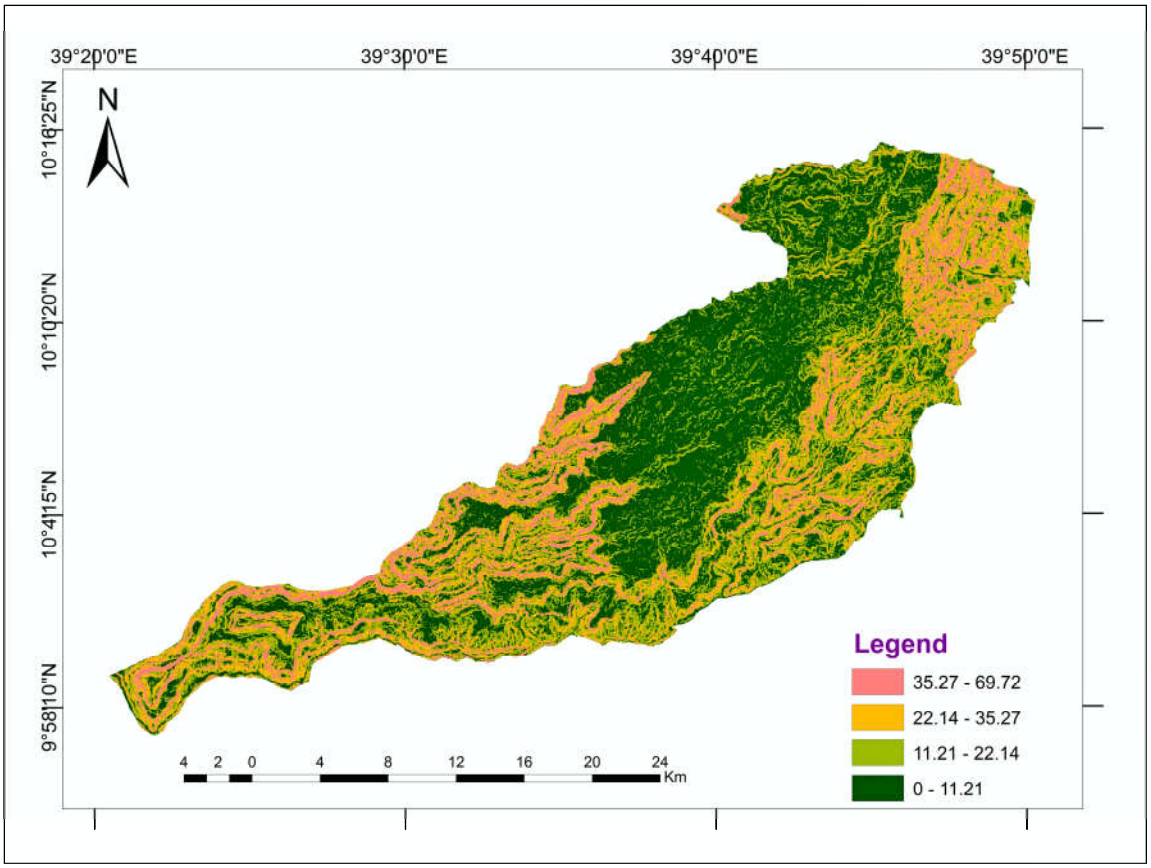

Figure 7: Slope map in degree

Figure 8 shows the combined LS factor of the study area which is calculated based on flow accumulation and slope. Accordingly LS factor of the study area ranges from 0 to 2,692.45. The values of cells are additively increased along the direction of steepest descent. For that reason Cells with high flow accumulation values are typically located where streams or rivers are located. The steeper and longer the slope will have the higher the risk for erosion. Soil loss increases significantly as slope length increases because greater accumulation of runoff on the longer slopes increases detachment and transport capacity. Soil losses per unit area are generally increases as the slope length increases due to the greater accumulation of runoff increases its detachment and transport capabilities. Therefore the higher LS-factor values are more rugged and hence are more exposed to erosion.

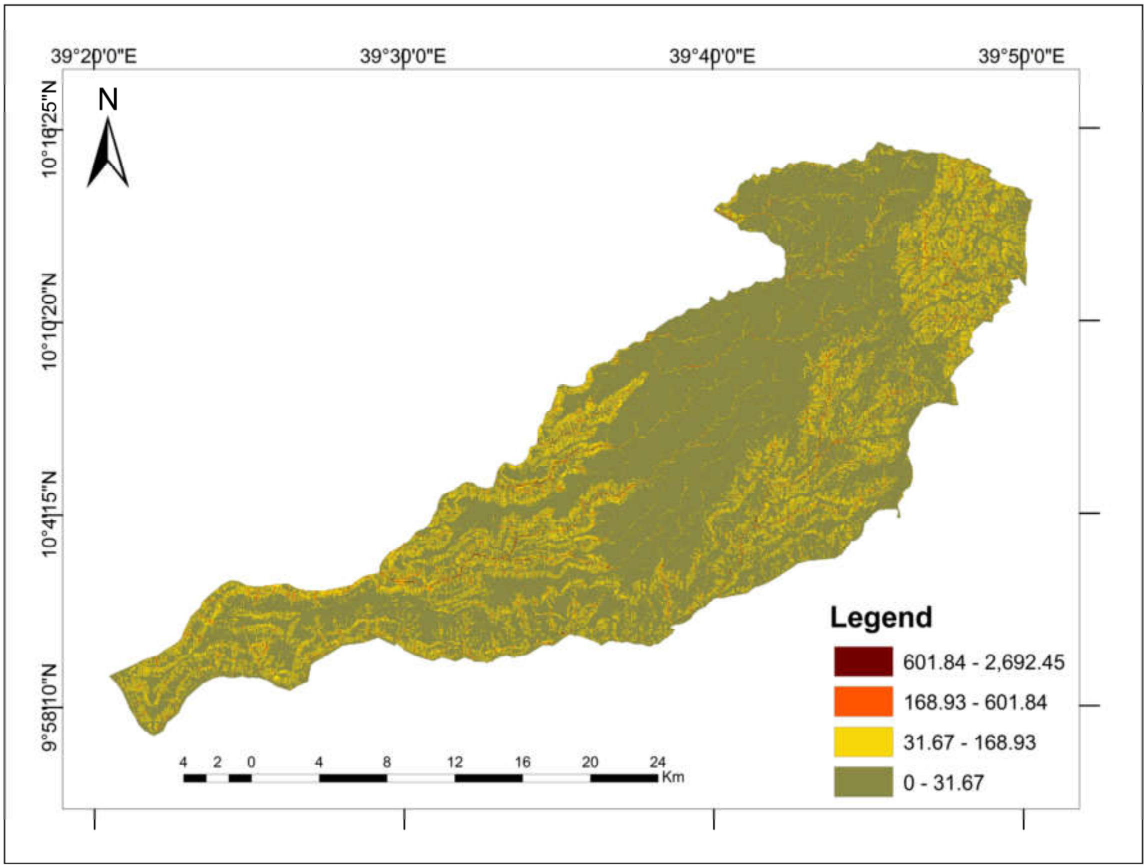

Figure 8: LS factor map

4.1.4 Land Use Land Cover Factor (C)

As shown in Table 4 and Figure 8 Seven land use and land-cover classes were recognized in the study area, dominantly by agricultural land (77.99%). In order to identify specific values for each land use/cover category, C-factor values were assigned to each of the land use/land cover classes recognized over the study area.

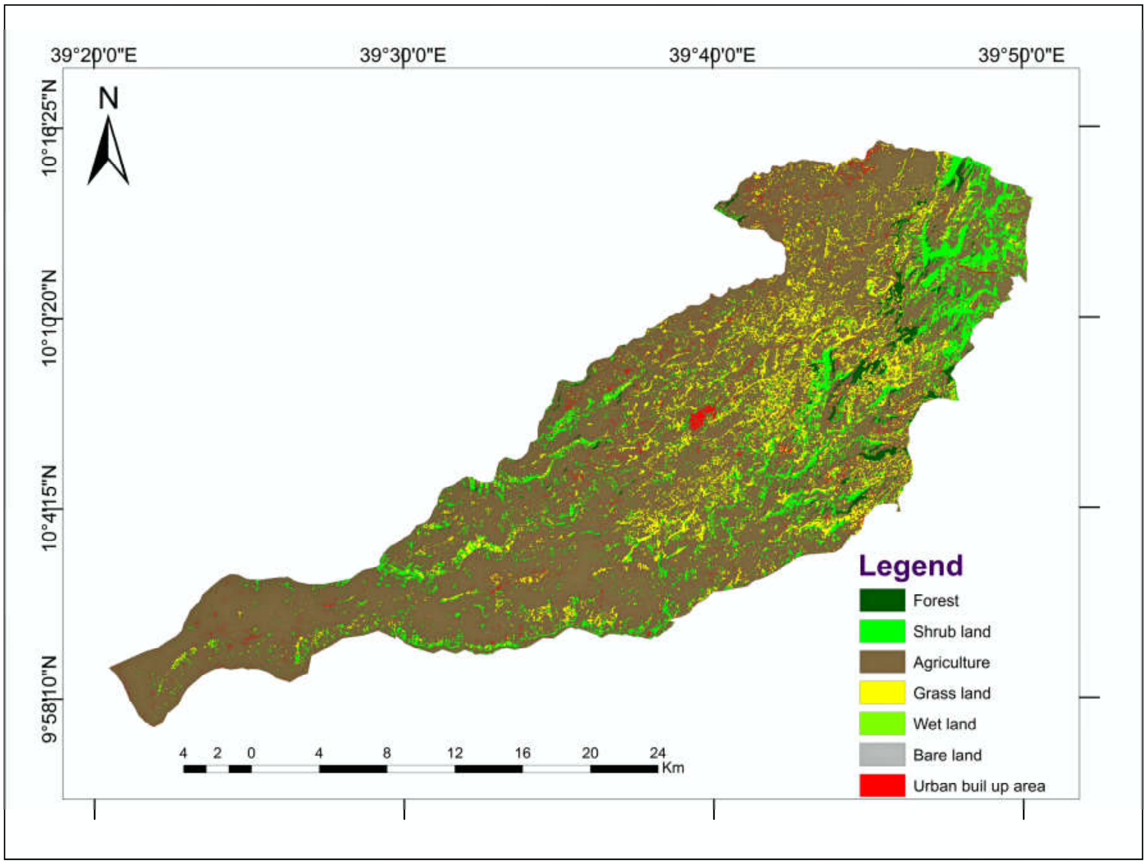

Figure 9: Land use land cover map

Table 4: Land use land cover classes

No.	Land use land cover types	Area coverage
1	Forest	1,182 (1.82)
2	Shrub land	5,572(8.56)
3	Agricultural Land	50,773 (77.99)
4	Grass land	5,805 (8.92)
5	Wet land	894(1.37)
6	Bare land	48(0.07)
7	Urban built up area	827(1.27)
Total		65,101(100)

Area coverage: number is area in ha; () = percent of area coverage

The C- factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith 1978). To determaine the impact of surface cover on erosion processes C-factor values are necessary. To pridicte C-factor values adopted for ethiopian condition (Hurni,1985; Bewuket and Teferi, 2009; and Nigussie et al., 2016) were used (Table 5).

Table 5: Land use land cover (C) factor values

Land use land cover type	C factor
Forest	0.01
Shrub land	0.02
Agriculture	0.25
Grass land	0.01
Wet land	0.01
Bare land	0.05
Urban built up area	0.05

As shown in Figure 11, the estimated land use land cover (C) factor of the study area shows that most parts of the lands were covered by agricultural or cultivated farmlands. It was exposed to erosion because the higher the C factor, the higher the soil losses. Forest and shrub lands land are found in the eastern and grass lands founds in most central part study area in scatter scene having low C-factor values. The remains are exists intermittently over the study area, whereas the urban built up area is found in central part. The C factor was high for areas with less vegetation cover. As a result areas with high C factors are more susceptible to soil erosion than the ones with low C factor. The C-factor values (Figure 8), of the study area range from 0.01 to 0.25. The C-factor values were high in the intensively agricultural land (0.25) where as the low C factor values were 0.02 to 0.05 for the other land use land covers (figure 10).

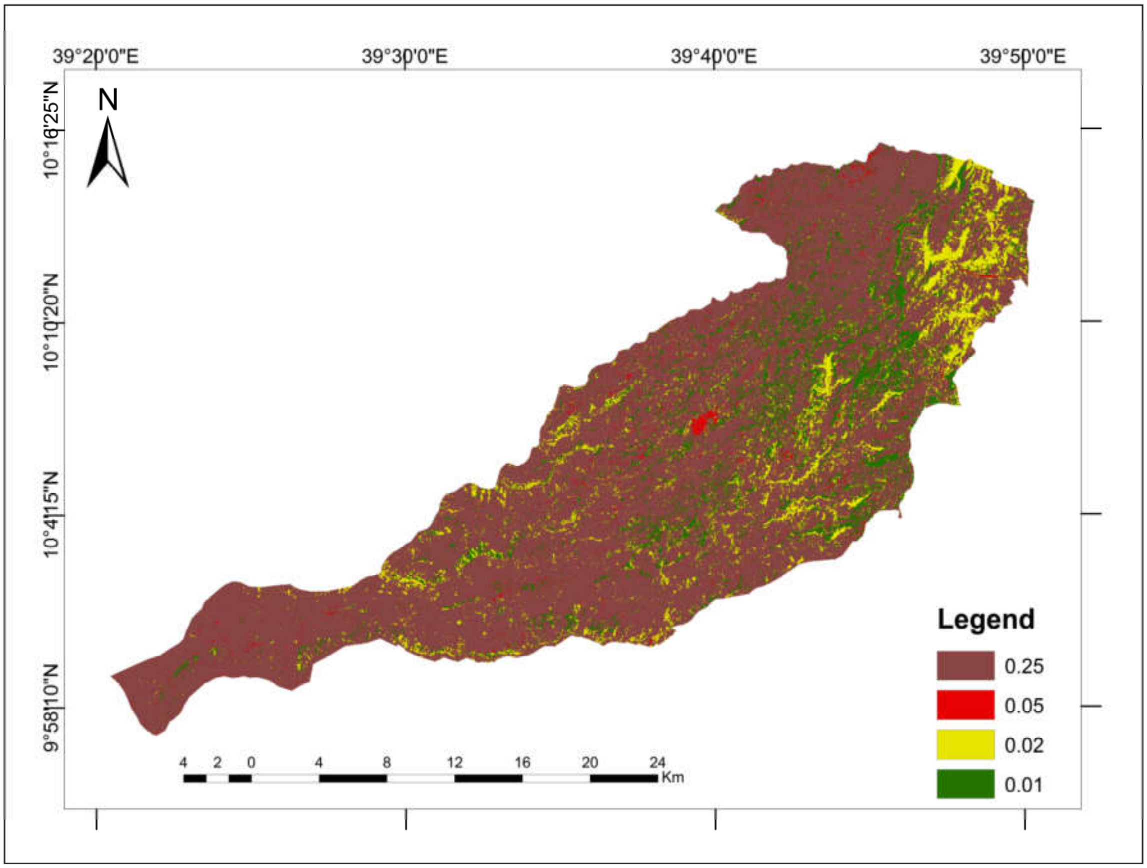

Figure 10: C factor map

4.1.5. Management (Support) Practice (P) Factor

The P factor gives the ratio between soil loss with a certain soil conservation practice to that with up-and down-slope caltivation. For this study, field observation was made to assess the study area in terms of conservation practices . Specific cultivation practices and conservation activities affect erosion by modifying flow amount, pattern and direction. In areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery (Renard et al, 1991). P factor map was prepared from land use land cover map. For this study P- factor values were assigned based on values suggested by Bewket and Teferi, (2009); Wischmeier and Smith, (1978). In the absence of any support practices, P should be assumed to be 1.0 in the RUSLE formula while with the use of appropriate conservation practice, the P factor can be reduced. For example, the practice of contouring, strip cropping or terracing on up down slope can reduce the P factor value. Therefore, the agricultural lands are classified into six slope categories and assigned P-values while all non-agricultural lands are assigned a P-value of 1.00 (Table 6).

Table 6: P factor values (Adopted from Bewket and Teferi, 2009; Wischmeier and Smith, 1978)

Land Use Land Cove Types	Slope (Percent)	P factor
Agriculture	0 - 5	0.1
	5 - 10	0.12
	10 - 20	0.14
	20 - 30	0.19
	30 - 50	0.25
	50 - 100	0.33
Other land	All	1.00

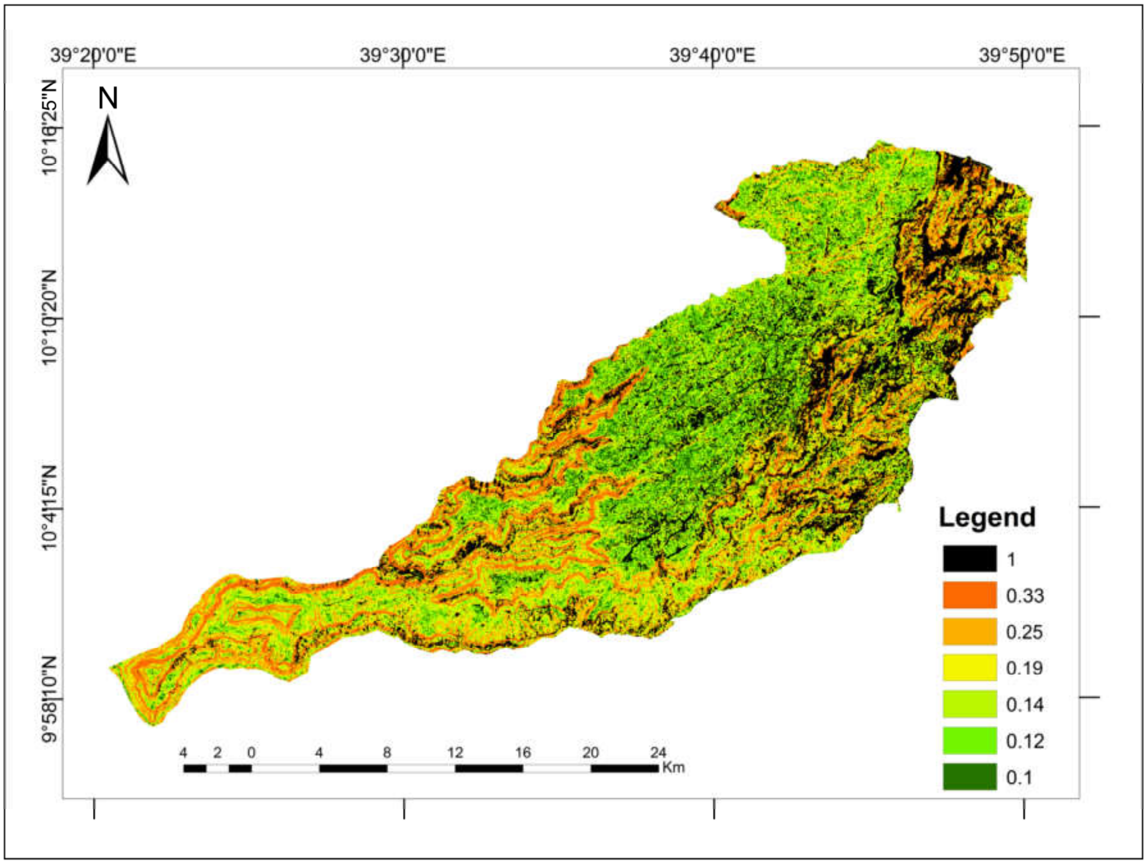

Figure 11: P factor map

As shown in Table 6 and Figure 11, the agricultural land of the study area have P-values ranges from 0.01 to 0.33 corresponding to topographic slope, whereas the other all land covers have P-values 1.0. The conservation practices factor reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. There are different and effective ways to control and prevent erosion to reduce soil erosion. In agricultural areas, conservation practices such as contouring, strip cropping or terracing can reduce soil losses by reducing runoff speed and increased infiltration. For this study, field observation was made to assess in terms of conservation practices and identify locations within study area where major conservation activities exist and evaluate their conditions. However this management practice (P values) was used the P-values suggested by Bewket and Teferi (2009); Wischmeier and Smith (1978) that considers only two types of land uses (agricultural and non-agricultural) and land slopes since as the data were lacking on permanent management factors available for the study area. Results show that most of the study area was covered by agricultural land.

In some agricultural lands of the study area, particularly in the flat terrain parts farmers use conservation practices such as terracing and stone bunds to soil conservation whereas, in the most steep slope areas farmers did not attempt any support practice to reduce soil losses. Much less attention has been paid to these vulnerable areas; soil erosion is significant and contributes to the soil degradation process occurring in much of the hilly upland areas of the study area. Therefore, farming has some harmful effects and can lead to soil loss in the step land area more severe with the effects of slope length and steepens.

4.1.6 Accuracy Assessment Result

The accuracy of a remotely sensed data product is important. Without known accuracy, the product cannot be used reliably, and therefore, has limited applicability because image classification using different classification algorithms may classify pixels or group of pixels to wrong classes. 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. One of the most commonly method used to assess classification accuracy is the use of an error matrix (sometimes called a confusion matrix). Therefore, to assess the classification accuracy of this study confusion or error matrix was employed. The Confusion or error matrix was obtained from reference data (GPS) with the help of ArcGIS 10.3 tool accuracy assessment operations; data management extensions (extract value to points, frequency and pivot table). 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. Then, overall accuracy and the Kappa coefficient were calculated from error matrices table (table 7).

Table 7: Error matrix showing classification accuracy of the true land use land cover

Classified	Forest	Shrub land	Agriculture	Grass Land	Wet land	Bare land	Urban built up area	Raw total
Forest	**9**	1	1	0	1	0	0	12
Shrub land	0	**11**	1	3	0	0	0	15
Agriculture	0	1	**17**	1	0	0	0	19
Grass land	0	1	1	**13**	0	0	0	15
Wet land	0	0	0	1	**13**	0	0	14
Bare land	0	0	3	0	0	**6**	0	9
Urban built up area	0	0	2	0	0	0	**15**	17
Column total	9	14	25	18	14	6	15	101

The overall accuracy index is produced by dividing all the pixels correctly classified by the total number of pixels in the matrix. By having this, in this study the overall classification accuracy is equal to 83.2%.

$$Total(overall)Accuracy = \frac{Number\ of\ correct\ plots(values)}{Total\ Number\ of\ plots(values)} \times 100$$

$$\text{Total (overall)accuracy} = \frac{(9 + 11 + 17 + 13 + 13 + 6 + 15)}{101} \times 100 = 83.2\%$$

The Kappa coefficient expresses the proportionate reduction in error generated by a classification process, compared with the error of a completely random classification (Congalton, 1991). The Kappa statistic incorporates the off-diagonal elements of the error matrices or classification errors and represents agreement obtained after removing the proportion. 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.

$$\hat{K} = N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})/N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})$$

Where: r is the number of rows in the matrix; x_{ii} is the total number of correct LULC classes in rows i and column i, $x_{\mathrm{i+}}$ is the total of row i (right of the matrix), x_{+i} is the totals of column i (bottom of the matrix); N is the total number of ground control points.

Therefore; Kappa coefficient (K) is equal to:

$$K = \frac{101(9+11+17+13+13+6+15)-[12\times 9)+(15\times 14)+(19\times 25)+(15\times 18)+(14\times 14)+(9\times 6)+(17\times 15)]}{(101\times 101)-[(12\times 9)+(15\times 14)+(19\times 25)+(15\times 18)+(14\times 14)+(9\times 6)+[17\times 15)]}$$

$$K = \frac{101(84)-[(108)+(210)+(475)+(270)+(196)+(54)+(255)]}{101^2-[(108)+(210)+(475)+(270)+(196)+(54)+(255)]}$$

$$K = \frac{8484-1568}{10201-1568} = \frac{6916}{8633} = 0.801$$

Finally, overall classification accuracy of 83.2% and overall Kappa statistics of 0.801% was achieved, which is feasible for further application.

4.2 Discussions

In order to estimate annual soil loss, the five factors were multiplied according to the relationship in RUSLE model. Based on the analysis, the estimated soil loss for the year 2017 of Menz Mama Midir District was ranges from 0 to 23,790.1ton/ha/year and the average annual soil loss for the entire study area was 32.2 ton/ha/yr from 65,101 hectare of land (Figure 13). This is the tangible indicator of the existence of risk of soil erosion in the area. The result shows that a majority of the high erosion risk sites are on the banks of rivers and on the steep slope land of the study area. This is due mainly to the high steep slopes along the river banks and the practice of agricultural activities in this area. Therefore; the slope length and steepness and land use land cover management are major factor contributing for high erosion in the area. After analyzing all five RUSEL model factor maps (R, K, LS, C and P) the erosion risk map looks similar to the LS and P factor map (figures 8 and 11). These indicate that in most areas where there agricultural activities practiced on a steep slope land or a long slope land there is a high erosion risk. As a result the slope length and slope steepness together with the land conservation practice factor (P) is also called as support factor make the area high value of soil erosion zone.

Highly to moderate erosive prone areas are mainly concentrated in higher altitudes of the study area. This area also experiences high rainfall intensity and high slope, which may be the contributing factor for the high erosion proneness. Furthermore, most of this area experiences negligible vegetation cover. The soil properties and degradation of vegetation cover occurrence in this area may probably become a factor to accelerate high soil erosion.

Low soil erosion area concentrated in the plain area. This might be the reason for low erosion occurred in this region. Based on the RUSLE model, this area shows low erosion rate. Comparatively low slope gradient may be the major factor lessening the vulnerability in this area even though the area experiences negligible vegetation covers in this region the erosion prominently.

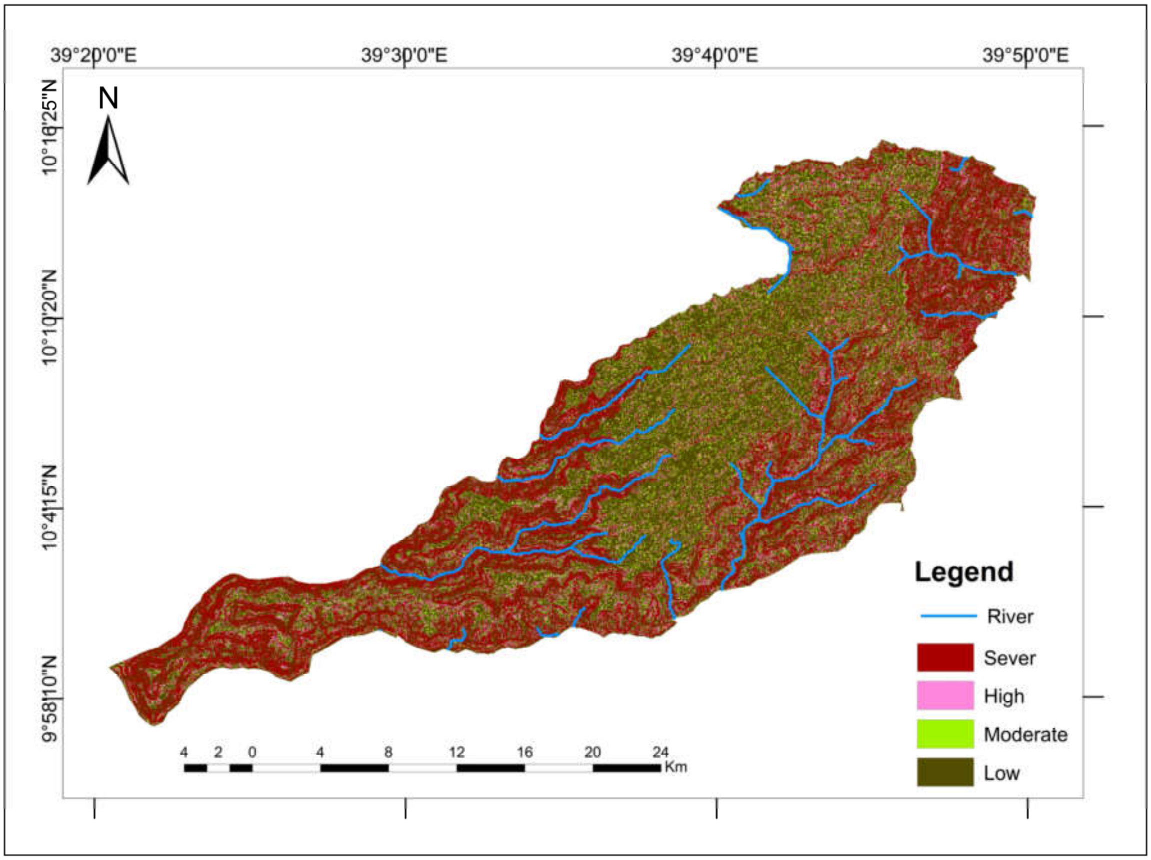

Figure 12: Spatial distribution of Soil loss risk map

The spatial distribution of the high soil erosion risk in the study area revealed that the highest soil loss is typically greater along the steeper slope and banks of the rivers whereas, most part of the plain area shows the less vulnerable to soil erosion (see figure 13). This is due mainly to the steep slopes along the banks these streams and rivers. As was seen in the on the erosion risk map, the steeper a slope the more susceptible to erosion, therefore steep slope area and stream banks are going to be highly vulnerable to erosion. The plain area of the study area shows the least vulnerable to soil erosion besides their area coverage, the topographic ruggedness and poor vegetation coverage contributes to the high rate of soil erosion. For the purpose of identifying priority areas for conservation planning, four categories of soil loss were used to indicate the magnitude of soil erosion risk of the study area by following basis of FAO and UNEP (1984) classification (Table 8). The predicted amount of soil loss and its spatial distribution can provide a basis for comprehensive management and sustainable land use for the study area. The areas with high to severe soil erosion demand special priority for the implementation of control measures.

Table8: Categorization of soil erosion risk

Average soil loss (t/ha/yr)	Severity classes	Priority class	Area(Ha)
0 -5	Low	4	31,928 (49.16)
5 - 11	Moderate	3	5,809 (8.94)
11 - 30	High	2	8447 (13.01)
>30	Sever	1	18,759 (28.89)

Area coverage: number is area in ha; () = percent of area coverage

In the study area four levels of soil erosion risk, i.e. low, moderate, high and sever were identified and mapped (Table 8 and Figure 12).The results showed that about 18,759 hectare which is about 28.89% of the total study area is classified as severe erosion areas, where the average soil loss rate is higher than 30 ton/ha/year, and about 8447 hectare (13.01%) of the area is classified as high erosion areas, moderate erosion risk class covers an area of 5,809 hectare (8.94 %), and the remaining 31,928 hectare (49.16%) are under low erosion risk classes. Based on the soil erosion severity class, it was possible to conclude that about 23.89% of the area is under severe erosion risk. A majority of the high erosion risk sites are on the banks of rivers and streams. This is due mainly to the high, steep slopes along the banks these streams and rive. Since Soil management is essential element of sustainable agriculture; GIS and RS applications provide a good estimate of soil loss rate and soil loss risk class over the study area. Therefore the output of the results of these study assist determining erosion control areas, starting regulation projects, and making soil conservation measures.

The annual soil loss estimated for the study area is within the range of estimates for several Ethiopian Studies. For example, Tadesse and Abebe (2014) estimated the mean annual soil loss of Jabi Tehinan District, Amhara National Regional State, Ethiopia is 30.6 ton/ha/yr, which make a total loss of 3,580,528 ton per year from 116983.5 hectares.

Amare, et al (2014) estimated the average annual soil loss of the Eastern Escarpment of Wondo Genet Watershed, Ethiopia was 26 ton/ha/yr and the total annual soil loss potential of the study area was estimated at 64,014 tons from an area of 2,472 hectares and Bewket and Teferi (2009), estimated 93 ton/ha/yr in Chemoga Watershed, Blue Nile Basin, Ethiopia.

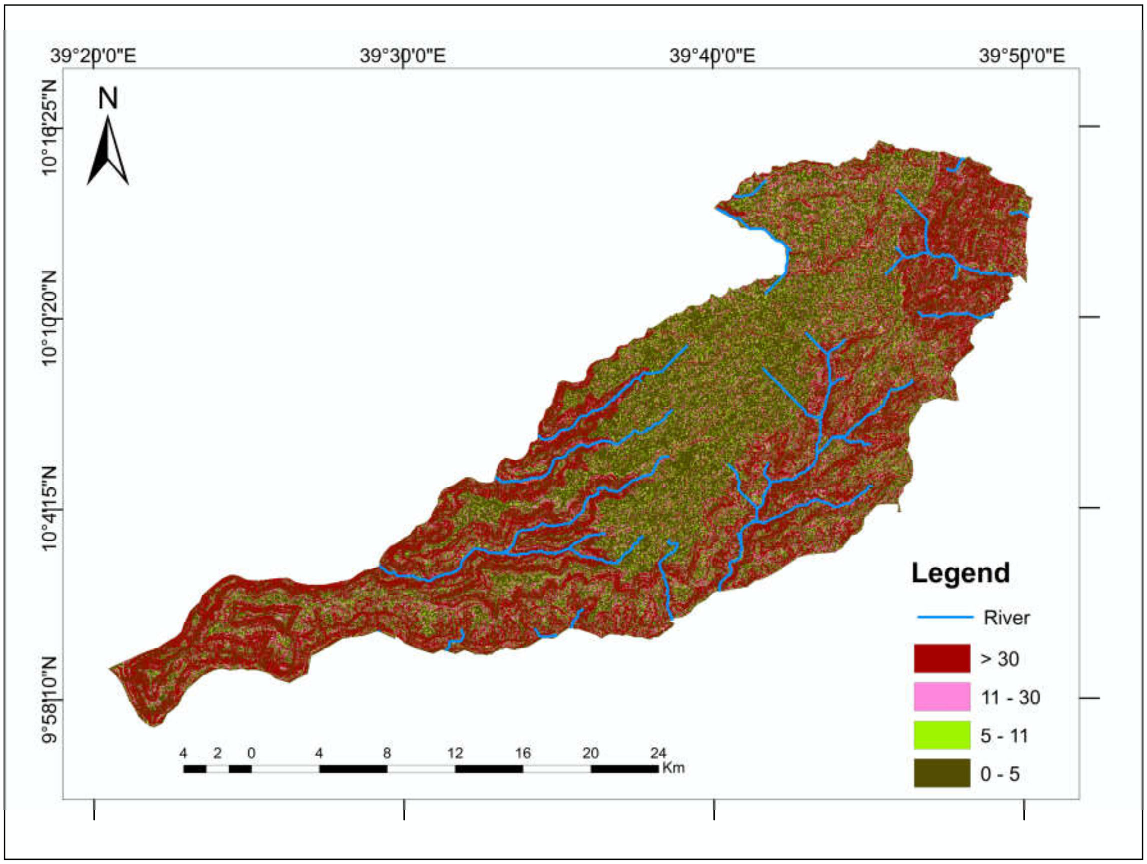

Figure 13: Average annual soil loss map

As shown in figure13, the proposed RUSLE model adopted for Soil erosion prone area identification contribute to soil erosion estimation and will help to facilitate conservation planning in the future, showing good potential for successful application for controlling soil erosion.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Assessment and management of soil quality for land use planning is increasingly important due to increasing competition for land among many land uses and the transition from subsistence to market based farming in many countries. Soil erosion removes valuable topsoil, results in lower yields production, land degradation and the disturbance ecosystem services. Soil conservation is about solving the problems of land degradation, mainly soil erosion. Hence, it is very important to study the regulation of soil erosion. The present study was aimed at to investigate areas prone to high risk of water erosion and to map the spatial variability of erosion area and the prioritization of conservation priority categories, which can be used for preparation of a conservation plan for management of the Menz mama District which is located at the eastern edge of the Ethiopian highlands in the north shewa. The soil loss estimation was carried out based 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, land use land cover and management practice. This empirical model was selected due to its universality and easily adaptability with little modifications. In the process it has been demonstrated that GIS and Remote Sensing is technically feasible to identify soil erosion risk assessment. This is an effective way to map the spatial distribution of soil erosion risks in a large area.

The result from RUSLE Model revealed that currently, about 23790.1 ton/ha/year of soil was eroded annually and the average annual soil loss rate for the entire study area was 32.2 ton/ha/yr from 65,101 hectare. From the study, it was found that the slope length and steepness and land use management factor have significant effect on the erosion proneness in the study area. The Soil erosion risk map produced can be used as a decision support system to provide mitigation measures for decision makers. The RUSLE model with the integration of GIS and RS adopted in this study is a significant tool to soil erosion assessment and can be facilitates conservation planning by showing risk areas for successful controlling soil erosion. The Soil erosion risk map produced can be used as a decision support system to provide mitigation measures for decision makers.

5.2. Recommendations

Proper management of soil resource is vital to sustain long term agricultural productivity. The findings of the study showed that the study area is prone to soil erosion. The conservation priority levels identified to facilitate the planning of future erosion conservation actions. Majority of the study area under sever soil erosion risk are located in the banks of rivers and on the steep slope land which are often cultivated without any conservation measures and requires appropriate intervention with soil conservation measures. As a result, the following recommendations were forwarded depending on the findings of the study.

- The study area which has high soil loss risk needs immediate attention should be taken in order to control and minimize soil erosion degradation. Therefore, the concerned organization and the regional government offices should take a serious action in designing and implementing soil water conservation strategies for better agricultural productivity.
- The next issue should be investigating the appropriate controlling factors in order to be able to design problem oriented conservation practices. Therefore; further studies should be done to determine what conservation mechanisms will be required for each severity classes to regulate the situation.

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ANNEXES

Annex 1: Monthly Rainfall Values

Stations	YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mehalmeda	2010	12.2	50.2	38.9	105.8	64.5	30.7	325.5	64.5	47.4	6.8	3.2	21.7
Mehalmeda	2011	2.3	2.3	63.2	45.3	71.2	12.9	181.4	292.5	70.6	1.6	6.7	0.0
Mehalmeda	2012	0.0	0.0	54.3	71.7	38.6	78.2	362.0	229.1	18.9	5.6	0.0	0.0
Mehalmeda	2013	0.0	0.0	43.6	26.3	15.8	69.2	364.4	264.4	72.9	60.9	2.0	0.0
Mehalmeda	2014	0.0	49.0	39.2	21.0	29.0	10.1	229.2	304.3	87.1	19.6	11.6	1.4
Mehalmeda	2015	0.0	13.2	18.2	0.0	64.7	111.7	44.6	214.3	47.4	0.0	0.0	0.0
Molale	2010	15.1	18.4	24.4	81.7	34.2	51.8	377.6	56.6	56.6	4.0	9.7	5.4
Molale	2011	8.6	0.0	42.6	111.7	93.4	72.5	116.8	228.0	37.9	0.0	4.0	0.0
Molale	2012	x	x	x	x	x	x	x	x	x	x	x	x
Molale	2013	0.0	0.0	114.3	55.5	25.5	132.5	496.6	347.7	82.2	107.0	11.1	0.0
Molale	2014	0.0	13.1	75.4	48.4	91.1	27.2	383.5	382.7	155.9	26.7	7.9	0.3
Molale	2015	1.0	0.0	16.2	11.6	44.8	32.1	42.3	305.9	52.4	0.0	0.0	0.0
Seladngay	2010	15.1	41.1	10.8	60.7	100.0	2.3	405.6	453.3	92.8	3.7	2.6	5.2
Seladngay	2011	0.0	0.0	81.6	88.7	71.2	42.1	177.4	406.4	121.7	0.0	12.3	0.0
Seladngay	2012	x	x	x	x	x	x	x	x	x	x	x	x
Seladngay	2013	0.0	0.0	21.8	35.9	38.9	71.1	473.9	355.7	118.8	53.3	22.2	0.0
Seladngay	2014	0.0	6.9	31.8	59.4	58.8	30.5	334.6	408.7	150.9	83.8	7.8	0.0
Seladngay	2015	0.0	0.0	17.2	0.0	117.2	94.7	50.1	305.9	65.0	0.0	0.0	0.0
Jihur	2010	1.6	55.8	41.4	56.9	59.9	25.4	299.8	334.0	76.1	0.0	0.0	20.7
Jihur	2011	2.3	0.0	94.3	46.2	67.3	33.1	106.9	187.1	86.4	0.0	3.9	0.0
Jihur	2012	x	x	x	x	x	x	x	x	x	x	x	x
Jihur	2013	0.0	0.0	44.1	31.5	25.5	24.6	322.5	356.1	58.9	41.6	0.0	0.0
Jihur	2014	0.0	7.0	85.8	13.1	26.6	22.2	367.2	284.8	92.0	0.0	0.0	0.0
Jihur	2015	0.0	0.0	27.9	0.0	60.0	101.1	50.1	305.9	76.1	0.0	0.0	0.0
Zemero	2010	7.4	61.8	39.8	100.3	79.6	24.3	313.6	258.0	90.2	2.4	9.7	10.6
Zemero	2011	0.6	2.8	63.2	65.0	71.2	39.9	142.2	256.2	113.1	0.0	6.6	0.0
Zemero	2012	x	x	x	x	x	x	x	x	x	x	x	x
Zemero	2013	0.0	0.0	24.8	56.3	46.4	70.1	350.5	306.7	61.8	33.4	8.1	0.0
Zemero	2014	9.3	37.7	78.8	33.7	44.8	11.5	383.5	354.5	130.4	3.4	0.0	0.3
Zemero	2015	0.0	1.7	18.5	0.0	51.3	93.7	74.5	266.6	97.0	0.0	9.7	0.0

Annex 2: Dominant Soil Types Considered and the Corresponding K Factors Used For the Initial Calibration of the Model (Hurni, 1985)

Soil types	Suggested k factor ranges
Alisols	0.30 – 0.40
Andosols	0.10 – 0.20
Arenosols	0.30 – 0.40
Chernozems	0.10 – 0.25
Cambisols	0.15 - 0.30
Fluvisols	0.15 – 0.25
Gypisols	0.30 – 0.40
Leptosols	0.15 – 0.25
Luvisols	0.20 – 0.30
Lixisols	0.20 – 0.30
Not defined	Case study average
Nitisols	0.20 – 0.30
Phaeozems	0.10 – 0.20
Regosols	0.15 – 0.30
Solonchacks	0.20 – 0.30
Solonetz	0.30 – 0.40
Vertisols	0.10 – 0.20

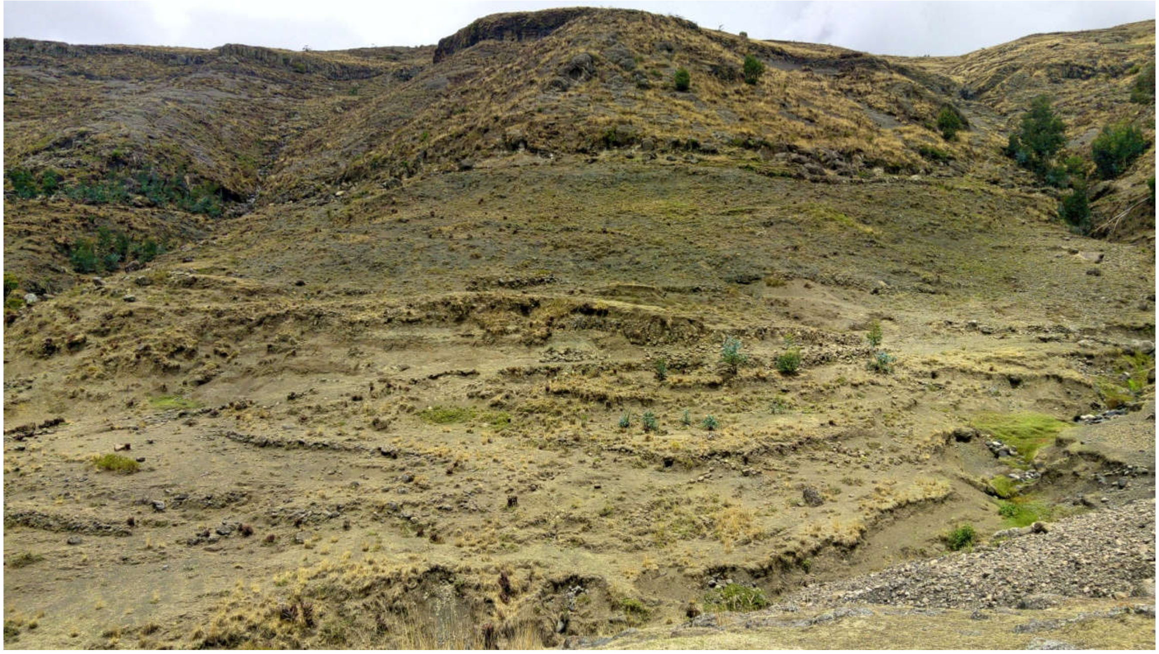
Annex 3: GPS Points Used For Land Use Land Cover Map Accuracy Assessment

No.	Land Use Land Cover Type	ID	Latitude	Longitude	Elevation
1	Forest	6	582850	1125369	3228
2	Forest	6	583881	1126545	3247
3	Forest	6	583853	1127171	3199
4	Forest	6	583336	1125475	3214
5	Forest	6	580749	1114805	3127
6	Forest	6	578886	1113624	2542
7	Forest	6	578966	1113693	2535
8	Forest	6	579733	1113233	2728
9	Forest	6	580071	1113270	2711
10	Forest	6	580151	1113345	2638
11	Forest	6	580193	1113402	2599
12	Forest	6	579124	1113148	2719
13	Shrub land	7	581114	1113889	2736
14	Shrub land	7	581294	1113937	2703
15	Shrub land	7	581532	1114089	2750
16	Shrub land	7	581971	1114355	2798
17	Shrub land	7	582077	1114424	2809
18	Shrub land	7	581997	1114439	2830
19	Shrub land	7	580965	1113926	2775
20	Shrub land	7	580564	1113953	2788
21	Shrub land	7	579065	1114315	2732
22	Shrub land	7	579176	1114407	2781
23	Shrub land	7	578622	1113816	2613
24	Shrub land	7	579442	1114144	2665
25	Shrub land	7	580628	1112406	2695
26	Shrub land	7	580256	1112222	2715
27	Shrub land	7	580087	1111984	2716
28	Agriculture	8	579077	1112926	2828
29	Agriculture	8	580892	1114361	3005
30	Agriculture	8	578072	1114632	2657
31	Agriculture	8	579187	1114950	2772
32	Agriculture	8	579532	1115260	2778
33	Agriculture	8	579617	1115803	2689
34	Agriculture	8	577206	1114528	2602
35	Agriculture	8	578954	1113167	2661
36	Agriculture	8	579327	1113266	2729
37	Agriculture	8	579666	1113421	2631
38	Agriculture	8	580759	1113491	2618

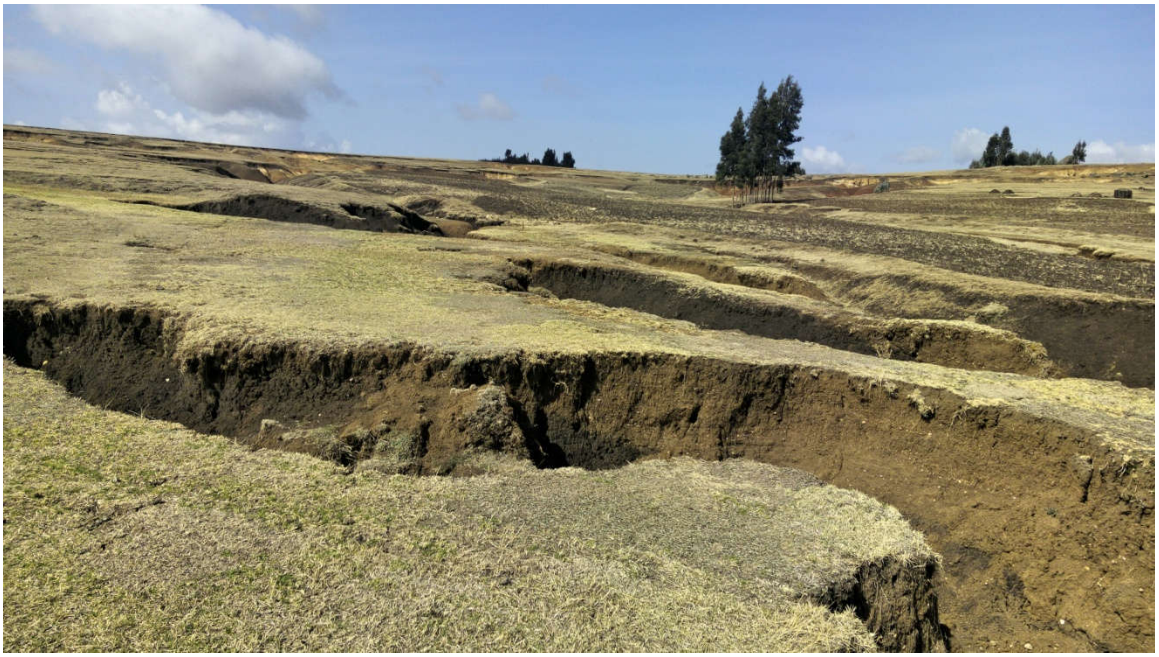
39	Agriculture	8	579659	1112907	2839
40	Agriculture	8	578778	1112703	2791
41	Agriculture	8	579306	1112758	2891
42	Agriculture	8	579300	1113386	2667
43	Agriculture	8	579377	1114013	2638
44	Agriculture	8	579158	1113949	2584
45	Agriculture	8	578904	1114055	2654
46	Agriculture	8	578700	1113977	2659
47	Grass land	9	581354	1114147	2844
48	Grass land	9	581157	1114380	2953
49	Grass land	9	580121	1115377	2883
50	Grass land	9	579556	1114364	2819
51	Grass land	9	579669	1114427	2847
52	Grass land	9	579699	1114230	2740
53	Grass land	9	579737	1111941	2762
54	Grass land	9	580553	1112598	2817
55	Grass land	9	580946	1112741	2816
56	Grass land	9	579624	1114275	2761
57	Grass land	9	582071	1114774	2945
58	Grass land	9	581830	1113081	2948
59	Grass land	9	581277	1113075	2902
60	Grass land	9	581381	1113111	2910
61	Grass land	9	577292	1113858	2755
62	Wet land	10	580160	1111403	2527
63	Wet land	10	578891	1111864	2628
64	Wet land	10	578060	1112779	2638
65	Wet land	10	580046	1114281	2797
66	Wet land	10	577612	1111249	2579
67	Wet land	10	577443	1111503	2637
68	Wet land	10	577305	1111898	2784
69	Wet land	10	578044	1112436	2668
70	Wet land	10	578576	1111743	2619
71	Wet land	10	578537	1111743	2620
72	Wet land	10	578983	1111607	2596
73	Wet land	10	580151	1111454	2532
74	Wet land	10	580426	1111529	2518
75	Wet land	10	578822	1112104	2655
76	Bare land	11	578372	1111792	2642
77	Bare land	11	577455	1111138	2547
78	Bare land	11	573948	1116866	3048
79	Bare land	11	574039	1116879	3048

80	Bare land	11	573980	1116925	3046
81	Bare land	11	577496	1111159	2552
82	Bare land	11	572056	1117612	2988
83	Bare land	11	571877	1117410	2978
84	Bare land	11	577454	1111138	2979
85	Urban	12	571831	1118190	3034
86	Urban	12	571850	1118533	3044
87	Urban	12	571896	1118757	3031
88	Urban	12	572225	1118771	3046
89	Urban	12	572422	1118693	3041
90	Urban	12	572688	1118959	3039
91	Urban	12	572848	1119037	3035
92	Urban	12	572683	1119188	3046
93	Urban	12	572825	1119248	3044
94	Urban	12	573054	1119156	3039
95	Urban	12	573082	1118776	3014
96	Urban	12	572294	1118753	3047
97	Urban	12	572088	1118712	3041
98	Urban	12	572221	1119055	3022
99	Urban	12	572203	1118849	3036
100	Urban	12	572729	1119115	3043
101	Urban	12	573064	1119220	3042

Annex 3: Pictures that are taken during the field visit

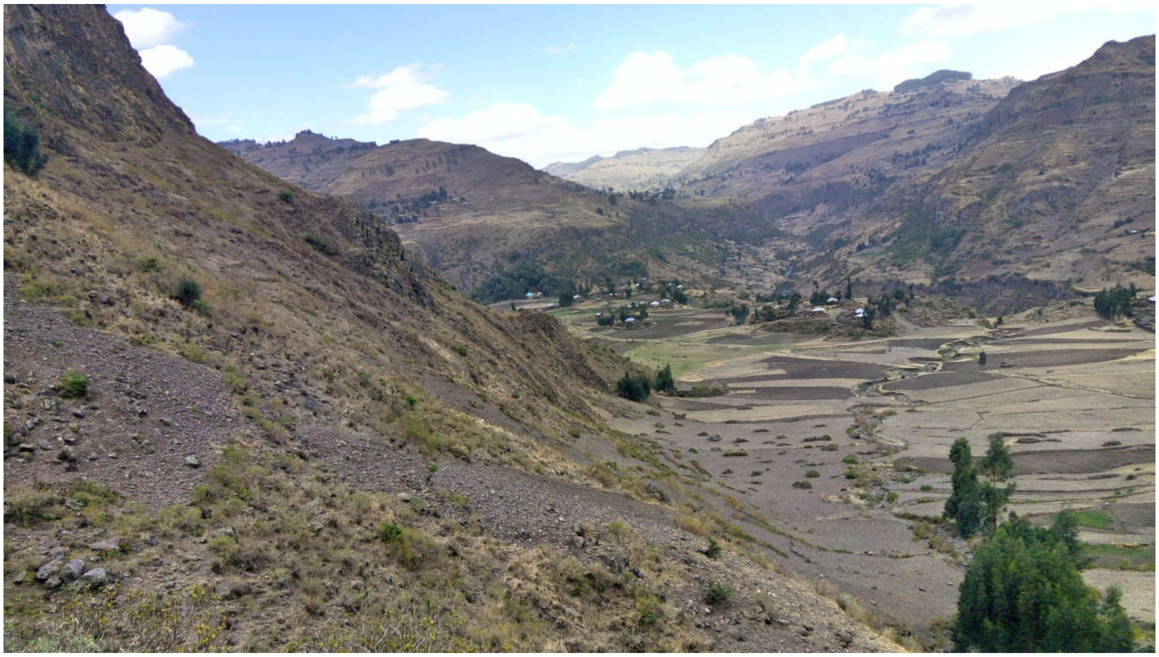


- Degraded land, which lost much of the topsoil



- Examples of gully erosion in the study area

- Example of agricultural land on the steep land



- Examples of study area showing high altitude difference and complex terrain with high Vulnerable for soil erosion