ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY, SCHOOL OF CIVIL AND ENVIROMENTAL ENGINERING

LAND USE AND LAND COVER CHANGE ON SOIL EROSION USING RUSLE MODEL: A CASE STUDY OF JEMMA CATCHMENT, ETHIOPIA

A Thesis Submitted to the Graduate School of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geodesy and Geomatics (Specialization in Geomatics)

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BY BIZUALEM MEKONNEN

May 2022

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List of Acronyms

AOI	Area of Interest
CORINE	Coordination of Information on the Environment
CSA	Central of Statistical Agency
DEM	Digital Elevation Model
DN	Digital Number
EGE	Ethiopia Geospatial Agency
EGA	Ethiopia Geospatial Agency
ETM+	Enhanced Thematic Mapper plus
FAO	Food and Agricultural organization
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land use/ Land cover
MoA	Ministry of Agriculture
MS	Micro Soft
OLI	Operational Land Imagery
RDE	Rural Development of Ethiopia
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
SRTM	Shuttle Radar Topographic Mission
UNEP	United Nations Environment Programme
USA	United States of America
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator
WEPP	Water Erosion Prediction Project
WGS	World Geodetic System

Abstract

Soil erosion is the deterioration of soil by straight forward of the physical movement of soil elements from a given site and the main catchment problems in the high land of Ethiopia. This research mainly aims to evaluate Land use and land cover change on soil erosion using RUSLE model and to investigate land-use/land-cover changes of 20 years using satellite image of Landsat 5 TM 2000, Landsat 7 ETM+ 2015 and Landsat 8 OIL2020. RUSLE model is used on the basis of the improved procedure parameter for. To achieve Ethiopian highland conditions and the rate of annual soil loss various spatial data were collected and used this objective, Digital Elevation Model (Mdemu et al.), Google earth map, Rainfall data and Digital soil map from FAO were used. The created factors were joined organized and used to compute the potential annual soil loss in the study area. The result of this study shows that the total amount of soil loss was ranges from 0.00 to22965.3 tons/ha/yr. Besides, the average soil loss for this catchment was calculated to be 208.5ton/ha/year from an area of 43,119.45 hectares of land. Accordingly the level of soil erosion rates, the catchment divided into seven priority categories for soil conservation. An areas which are also classified, as severe to extremely sever the erosion classes which covered an area of 500.65 ha, (1.1%) of the total catchment, while high to very high erosion classes reports an area of 1971.2 ha (4.6%) and 1230.9(2.9) respectively, and which founds northeastern, south eastern, south and some central parts of the Jemma catchment. On the other hand, low erosion classes covered an area of 34359.8ha (79.7%), and moderate erosion risk class covered an area of 5057.9 (11.7%) and which founds most of the central and north western parts. To prioritize the catchment was identified based on their average annual soil loss for future intervention and soil and water conservation measures:-

AS the study recommended that the rate of erosion which greater than (>45tons/ha/yr) should be given first priority during the introduction of intensive and well-designed integrated management interventions for soil conservation.

Key words: Catchment, Prioritization, GIS, and Rainfall, Remote sensing

CHAPTER ONE

1. Introduction

1.1. Background

As most of the current researcher confirmed the terminologies of Land use/land cover is two dissimilar words and becoming recently issues, which have been used interchangeably (Dimyati et al., 1996.). On the other hand Land cover refer to the physical features of the earth surface and the collection of captured in the dispersal of vegetation, water, soil and other physical feature of the earth those created only by the people daily works. On the other hand land use means to the mechanism by which land has been used by the people and their habitat, usually by the group of people uses for functional role of land for the economic activity(Rawat, 2015). According to (Leh et al., 2011) land use/ land cover change is a powerful and difficult process that can be exacerbated by a number of people activities. Causes driving land use change include an increase in human population and population response to economic prospects. The overall land use/land cover changes is widespread and speed up the process, mainly caused by natural phenomena and anthropogenic activities, which in turn drive change that would affect the earth ecosystem(Turner and and G., 2004).

Soil erosion is a naturally going on process and it is a usual geological occurrence associated with the Hydrologic cycle. It is a gradual progression which arises due to the effect of water detaches and removes soil Particles causing the soil to deteriorate(Aafaf El Jazouli et al., 2017). On the other side Soil erosion is one of the major threats to the sustainability ideal. It is a natural phenomenon that removes and transports soil through the action of an erosive agent. Possible erosive agents are which facilitate erosion include water, wind, gravity, and anthropogenic perturbations(Vrieling, 2007). Soil erosion by way of water is the most extreme land degradation trouble in the worldwide (Minwer Alkharabsheh et al., 2013) and could have high environmental results and excessive financial expenses with the aid of its effect on agricultural production, infrastructure and water first-class(Lal, 1998). About 2 billion hectares of land are affected by soil erosion due to the participation of the people. Soil erosion mainly takes place because water and wind. In this study it was revealed that 1100 Mha of land territory is influenced by soil disintegration and 550 Mha by wind disintegration in the (Saha AK et al., 2002). On the other hand Soil erosion is one of the most important factors for land degradation throughout the universe(Aafaf El Jazouli, 2018), and the result leads to harmfully significant on the socio-economic and environmental implications at on-site and off-site scales(Zema Da et al., 2012). Soil erosion is the most serious environmental problem in world wide. The major causes that affect the amount of soil erosion include vegetation cover, topography, soil, and climate(Alaaddin Yuksel et al., 2008).

Soil erosion by water is the most very serious land deterioration problem in Ethiopia due to its topography features(Lemlem Tadesse et al., 2017). The result should have serious implications on environmental impacts and high economic costs by its effect on agricultural production, infrastructure and water quality. There are so many interacting forces, which have caused for Soil erosion is and currently becoming threatening and global issue which is complex process, generally caused by human activities and it has multiple and hidden social and environmental impacts, and which are becoming threatening for human existence(Ownegh, 2003). This amount is found to be equivalent to an average soil loss of 130 tons per hectare per year from agricultural lands. The same study show that about 50% of the highlands of Ethiopia have significantly eroded and 25 percent seriously eroded (Gete Z, 2000).

To predict soil erosion usually includes uses of empirical models such as the Universal Soil Loss Equation (Wischmeier and and Smith, 1978), currently becoming a well-known and used this soil erosion model all over the universal. In this connection the United States Agricultural Research Service edited (USDA-ARS) in 1980 the Universal Soil Loss Equation to the Revised Universal Soil Loss Equation (RUSLE), which was the altered version of USLE with the modern new methodologies and correct the limitations of the USLE model. As the current literature revealed the changed model which means (RUSLE) have the same formula as USLE but have several improvements and becoming the main tools in the determining factors and have so many application to different situations, including forest lands, range lands and disturbed areas compared to USLE (Trojacek and R, 2004). For estimating soil erosions on the catchment scale important for the following purposes. Such alike:- site evaluation and planning purposes, and also effective in the judgment process of selecting erosion control measures. While the above result offers estimation of severity of loss and also provide arithmetic results which validate the benefits of planned erosion control measures catchment(Silleos, 1990). While their crops include,(Barely, pepper, onion, potato, maize, teff, and wheat. In this area Cultivation continuously with, unplanned land use, overgrazing, destroying forests and using crop residues for animal feeds are the fundamental factors for soil erosion and becoming the world issues which cause soil fertility decline from year to year. Soil erosion through water currently becoming the world issues which occurs when the impact of water detaches and removes the top soil Particles. As a result, it is causing the soil to deteriorate. In fact, the result of increasing soil erosion currently becoming the world issues, and could affect agricultural productivity, fertility of the soil as well as in increasing poverty and famine on the livelihoods. While understanding the degree of soil erosion risk area and its destructive effect are pre-requisites for catchment management programs and conservation practice. In this connection Understanding of the the problem is better to leads for appropriate management preparation is significant to maintain soil fertility, decrease soil erosion and to recover eroded areas(Bobe Bedadi, 2004).

1.2 Statement of the Problem

Since Ethiopia is agrarian country, agriculture is the major income source and bases for the economy for livelihood of the people. In this connection the economy is depending on the farming, so soil resources recently becoming as threatening and has a great role in the countrywide productivity. Agricultural land in Ethiopia most frequently affected by degradation of soil fertility this lead to decrease agricultural productivity (MoA and RDE, 2005). Currently as most of the literature agree when the beginning of plough the majority of the land cover of the country was believed to have been shrub and forest(Krauer, 1988). Meanwhile Cultivation continuously with, further farm expansion, grazing land, extraction of fuel, unplanned land use, such as establishing industrial facilities, uncontrolled urban development and destroying forests are fundamental factors of soil erosion. This problem is of course totally parallel to the population growth, due to more land is used for agricultural purposes for their daily activity (Ustun Berk a, 2008). The current literature revealed, soil erosion hazards in the highlands of Ethiopia becoming the threatening issue and which assessed by other researchers using RUSLE model rather than other models that used for soil assessment. Applying this model many different soil loss assessments have been assessed in Ethiopia. Therefore this Studies suggests that "Currently soil erosion becoming the core issue in the high land of Ethiopia and once estimated to be about 20 ton per hectare, i.e., about 1 mm of soil depth per year. However to the best of my knowledge, no one of them studied and mapped the impact of land use change on soil erosion risk in Jemma catchment as its severity of the problem. Because most of the above problems are quite frequent available in this study area. Soil erosion is the main cause of degradation of the soil capital, environment and will continues to exist these problems particularly threaten for Jemma catchment in general have adverse impact on the farmers' life and agricultural production. This problem may make the people in the catchment to be question its impact on food security.

Jemma catchment is one of the tributary for Abbay River and source of water for the people who live in around like, abromenor, tirumeda, bahura, aguga and the like. The amount of annual rainfalls in this area is 1486.33mm, which is relatively high and an intensive cause severe soil erosion risk problem. The rugged the topography, high population pressure, high and intensive rainfall combined with the poor and traditional agricultural practices caused severe soil erosion (Lemlem Tadesse et al., 2017) and seriously impacts and high economic costs by its result on agricultural production, infrastructure and creates strong environmental water quality. As result the sustainability and agricultural productivity question its impact on food security. Soil erosion becoming the current issues in Jemma catchment, therefore objective of the recent study to assess extent and mapping soil erosion risk area using GIS and RS technique which could be simply detect areas that are potentially risk and extensive soil erosion in catchments. To achieve this study spatial variations, with sound information in the soil erosion is crucial when planning conservation efforts(Tamene et al., 2006). Due to these problems, this study was conducted to estimate actual soil loss and to analyze the impacts of Land use Land cover change on soil erosion potential with in the water catchment.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of this study is to evaluate and map the impact of land use and land cover changes on soil erosion risk by RUSLE model using GIS and Remote sensing data.

1.3.2. Specific Objective

- To analyze and quantify the time series (2000, 2015 and 2020) land-use and land-cover changes.
- To estimate soil loss of the study area using RUSLE models.
- To organize and prepare Erosion risk maps of the catchments.

- To analyze the impacts of Land use Land cover change on soil erosion potential with in the catchment.

1.4. Research Questions

How to analyze and quantify the time series of land-use and land-cover changes?

How to estimate the soil loss of the Jemma catchment using RUSLE models?

How to organize and prepare Erosion risk maps of the catchments?

How to analyze the impacts of Land use Land cover change on soil erosion potential with in the catchment?

1.5. Significance of the Study

It is known that determination of soil loss using appropriate models and then identification different river catchments on specific area are important for soil erosion planning. In addition, the final output of the study used for academicians, researchers and practitioners either for academic purpose or decision-making. The responsible offices are Amhara Environmental Protection Authority and Mecha Wereda Environmental Protection Office, for researchers, it would be as a source of information or used as a reference for further study in similar topic.

1.6. Scope and Delimitation of the Study

This study would be focused on mainly on the issues related with the topic, degree and changing aspects of soil erosion with in the catchments. In addition, the study only gives attentions on quantifying the amount of soil loss caused by land use and land cover change from Jemma catchment. Therefore, the scope of this research would be limited to prioritize the catchments depending on soil loss based on RUSLE Models. This study determined soil loss induced by rainfall events and focused on Jemma catchment, Upper part of Blue Nile Basin, Ethiopia.

1.7. Organization of the Thesis

Hence the researcher organize the thesis in to six separate chapters and the first Chapter discusses with the background, statement of the problem, objectives, scope, significance and organization of the thesis. The second chapter contains different literatures of reviews. The study area description, methodological, way of analysis, material used and data issues were presented in chapter three. The four chapter is totally focused on the study Results. While chapter five deals about discussion. Conclusion and Recommendations were also presented in chapter six.

CHAPTER TWO

2. Literature Review

2.1 Definitions of Land Use and Land Cover Change

The terminology of land use /land cover is two separate words which are often used interchangeably but they refer to two different meanings (Dimyati et al., 1996.). Land cover denote the physical cover of the surface of the earth's, which consist of the distribution of natural features like, vegetation, water, soil and other physical feature of the earth, including those created solely by human activities e. g settlement, cultural heritage, canal, dam. On the other hand land use refer to the purpose in which land has been used by the people and their habitat, usually with the way in which the people in the particular area involves on the functional role of land for economic activity. As the preceding learn about suggests land use/ land cover is pattern of a region in which moreover the final result of natural and socio economic characteristic and their utilization via the every day human being intervention in time and space(Biddoccu a et al., 2020). Generally land use/land cover exchange is an effective and it is no longer handy process that can be exacerbated through one-of-a-kind every day human being intervention. The social induced change related with socio economic event such as agriculture, mining, forestry, forest extraction, wares, settlement and policies. On the other hand the current studies shown that weather and climatic fluctuations, ecosystem geological dynamics, and others are considered as the natural driver (Riebsame.l.W. et al., 1994). "huge amount of land use/land cover change can have an impact on various forms of land resource degradation"(Berhan et al., 2014). In general the speedy process of land use/land cover change is mainly occurred by natural phenomena and anthropogenic activities, which affect the earth ecosystem(Turner and and G., 2004). Hence clearly understanding of the land scape patterns, change and interactions between human activities and natural phenomena are vital issue for proper land management and decision support. Recently the earth artificial satellites data are very essential for land use/ land cover change detection studies(Yuan et al., 2005b). Therefore the application of remote sensed data can have potential to the study changes in land use/ land cover in less time, at low cost and with better accuracy by integrating GIS and ERDAS software that offer platform for analysis, update and retrieval the appropriate input data (Chilar, 2000).

2.1.1 Causes of Land Use and Land Cover Changes

Generally land use land cover change is affected by the multiple factors that is directly or indirectly related to human population and economic growth, technology innovation and environmental changes(Fu et al., 2021). At the same time (Lambin, 2001)agree that factor that affects land use/land cover change include an increase in number of population and the population response to the economic opportunities. Because day to day human activities can affect the land cover of an area and changes in land cover also can directly affect land use of an area. On the landscape can have a strong impact upon variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere both in terms of their quantity and their quality(Riebsame.l.W. et al., 1994). On the other way large scale of economic production, unplanned land use, uncontrolled urban development Agricultural intensification, rapid urbanization, range land modification, globalization and also destroying forests are the major causes of land use land cover change of the World(Lambin, 2001). According to (Ramankutty and and Foley, 1999) their conclusion indicate that almost 6million km of forests/woodlands and 4.7 million km savannas/grasslands/steppes were deforested and converted to crop land throughout the world.

Ethiopia has shown that there were significant LULC changes in the country for the period of the second half of the 20th century(Belay, 2002). Most of these studies indicated that destroyed forests and intrusive of cultivation into marginal areas were the major causes of land degradation, particularly in the highland part of the country. In Ethiopia the major LULC changes happened in dense populated areas, mainly in the highlands part of Ethiopia (Amsalu A et al., 2006). The changes were mainly caused by conversion of forest and grasslands into agricultural and animal grazing area. With the increasing population, large forest areas were deforested and converted into agricultural land in response to the ever increasing demand for food, grazing land and wood(Hasen M and T, 2009). At times such changes have beneficial while at other times they have been damage and negative impacts on the environment, country economy and people’s livelihoods(Briassoulis, 2000).

2.1.2. Impacts of Land use Land Cover Changes

The impact on land use and land cover changes, especially in relations of changes from plantation cover to residential, commercial, agricultural land and other land cover, has been one of the most important issues on land use change research.

Because this may consequence in environmental, social and economic influence of greater damage than benefit to the area when there is unsuitable conversion of one land use to new land use types(Kidane and ,2015). While land use changes were driven by a number of economical, socio-political and biophysical factors. Over the last two decades, the development of land use became radical in the urban and rural areas. As a result, most of the terrestrial areas have been converted to non-agricultural activities particularly for industry, housing and commercial activities(Leh et al., 2011). Land use and land cover are rapidly changing, Due to human day to day activities and nature resulting in various kinds of impacts on the global ecosystem. In general (FAO, 1984) report shows that land use influences have the potential to significantly affect the sustainability of the agricultural and forest systems.

As the recent studies indicates that in Ethiopia the change of land use and land cover class may not basically result in land soil erosion and degradation. Nevertheless, if the change of land use land cover class is quickly expanding into farm land, grazing land and barren land, fertile soil is more easily influenced to great erosion and deterioration, mainly the land surface without dense forest. This shows that how land use and land cover class change over a period time, which makes it aggravated erosion and deterioration associated with the consequence. The shift of other land use land cover class into farm land towards steep slope and barren land is the main causes for accelerate erosion, massive degradation, siltation, water borne disease, and flood. Likewise, quick expansion of agricultural land into steeper slope has hurries for erosion and degradation in the high land of Ethiopia (Tegene, 2002). Land use and land cover change have resulted in soil deterioration the removal of topsoil, leading to loss of soil fertility, and the depletion of biodiversity, which in turn leads to irreversible degradation, of natural resources in most part of Ethiopia. Generally modifications of land use and land cover type have been limitless have an effect on natural resources and biodiversity of the earth ecosystem. Hence land use/land cover change have been detrimental and adverse impacts on the natural environment as general and particularly people’s livelihoods(Daniel, 2008). From this fact the data on the land use/ land cover change have the best importance for planners in monitoring the consequences of land use and land cover .The distribution of population can occur through change from one land use to another, for example, changing agriculture lands into residential, industrial, commercial or other land uses.

2.1.3. Interaction of Land Use and Land Cover Change and Erosion

In order to understand how LULC affects and interacts with universe, information is required on what changes occur, where and when they occur, the degree at which they occur, and the social and physical forces that drive those changes. The impact of people on global land cover change, especially in terms of change from forest cover to agriculture land cover and Vis versa, has been one of the important issues in the world wide change research(Abdrhman, 2011). While recently the world populations' increase rapidly. As a result race to urbanization at an accelerated and still increasing speed. The urbanization process, people plays a crucial role in the large-scale modification of global environment. Due to this reason, rapid urbanization or sprawls have rigorously altered the value of the environment. The rapid urbanization is that is implies quite a significant increase in space occupied urban area and cities. The rapid growth of the cities leads to expansion in to rural and often agricultural land. While the increasing of the population rapidly increasing demand to the food with large scale of economic production. Cultivated farm land continuously, unplanned land use, such as :- establishing industrial facilities or constructing summer houses on the agriculture land, uncontrolled urban development and destroying forests are fundamental factors of soil erosion (Ustun Berk a, 2008). At the same time changes in LU/LC pattern due to agricultural intensive practice and deforestation, in relationship with the population growth, the main causes for erosion and fertile land degradation processes. Soil erosion by water is one of the focal processes causing land degradation in the world(Blanco et al., 2017) and consequently, led to soil productivity reduction, flooding, and habitat losses. As a result extended to affects global food security(Kidane and ,2015). Also LU/LC change and erosion have direct relation. Because Soil erosion is directly affected by land use changes. Therefore, modeling of land use/land cover change is important with respect to show the prediction of soil erosion and to alleviate the problem (Leh et al., 2011).

2.2. Soil Erosion

A countries economic growth usually depends on industrialization and agriculture sector of the economy. Both Agricultural and Industrialization depends on directly or indirectly on the soil conservation whereas crop production has a direct relationship with soil loss. Around 2 billion hectares of land have been affected by soil erosion due to the humans' activities. The common factor of Soil erosion mainly water and wind. In the investigation it was discovered that 1100 Mha of land territory is influenced by water soil disintegration and 550 Mha by wind disintegration(Saha AK et al., 2002).

Soil erosion is a naturally existing phenomenon and it is a usual geological happening process associated with the Hydrologic cycle. It is also changing over a period of time which occurs when the effect of water detaches and removes soil particles causing the quality of soil destroyed. The erosion of Soil currently becoming threatening issues in the catchment areas and happening deposition in rivers, lakes, and reservoirs are of great concern for two reasons. The first one, fertile soil is eroded in the catchment areas. The Second one, there is a decrease the performance of reservoir capacity due to deposition and degradation of downstream water quality. Soil loss is the result of soil erosion. This, is become, declines the soil fertility and decreases crop yield(Aafaf El Jazouli et al., 2017). While Soil erosion is the major problems almost all over the worlds and causes for land degradation, to the conservation of the soil and water resources. Even if the major cause of soil erosion is considered by geomorphological and anthropological processes which is mainly caused by day-to-day human activities. Soil erosion has accelerated on most of the world, especially in developing countries, due to different socio-economic, demographic factors and limited resources(Minwer Alkharabsheh et al., 2013). For example, (Biard and Baret, 1997) study show that increasing population, Deterioration, unplanned land cultivation, uncontrolled grazing and higher demand for fire often cause soil erosion. Due to this reasons some scholars questioning its impact on world food security(Aafaf El Jazouli et al., 2017), soil erosion creates strong environmental threat, among other and create high financial cost by its consequence on agricultural production, infrastructure and water quality(Lal, 1998). More importantly, erosion results in release of soil organic carbon to the air in the form of CO_2 and CH_4 causing for global warming(Lal, 2001). On the other side global warming in turn is expected to increase erosion rates(Nearing MA et al., 1999). Suitable evaluation of erosion issues is seriously dependent on their spatial, economic, environmental, and cultural context (Wang G et al., 2002).

In general there are two major types of soil erosion, namely geologic and accelerated erosions.

Geologic erosion: - is a usual process of weathering that generally happens at minimum rates in all soils as part of the natural soil forming processes. It happens over a long geologic time horizons and is not affected by human activity.

Accelerated erosion:- this type of soil erosion becomes cause to worry when the rate of erosion go beyond a certain threshold level and becomes rapid, known as accelerated erosion. This type of erosion is created by anthropogenic causes such as deforestation, slash and burn agriculture land, intensive plowing, intensive and uncontrolled grazing, unplanned land use and biomass burning(Habtamu Atoma, 2018).

2.2.1. Major Causes of Soil Erosion

Recently one of the major problems on the world is rapidly increasing food consumption. This consumption is of course totally parallel to the population growth. Even though more land is used for agricultural purposes daily. The amount of agricultural land without using particular governor mechanism, unplanned land use, such as establishing industrial facilities or constructing summer houses on the agriculture land, uncontrolled urban development and also destroying forests by human being intervention are the main reason of soil erosion(Biard and Baret, 1997). However soil erosion can be caused by geomorphological processes and anthropological, which are fundamentally triggered by human intervention, is the major factor for the loss of soil and water resources. Soil erosion has been accelerated on most of the world, especially in developing countries, due to dissimilar socio-economic, demographic reasons and inadequate resources(Ananda. and G, 2003). Land use/land cover change has been shown harmful effect on stream water quality and quantity as well as stream ecosystems(Zampella Ra et al., 2007). At the same time changing of land use and land management has also been shown to affect the weather condition and patterns as well as may increase soil erosion(Stohlgren TJ et al., 1998). While, a lot of researches have shown that increase in agricultural land use has direct consequences on sedimentation, nutrients and pesticides in the streams(Boglárka Keller et al., 2021). The revealing land use change is therefore a serious criterion for the valuation of potential environmental impacts and developing effective land management and planning strategies. Soil erosion is directly affected by land use change. Consequently, prepare modeling of land use change is mandatory with respect to the prediction of soil erosion and deterioration(Leh et al., 2011). At the same time (Bikram Prasad and Tiwari, 2019) study show that the main reason that responsible for the soil erosion is the intensity of rainfall, types of soil in that area, slope of land, diverse types of crop growing in that area and variety types tools and machinery used for cultivation. Soil erosion is one of the main global issues because it affects the agricultural land by eliminating the top fertility of land. On the other hand it also pollutes the drinking water and irrigation by the siltation in the reservoirs.

These facts designate that the condition in other countries is so worst. If this is a fact, it will be worth to question the reason may well be that our policies; strategies and the approach to soil conservation practice have been faulty. Currently in Ethiopia Soil erosion is one of the primary elements for extreme land degradation problem, due to unsuitable land use exercise ensuing in great land degradation processes. As a result it is becoming threatening issue for the cultivated land productivity and very survival of the overwhelming of the majority of the agrarian population. The literature indicates the degree of soil loss and nutrients as a consequence is very high and much faster than any other that can be replaced of the eroded(Aschalew, 2010). “The Highland of Ethiopian Reclamation Study (FAO, 1986) estimated that water erosion moves nearly 1.9 billion tons of fertile soil from highlands annually.”

2.2.2. Assessing Soil Erosion problem in Ethiopia

Currently Soil erosion is becoming the major threatening in the East African highlands due to nature of landscape, where that is the reason widespread land degradation, deforestation and negatively affects the environment(Gachene, 1995). Since Ethiopia has different topographic feature. As result Soil erosion is the severe problem in Ethiopia because of the topographic as well as steep slope features. Soil erosion affects land qualities and water resources. Consequently creates strong environmental influences and high financial costs by its effect on agronomic production(Lemlem Tadesse et al., 2017). Although the main reason for soil erosion in Ethiopia is rapid on the increase of population, the destruction of forests by people daily activities, lack of properly land use management, low vegetative cover as well as unbalanced crop and livestock production(Girma, 2001) . In this situation, the Ethiopian highlands are highly influenced by land degradation, which have eroded the natural resource bases of the area(Tilahun A et al., 2001). LU/LC changes and land degradation are related each other (Messay, 2011) because LU/LC changes are associated with deforestation, biodiversity loss and land degradation as well as unplanned land use(Maitima J et al., 2009). As (Abate, 2011) show that LU/LC is taken creates strong environmental influences, on global warming in turn is expected to increase erosion rates and high financial costs by its effect on agronomic production, infrastructure and water quality. Similarly,(Tilahun A et al., 2001); stated that LU/LC changes towards cultivated land aggravates soil erosion problems unless proper management are undertaken. On the same way (Hurni, 1985a) study make seen that degradation loss of soil becoming the threatening in our country and when we come to the resulting from soil erosion was assessed about 20 ton per hectare that is about 1 mm of soil depth yearly. As the previous literature shown, the deterioration of land by soil erosion is becoming threatening issues and increasing an alarming rate, that is why Ethiopia loses about 1.9 billion metric tons soil resources each year (Hurni, 1989). At the same time (FAO, 1986) reported indicate that in Ethiopian soil erosion becomes threatening issues and highlands reclamation finding forecasted to cost the country losses about 1.9 billion US dollar between 1985 and 2010. From this the effects of soil erosion becoming the threatening and can be the worst in in the developing country like Ethiopia, because the farmers are extremely reliant on intrinsic soil resources, but they are not improving the soil fertility through application of additional inputs like natural fertilizer (Lulseged and 2008). Agronomic sector in Ethiopia is under small holder agricultural mechanism which responsible for more than 90% of agricultural goods, about 95% of cultivated land and support employment for some 7 million farmers (Tesfaye and Asefa, 2003). Ethiopia has the great interest to increase agricultural production, but they couldn't find the way of deal with source of food insecurity due to several factors which are deteriorating, vulnerability out of which land degradation mainly due to soil erosion, deforestation, unpredictable and insufficient rainfall are the main reasons(Drimie et al., 2006). In Ethiopian highlands part of the country only the annual rate of soil loss reaches up to 200-300 tons ha-1yr-1, while the soil loss can reach to 23400 million metric tons every year (Hurni, 1993).

In general, the Ethiopian highlands can accommodate large amount of people in the country with elevation more than 1500 m above mean sea level. In addition to human, livestock population is extremely affected by very serious land degradation. The soil erosion processes, which bring about a permanent damage is posing an immense effect on agronomic production in Ethiopia. For instance, loss of top productive soil, which cannot be returned with in short period of time, is an indicator of the problem. Moreover, it shows the main cause of land degradation is poverty. Poverty by itself is the result of low productivity, low investment, and lack of farmer's knowledge among others. These restrictions are worse the population growth which depends on agricultural production. When the number of population increase requires more lands for cultivation, fuel wood, and construction materials among others. These in turn encourage deforestation, and over cultivation(Aschalew, 2010) .

2.3 Soil Erosion Models

Soil erosion modeling is the method of describe mathematically the fertile soil detachment, transport and deposition on land surfaces as well as on the dam. Soil erosion models to be able to pretend erosion procedures in the watershed and may be able to take into account many of the complex interactions which affect rates of erosion. Erosion model is the main predictive mechanism for evaluating soil loss, make conservation planning, soil erosion inventories and project planning. Additionally, they can be used as tools to know the erosion processes and its influences(Nearing et al., 1994). In general the invention of soil erosion modeling approaches is not new concepts. Nevertheless, these technologies invented after mainframe computers became readily accessible and the attention of soil erosion was stimulated by concern for surface water quality in the 1970s. Here there are, many types of erosion assessment methods have been developed: each of them are the best at performing a particular task. Hence, no single prediction mechanism meets all needs(Foster, 1988).

The objective of soil erosion models is either predictability or explanatory(Petter, 1992). Due to this reason available model can be grouped in a number of ways. As the previous studied indicates there are number of soil erosion models can be found in literature and can be categorized according to principles used in the development of model. Soil Erosion models broadly can be categorized into three categories that can be used to assess soil erosion, based on the development principle. The name of these soil erosion models which include empirical or statistical, conceptual and physically based or analytical component models (Morgan, 1995).

2.3.1. Revised Universal Soil Loss Equation (RUSLE) Model

Universal Soil Loss Equation (USLE) the maximum generally used and, which is an empirical or statistical model evaluating long time averages of sheet and rill erosion based totally on plot statistics collected, which is adopted in eastern USA. To offer the better predictions there are several similar but adapted models were built, like MUSLE, RUSLE, WEPP, USLE-M, LAPSUS

LISEM, SWAT, MMF, WEP, SLEMSA, HSPF, AGNPS, ACRU etc.; while the new ones require a lot of input parameters. This can be the reason that is why RUSLE (Revised Universal Soil Loss Equation) is still one of the most commonly used models in the recent study. Compared to other models, RUSLE is still the most cited of all soil erosion models. RUSLE model has been accept that need to predict soil losses on a shorte-term, which resulted in many studies with rainfall simulation measurements(Wischmeier and and Smith, 1978).

RUSLE model retains the factors of the USLE by including improved means of computing soil erosion factors. Recently we chose the method RUSLE model is the most used for the quantification of surface erosion and used to provide estimates of soil loss. At the same time the Revised Universal Soil Loss Equation (RUSLE), most common experimental erosion prediction models by integrating with RS and GIS, the Water Erosion Prediction Project (WEPP), and Coordination of Information on the Environment (CORINE), which can be used for erosion risk mapping. The RUSLE was invented to evaluate the yearly soil loss per unit area based on erosion factors including soil erosion; topography, rainfall, and vegetation cover. While RUSLE model calculate the soil erosion equation mathematically by describing how climate, soil, topography, and land use/land cover change affect rill and inter rill soil erosion caused by raindrop impact and surface runoff (Renard et al., 2007). It has been deliver that to evaluate soil erosion loss, to decide the soil erosion risk, and to show ways development and conservation plans in order to control erosion under different land cover conditions, such as croplands, rangelands, and disturbed the forest area(Angima et al., 2003) .

Even if Revised Universal Soil Loss Equation (RUSLE) has own advantage, this model does not estimate sediment deposition and gully erosion. RUSLE model computes the average annual erosion as a function of by using six factors. The equation of RUSLE model computes average annual erosion as:

$A = R \times K \times LS \times C \times P$(Renard et al., 1997).

Whereas, the above equation A stands = computed average annual soil loss in tons/ha/year; R stands = rainfall erosivity factor; K stands = soil erodibility factor; L stands = slope length factor; S stands = slope steepness factor; C stands for = cover management factor and P stands for = conservation practice factor of the study area.

2.4. The Use of Remote Sensing and GIS in Soil Erosion Modelling

The sources GIS data which can be referenced spatially can be used in this type of situation such as digital map of soil type, land use/land cover classes, soil erosion, forest species, road networks and many others, depending on the application. It is now being widely used in crop management. Remote sensing and GIS have made extensively large impacts on how those in the agricultural industry are observing and managing crop lands and predicting biomass or yields(Basudeb Bhatta, 2011). Maps are usually derived and prepared from remote sensing and critical component of GIS. Remote sensing science is an important technology to study both spatial and temporal phenomena and monitoring. However the analysis of remote sensing data, one can change various types of information that can joint with other spatial data within GIS. The integration of the two technologies generates a synergy in which GIS technology can improves the capacity to extract information from remotely sensed and remote sensing in turn keeps the GIS up to date with actual environmental information. As a result huge amount of data can now be integrated and analyzed.

Evaluating the soil erosion rate is crucial for the development of enough erosion prevention mechanism for sustainable management of land and water resources. In the last decade, many scientific works using Geographic Information System (Maitima J et al.) and remote Sensing technologies are valuable tools have been carried out to characterize soil erosion in large area (Sheikh et al., 2011) . In fact these methods can providing enjoyable information about eroding areas, like soil types, lithological units, and vegetation cover, with cost effective estimates and good accuracy. As previous studies shown, the integration of GIS and remote sensing, a number of models for predictive assessment on soil erosion by water have been reported in some literature (Wischmeier and and Smith, 1978). In general, the efficiency of this technologies increase when they are integrated with empirical erosion prediction models as well as gives fast and reasonable cost estimates, good accuracy 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(Dangerrnond, 1991). Because the empirical models can compute the amount of soil erosion based on the relationship among different erosion factors, while RS and GIS integrated erosion prediction models do not only estimate soil loss but also deliver the spatial distributions of the annual soil erosion(Okalp, 2005). The first demonstrated of the potential of GIS for erosional soil loss assessment using USLE model and Soil erosion is most frequently assessed by USLE. As the recent literature (Renard et al., 2007) shown that Universal soil Loss Equation (USLE) is considered as the most suitable model and being used worldwide for the estimation of surface erosion. This can be the cause that is why USLE (Universal Soil Loss Equation) is still one of the most commonly cited empirical models in the current study.

2.4.1 Use of Remote Sensing on Erosion

Remote sensing is to the science, technology or art of acquiring information of an object or phenomena without any physical contact with it or acquiring information from the distance. And this can be done though sensing and recording of either reflected or emitted energy or the information being processed, examined and applied to a given problem(Campbell and Wynne, 2011). Remote sensing of land use/land covers by integrating the existing knowledge and scientific understanding and offers an outlook for the future. Specific topics focus on existing and emerging concepts in land-use/land-cover mapping on erosion, an overview of advanced and automated land-cover interpretation methodologies, and an explanation and future projection of the major land-cover types of the worldwide(Chandra.P. and Gri, 2012). Remote sensing technology is create a new epoch in order to planning and development of watershed resource management, when the satellite image offers a very fast and cost effective way to investigate large area catchments(Jain and Goel, 2002). As a result this technology has the advantage to prepare maps for land use/land cover and in order to monitoring and land resources management. At the same time remote sensing literature shows that a great number of efforts have been required for mapping, monitoring, and modeling land use/land cover at the local, regional and global scales(Chandra.P. and Gri, 2012). In the same way remote sensing images are often composed of different spectral levels which are relatively uniform in brightness levels across in several bands. In general these images data are very important for accurate analysis of land use and land cover mapping in a particular area, because land cover information can be read more or less directly from data which is visible on satellite images. Images from the satellites are helpful to the mapping, monitoring and management of land resources. In fact land use land cover, maps are prepared from these remotely sensed and aerial photo data (Luong, 1993).Additionally remote sensing data used for soil erosion assessment in watershad and eroded area to the analysis erosion features and to gaining the erosion model input data form different sources(Petter, 1992).The current literature suggested Remote Sensing can simplify studying reasons improving the methods, Like soil type, slope gradient, drainage, geology and land cover. When the Digital Elevation Model (Mdemu et al.) is one of the most major inputs data that could be by the analysis of stereoscopic optical and microwave remote sensing data (Pande et al., 1992).

2.4.1.1. Digital Image Processing

Raw digital images usually have some geometric distortions due to the variations in altitude, Earth curvature, atmospheric refraction, relief displacement, and nonlinearities in the sweep of a sensor(Lillesand et al., 2004). These errors should be amended to ensure the accuracy of the final results. Generally, there are two types of data correction: radiometric and geometric. Radiometric correction can addresses the level of gradual change in the pixel intensities (DNs) that are not caused by the object or scene being scanned. These gradual changes includes: differing sensitivities or malfunctioning of the detectors, topographic effects and atmospheric effects. Geometric correction addresses errors in the relative positions of pixels. These errors are induced by: sensor viewing geometry and terrain variations(Tesfaye, 2015).

2.4.1.2. Image Classification

GIS and remote sensing image classification belongs to a very active field in computing research, that of pattern recognition. The image pixels can be categorized either by multivariable statistical properties, such as the case of multi-spectral classification (clustering), or by segmentation based on both statistics and spatial associations with the neighboring pixels. Surprisingly for a well-mapped area, unsupervised classification might shown some spectral features which were not able to be seen beforehand. The result of an unsupervised classification is an image of statistical clusters, where the thematic contents of the clusters are not known. Ultimately, such a classification image still needs interpretation based on some knowledge of ground truth. While the supervised classification is made on the statistics of training areas define diverse ground objects carefully chosen subjectively by users based on their own knowledge or experience. The classification is controlled by users' knowledge but, on the other hand, is constrained and may even be biased by their subjective view(John and Sons, 2009). There are a number of supervised classification algorithms mechanisms in remote sensing technology namely: maximum likelihood, parallelepiped, minimum distance to mean and spectral angle mapper classification methods and neural net classification. From the above listed technique, maximum likelihood classification is one of the most presently used of image classification in ERDAS image software(Coppin et al., 2004).

2.4.1.3 Use of Geographic Information System on Erosion

Nowadays GIS technology is emerging as a powerful tool to decide the amount of risk and management of Natural Dangers. Due to these techniques, natural hazard mapping can be prepared now to delineate erosion prone areas on the map. As such types of maps make easier to the civil authorities for quick valuation of potential impact of a natural hazard and initiation of appropriate measures for reducing the impact. As such data make it possible the planners and decision-makers to take constructive and in time steps during pre-disaster situation. It will also help them during post disaster activities for the assessment of damages and losses occur due to erosion. Moreover, GIS provides a broad range of tool for determining areas affected by erosion or transportation, site selection models forecasting areas likely to be eroded due to high discharge of the river or wind (Dangerrnond, 1991). The assessment of soil erosion rate is necessary for the development of enough erosion prevention measures for sustainable management of land and water resources. In the last decade, many scientific works using Geographic Information System (Maitima J et al.) technologies are valuable tools have been carried out to characterize soil erosion in large area (Sheikh et al., 2011). Recently to map soil erosion using GIS and remote sensing becoming the key tools to certainly classify areas which, potentially hazard of soil erosion and provide valuable evidence on the assessed value of soil loss at different sites in the catchments(Shi et al., 2003).

CHAPTER THREE

3. Methods and Material Used

3.1. The Study Area Description

Recently rapid soil erosion becoming threatening issues in globally, negatively affect the soil quality, decreasing agricultural efficiency, water intention properly, flooding, and habitat destruction as a whole, Jemma catchment has been selected as the study area for this research. The Jemma catchment is located on western part of Amhara regional state at the distance of 512km from Addis Ababa city in the northwest direction. The study area is geographically bounded by 11°8' 0″N --11°24' 0″N latitudes and 37°0' 0″E--37°18' 0″E longitudes, and with the elevation range between 1885 and 3121 meters above the mean sea level (Fig 3.1). This study area has five kebele administrations and covers 43119.45hectares. Jemma catchment stands/starts from east part of Mecha woreda specifically which is called Worda Mountain pass across Mecha woreda, after going 35.6 km can join with Abbay at a place Bicolor which is called Bicolo Abbay.

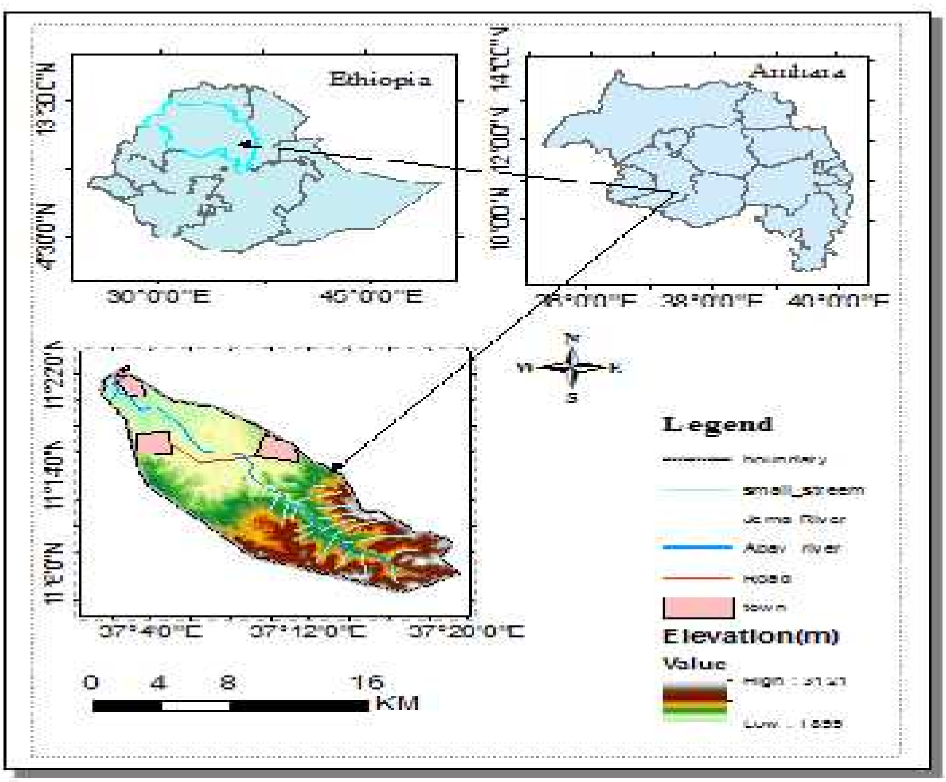

Figure3.1. Location map of the study area

3.1.1. Agro-geology and Physiography of the Study Area

Based on the classifications of Ethiopian climatic zone Jemma catchment is characterized by woynadega (mid and high altitude) and Kolla (low altitude).

When we come to the topographic nature of Jemma catchment, the total area of the catchment is about 43119.45 hectare. The Jemma catchment area is characterized by different topographic features. According to Mecha Woreda Agricultural and Natural Resource Office, the topographic arrangement is 15% valley, 30% Mountainous, 45% Hill slope and 10 gently sloped. The altitude of the study area rises from 1885-3121m above sea level.

High Mountains rise up to 3121 m above the sea label and whereas the lowland part of the River catchment is gently sloping that is 1885m above sea level(Tegegne Molla and Biniam Sisheber, 2016). Due to the nature of the topographical features the area very liable to heavy fast flowing stream formation and extensive soil erosion(Natnael, 2017).

3.1.2. Climate Condition

According to Mecha Woreda Agricultural and Natural Resource Office, the climatic condition of study area is semi temperate to temperate climate with the mean annual rainfall is 1486.33mm and temperature varying from and 17.1°C and 28.4°C. The mean monthly rainfall data was obtained from seven selected rainfall station in the catchment, which organized by National Metrological Agency of Ethiopia. These stations are included Bahir Dar, Mesheni, Merawi, Adet, Dangila, Sekela and Durbetie. This study area is characterized by four main seasons. “These are summer, spring, autumn and winter. The area experiences the main rainy season ‘meher’ which commences in June and extends to September(Natnael, 2017)”. When the increasing rainfall with related to increments of altitude is differ in the high altitude area by the influence of the high mountain, which might be causes either rain shadow or area of heavy orographic rainfall. The River catchment consists five kebeles (smaller administrative unite) in the catchment area. The total living population of the catchment excluding the local capital Merawi Town was assessed to be around 27, 435, (15,256 male and 12,179 female). From here almost all of the populations are an agrarian.

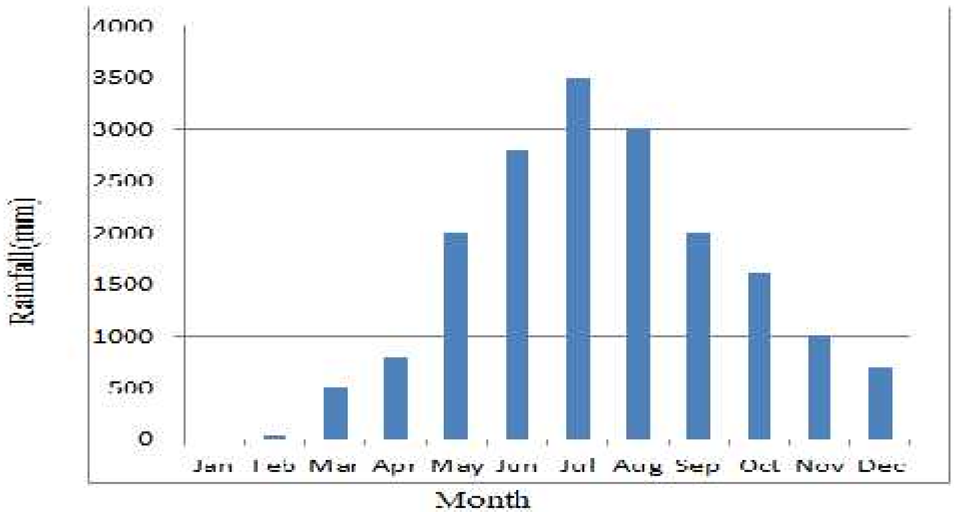

Figure3.2 Mean monthly rainfall of the study area.

3.1.3. Soils Type and Land-use/Land-Cover of the Study Area

The soil data for the recent study would be obtained from digital soil map of Abbay Basin (2012). Since it is the polygon feature the soil map of the study area would be obtained by clipping tool from the Abbay Basin soil map in the study catchment with in the GIS technique. Finally the k factor would be determined. According to Mecha Woreda agricultural and natural resource office the most dominant soil types are in a catchment associated with the tabular database were identifies. These are Eutric Cambisols, Haplic luvisol, and Eutric vertisols that covers the total land mass of the study area. Since nutrients are concentrated in top soil and they have high levels of organic matter. Due to this reason, it affected by repeated cultivation/ due to unplanned land use and deforestation. From the other soil types Haplic luvisoils is one of the top and greatest fertile soils in the tropics. This soil type causes for acidity and when the organic carbon reduces, they become very susceptible for erosion. Haplic luvsoils have moderate flexibility and moderate up to low susceptibly. Finally, the other three most dominant soil types, which found in Jemma catchment, are susceptible to water and rail erosions.

The dominant land covers in the study area are Shrub land, forest land, cultivated land, Built up area, River, and bar land. People who live in this area are economy is dependent on Agricultural product. The main products are Maize, Teff, Millet, Barley, Wheat, Onion, Potato, and 'Dagussa'. On the other hand form bushes a small number of scattered trees such a like Acacia albida, Cordia African and Juniperus procera are founds around cultivated lands whereas, Eucalyptus camendulensis are grown-up around the homestead. To produce more output from cultivated lands; the agrarians who live in the study area were using man made in organic fertilizer; like Dap, Urea etc. and they usually use crop residues for livestock feed.

3.1.4. Socio Economic Condition

Most of the people, who live in around the catchment area be dependent on Agriculture involving mixed farming of crops and livestock farms is the basis of the economy population inhabiting the Woreda. About 92% of the Woreda's economy is dependent on Agriculture. The main products are Maize, Wheat, Barley Teff, Millet and 'Dagussa'. These communities are rainfall dependent. While there is no adequate land available for open grazing due to the population density and topographic nature, the public uses stalk feeding. The availability of land holding in these communities is on average 1.2 hectares, which are the economy base of the societies. In contrast the communities those who didn't have a agricultural land are joining in daily labor works at nearby Merawi Town and Bahirdar City.

Deforestation is one of the main problems in the study area as practical during the site assessment and observation. Farmers within the study areas cut down tree to obtain wood for fuel, home construction, prepare fence and free domestic animal grazing. As a result deforestation has serious environmental consequences, including increasing surface run-off with severe erosion.

Figure 3.3. Shows part of view for land-use/land-covers of the catchment.

3.2. Methodology

3.2.1. Software and Material Used

To achieve the objectives of designed study I was used the following software's and materials

Table3.1. Materials Used (Hardware and Software)

No.	Item	Specifications	Purpose
Soft wares			
1	ArcGIS Software	Version 10.5	For the purpose of creation Database, preparation a dataset, for raster calculator, displaying and viewing Spatial and none spatial data as and map lay out preparation.
2	ERDAS Imagine Software	Version 2015	used for pre-processing to Images, for the classification purpose as well as Post Classification and finally Change Detection
	Google earth Software	Google earth pro	To identify the study area and soil erosion affected area.
4	MS word	2010	For editing purpose
5	MS excel	2010	To store attribute information collected
Materials			
No	Item	specification	purpose
1	Personal computer	Toshiba	Used to run d/t soft wares
2	printer		To print the final output of the study
3	Color printer		To print clear images, maps
4	papers	A4	

3.2.2. Data Types and Sources

Reliable data is necessary to realize the designed objectives. The study was based on both primary and secondary data. Therefor to achieve the objectives of designed study I would use the following data and sources.

3.2 .2.1. Landsat Image

For the recent years, three periods of freely available Landsat images would be use. A time series Landsat is produced from satellites with different type of sensors that is (TM, ETM+ and OLI, that is 2000, 2015 and 2020 respectively) of the satellite data, 30 m spatial resolution with path and row 170/52. In order to identify path and raw of the project area, overlaying this shape file over the existing path and raw data file may require. Prior to the overlay, define project and re-projection was perform since the shape file is unknown coordinate system and simultaneously its coordinate system do not much with the shape file that have path and raw information.

The digital image satellite data that is TM, ETM+ and OLI files would be download in zipped files from the United States Geological Survey that is(USGS) the archive website: (http://earthexplorer.usgs.gov). Remote sensing data is secondary data, for further detail of Landsat image in the (Table 4.2.)

3.2.2.2. Ancillary Data Source

This Secondary data sources might be collected from different source and reports as well as government organizations in the study area. The Soil maps gotten from the soil database which bring together by Food and Agricultural Organization (FAO) were collected from Ministry of Agriculture (MoA and RDE). While the department of GIS used in the analysis and interpretation of the results. The rainfall data that is from 2005 to 2020 were got from National Meteorological Agency which found near to the catchment area (NMA) and used for the analysis and interpretation of the results. The data would be used to improve precision of the classification and to support the interpretation of land cover change.

3.2.2.3. Field Work

First reconnaissance survey require to understand the location of the study area, such as a land cover type, may be known through field observations that acquire knowledge about the observation, analysis of aerial photography, personal experience, etc. Because of Field data are the most accurate data available about catchments. The collections of filled data would be bearing randomly in order to identify the classified the image data and prove necessary land-use/land-cover data for accuracy assessment purpose. However, all field data may not be completely accurate because of different errors. As a result Global Positioning System receivers would be useful instrument to conduct ground truth studies and collect training sets. In this recent study would be used hand held GPS to collect feature class types and important coordinates which were training samples. Training samples are sets of pixels that represent what is recognized as a discernible pattern.

Table 3.2: Show that the remotly sensing data with the source.

No	Data type	Description	source
1	Land sate image that is (TM,Jan,30,2000, ETM+, Jan 25, 2015 and OLI, Jan 28, 2020)	30m spatial resolution 8 bit spectral resolution Path and row 170/52	USGS
2	DEM	Derived from a 30 m resolution and obtained.	USGS
3	Digital Soil map	digital soil map of Abbay Basin (2012)	Brings from Agricultural Minister (MoAE)
4	Rainfall data	The 15 years that is since2005-2019 RF data for 7 stations near to the Jemma catchments	Brings from the National Metrological Agency Agency
5	Ground control points (GCP) which means coordinates	Random coordinates from each use type using hand held GPS model GARMIN etrex 12 channels	From field work

3.3. Way of Analysis

3.3.1. Digital Image Data analysis

To achieve the objectives of the study, the following way of analysis would be performed.

3.3.2. Image Preparation

The Landsat imageries of the catchment have been imported to ERDAS imagery version 2015 image processing software Environment. Image pre-processing, enhancement, classification would be applied on the raw image.

Because the satellite images may distorts due to noise, haze problems and need image correction hence, before proceeding to extracting of information, image processing activities would be taken place because it is necessarily. The purpose of pre-processing was to enhancement of the remote sensing data, which prevent undesired distortions or enhances some image features important for additional processing and analysis the task(Coppin et al., 2004). In this case the preprocessed data would be undertaken in ERDAS Software version 2015 for the purpose of Geo-referencing and Sub-setting of the image as well as for the area of interest (AOI).

By Using ERDAS Software image preprocessing techniques would be conducted. This techniques are:- image extraction, rectification, restoration, atmospheric refraction and sun angle correction, radiometric correction and classification would be used for analysis of satellite imageries. The classified images would have been used in the extraction of information on land use /land cover map and then quantification of support practice (P) factor value in GIS environment(Natnael, 2017).

3.3.3. Image Classification

Classification of image data is the technique of arranging pixels into restricted number of separable classes based on their DN (pixel) values. The main aim of remotely sensed data classification was to select equivalent levels with respect to groups with homogeneous characteristics with the purpose of discriminating multiple objects from each other within the image data. Supervised classification was spend time on the Landsat images of 2020 with the help of field reconnaissance. It gives the general overview of the study area. Based on the outcomes of supervised classification dominant LULC classes would be selected. A supervised classification algorithm needs a training sample (AOI) for each class, that is, a group of data points known to have come from the class of interest(John and Sons, 2009).

Thus the classification would be based on how nearby a point to be classified is to each training sample. There are many types of supervised classification algorithms i.e.: maximum likelihood, parallelepiped, minimum distance to mean and spectral angle mapper classification methods and neural net classification. Google earth would be the main secondary means for supervised classification. In this study the researcher uses supervised classification would be grounded on the maximum likelihood algorism method for the removal of land use/ land cover change of the catchments area in the ERDAS imagine software. While this technique automatically classify all pixels in the image of a terrain into the land covers classes. This idea shows under the broad subject, namely, Pattern Recognition(Coppin et al., 2004). Using the technique of spectral pattern recognition signifies to the family classification method and uses pixel-by-pixel spectral data as the main basis for computerized land use/land cover classification.

3.3.4. Models and Their Analysis

3.3.4.1. Model Description

As the current literature suggested Universal Soil Loss Equation (USLE), most frequently used model to estimate soil erosion threatening which is global issue today, is an empirical model used to evaluating long term averages of sheet and rill erosion based on data collected in eastern USA(Wischmeier and and Smith, 1978). Therefor the physical measurement of soil erosion is describe mathematically by RUSLE model approved the same empirical ideas and the important structures as the USLE model, considerable modifications of the USLE were carried out which cover all aspects of the model to support with computations and wider applications especially in developing countries.

While to achieve the objectives of the study, the following six parameters will be use to estimate soil loss. The equation of RUSLE model computes average annual erosion as:

$A = R \times K \times LS \times C \times P$ (Renard et al., 1997).

Whereas, each stands A = computed average annual soil loss in tons/ha/year, R = rainfall erosivity factor, K = soil erodibility factor, L = slope length factor, S = slope steepness factor, C = cover management factor and P = conservation practice factor respectively. From here the researcher detects the spatial patters of the can achieve soil erosion threatening in the Jemma catchment, and all of directly above six soil erosion factors would be surveyed and calculated depending on the finding of(Hurni, 1985a), according to the Ethiopian context. The Individual GIS files for the RUSLE would be significant to built combined on a cell by cell grid modelling technique and the individual factor grid had a cell size of 30 m resolution in ArcGIS 10.5 to forecast soil loss in a spatial domain. All layers data would be projected and converted with Adindan UTM Zone 37N using the WGS 1984 datum.

The equation of RUSLE model computes average annual erosion as:

A = R × K × LS × C × P (Renard *et al.*, 1997).

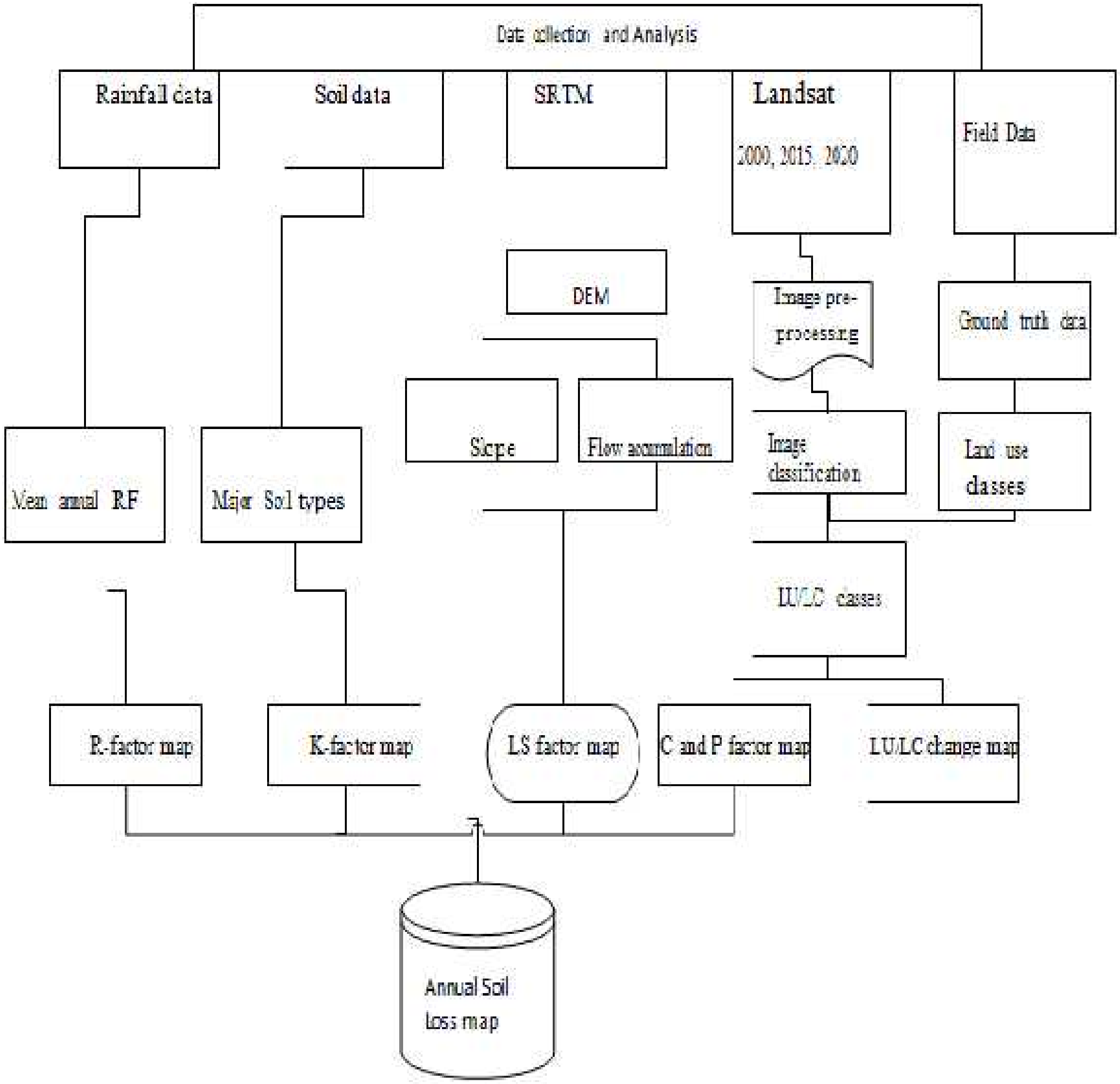

Figure 3.4 Methodology of flow diagram

3.3.4.2. Rainfall Erosivity(R) Factor

Which the ability to concern rain to causes the top soil depletion and provide result of the overall energy of rain storm. This shows that soil loss potential of a given rainstorm event. As a result the yearly erosivity result could be evaluated by summing of rainfall the erosivity individual erosive rainstorms of the season(Wischmeier and and Smith, 1978). Yearly erosivity needs the long term data of rainfall aggregates, which might not be available for most of the study catchments and for that reason, the correlation between rainfall erosivity index and yearly rainfall was developed with the data accessible from several meteorological stations nearby the catchment area and interpolated to evaluate the rainfall data within the catchment in ArcMap10.5 by IDW interpolation technique. The current research, a time sequence rainfall data for 15 years were used to evaluate “R” factors from the period of (2005 -2019). After having the interpolated rainfall data using Spatial Analysis Tool by IDW interpolation technique, R-factor within the catchment area were assigned based on the model developed by (Hurni, 1985b)for Ethiopian condition, as described by equation:

R= -8.12 + (0.562 × P) ---Eq3.1

Where P is the mean annual rainfall in mm

To estimate R factor for the catchment area the nearest seven meteorological observatories mean annual rainfall of 15 years were used. These are Bahir Dar, Meshent i, Merawi, Adet, Dangila , Sekela and Durbetie as shown the table 3.3.below. Appendix 1 shows fifteen years of monthly rainfall data for each station.

Table 3.3: The mean annual rainfall data

No	Name of RF stations	Location		Altitude	Mean annual Rain fall	Year range
		Latitude(Y)	Longitude(Chan dra.P. and Gri)			
1	Bahir Dar	11.59	37.388	1800	1602.00	2005-2019
2	Meshenti	11.50	37.30	1969	1300.45	2005-2019
3	Merawi	11.45	37.164	2000	1707.07	2005-2019
4	Durubetie	11.359	36.956	1984	1681. 57	2005-2019
5	Sekela	10.9882	37.214	2715	2059.062	2005-2019
6	Adet	11.2745	37.49312	2179	1212.694	2005-2019
7	Dangila	11.4337	36.846	2116	1684.626	2005-2019

Source Ethiopia metrological agency, 2021

As shown in Figure3.4(B), the spatial distribution of the computed rainfall erosivity ranges from 896.236 to 1026.29 MJ mm/ha/yr.

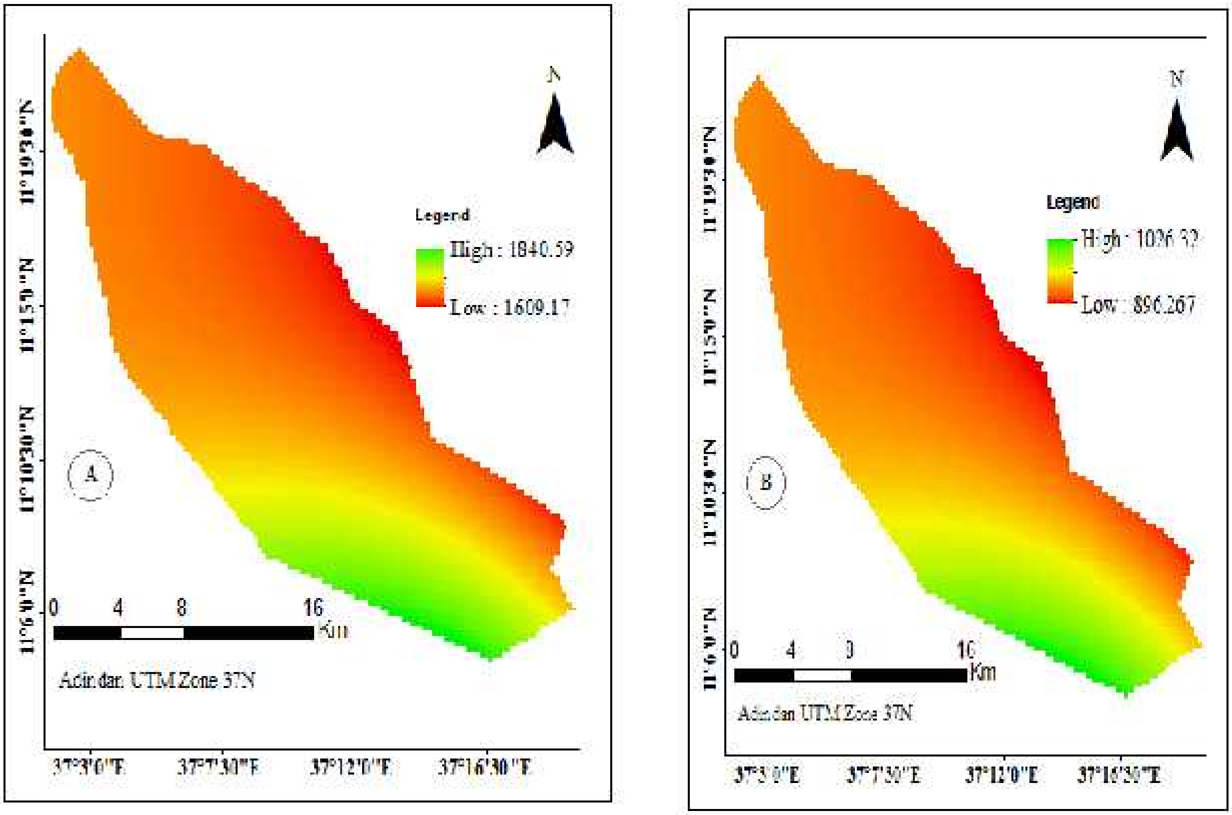

Figure 3.5. The interpolated mean annual rainfall (A) and erosivity(R) factor (B) maps

3.3.4.3. The Factor of Soil Erodibility (K)

The factor of soil erodibility (K) was described by susceptibility to soil erosion threat by the result of rain storm and runoff. Soil erodibility differs with different cohesive force between the soil particles such as soil texture, aggregate stability, shear strength, infiltration capacity and organic matter and chemical content of the soil. This shows that Soil texture, organic matter, structure and permeability can govern the erodibility of a soil type (Efe et al., 2008). While K factor indicates, which the mean annual rainfall soil loss per unit of R for a standard condition of bare land soil, currently tilled up-and-down with slope with no conservation practices and on a slope of about 5and 22 m length(Morgan and .R.P.C, 1994). I t refers to susceptibility of the soil by rainfall, rainstorms, runoff, and the infiltration of soil, as the impact of soil properties on soil loss during rain storms events on plateau area/topography(Lu et al., 2004). According to Ethiopian condition, the classification was made based on the major soil types of the study area depend on the performance of their color from the FAO soil database (Fig 3.5A). In this research, the digital soil classification map of the study area was obtained from Ministry of Agriculture (MoA and RDE). This techniques held on by using clipping tool "K" value of each soil type was assigned based on their color as indicated by (Hurni, 1985b). The study area of the soils contains two distinctive erodiblity values. As shown Table 3.4 below the detail of soil type, soil color and erodiblity factor value in the catchment. Accordingly soil erodiblity in the watershed ranges from 0.15 to 0.25 metric tons ha^{-1}. The higher values of soil erodiblity indicate its higher susceptibility to erosion.

Table 3.4: The major soil types and erodibility factors

NO.	Soil type	Soil color	Erodibility Factor (K)	Area(ha)	Percent
1	Eutric vertisol	dark gray or black	0.15	7731	17.93
2	Eutric Cambisols	dark gray	0.15	18990	44.04
3	Haplic luvisol	Reddish	0.25	16398	38.03

Source: Hurni,(1985a)

The digital soil map data that obtained from the MoA was vector data format. After changing the vector format in to Raster data, the Raster data was reclassified rendering to the K-value of each soil class in ArcGIS 10.5 as shown in Figure 3.5(B**)** below raster map of soil erodiblity factor "K" in the catchment. Hence data which gotten from the MoA and conferring to RDE Eutric Cambisols, Haplic luvisol and Eutric vertisol were well known in the study area. In this study, Haplic luvisol with erodebility factor 0.25 ton $ha^{-1}MJ^{-1}mm^{-1}$, covers an area of 16398 hectare of the of the catchment which is about 38.03 % of the total study area, while Eutric Cambisols and Eutric vertisol together accounts 26,721 hectare of the catchment area which are 61.97 % with a soil erodibility factor of 0.15 ton ha.

This means Eutric Vertisols soil and Eutric Cambisols type has less suffered with erosion than others because of its erodiblity factor value.

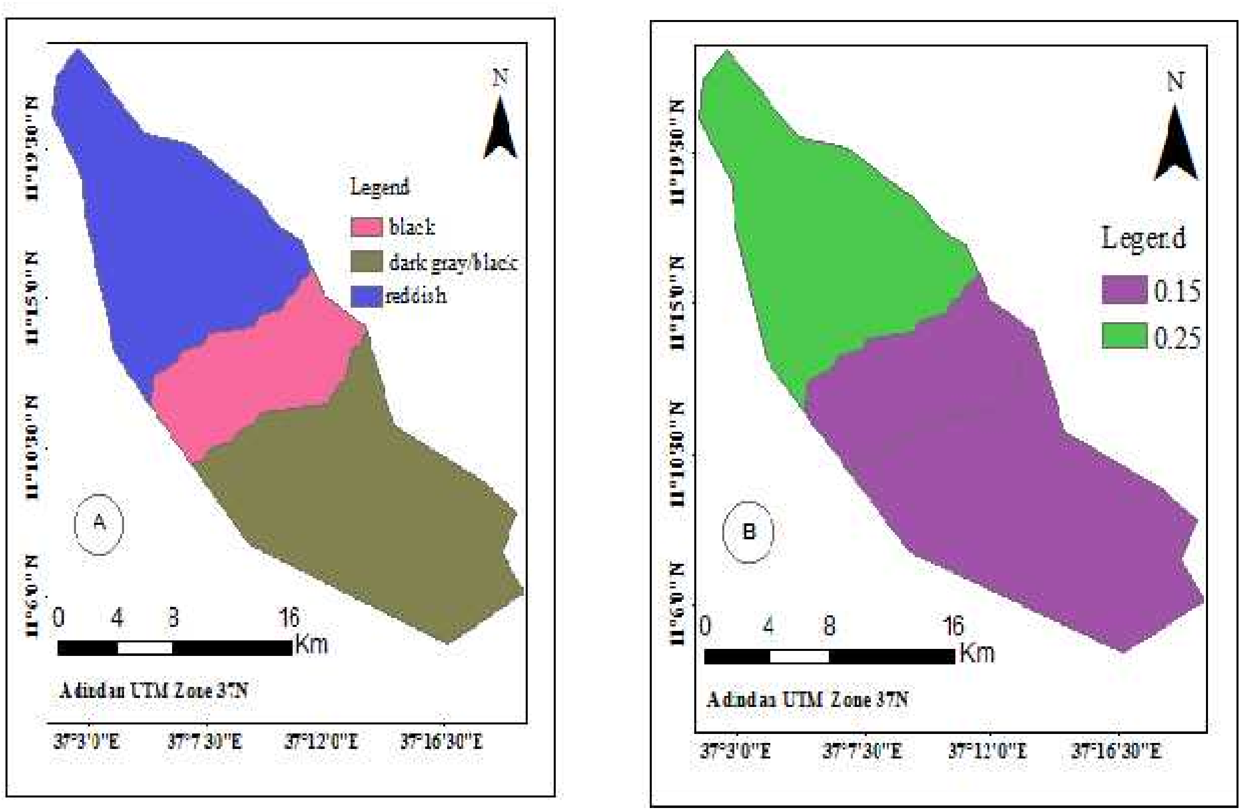

Figure 3.6. the soil type (A) and its erodibility factor (k) (B) maps

3.3.4.4. Slope Length and Slope Steepness (LS)

Slope length and steepness (LS) factor in RUSLE model which, indicates that it is a result of landscape on erosion risk. At the same time researcher agreed that Slope steepness and erosion have direct relations which means increasing in slope length and steepness can bring about higher overland flow velocities and the result causes for higher erosion would be happened(Haan C. et al., 1994). Additionally, slope steepness is more affected or changed by gross soil loss than slope length(McCoolDK et al., 1987). Slope length (L) factor defines the impact includes from the distance between the point of beginning to overland flow to at that point, where the runoff water enters a clearly stated channel, or the slope gradient decreases enough that depositions begins(Wischmeier and and Smith, 1978). While the local slope steepness factor (S) shown that the consequence of slope gradient on erosion. The Particular impacts of the topography on soil erosion can be assessed by the dimension less LS factor that is slope length (L) and slope steepness (S) gives together.

DEM with30m resolution was clipped by including the zone of interest and used for creating LS factors. Recently in the developments of GIS software have allowed exact estimation of about slope length as well as the steepness.

To develop the LS-factor maps first, a sequence of digital elevation model was derived by means of ArcGIS 10.5, with the extension lead of Arc hydro tools 10.5. From here, the Equation.4.2 factors were used to calculate and map the LS-factor as shown the (Fig.3.6) has been applied by other studies such as(Ayalew et al., 2015) according to Ethiopian condition. While based on the flow accumulation and slope in degree of the local area LF factors might be calculated. Finally multiplied by "spatial analysis tool Map algebra raster Calculator" in ArcGIS software to calculate and map the slope length (LS factor) as shown in equation (3.2) and defined by(Mitasova H et al., 1999) and changed to ethiopian condition by (Habtamu, 2016).

$$LS = (\text{Flow Accumulation} * \text{Cell Size}/22.13)^{0.4} * (\text{sinslope} * 0.01745/0.0896)^{1.3} \quad \text{……………..….Eq (3.2)}$$

Whereas FA is flow accumulation, the cell size is the resolution of the grid *(i.e.*, 30 m), 22.13 is the length of the research field plot.

In this procedure, Flow Accumulation was obtained from the DEM after performing Fill and Flow Direction procedures in Arc GIS 10.5 with the extensions of Arc Hydro tool. Slope in degree also derived from the DEM Arc GIS 10.5 with the extensions of Arc Hydro tool according to the local area (figure 3.6A) and m value was assumed by classifying the slope of the study area according to (Wischmeier and and Smith, 1978) as follows. The discussions of the finding shown, the LS factor in the catchment ranged from 0 to 990.124, with the average mean value for this catchment approximately 4.314 and the value of standard deviation of 14.388 (Fig 3.6B).

Table 3. 5: m - values for different slope classes according to (Wischmeier and Smith 1978)

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

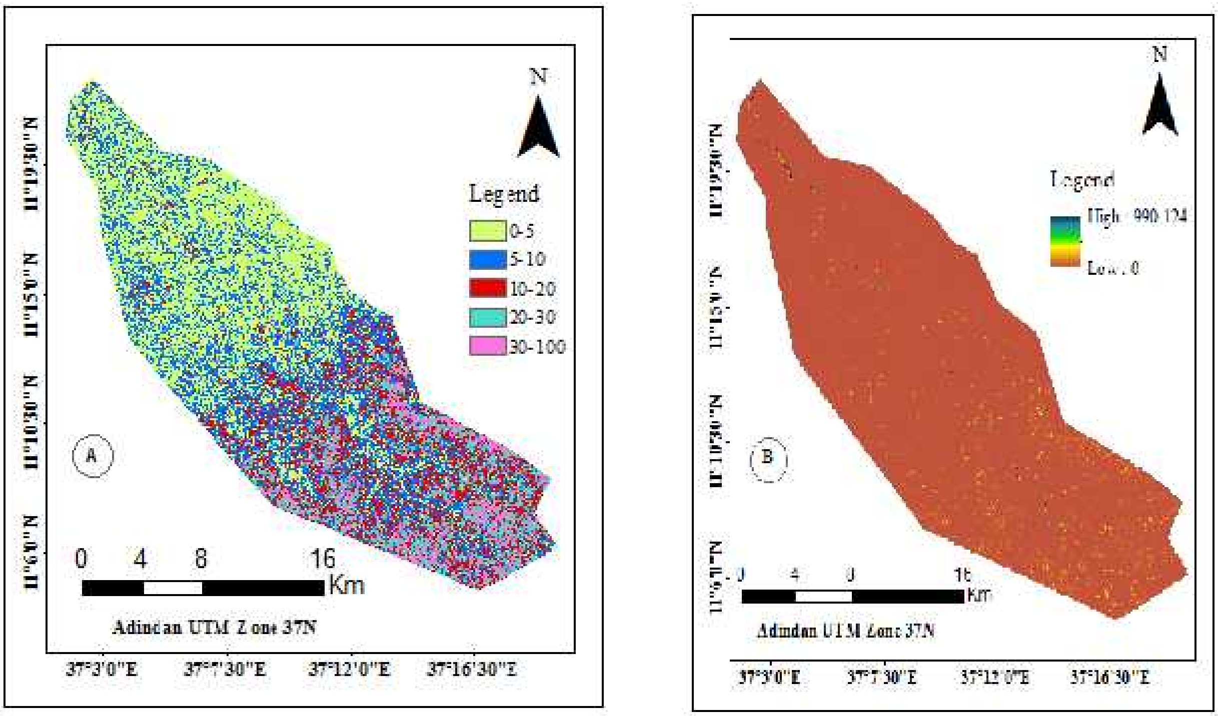

Figure 3.7. Slope map(A) and LS factor map (B)

3.3.4.5. Cover Management (C) Factor

The current literature agrees (C) factor represents the outcome of cropping and management practices on the cultivated land management system. Commonly affect different vegetation covers like ground tree, and grass covers on reducing soil loss in non-agricultural lands. Hence among the vegetation cover, together with slope steepness and length factors becoming the sensitive issues to soil loss in the recent study(Biesemans J et al., 2000).

While the vegetation cover join together with ground cover, level of the production, and the associated cropping technique. To estimated national scale the C factor can be used mid-resolution satellite images (land sat 8). For the classification accuracy Google earth pro, reconnaissance survey and ground coordinates data collection were used. While after the classification, the raster data was converted to the vector layer and the C- factor value was assigned for each land use/ land cover class based on the recommendation of(Hurni, 1985b) and(Wischmeier and and Smith, 1978), which is adopted Ethiopian condition. Hence to classify exact value for each land use/ land cover unite the image data was classified according to six classes (Fig 3.7A). From here the majorities of the catchments area are cultivated lands, built up area, shrub land and in some extent bare land respectively. As result it was affected by erosion since the higher C-factor which have, the higher soil loss would be followed.

In most situations, cover management reduces soil erosion, speed of the surface runoff and decreasing the amount of filtration of water into the soil. While the current literature suggested Vegetation cover retaining the roughness of the soil surface, recover the chemical and biological properties of the top soil (De Asis et al., 2007) and in the form of crop plants, mulches, can protect soils from wind and water erosion and help maintain organic matter (Bobe Bedadi, 2004). Hence, the vegetation covers which have low C-factor value have low contribution to the soil loss, the ranges of the catchments area C-factor value from 0to1 (Fig3.7B).

Table3.6. Cover management (C) factor values of the study area

No	Land use land cover type	C – factor	Referance
1	Shrub land	0.014	Hurni (1985), by
2	River	0	Girma and Gebre(2020)
3	Forest land	0.001	Hurni (1985)
4	Built up area	0.6	Hurni (1985)
5	Bare land	1.00	wegetal.(1998);Hurni(1985)
6	Cultivated land	0.15	Hurni (1985)

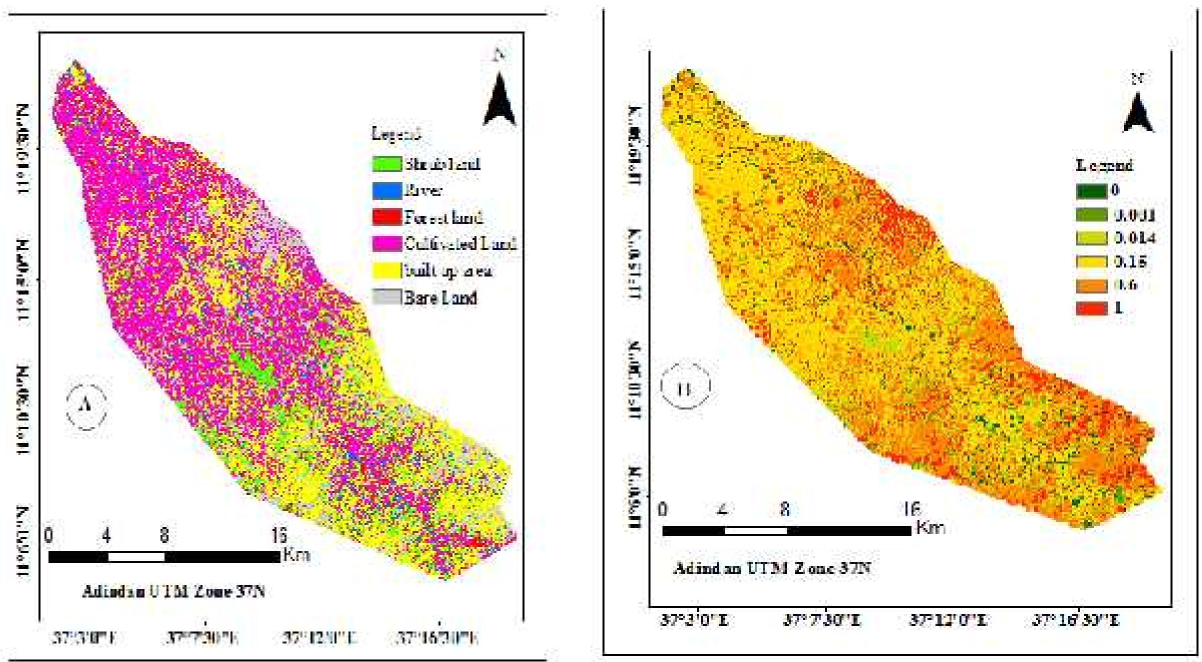

Figure3.8. land use /land cover as well as management practice(C) maps (A) (B) respectively

3.3.4.6. Factors of Conservation Practice (P)

Commonly the ranges of P-factor could be varies from 0 to 1.The smaller value of (p) factor is the more effective in the conservation practice technique. Therefore the whole study area of data in the study area on ongoing management factors and lack of soil management not treated with better-quality and permanent soil and water conservation technique. Since the absence practices, P-values, suggested by(Hurni, 1985b), intended based on Ethiopian condition. The P-factor which estimated from land use/ land cover class, that obtained from landsat8 image (TM, ETM+ and OLI). The recent study classify particular values for each support practice category, the image data was categorized into six foremost land use/land cover categories (Fig 3.8, A). The (P) factor value were assigned for each individual category according to(Hurni, 1985b), for Ethiopian condition. Then equivalent P-value was assigned to each land-use /land cover type by using spatial analysis tool the reclassify method was done with Arc GIS 10.5 (Fig 3.8B).

Practically in order to prevent the soil loss, the recent literature advised the following techniques which include horizontal plowing, cover cropping, managed grazing, strip cropping, crop rotation, etc. to keep soils loss from rain fall erosion by decreasing the slope length. Cultivated land as indicated by the (Table 3.7) require high level of conservation practice to because which have the lower P-value the more effective in the conservation practice.

Table 3.7: P-value suggested by Hurni (1985); adapted for Ethiopian condition

No	Land use land cover type	P – value
1	Shrub land	0.63
2	River	0
3	Forest land	1
4	Built up area	0.63
5	Bare land	0.9
6	Cultivated land	0.73

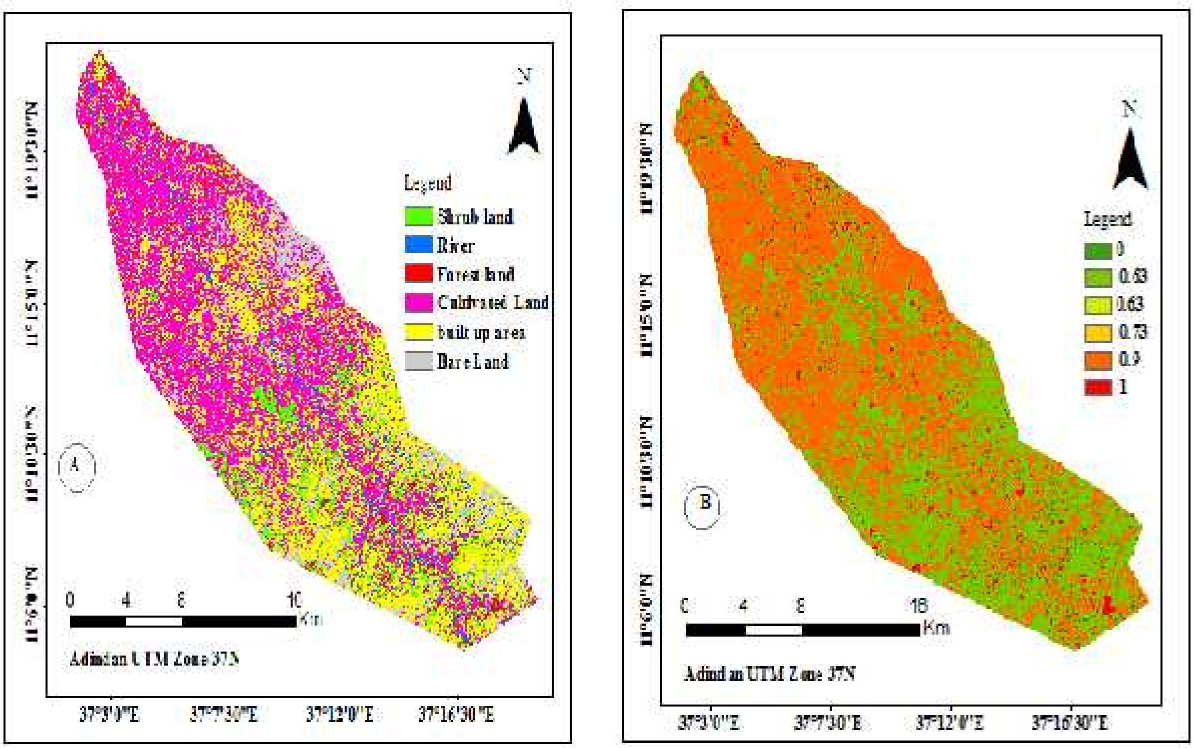

Figure 3.9. land use/ land cover map (A) as well as Conservation practice (P) map (B)

CHAPTER FOUR

4. Result of the Study

4.1. Land use/Land cover change Analysis of the Study Area.

Based on the analysis, proper management of the catchment needs precise measurement of the former and current land use/land cover changes. In addition to this the present research shows the impact of land-use and land cover change on erosion risk of the study area. Also, Jemma catchment has been covered by Varity different land use/land cover type. Figure5.1shows the distribution of land use/land cover change maps of the area from 2000, 2015 and 2020 were prepared, respectively. As the finding of result suggested and analyzed the area of each LU/LC change distribution in hectare and percentage the coverage of different periods is tabulated on (Table 4.1). The change shows among 2000, 2015 and 2020 land use/land cover classes of the catchment was measured.

After producing land use/land cover maps generated a maximum likelihood supervised classification as well as a post classification algorithm are presented in figure 5.1 and Table 5.1 respectively. As shown from the table 5.1 LULC in 2000, 10.23% of bare land and it increased to 12.08% in 2015. While in2020 also increased to 13.91%. On the other hand forest land covers the area 5.38% in 2000 then, decreased to 3.25% in 2015 and remain constant in2020. Shrub land covers the area of 23.59% in 2000 then, decreased to 9.63% in 2015 and decreased to 4.57% in 2020. Cultivated land was cover the area of 31.02% in2000 then, increased to 40.95% in 2015 and also increased to41.32% in2020. In addition to this about 22.16% that was covered by built up areas in 2000 while at the same time in 2015, increased to 31.06% and in 2020 reached to33.92%. The River covers from the total of the study area3.03%. This implies that much of other land use / land cover transformed to built-up area and cultivated lands. The change land use land covers in hector and in percentage shows in the following table 4.1.

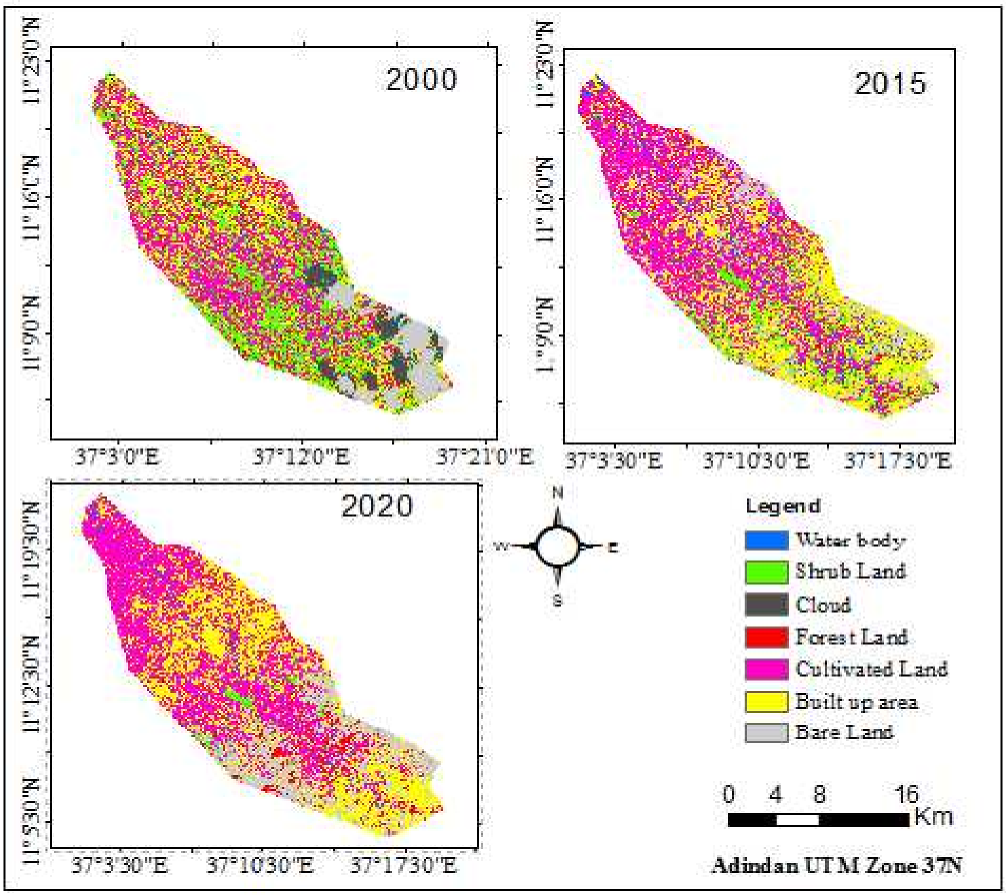

Figure 4.1. Land use/land cover maps of Jemma catchment from 2000, 2015 and 2020

Table4.1. Land use/Land cover classes in area with percentage of different periods.

Classes Name	2000		2015		2020	
	Area(ha)	Area (%)	Area (ha)	Area (%)	Area(ha)	Area (%)
Bare Land	4412.97	10.23	5209.69	12.08	6001.14	13.91
Forest Land	2320.47	5.38	1401.2	3.25	1400.25	3.23
Shrub Land	10170	23.59	4152.57	9.63	1969.81	4.57
River	1 305.59	3.03	1305.58	3.03	1305.58	3.03
Cultivated Land	13373.77	31.02	17656.1	40.95	17816.37	41.32
Built up area	9556.2	22.16	13394.3	31.06	14626.3	33.92
total	43119.45	100	43119.45	100	43119.45	100

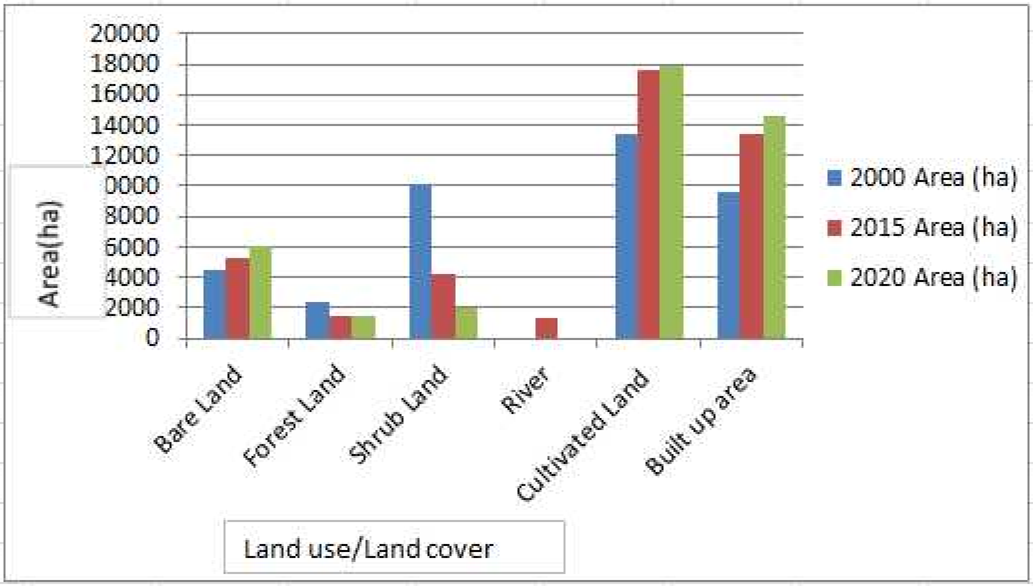

Figure4.2 shows the distribution of land use/land cover class from 2000 to 2020

4.1.1. The Trends of Land use /Land cover class in Jemma from 2000-2020

In order to display the trends of LU/LC change presented in the (Table4.2) bellows. The negative value rate of change indicates declined in that particular land use/ land cover change type and the positive value which indicates the greater than before of land use/land cover change types. The findings of this research shows, the bare land covered the study area increased by 5.02% from 2000 to 2015 and at the same time increased by 18.12% in 2020 as shown in Table 4.2. From 2000-2020 it was increased about 7.85% when compare to the previous coverage. When we come to cultivated lands and Built up areas were increased rapidly from the year of 2000 to 2020. Shrub land is one of the land-use/land-cover types of the study area, which decreased about 37.96% in 2000 to 2015 and decreased by 49.98% from 2015 to2020. Generally from2000-2020 the trends of shrub land are decreased about 40.55% from the previous coverage. The water body covers only 3.03%. While the Forest lands, which were initially consist of about 5.38% of the LU/LC in 2000 and has decline to 4.53% in 2015 and further decreased about 0.02% in 2020. So, the extents of forest land decreased by 4.55% from 2000 to 2020 (Table 4.2). Generally Jemma catchment was experienced by different LU/LC change since2000 - 2020. Land which covered by forests and shrub land shows decreased continuously during the indicated period. On the other hand, bare land, cultivated land and built up area shows continuous increment quickly in this trend among the study period (2000-2020) as shown by (Fig 4.3).

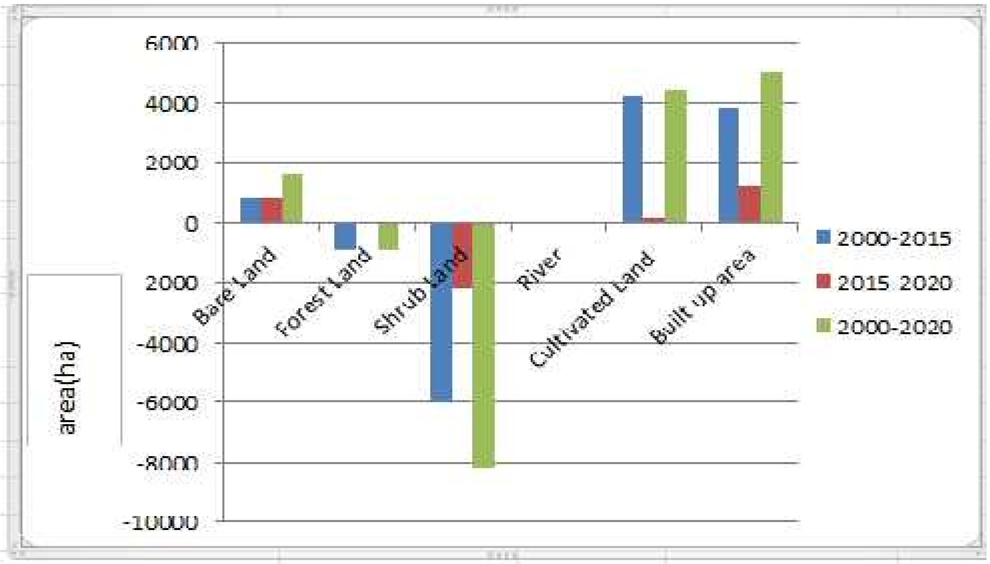

Figure.4.3 shows the trends of Land use/Land cover change in Jemma

Table.4.2 shows Land use/Land cover change in Jemma since 2000-2020

Class Name	2000-2015		2015-2020		2000-2020	
	Area(ha)	Area (%)	Area (ha)	Area (%)	Area(ha)	Area (%)
Bare Land	796.72	5.02	791.45	18.12	1588.17	7.85
Forest Land	-919.26	-4.53	-0.96	-0.02	-920.22	-4.55
Shrub Land	-6017.43	-37.96	-2182.76	-49.98	-8200.19	-40.55
River	0	0	0	0	0	0
Cultivated Land	4282.33	27.01	160.27	3.67	4442.6	21.97
Built up area	3838.1	24.21	1232	28.21	5070.1	25.07

As the study shows shrub land had the largest decrements by rate of 410he/yr from 2000 to 2020. While the settlements area shown largest increment and estimated as 253.5ha /yr in the period from 2000 to 2020 as (Table 4.2). On the other hand for the duration of 2000 and 2015, the land which covered by the shrub land decreased by means of 37.96%), while the extents of built up area, cultivated land, and bare land have increased by 24.21, 27.01 and 5.02

respectively (Table 4.2). The conclusion of study area recommended land-use/land-cover change is becoming the most threatening global issues today, and shows that the degrees of built up area cultivated land constantly increments, while shrub land continuously decrement. While the period from 2015−2020 shown that, land which categorize under shrub land and forest land cover had speedy decrease by 49.96% and 0.02%, respectively as compared to the first phase of the study period that is from (2000−2015). Whereas, the levels of agricultural land and built up area shows continuously to increment in the second study period which means(2015-2020). At the same time the bare land has increased by18.12%, as indicated by the table (table4.2).

4.1.2. Accuracy Assessment

To represent classification accuracy assessment 48 GCP for each land use land cover class were collected totally 288 GCP points from each years that is 2000, 2015 and 2020. The high resolution Google Earth *i.e*. Google earth pro, data was making use of the classification reports as free from the data set which classification accuracy was compared. As the finding suggested that an overall accuracy of the current study revealed 88.65%, 86.67% and 96.77% was achieved, and the Kappa coefficient of 0.87, 0.84 and 0.96 for the three Scenes (Landsat TM 2000, ETM+ 2015 and OLI 2020), respectively. This shows the result of this accuracy assessment is reliable. Table4.3, table4.4 and table4.5, shows Classification of accuracy assessment report for image, 2000, 2015 and 2020 respectively.

Table 4.3 accuracy assessment report for land-use/land-cover change 2000 image

Class Name	Reference total	Classified total	Number Correct	Producer Accuracy	User Accuracy
Bare Land	29	24	24	82.76%	100.00%
Shrub Land	20	27	20	100.00%	74.07%
Built up area	20	27	19	95.00%	70.37%
Cultivated Land	20	16	16	80.00%	100.00%
Forest Land	20	16	16	80.00%	100.00%
Water body	20	18	18	90.00%	100.00%
Totals	141	141	125		
Overall Classification Accuracy = 88.65%					
Overall Kappa Statistics = 0.87					

Conditional Kappa for each Category.

Class Name	Kappa
Bare Land	1

Shrub Land	0.70
Built up area	0.65
Cultivated Land	1
Forest Land	1
Water body	1

Table 4.4 accuracy assessment report for land-use/land-cover change 2015 image

Class Name	References Total	Classified Total	Number Correct	Producer Accuracy	User Accuracy
Bare Land	23	14	13	56.52%	92.86%
Shrub land	23	28	23	100.00%	82.14%
built up area	23	31	23	100.00%	74.19%
Cultivated Land	23	24	22	95.65%	91.67%
Forest land	23	18	18	78.26%	100.00%
River	20	18	18	90.00%	100.00%
Totals	135	135	117		
Overall Classification Accuracy = 86.67%					
Overall Kappa Statistics = 0.84					

Conditional Kappa for each Category.

Class Name	Kappa
Bare Land	0.91
Shrub Land	0.78
Built up area	0.69
Cultivated Land	0.90
Forest Land	1
Water body	1

Table 4.5 accuracy assessment report for land-use/land-cover change 2020 image

Class Name	Reference Total	Classified Total	Number correct	Producer Accuracy	User accuracy
Bare land	21	20	20	100.00%	100.00%
Built up area	21	21	21	100.00%	100.00%
Shrub Land	20	22	20	100.00%	90.91%
Cultivated land	21	23	21	100.00%	91.30%
Forest Land	21	19	19	90.48%	100.00%
River	20	18	18	90.00%	100.00%
Totals	124	124	120		

Overall Classification Accuracy = 96.77%
Overall Kappa Statistics = 0.96

Conditional Kappa for each Category.

Class Name	Kappa
Bare land	1
Built up area	1
Shrub Land	0.89
Cultivated Land	0.89
Forest Land	1
River	1

4.2. The Valuation Soil Erosion Rate in Catchments

As the current finding suggested Soil erosion threats were evaluated by RUSLE model from the data and the map outputs multiplied by the parameter layers, such a like rainfall erosivity (R), soil erodibility (K), Slope length (L) and slope steepness, cover management (C) and support practice (P) factors. At the same time the area of distribution of annual soil loss of the catchment is somewhat vary that is from 0.00t/ha/year in the plain area to 22966t/ha/yr around rugged landscape (Fig 4.4). Categorization of different erosion potentials followed the FAO basic classification of desertification (FAO, 1986)with some modification to suit the features of the study area according to (Shiferaw and Holden, 2011) as shown table 4.6. Soil loss tolerance (SLT) represents the extreme tolerable soil loss that will sustain an economic and a high level of productivity (Wischmeier and and Smith, 1978)&(FAO, 1984). The normal SLT values range from 5 to 11 tons ha-1yr-1(Renard et al., 1996). The assignment of a range depended on the judgment of how much erosion would be harmful to the soil.

On the recent study the annual/soil loss ranged from 0.00t/ha/year in the plain area of the studied Woreda area to over 22965.3t/ha/year in much more the steeper slope banks of the tributaries. The earlier finding revealed the area which increases in slope steepness and slope length can create higher overland flow velocities and correspondingly would have higher erosion rate (Haan C. et al., 1994) . As the above researcher agree that places where rate about 22965.3t/ha/yr is much steeper. When the mean average annual soil lose rate was calculated to be 208.5t/ha/year. The (FAO, 1984)study shows that, the annual soil loss of in the highlands of Ethiopia ranges corresponding to 16 to300 t/ha/yr. On the other hand (Bobe Bedadi, 2004)agree that, the Ethiopian highlands has also been estimated the annual average soil lose about 70t/ha/year. At the same time, the empirical study explained by (Tesfaye, 2015)in Cheraqe Watershed, shown that the rate of soil lose from the cultivated land was 68.7t/ha/yr. In the current research by (Gelagay and Minale A, 2016) indicates in the Koga watershed of the upper Blue Nile basin explain average soil erosion rate of 47.4t/ha/year. (Negese, 2021) About 50% of the Lake Tana basin is faced high to very high risk the mean average of soil erosion rates, in some cases reaching as high as 256t /ha/year. At the same time (Gete Z, 2000) assessment shows in northwestern highlands and reported a very high rate of erosion ranging from 130 to 170 t/ ha/year. Consequently in the current study assessed mean average soil loss rate *i.e*.208.5 t/ha/yr in Jemma catchment and the area of the study is generally truthful, when it compares to the results from earlier researches which have been done in Ethiopia. To compare the level of threat area; the average soil loss of the catchment was first categorized into seven different severity classes grounded on suggestions of FAO's classification (FAO, 1984) with some modifications to suit Ethiopian condition Adopted from abate shiferaw, (2011). The method used to categorization of the severity classes was Soil Loss Tolerance (SLT) value.

The finding suggested that the assessable output of the actual soil erosion rate for Jemma catchment were computed and grouped into seven severity class. The soil erosion severity class depends on the average soil erosion level and the annual soil destruction from the study catchment.

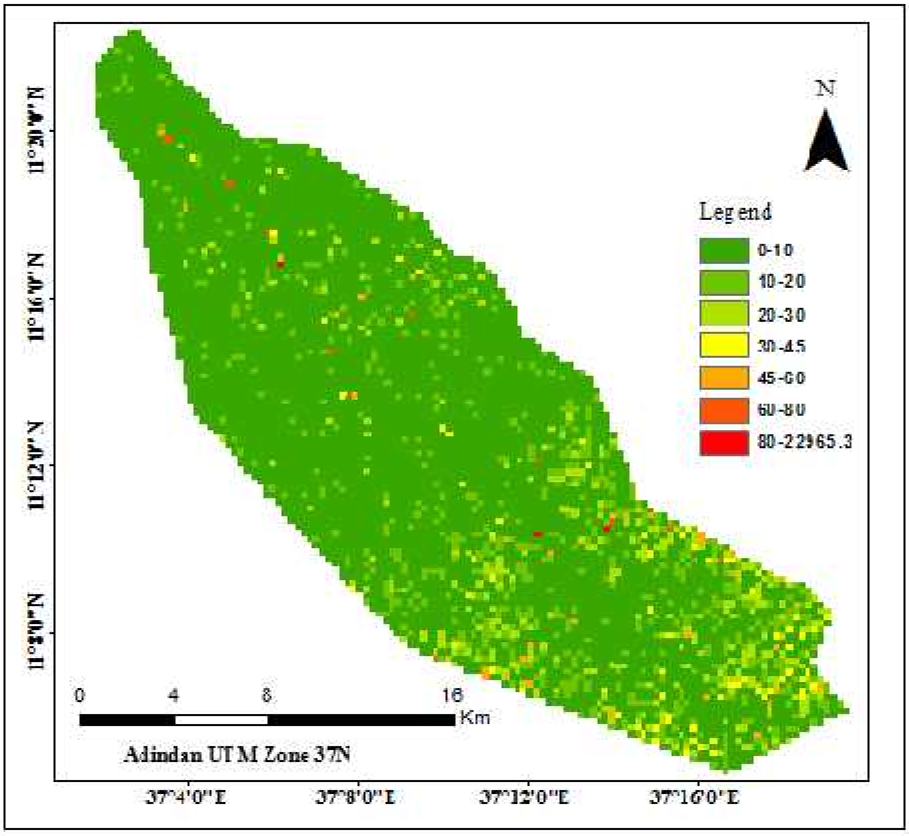

Figure.4.4. shows the assessed map of yearly soil erosion the study catchments.

Table4.6. the anusl soil erosion rate and severity calass of catchment

Soil erosion risk class	Average Soil loss (t/ha/yr)	Area	
		Hectare(ha)	Percent (%)
Low	0 -10	34359.8	79.7
Moderate	10-20	5057.9	11.7
high	20-30	1971.2	4.6
Very high	30-45	1230.9	2.9
Sever	45-60	413.5	0.96
Very sever	60-80	76.3	0.11
Extremely sever	80-22965.3	10.85	0.03
Total		43,119.45	100%

Source: FAO and UNEP (1984), Adopted from abate shiferaw, (2011)

5.2.1 Validation of Erosion for Erosion Risk Areas

The result of RUSLE was validated using high resolution Google earth (*i*.e. Google earth pro). For validation fifteen points (three from extremely sever class, four very sever class, four from sever class and four from very high erosion class) were taken. Validation of the erosion areas has been shown in appendix 2.

Table4. 7: Validation of erosion prone areas comparing with Google earth

No.	Sample code	Erosion severity class	Google earth interpretation	Matching status
1	4	Very High	bare land	Agree
2	4	Very High	Bare land	Agree
3	4	Very High	Shrub land	Disagree
4	4	Very High	bare land	agree
5	3	Sever	bare land	Agree
6	3	Sever	bare land	Agree
7	3	Sever	forest land	Disagree
8	3	Sever	Bare land	Agree
9	2	Very Sever	bare land	Agree
10	2	Very Sever	bare land	agree
11	2	Very Sever	Bare land	agree
12	2	Very Sever	bare land	agree
13	1	Extremely sever	Cultivated land	Disagree
14	1	Extremely sever	bare land	agree
15	1	Extremely sever	bare land	agree
Matching statistics	Validation accuracy	=(12 agree points from 15 total points*100=80%		

As mention above, among fifteens points only three points weren't matched with Google Earth. For interpretation the main goal of the researcher used the cover type basically the area was estimated as prone to erosion if the land was Bare or mountainous. Based on this, the matching statistics show the result was 80 % valid**.**

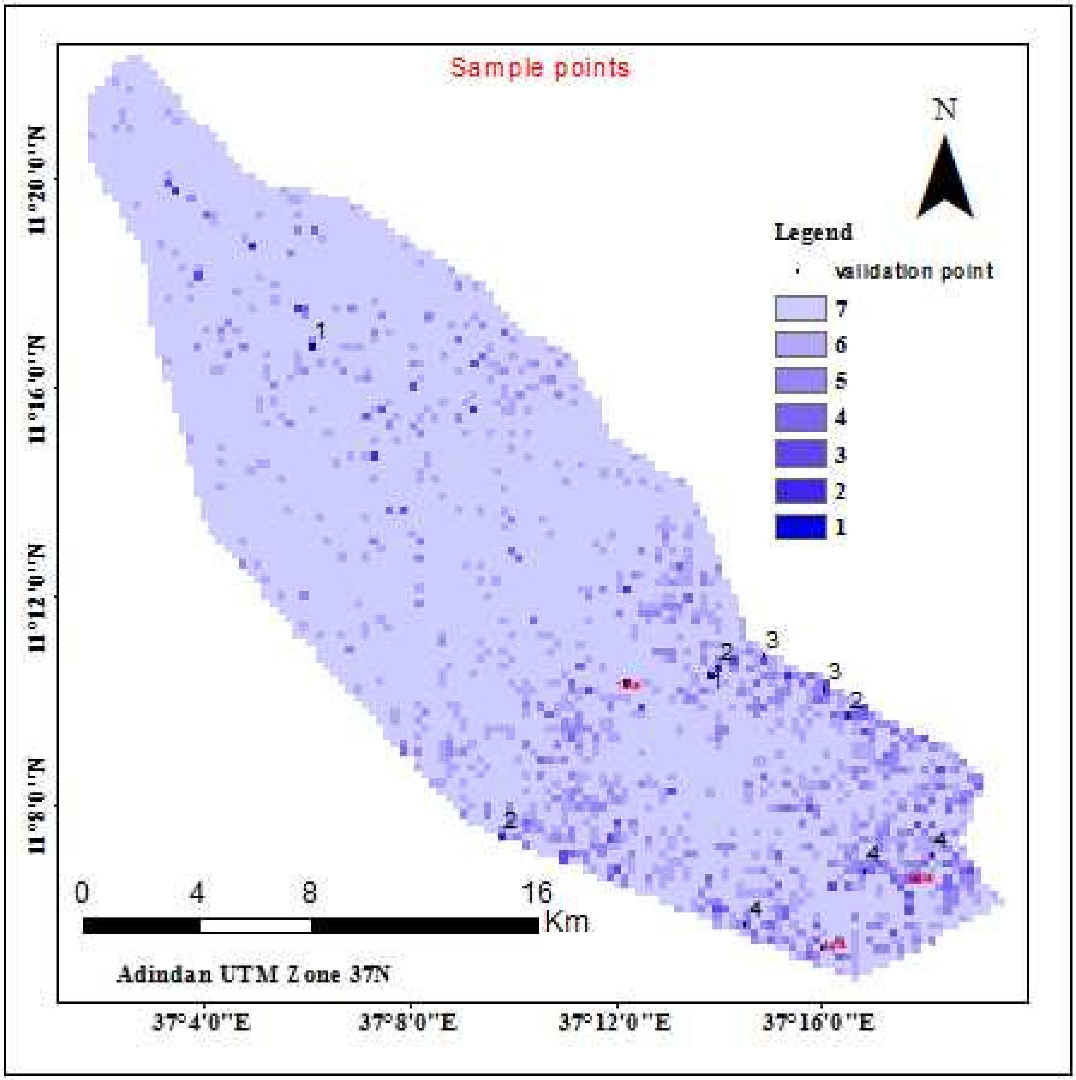

Figure4. 5: The location of validation points at erosion for erosion risk areas

As seen from the graph the legend number shows level of severity that is from extremely sever (1) to low (7) level of severity class.

Figure4.6: The location of validation points on Google earth to validate erosion risk areas

As seen in the Figures 4.6, only three points namely dia and color red (1 dia , 3 dia and 4dia) points didn't match with result of soil erosion prone areas. These points were NO 1(1 red dia) laid on the area of cultivated land, No3 (3 red dia) and No4 (4 red dia) laid on the area of forest land and shrub land respectively.

4.3 Prioritization Critical Sub-Catchment for Treatment

As the recent different literature discussion suggested, the slope factors in RUSLE indicates the outcome of landscape on soil erosion. Which means that rises in slope length and slope sharpness have the effect of higher overland flow velocities and correspondingly higher erosion risks(Haan C. et al., 1994). Furthermore, the great soil erosion is significantly more sensitive to change the slope steepness when compare to changes in slope length (McCoolDK et al., 1987). While the soil erosion rate in the Jemma catchment varies with slope. As shown in the figure4.5 on the recent study the direction of north, north east, and south east of the study area is extremely affected by heavy erosion.

In this study, from the total of study area was delineated based on slope and soil erosion ranks, as the final point erosion risk map was reclassified based on prioritizing (Fig 4.5). The ranking of sub catchments involved for handing over for diverse erosion risk class, agreeing to the order in which there might be taken up for erosion control measures, by considering the quantity of average annual soil loss occurred in these catchment. From here as the finding suggested the area which were categorized under extremely severe erosion ranges class covers the area of 10.85 ha which is about 0.03 % of the total study area, while very sever class covered 76 ha (0.11 %), sever erosion risk class covers an area of 413.5 ha (0.96 %), very high class covers an area of 1230.9 ha(2.9%) high erosion risk class covers an area about 1971.2 ha (4.6%). When we come to moderate and low erosion risk class covers an area about 5057.9 ha (11.7%), and 34359.8 ha(79.7%) respectively. As shown in Table 4.8, the spatial locations of the areas highly affected by soil erosion in the study area are the steeper slope banks of tributaries where they together cover about 3,706.75 hectare (8.6%) of the total study area. These areas have ranges of the erosion severity classes of extremely severe, very severe, severe, very high, and highly eroded, where conservation priorities of the first, second, third, fourth and fifth order are needed. The study areas which, very high up to extremely sever soil destruction area selected first for soil erosion control practice. As result the critical sub catchments were ordered and recommended for treatments in order to solve the soil losses problems and to control the erosion within the watershed.

Table 4.8 Average annual soil erosion rate and and level of severity class in the study catchment

Soil erosion risk class	Average Soil loss (t/ha/yr)	Area	
		Hectare(ha)	Percent (%)
Low	0 -10	34359.8	79.7
Moderate	10-20	5057.9	11.7
high	20-30	1971.2	4.6
Very high	30-45	1230.9	2.9
Sever	45-60	413.5	0.96
Very sever	60-80	76.3	0.11
Extremely sever	>80	10.85	0.03
Total		43,119.45	100%

Source: FAO and UNEP (1984), Adopted from abate shiferaw, (2011)

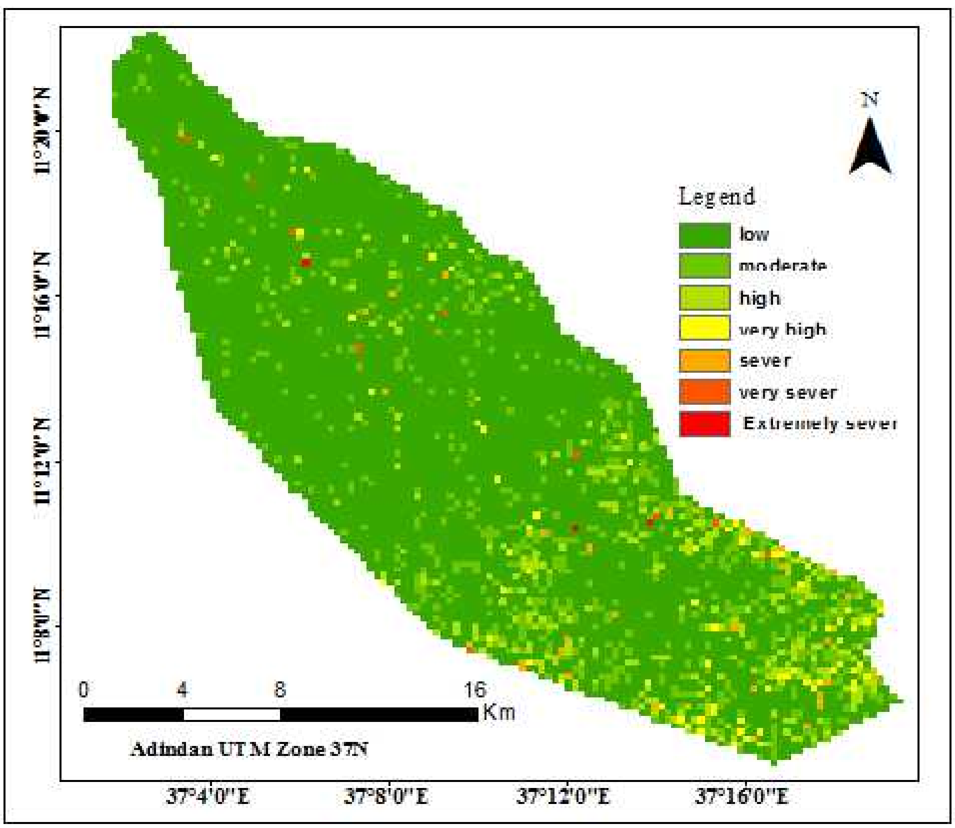

Figure 4.7 Map of the level of severity class of erosion in the study area

4.4. To Analyze the Impacts Land Use Land Cover Change on Soil Erosion the Study Catchment.

In this section explains effects of land use/land cover change on soil destruction potential with in the study catchment. Land use/ land cover change has directly related to on soil erosion. The study area faced several changes with land use/ land cover change. The implication of land use land cover change was described based on observation. The impacts are directly related to such underlying factors as socio-economic activities and poor environmental management and inseparably connected to one another. The large amount of cultivated land without using specific control mechanism, unplanned land use on the agriculture land, uncontrolled urban development and also destroying forests are main factors of soil erosion(Biard and Baret, 1997). Soil erosion is the severe problem and affects land qualities as well as water resources in Ethiopia because of its topographic features. Consequently creates strong environmental influences and high financial costs by its effect on agronomic production (Lemlem Tadesse et al., 2017). Rapid population increase, deforestation, improper land use management, low vegetative cover and unbalanced crop and livestock production were the main causes of soil erosion in Ethiopia (Girma, 2001). In this situation, the Ethiopian highlands are highly influenced by land degradation, which have eroded the natural resource bases of the area (Tilahun A et al., 2001).

In the same deforestation, improper land use management, low vegetative cover and unbalanced crop and livestock production has positive impact on erosion. In the study area affected by erosion are observed (fig4.5). The impact Erosion is hazardous particularly during the start of rainy season for the land is nearly bare because the prevalence of removal of tree and vegetation for cultivation and built up purpose. As can be observed from (fig4.5) the escarpment is totally bare, and at the same time the high lands are not covered by crop lands. Hence, during the start of rainy season, the flood come from the high land and eroded the escarpment t of the study area. As the latest learn about noted that, the impacts of land-use and land cover exchange on Jemma catchment experienced variety sorts of land-use/land-cover change. As result the erosion rate increased year to year.

CHAPTER FIVE

5. Discussion

Land-use/land-cover changes in Jemma catchment the most threating issue for the global and the finding suggests most of the area is cultivated land (41%), built up area (33.92%), bare land (13.91%), shrub land (4.57%) and forest land (3.25), the smallest coverage of the study area was the river covers (3.03%) from the total area. The finding of the study indicates that cultivated lands, built up area, bare land were increased during 2000 to 2020. The earlier studies conducted in Koga watershed in the highlands of Ethiopia such as (Tegegne Molla and Biniam Sisheber, 2016), (Gelagay and Minale A, 2016) and (Natnael, 2017), documented reduction of area under shrub land, forest land and increase in area under cultivated land, built up area. Here might be so many motives, which cause for land-use/land-cover changes in the study catchment, like:- human population growth, agricultural expansion and non-agricultural activities (charcoal production, firewood collection etc.) on a marginal scale. Increased anthropogenic activities have altered the land-use/land-cover (Mdemu et al., 2012). Satellites image which have 30 m spatial resolution has agreed the required accuracy and the final result achieved during classification method for Jemma catchment were 88.65%, 86.67% and 96.77% in2000,2015 and2020 respectively which is equivalent with (Lemlem Tadesse et al., 2017). The overall classification accuracy results achieved by Lemlem research were 85%, 91% and 93.2%. Due to this reason the supervised classification of mine is valid/ reliable.

Soil erosion is the most severe problems almost all over the worlds and causes for land degradation, which has influenced extremely bad burden on productivity and environmental stability of high land areas. Even if soil erosion can be caused by geomorphological processes, accelerated erosion, which is mainly caused by human activities, is the major factor for the loss of soil and water resources(Minwer Alkharabsheh et al., 2013). The speedy population growth, deforestation, un proper land use management, low vegetative cover and unbalanced crop and livestock production are the main causes of soil erosion in Ethiopia (Girma, 2001).

Now a day Soil erosion is becoming one of the most threating issues for the world, to evaluate the eroded area the most commonly used model is the Universal Soil Loss Equation (USLE), which is an empirical model measuring long term averages of sheet and rill erosion, based on plot data collected, was initially established in USA(Wischmeier and and Smith, 1978).

In general RUSLE model is the most used for the quantification of surface erosion and used to provide estimates of soil loss based on the geospatial data. Therefore it is possible to produce maps for spatial distribution of soil erosion threats by using remote sensing and GIS data. From here five factors were derived from dissimilar data sources, such a like DEM, soil map, rainfall data, and remotely sensed data (Landsat image TM, ETM+ and OLI).

The area of distribution of potential annual soil loss of the catchment is somewhat representative that compared to the practical in the field as well as from the results of former research. While (Woldeamlak et al., 2009) study shown that the average annual soil loss for Chemoga river in the upper Blue Nile Basin in Ethiopia, was measured at 93 metric tons/ ha/yr. About 50% of the Lake Tana basin is faced high to very high risk of soil erosion rates, in some cases annual average soil lose reaching as high as 256t /ha/yea(Negese, 2021). At the same time (Gete Z, 2000) assessment shows in northwestern highlands and reported a very high rate of erosion ranging from 130 to 170 t/ ha/year.

When the result of the present-day study was interpreted, the average annual soil lose as shows to the catchment erosion becoming global threating and the finding suggested that the magnitude of annual soil loss reported in Table 4.8 was greater than the tolerable soil loss of 2 to 18t/ha/year estimated for Ethiopia by (Hurni, 1985b), except smooth landforms of the catchment. The suggestion is that there must be participate to develop conservation practices so that to decrease the amount of soil loss in south, south-east and north-east part of the catchment, to a hard tolerable for the country. As finding of the present results stated, the soil loss in Jemma catchment quantified value of erosion rate ranging from 0-22965.3 t/ha/year. The average annual soil loss ranges from the catchment was to be calculated 208.5t/ha/year. Therefore, the estimation of soil loss rate using RUSLE model and land-use/land-cover change detection revealing in this research is a nearly good agreement with those obtained by other studies. Hence this study shows that, potential soil loss outcomes in the northeastern , south eastern, south and central parts of the Jemma catchment value falls with high to extreme severe class of soil erosion.

This can be the reason that is why area has mountainous and rugged landscape that compared to other parts of the catchment area. The central parts of the area affects due to soil type (Haplic luvisol) and it have a high K factor value of 0.25 when, compared to other soil types, this is because the highest k value more affected by erosion. That might be the reasons; the soil type together with the rugged landscape makes the area more affected water erosion. As the finding suggested results of estimation land use land cover change detection analysis soil erosion in Jemma catchment shown, majority of the study catchment characterized by low erosion risk levels.

Thus, the current finding indicates result of RUSLE model that it is more reliable when compared to previous researcher. As the recent study suggested that, around 50% of the Lake Tana basin is challenged from high to very high hazard of soil erosion rates, in some belongings reaching as high as 256t /ha/year (Negese, 2021). At the same time (Gete Z, 2000) assessment shows in northwestern highlands of Ethiopia and reported a very high rate of erosion ranging from 130 to 170 t/ ha/year. The current finding was suggested that assessment of soil loss and categorizes the land-use/land-cover change in the catchments area and Prioritizing depend on the average Soil loss rate 0-10t/ha/yr is low, Average Soil loss rate 10-20 t/ha/yr is moderate, while Average annual Soil loss rate ranges from 20-30t/ha/yr, 30-45t/ha/yr, 45-60t/ha/yr, 60-80t/ha/yr and 80-22965.3/ha/yr high, very high, sever, very sever and extremely sever respectively to be classified based on the data available and FAO and UNEP (1984), Adopted from (Abate' et al., 2011). The present study revealed that integrating GIS and RS technology and RUSLE model is the feasible way to evaluate average annual soil loss and prioritized based on the average annual soil loss. As indicated by, (Fig 4.4, Table 4.6), From the total study area(43119) hectors approximately about 3,706.75 hectare (8.6%) of the total study area require immediate attention to implement different types of soil and water conservation measures .

CHAPTER SIX

6. Conclusion and Recommendation

6.1. Conclusion

In this study try to assess the actual average of annual soil loss from Jemma catchment by RUSLE model and using geographic information system and Remote sensing (Maitima J et al.) techniques and examining and measuring the twenty years' time sequence land-use and land-cover changes in the study catchment west Gojam zone, Amhara Regional state, on south Ethiopia was investigated. As stated by the current finding results and the additional analysis, the following conclusions could be given. Firstly, as the finding suggested that the land-use/land-cover change detection was investigated in Jemma catchment. After the investigation of this study land use/land-cover change of twenty years was determined. As the finding reveals cultivated land and built up area in the catchment shows an increment by 4442.6 hectares and 5070.1 hectares respectively from the years of 2000 to 2020, at the same time bare land is increased by 1588.2 hectares from the year of 2000 to 2020. While shrub land and forest land in the catchment area was decreased by 8200.2 hectares and 920.2 hectares respectively from the years of 2000 to 2020. Finally, the river was which, cover small area (3%) from the other land use land cover types and remain unchanged from2000 to 2020. Secondly, integrating RUSLE model with RS and GIS data and with the help of field observations revealed, that some part of the catchment area which experienced to soil erosion hazards. While the present study revealed the potential soil erosion rate in Jemma catchment was assessed to be in the range of 0.0 to 22965.3ton/ha/year. The average soil loss for the whole catchment was calculated to be 208.5ton/ha/year from the total area of 43,119.45 hectares. The results of the current study showed that almost the entire study catchment which covers an area of about 3,706.75 hectares or (8.6%) of the annual soil loss rates and the severity classes is categorized under high to extremely severe soil erosion class. This study also tried to prioritize the catchment based on the average annual soil erosion rate. Therefore according to this study, the areas which are categorized as extremely sever, very sever, sever and very high 10.85ha (0.03%), 76.3ha (0.11%), 413.5 ha (0.96%) and 1230.9ha (2.9%) erosion class covers respectively and the total area covers 1,735.55hectares of land, which is about 4% of the total study catchment, while high erosion classes covers an area of 1,971.2 ha (4.6%) and moderate erosion classes covers an area of 5057.9ha (11.7%), and the other remaining 34359.8ha (79.7%) low erosion risk area. From here the area, which included in high to extremely sever possible soil loss area were need immediate interference by soil conservation measures. While the sever sub-catchment was suggested for sub catchment treatment mechanism to reduce the soil losses and to conserve the natural resources within the catchment. As the result of the study showed, immediate attention for soil conservation measures must be given to extremely sever, very sever and sever erosion risk area in the first stage, very high sub catchment can be considered in the second stage and high erosion risk area in the sub-catchment were could undergo at the last stage for this investigation. Thirdly, the Speedy increment of Population is related with to shortage of farm lands, this also the master problem that caused for land use/land cover change in the study catchment. As a result the local farmer need to expand their cultivated land especially small-scale cultivated by small holder farmers this is main problems for LU/LC change in Jemma catchment causing loss of several hectares of shrub lands and forest lands.

6.2 Recommendation

- This finding put forward that increments of cultivated land mainly small-scale cultivated by small holder farmers is the main causes of LU/LCC in Jemma catchment causing loss of several hectares of shrub lands and forest lands. Establish, controlling mechanism the increments of cultivated land at the expense of shrub lands and forest lands requires the right policy packages by national and regional governments such as livelihood diversification and improving the productivity of existing agricultural land by suppling of improved production inputs.
- The problem of food scarcity directly related to population growth and shortage of farm lands were the main reasons for land use/land cover change in the study area. To alleviate this problem; necessitates planning of good polices and strategies. As a result, the considered decision makers should prepare policies and strategies like creating and strengthening environmental friendly non-farm income generating activities.
- The catchments of the study area which has the soil loss further away from soil lose tolerable level requires special treatment. According to the areas which have fall down under very high, sever, very sever and extremely sever classes need immediate attention in their order of soil erosion potential.
- From the time when the highest part soil of the catchment is lost by water erosion, here the water-holding capacity and nutrient availability of the soil would be declined. Therefore concerned bodies like Abbay Basin Authority, Wereda & Local Managers should incorporate water and soil resource conservation and management practices during land use planning.

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8. Appendix 1: Rainfall Data of Fifteen Years (2005-2019)

A. Monthly rainfall data of Bahir Dar station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	0.7	9	85.6	25.6	57.1	141.8	496.7	292	278	52.8	6.7	0
2006	0	0	0	7.1	130.2	196.8	583.1	394	194.9	158.9	0	6.9
2007	0	0	1.8	34.2	41.4	315.4	744	407.7	286.3	110	9	6.9
2008	9.7	0	0	104.3	97.8	292.8	725.5	407.5	209.6	59.5	11.4	0
2009	0	0	6.6	2.9	13.7	59.5	419.3	618.5	77.5	54.5	1.3	0
2010	13.3	0	0	34	72.1	178.3	543.3	606.3	182.2	108.8	0.6	0
2011	1.6	0	28.4	5.7	175.7	257.4	529.1	394.6	144	19.5	28.1	0
2012	0	0	3.6	0	25.4	184.2	515.9	524.9	334.4	4	7	25.5
2013	0	0	0	4.1	105.2	206.5	765	460.6	107.1	155.1	25	0
2014	0	1.1	86.3	35.1	156.4	169.6	356.6	502.2	247.9	130	0.7	0
2015	0	1	0.2	0	160.8	137.7	383	266.1	170.1	116.7	13.5	34
2016	0	0	23.8	8.5	17.4	224.4	462.5	281.2	241.4	97.5	0	0
2017	0	59.4	4.5	25.061	86.025	78.8	502.5	400.5	189.5	105.9	3	0
2018	0	7.786	19.198	27.28	89.433	197.44	528.6	416.8	210.52	85.164	21.811	4.568
2019	4.1	0.5	4.6	30.1	113.2	378.4	353.6	276.9	239.1	63.8	148.4	4.829

B. Monthly rainfall data of Meshenti station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	0.500	0.000	22.800	16.600	44.400	161.300	383.700	222.700	228.300	89.200	12.000	0.000
2006	0.000	2.400	0.000	20.600	176.400	371.800	552.900	370.500	254.700	252.100	0.000	41.700
2007	24.900	2.900	18.600	31.800	109.300	382.300	268.600	295.300	123.900	164.900	28.700	0.000
2008	19.500	0.000	0.000	36.500	**129.946**	201.200	344.100	310.600	154.200	86.700	13.200	0.000
2009	0.000	0.000	12.900	10.300	27.300	67.300	330.800	300.400	75.800	105.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	143.200	64.600	434.100	434.100	133.300	79.500	6.400	0.000
2011	0.000	0.000	0.000	0.000	**129.824**	343.200	306.900	436.800	220.000	29.800	13.900	0.000
2012	0.000	0.000	15.900	0.000	8.300	247.400	752.500	273.600	247.400	11.700	0.000	**3.561**
2013	0.000	0.000	41.300	9.100	119.800	136.700	559.700	328.900	130.900	50.800	25.300	0.000
2014	0.000	4.800	48.500	73.900	215.700	149.200	461.600	215.700	224.900	64.400	0.000	0.000
2015	0.000	**4.706**	**17.389**	**35.168**	363.100	372.200	71.700	30.500	51.900	49.700	10.100	0.000
2016	65.500	20.300	16.000	3.400	135.400	239.100	31.700	61.600	42.800	0.000	0.000	**3.023**
2017	53.000	28.600	51.600	167.300	144.000	279.900	162.300	211.200	70.900	0.000	0.000	0.000
2018	**13.469**	**5.388**	**19.519**	**30.445**	**140.633**	**228.354**	**358.131**	**270.134**	**148.850**	80.500	**9.830**	**2.825**
2019	**13.195**	**4.027**	**20.182**	**28.493**	**141.428**	**236.619**	**358.435**	**265.077**	**151.699**	80.500	**9.084**	**4.538**

C. Monthly rainfall data of Merawi station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	3.99	2.7	16.8	20.4	107.3	214.6	445.7	285.3	296.5	109.6	17.75	0
2006	0.4	0	0.8	46.44	235.2	407	536.1	448.9	285.4	164.2	0.2	11
2007	0	0.7	26.9	26.7	111.3	455.2	273.5	270.5	279.6	86.9	52	0
2008	11.2	0	0	141.9	188.9	338.9	386	302.5	190.3	57.2	31.2	0
2009	0	5.5	31	15.7	57.1	199.4	469.4	469.3	115.7	108.1	19.9	22
2010	11.5	0	0.9	27.6	166.8	328.7	333.7	330.6	145.7	71.1	24.4	0
2011	20.6	0	17.5	10.3	164.3	401.5	427.9	337.5	264.4	84.4	27.5	0
2012	0	0	4	2.1	35.9	249.8	579.8	437	282	18.7	11.6	1.5
2013	0	0	0	15.6	154.4	220.7	510.9	239.9	159.6	135.6	27.6	0
2014	0	3.5	74	157.2	182.9	243.7	243.2	361.5	181.3	105.4	5	0
2015	0	0	8.4	0	226.1	244.4	282.2	208	124.7	0	18.16	0
2016	0	0	50.6	9.3	185.5	418.2	227.1	144.7	104.7	76.3	0	0
2017	0	51	1.4	47.5	199.1	182.3	152.7	175	249.5	30.8	0	0
2019	0	18.1	4.9	89.3	61.4	732.9	743.6	665.3	555.2	79.26	19.33	3.3
2019	0	18.1	4.9	89.3	61.4	732.9	743.6	665.3	555.2	81.32	17.9	3.4

D. Monthly rainfall data of Durbete station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	0	0	17.022	45.1	155.5	291.01	424.233	410.33	230.52	94.15	24.636	0
2006	0	0	2.3	30.3	232.8	454.5	528.8	320.7	228.8	166.7	1.5	32
2007	0.3	1	15.1	35.1	135.9	300.8	329.3	364.7	181.2	66.6	48.8	0
2008	27.7	0	1.3	64	152.5	334.9	566.1	440.6	210.4	28.7	10.8	1.8
2009	0	16.6	88	0.8	31.8	313.4	456.6	514.6	160	83.7	4.9	31.2
2010	17.7	0	0	19.3	92.1	210.1	360.2	279.5	180.6	43.7	7.5	7.9
2011	18.5	0	19.3	0	205	377.4	348.7	585.5	326.3	41.9	12.3	0
2012	0.4	0	0	4.3	102.4	389.4	456.3	390.6	243.8	36	26.7	14.2
2013	0	12	1.9	20.9	146.3	179.9	578.1	429.8	199.7	87.2	48.9	0
2014	0	4.5	43	104	282.4	302.9	306.3	314.1	214.1	192.7	28.5	0
2015	0	0	5.4	0.3	183.5	217.5	424	409.5	176.6	85.8	59.7	40
2016	0.9	0	10.7	64.6	243.1	347.2	389.8	307	217.3	70.3	12.9	0
2017	0	27.5	11	55.9	193.7	251.3	431.8	493.1	248.4	78.1	39.2	0
2018	0	6.461	19.056	42.8	150.7	291.08	425.617	312.7	228.78	91.85	25.701	10.09
2019	0	18.8	17.2	116	82.7	192.3	340.7	398.1	286.5	157.5	25.21	9.562

E. Monthly rainfall data of Sekela station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	2.000	**4.323**	81.200	43.800	101.200	377.500	499.900	337.500	271.200	161.400	56.700	2.700
2006	**12.265**	8.400	14.000	43.200	264.500	342.400	436.200	579.300	332.600	239.200	41.600	40.000
2007	50.800	3.700	35.100	88.300	181.900	375.500	397.500	314.800	331.400	111.900	41.500	0.000
2008	46.300	5.000	0.000	188.400	309.900	318.800	421.700	348.500	272.000	117.500	32.500	11.500
2009	0.000	1.500	59.200	78.200	44.900	319.600	516.300	453.600	152.400	190.300	19.200	58.900
2010	10.900	0.000	0.000	51.000	193.300	585.900	625.200	695.900	461.900	74.000	**45.410**	23.200
2011	19.100	0.400	81.900	36.100	169.900	325.400	**496.325**	453.300	286.800	51.100	62.900	**14.888**
2012	0.000	0.000	30.500	5.300	23.600	**349.830**	**508.478**	**455.497**	**261.261**	**131.326**	**47.436**	**15.028**
2013	**12.824**	**4.437**	**35.683**	**53.292**	**176.459**	**365.918**	467.600	308.800	158.600	39.600	12.400	0.700
2014	0.000	0.000	23.000	0.000	268.900	238.800	320.400	402.200	180.900	148.700	100.000	23.300
2015	6.000	0.000	17.400	0.000	211.400	289.900	384.100	384.100	244.900	143.700	0.000	0.000
2016	0.000	21.200	**36.794**	**54.096**	**176.974**	380.200	628.400	468.700	131.800	189.700	82.500	0.000
2017	**12.104**	**3.672**	**35.874**	**54.431**	**175.816**	**356.433**	849.700	627.700	472.000	**134.303**	**47.340**	**15.269**
2018	**12.704**	**3.594**	**35.661**	**54.425**	**181.158**	**353.462**	**492.249**	**449.109**	**285.096**	**137.015**	**44.018**	0.000
2019	0.000	**3.976**	**33.922**	**52.369**	**183.956**	**357.821**	**516.135**	**436.784**	**284.434**	**144.881**	**44.659**	**14.719**

F. Monthly rainfall data of Adet station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	1.700	0.000	27.900	40.400	**118.253**	105.100	331.600	213.600	192.600	**90.764**	27.400	0.000
2006	0.000	0.800	4.300	19.000	116.400	175.000	439.300	**234.312**	236.500	150.300	17.500	27.500
2007	3.500	1.000	14.100	19.700	94.300	271.900	313.800	**239.977**	137.700	60.200	27.000	0.000
2008	15.100	1.000	0.000	168.200	150.600	142.600	331.200	320.000	167.100	79.700	23.800	0.000
2009	0.000	10.900	34.700	32.600	46.000	100.700	297.700	281.500	124.900	80.200	7.300	15.000
2010	22.500	0.000	0.000	44.700	78.600	160.000	364.200	249.300	182.900	69.600	1.200	1.500
2011	21.200	0.000	23.900	70.500	161.600	83.600	338.700	213.600	155.000	69.500	1.200	1.500
2012	**4.770**	**8.837**	**29.522**	**58.450**	35.000	177.600	**320.323**	297.200	142.900	27.000	76.500	13.800
2013	0.100	**8.212**	11.000	5.700	112.700	157.600	373.800	266.500	112.600	110.100	25.200	0.200
2014	0.000	3.500	114.200	85.600	188.300	130.600	210.800	200.200	151.800	108.500	21.700	0.000
2015	0.000	1.800	22.300	0.800	139.300	141.700	181.100	188.500	124.300	155.900	49.500	26.400
2016	0.000	2.500	73.800	21.400	201.200	161.000	294.800	142.800	96.200	90.600	0.200	0.000
2017	0.000	40.900	17.700	121.900	110.500	80.000	402.200	181.300	143.400	103.900	53.400	0.000
2018	0.000	**8.320**	**30.839**	**54.144**	**115.489**	**164.167**	307.800	**241.950**	**156.896**	**89.587**	**25.735**	**6.251**
2019	0.000	29.900	29.200	65.900	105.700	301.600	362.700	306.800	235.500	57.200	**26.237**	**7.382**

G. Monthly rainfall data of Dangila station

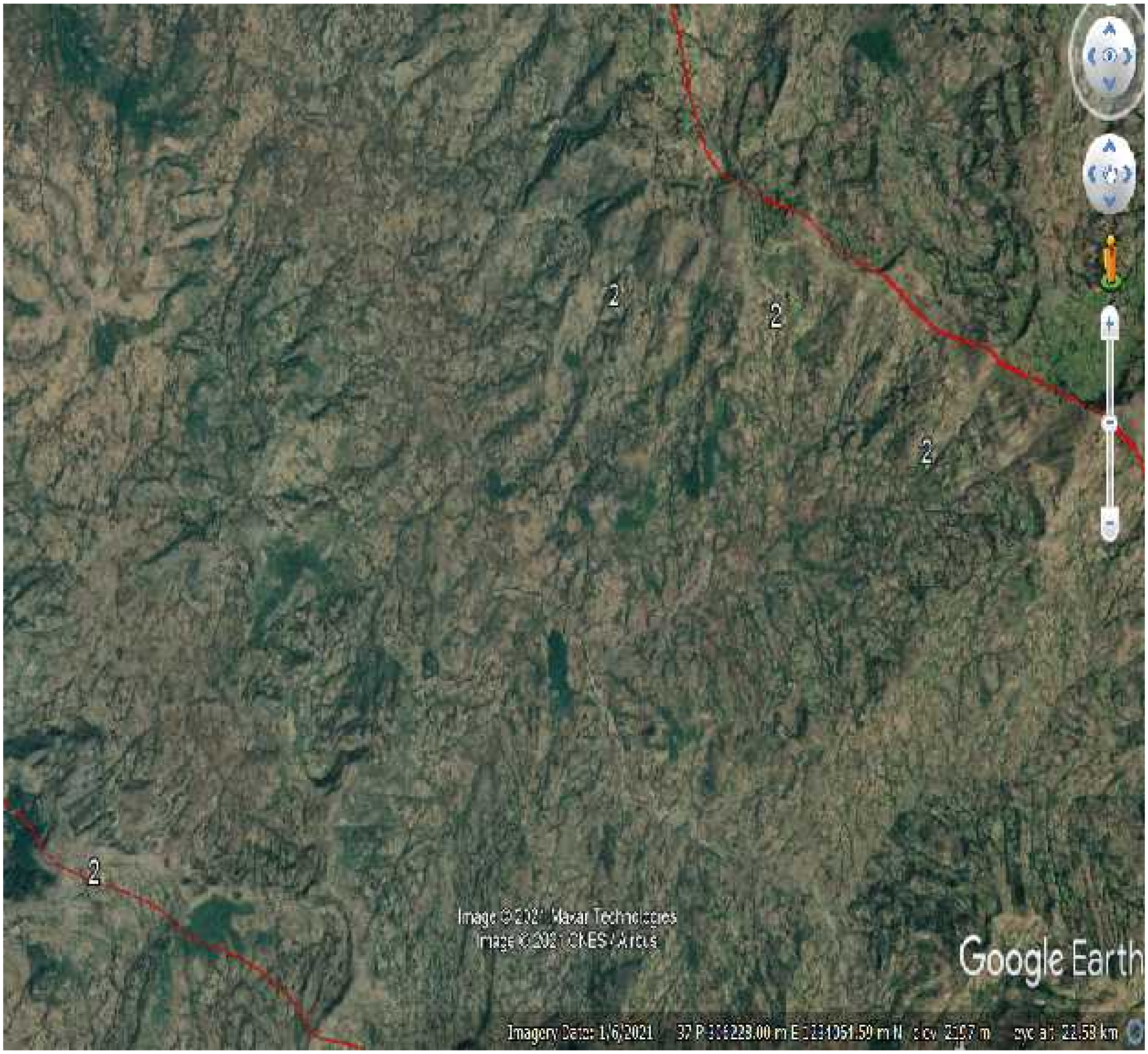
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	4.000	0.500	29.200	7.400	48.100	270.900	318.500	344.700	320.700	54.100	7.300	0.000
2006	2.900	0.000	0.000	47.900	258.900	339.700	440.200	392.900	227.600	133.100	6.800	19.000
2007	0.000	1.000	12.300	50.600	131.700	268.100	314.300	384.400	197.700	60.300	58.300	0.000
2008	40.100	0.000	4.800	119.700	251.100	292.100	434.600	421.900	256.400	28.600	6.800	2.000
2009	0.000	6.900	18.800	11.900	24.000	317.000	334.100	433.000	121.300	160.700	26.600	0.300
2010	0.000	0.000	0.500	31.500	149.900	192.000	339.900	431.500	290.100	67.300	14.200	4.800
2011	4.000	2.000	31.200	20.500	228.800	271.900	339.000	432.700	217.100	48.000	4.000	0.000
2012	0.000	0.000	2.700	0.000	63.800	286.900	412.600	500.600	189.700	52.700	107.600	23.800
2013	0.000	0.000	5.600	0.000	169.400	207.300	570.200	376.100	391.700	189.400	13.200	1.700
2014	0.000	3.900	56.500	134.700	302.500	248.600	360.400	314.400	341.200	195.700	49.000	1.300
2015	0.000	0.000	41.100	1.000	272.000	269.100	258.800	355.400	290.300	86.400	137.600	19.300
2016	0.000	0.000	29.900	28.700	223.300	158.600	409.500	413.200	221.400	109.900	1.000	0.000
2017	0.000	44.500	0.000	198.100	302.400	240.800	332.300	356.600	321.500	106.700	0.300	0.000
2018	0.000	**5.045**	**20.192**	**53.187**	**177.157**	**260.719**	**378.143**	287.500	238.700	139.600	**31.953**	**4.739**
2019	0.000	**5.030**	**17.736**	**50.086**	**184.948**	**254.372**	**377.190**	**393.242**	**257.243**	**103.774**	**33.992**	**5.247**

9. Appendix 2 Validation of Erosion Prone Areas

A. Validation of Very High erosion areas

B. Validation of sever eroded areas

C. Validation of very sever eroded areas



D. Validation of extremely sever eroded areas