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Geo-Environmental Impact Assessment Using Integrated GIS and Remote Sensing Technique: A Case Study on the Halele-Werabesa Stage I Hydropower Plant, West-Showa Jimma Zone, Oromia, Ethiopia

By

MEKDES ZENEBE KETEMA

A Thesis Submitted to
The School of Earth Sciences Presented In Partial Fulfillment the Requirement Degree of Master of Science in Remote Sensing and Geographic Information Systems (GIS)

Addis Ababa University
Addis Ababa, Ethiopia
MAY, 2014

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This is to certify that the thesis prepared by Mekdes Zenebe entitled: *Geo-Environmental Impact Assessment Using Integrated GIS and Remote Sensing technique: a case study on the Halele-Werabesa Stage I Hydropower plant, West Showa, Jimma Zone, Oromia, Ethiopia* and submitted in Partial Fulfillment the Requirement Degree of Master of Science in Remote Sensing and Geographic Information Systems (GIS) compiles with the regulation of the University and meets the accepted standards with respect to originality and quality.

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Table of Contents

List of Figures

List of Table

ACRONYUM

ASL	Above mean Sea Level
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EEP	Ethiopian Electric Power
EEPCO	Ethiopian Electric Power Corporation
EIA	Environmental Impact Assessment
EIGS	Ethiopian Institute of Geological Survey
EMA	Ethiopian Mapping Agency
FAO	Food and Agriculture Organization
GEIA	Geo-Environmental Impact Assessment
GIS	Geographical Information Systems
LR	Logistic Regression
LU/LC	Land Use Land Cover
MoA	Ministry of Agriculture
NMSA	National Meteorological System Agency
PHE	Population, Health and Environment
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
SNNP	South Nation Nationalities and Peoples
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator

ABSTRACT

Geo-environmental impact assessment is often evaluated systematically in order to assess the nature of hazards and their potential damage to human life, land, buildings and other property. This study reports geo-environmental impact of Halele - Werabesa stage I dam reservoir and its surrounding environment located within Omo-Gibe Basin 170km south east of Addis Ababa. The main objective of the present study was to assess the potential Geo-environmental impact using integrated methods of GIS and remote sensing. To end up with mass wastage risk map of the study area two models were devised namely landslide susceptibility and soil erosion risk models. Seven landslide-controlling parameters namely lithology, slope, aspect, drainage density, lineament density, soil and land use were identified in order to detect Landslide susceptibility risk using logistic regression model. As result landslide susceptibility of the study area varies from very low (28.3%), low (40.8%), moderate (21.5%), high (7.8%) and very high (1.6%). This is mainly the result of slope and soil type in the area. The soil erosion risk analysis was also conducted using RUSEL model in GIS environment. It is conducted using R, K, C, P and LS factors. Result of the analysis shows the total amount of soil loss in the study area is about 294 tons per year from a total area of 7197.8 km^2. Most of watershed area falls within the low soil erosion risk category (76.1%) which is mostly seen in the west and central parts of the watershed. While 0.6 % of the watershed is categorized as very high soil erosion risk area. By combining the landslide susceptibility and soil erosion risk map of the study area mass wastage map is prepared; which shows area which needs conservation priority. The results indicated that 78.8%, 16.2%, 4.3%, 0.7%, of the study area was under low, moderate, high and very high mass wastage risks, respectively. Since 5% of the study area is under high and very high risk these areas need conservation priority.

Keywords: GEIA, landslide susceptibility, logistic regression, mass wastage, RUSEL

CHAPTER ONE

INTRODUCTION

1.1 Background

During the 20th century large dams emerged as symbols of modernity. Hailed for being an effective way to harness water resources for food production, energy generation, flood control and domestic use, dams became synonymous with progress and economic development (Namy, 2010). As of 2005, hydroelectric power, mostly from dams, supplies some 19% of the world's electricity, and over 63% of renewable energy, much of this is generated by large dams. Although China uses small scale hydro generation on a wide scale and is responsible for about 50% of world use of this type of power (http://en.wikipedia.org/wiki/Dam).

Ethiopia has a huge potential for hydropower development. It's a generation capacity is estimated at 45,000 MW. However, so far, the utilization of this potential is limited to 2,000 MW which is less than 4.5 % of the existing potential. Despite the availability of such huge hydropower potential, currently access to electricity in Ethiopia is only about 35 % and only 5,189 towns and villages out of 7,000 are electrified. Most of the populations in the country live in poverty and energy insecurity. Use of traditional fuels such as fire wood still continues aggravating the soil erosion and forest destruction (EEPCO, 2010).

As effective development and management of hydropower is central to the quest for sustainable development, meaningful economic growth to the country's industrial and agricultural development, the Government of Ethiopia has given due attention and commitment to the power sector and has devoted itself to develop the electric power generating capacity of the country through harnessing the huge water resources potential available (EEPCO, 2010).But according to Buzayehu 2006 there are risks related to change in climatic conditions and geo hazards which might influence the expected benefits. As a result the existing and the new dams of Ethiopia are under threat of several impacts such as siltation, landslide and soil erosion which has been the major factors affecting the life span of the different hydroelectric power structures.

A degraded local environment also increases the cost of hydraulic structures and reduces their valuable life span. Vegetation losses and consequent soil erosion makes dams to silt up much faster, leading to situations of below optimal production of power than planned. Sediment accumulation and outlet hampers proper operation of dams and also causes reservoirs to submerge more area with consequent lose in land use, biodiversity and social impact (Buzayehu, 2006). Thus it is a paramount importance to carry out Geo-environmental impact assessment of reservoir and the surrounding watershed.

Geo-environmental impact assessment has been recognized as an integral part of early planning studies of any project which have a significant adverse impact on the reservoir and surrounding environment. It enables to identify any expected negative impacts and to suggest the necessary actions. In addition, it also considers different designed alternatives for the project as an essential step for better decision making (Balram *et al*., 2013).

The application of geographic information systems and remote sensing can facilitate the assessment of geo-environmental impact of a reservoir for a better outcome. Besides, these applications facilitate the assessment of geo-hazards. Results arising from such assessment studies are important for planning and decision making processes.

1.2 Statement of the Problem

Hydropower is currently the most common form of renewable energy and plays an important part in global power generation. However, it has its own potential negative consequences in terms of its vulnerability to impacts of climatic changes, geo-hazards, and manmade adversities like deforestation and other anthropogenic activities. This might challenge the economic life span of hydraulic structures of hydro power plants like reservoir and dam (PHE, 2010).

Effective development and management of hydropower is central to the quest for sustainable development and meaningful economic growth to country’s industrial and agricultural development. Sustainable development in its simplest form advocates that the present generation develops and manages the available resources to achieve growth and social and economic well-being in such a manner that will not jeopardize the chances of generation yet unborn in meeting their own needs (Innocent and Ukoje, 2009). However, there are risks related to change in climatic conditions and geo-hazards which might influence its expected benefits of hydropower development.

Geo- hazards such as landslide, soil erosion and siltation increase the cost of hydraulic structures and reduce their valuable life span. If the dam silt up much faster cause reservoir to submerge and as result lose in land use, biodiversity and social impact. Hence, the extent of geo-environmental impact should be studied at this stage of the dam construction which helps to mitigate the negative impact of the project in its early stage to secure better and long lasting advantages (PHE, 2010).

The main concern of this research work is thus to assess the geo-environmental impacts which affect the Halele-Werabesa stage I Hydropower plant using remote sensing and GIS. Remote sensing is one of the approaches to better understand and predict impact of surrounding area on the life span of the reservoir (Cawley, 2012). In addition, analyze the existing interaction and interrelation among the environmental elements and there by reach at conclusions.

Regarding similar works on the site, as result of inaccessibility of the study area EEP (Ethiopian Electric Power) studies only the dam site. In this study, the researcher conducts research for the whole watershed where the reservoir covers, using integrated methods of remote sensing and GIS. This decreases the cost and time needed to conduct research covering the whole watershed besides enables to cover inaccessible areas.

1.3 Objective

1.3.1 General objective

To assess the potential Geo-environmental impact which affect Halele- Werabesa stage I hydro power plant and its surrounding environment using integrated methods of GIS and remote sensing techniques.

1.3.2 Specific objectives

- Locate areas which are susceptible to landslide.
- Estimate the actual annual soil loss from the watershed.
- Produce mass wastage risk map.

1.4 Significance of the study

Geo-environmental impact assessment using integrated methods of remote sensing and geographic information systems allows mapping possible locations of geo hazard. In doing so it is possible to relinquish the existing signs of environmental disasters and its forthcoming consequence.

The thesis has special contribution in identifying the geo-environmental impacts in the watershed and addresses them in more scientific ways. Furthermore; it helps in identifying the future possibilities of occurrence and trend of the negative consequence so as to take positive measures and avoid the occurrence of similar glitches. On the other hand the paper can give a yellow light for the concerned body to take justifiable action at the right time and place. Finally, the findings of the research can serve as an input for further investigations and studies.

1.5 Scope of the study

This study considers only landslide susceptibility, soil erosion risk and mass wastage as parameter to assess geo-environmental impacts in the study area. Also to come up with mass wastage risk map only landslide and soil erosion are used. Study area is delineated with special attention to watershed of Halele-Werabesa stage I Hydropower plant area that includes fourteen woredas namely Sibu Sire, Billa Seyou, Chelia, Bako Tibe, Wama Boneya, Tikur, Dano, Nonno, Limu Seka, Limu Kosa, Sekoru,Tiro Afeta, Kersa and Gorro. This is believed to show the direct and indirect impacts of the flanking areas in addition to the project site. Taking the available time and resource into consideration, it is reasonable and convincing to limit the scope of the research topic on the above stated parameters.

1.7 Limitation of the study

The study has faced lack of up-to-date high resolution satellite images which covers the whole study area.

1.8 Organization of the thesis

This thesis is composed of six chapters. The first chapter introduces the background, problem definition and general and specific objectives of the thesis. In addition it deals with the significance, scope of the research work and the limitation with results inadequacies.

The second chapter mainly deals with review of related literatures on geo-environmental impact assessment, Hydropower and role of GIS and remote sensing in geo-environmental impact assessment.

The third chapter gives the general description of the study area as well as the materials used and the methodology adopted so as to achieve the intended objective.

The fourth chapter deals with analysis and interpretation of different parameters used in the study.

Under Chapter five, the landslide susceptibility, soil erosion risk and mass wastage in the study area are discussed. It also identifies areas with risk of these geo-environmental impacts.

The final chapter gives summary of the study and forward feasible recommendations helpful for geo-environmental conservation and sustainable power development.

CHAPTER TWO

LITERATURE REVIEW

2.1. Hydropower Development in Ethiopia,

According to CSA 2007 report Ethiopia is a country with an estimated population of 73 million, the second most populous country in Sub-Saharan Africa. There are an estimated 15.6 million households in the country of which only some 4.5 % are supplied with electricity. Much of the remaining population survives in conditions of relative poverty and energy insecurity. They use firewood for cooking and heating thereby exploiting an ever diminishing resource and contributing to soil erosion, soil degradation and habitat destruction. If the quality of life of that population is to be improved and environmental degradation halted then a considerable amount of new electricity generation capacity must be constructed.

Expansion of power system and energy is central to transform the development. Per capita consumption of electricity is only 7% of the sub-Saharan average, despite the capacity to produce up to 45,000 MW from power generation mix. It is undeniable that the power is crucial for economic development. Peak demand and sales on the interconnected systems shot greater than 25% from 2009 onwards by industry, commercial and domestic customers (PHE, 2010).

However, so far the utilization of this potential is limited to 2,000MW which is less than 4.5% of the existing potential. Currently, access to electricity in Ethiopia is only about 35% and only 5,189 towns and villages out of 7,000 are electrified. In Ethiopia, the average per capita energy consumption is about 36kWh while the minimum average level of consumption per capita for reasonable quality of life is about 500kWh. This corresponds to an annual electricity consumption of 46,344GWh based on current population (EEPCO, 2010).

Hydropower generation is the major source of energy in this future plan, accounting about 95% of the total power generations. The midterm expansion plan to 2015 mainly contains hydropower plants thus increasing the hydropower share to nearly 100%. Nonetheless, dependence on such a predominantly hydropower system has its own potential negative consequences in terms its vulnerability to impacts of climatic changes, geo-hazards, and manmade adversities like deforestation other anthropogenic activities. This might challenge the economic life span of hydraulic structures of the hydro power plant like dams and reservoir (PHE, 2010).

Despite its importance, change in climatic condition resulting in huge form of flooding and raise in evaporations, Geo hazard problems like landslides, gullies and siltation are some of the anticipated challenges and environmental problems threatening the long benefits of the dam and hydropower development.

2.2. Geo-Environmental studies definition,

Balram *et al*., in 2013 define Geo-environmental studies as it aim to predict geosystem response to various types of active interactions. It is an in depth treatment of the relations between man and his geologic, geomorphic, physical and cultural environments. Environmental geology is essentially the geology of interactions amongst various geo-factors, environmental geological assessments of landscape recognizes potential hazards and natural resources potential and deals in both the site-specific or theme-specific aspects of environmental impacts. Investigations on geologic environments include: river basins or hydrological systems, contamination of groundwater, dry land environments such as the deserts and desertification; coastal environments and processes of erosion and deposition; cold environments and glaciers, earthquakes, active faults, volcanic eruptions, mud flows, landslides and mass-wasting events, etc. and above all the bio-geochemical cycles and human health.

Geo-environmental investigations are multi-disciplinary and require a comprehensive and integrated approach. These include flood hazards, landslides, and earthquake-related natural hazards, water-logging and salinity/alkalinity aspects, urban and rural development, environmental degradation due to resource exploitation, mining areas and soil erosion and watershed management, environmental impacts of surface water reservoirs, dams and barrages, coastal dynamics and shore-line changes, medical geology and geo-tourism studies etc. (Balram *et al.*, 2013).

The ultimate goal of a geo-environmental assessment is to divide the study area into homogeneous units that can show the differential suitability for intended land-use and also vulnerability for a certain problem. The results of suitability and vulnerability assessment can be professionally mapped to show diverse areas with different levels (Ju *et al.*, 2012).

Proper investigation, interpretation and analyses of different terrain parameters such as elevation, topography, slope instability and geology of the dam site hold the key for the success of the dam in terms of economic sustainability and durability (Khan *et al.*, 2011).

2.3. Geo-Environmental Hazards Affecting Dams

Dams provide multifaceted purposes to the socio-economic development of a nation through irrigation in agriculture and generation of hydro-electric power in the supply of energy. It is a bold fact that the hydroelectric power generated using dams are environmentally friendlily and introduced clean and green technologies to the nation. However, due to environmental phenomenal happening and persistent human action around watershed dams are facing problems in relation to siltation, landslides and degradation and nutrient accumulation (PHE, 2010).

Most of the hazards occurred during the construction and commissioning/impoundment phases of dams and reservoir. Excavation scars the natural landscape and changes the shot-period stress distribution of the slope. This sometimes gives rise to landslides, collapses and debris flows. Furthermore, excavation causes floating dust that pollutes the air, destroys vegetation, and causes water loss and soil erosion (Ju *et al.*, 2012). As a result, it cause increases the cost of hydraulic structures and reduces their useful life span. Vegetation losses and consequent soil erosion makes dams to silt up much faster, leading to situations of below optimal production of power than planned. Sediment accumulation and outlet hampers proper operation of dams and also causes reservoirs to submerge more are with consequent lose in land use, biodiversity and social impact (Buzayehu, 2006).

2.3.1. Landslide

Landslide hazard zonation helps in identifying strategic points and geographically critical areas prone to landslides. Landslide hazard zonation simply means the division and preferably subdivision of land surface in to various zones according to the degrees of actual potential hazard caused by landslides and related phenomena. The key factor in landslide hazard mapping is the assessment and grading of risk associated with the failures (Baban and Sant, 2005).

According to Schuster (1979) as cited in Petley (2013) reviewed landslides induced by reservoirs, noting that the failure of slopes into lakes can induce the following hazards:
(1) Water waves that can cause local damage along the reservoir shoreline and, if overtopping occurs, to structures downstream of the dam;
(2) Damage to the dam itself and to its associated infrastructure;
(3) Loss of storage capacity;
(4) Delays to the construction of the project.

In addition, landslides on the flanks of reservoirs can cause environmental problems, such as the loss of ecosystem services. Landslides impact upon dam construction and operation at all phases of such a project, but the greatest impacts usually occur in the construction and commissioning/impoundment phases of a project (Petley, 2013).

Landslide is one of the major hazards associated with the dam. Landslide can also induce further landslides, barrier lakes and landslide induced flood. Hard accessibility and large spatial extents makes management of landslide hazard difficult and dangerous. Today remote sensing technology makes the landslide hazard management easier as it provides real time information and has the ability to analyze the information addressing the large spatial extents and tough accessibility problems (Li *et al*., 2012).

2.3.2 Landslide Susceptibility Analysis

According to Soeters and van Westen (1996) as cited in Baban and Sant (2005) the major approaches to landslide susceptibility analysis are as follows:

Deterministic approaches: These are dependent on utilizing numerical models for slope stability analysis at large scales. Furthermore, they require a large amount of detailed parametric data, such as geotechnical and groundwater condition as inputs. The outcomes from analyses are often detailed expressions of the hazard either in an absolute form or as engineering based safety factor for slopes. This approach does not seem to be well suited for regional analyses due to its requirements for large amounts of parametric data that are often unavailable and economically prohibitive to acquire.

Statistical approaches: These are generally grouped into either bivariate or multivariate analyses. The combination of landslide conditions at known landslide sites is statistically analyzed using large amounts of data and predictions are generated for areas currently free of landslides. In this approach, past landslide conditions are utilized to provide an indication for forecasting potential landslide sites in the future.

Heuristic or an expert driven approach: This approach requires a geomorphologist's input into determining the type and degree of hazard within an area either by direct mapping in the field or indirect mapping often based on utilizing remotely sensed data.

2.3.3 Soil erosion

Soil erosion in watershed areas and the subsequent deposition in rivers, lakes and reservoirs are of great concern for two reasons. Firstly, rich fertile soil is eroded from the watershed areas. Secondly, there is a reduction in reservoir capacity as well as degradation of downstream water quality (European Environment Agency, 1995as cited in Arekhi *et al*., 2012).

According to Pimental (1998, as cited in Arekhi *et al*., 2012) although sedimentation occurs naturally, it is exacerbated by poor land use and land management practices adopted in the upland areas of watersheds. Uncontrolled deforestation due to forest fires, grazing, incorrect methods of tillage and unscientific agriculture practices are some of the poor land management practices that accelerate soil erosion, resulting in large increases in sediment inflow into streams. Therefore, prevention of soil erosion is of paramount importance in the management and conservation of natural resources.

Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and the very survival of the overwhelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced (PHE, 2010). According to FAO (1986, as cited in PHE, 2010) estimated that water erosion moves nearly 1.9 billion tons of fertile soil from highlands of Ethiopia annually.

The removal of natural forests for the expansion of arable land, for fuel wood, charcoal and construction materials, overgrazing, intensive cultivation and poor cultural and land management practices have been stated as the major cause of soil erosion (MoA, 1989 as cited in PHE, 2010).

Weather, soil, vegetation cover and topography are the main factors which determine the amount of soil erosion. Rate of sedimentation in water reservoirs have spatial and temporal variation. Initially, fine grained sediments usually consist of muds and silts having a tendency to be localized and transient on the downstream part, temporary fills the pools in the reservoir. Geo-Spatial Techniques made analysis of these factors quite easy and accurate; hence simplify mapping of soil erosion susceptible areas (Ahmad *et al*., 2013).

2.3.4 Mass Wastage

Mass wastage is the transfer or movement of rock or soil down slope primarily by gravity. Typically, slope movement, landslides, mud flows, topples, falls and slides are being categorized as different types of mass wasting or mass movement phenomena (Farrokhnia *et al*., 2010). Landslides and soil erosion are mass-wasting events where large amounts of weathered rock and soil material slide down a hill slope or mountain side

(ftp://ftpdata.dnr.sc.gov/geology/Education/PDF/Weathering%20and%20Erosion.pdf).
So in this study by combining soil erosion risk map and landslide susceptibility researcher prepared mass wastage map of the study area. This map can be used to determine areas which need conservation priority.

2.4. Application of GIS and remote sensing in Geo-environmental impact assessment

According to Sanderson (2005) remote sensing can be broadly defined as the collection and interpretation of information about an object, area, or event without being in physical contact with the object. Aircraft and satellites are the common platforms for remote sensing of the earth and its natural resources. It relies upon measurement of electromagnetic energy reflected or emitted from the features of interest.

The electromagnetic (EM) spectrum is the continuous range of electromagnetic radiation, extending from gamma rays (highest frequency & shortest wavelength) to radio waves (lowest frequency & longest wavelength) and including visible light. The major regions of interest in satellite sensing are visible light, reflected and emitted infrared, and the microwave regions.

In remote sensing, a detector measures the electromagnetic (EM) radiation that is reflected back from the Earth's surface materials. These measurements can help to distinguish the type of land covering. Soil, water and vegetation have clearly different patterns of reflectance and absorption over different wavelengths. The capacity of remote sensing to identify and monitor land surfaces and environmental conditions has expanded greatly over the last few years and remotely sensed data will be an essential tool in natural resource management (Sanderson, 2005).

According to Bahiru Girma (2010) Geographic Information System (GIS) is a computer-assisted system for handling spatial information. GIS software can be considered as a collection of software programs to acquire, store, analyze, and display information. The input data can be maps, charts, spreadsheets, or pictures. The GIS software can analyze these data using image processing and statistical procedures. Data can be grouped together and displayed as overlays.

A geographical information system (GIS) is a powerful tool for geo-environmental evaluation in urban planning and designing. The spatial analysis power of GIS has been widely used to assess land use suitability by mapping and analysis (Balram *et al*., 2013).

GIS as a decision support tool, it can also be used to display the results of other environmental models such as air and water pollution dispersion models together with other layers of information held in the GIS to 'add value' to analytical results and their implications. GIS can be particularly valuable in an environmental monitoring role to identify and delineate spatial changes in environmental conservation provides a measure of flexibility and timeliness when responding to environmental questions. Since the GIS data set can be readily updated in the light of new information or changes in environmental conditions it maintains a far greater currency than a paper map which may be several years old and represents only a snapshot of environmental conditions at a point in time. When the environmental GIS are updated the result of the query is also updated, as the results of the environmental model to which that new data element was added. Hence the environmental GIS can be used for environmental contingency planning or disaster management (Bahiru Girma, 2010).

Spatial data processing especially using GIS techniques has been playing an important role in different applications. Multiple source spatial and non-spatial data can be processed and integrated for the analysis of spatio-temporal dimension of a given area (Qureshi *et al*., 2012 as cited in Ahmad *et al*., 2013).

Geo-Spatial Techniques used to analyze spatial and temporal changes in the surface geomorphology proved very useful in major engineering projects like dams. Physical data collection can be a very difficult job for dam design due to the inhospitable environment, cost, harsh weather conditions and security issues. Consequently, Geo-Spatial Techniques will provide not only fast and accurate but also reliable data, which can be further analyzed in order to give complete picture of the dam site (Salih and Al-Tarif, 2012).

Under this study of Geo-Environmental studies is selected the main objective of the work to apply remote sensing data to study of natural resources including landforms, soil, vegetation, slope for geo-environmental investigations of resources, from the geo-environmental appraisal point of view highlighted the significant impact on the Halele-Werabesa stage I project.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

The Halele -Werabesa stage I Dam (Halele Dam) is located 170 km east-south-east of Addis Ababa within the Omo-Gibe Basin. The study area falls under the jurisdiction of the Oromiya and SNNP National Regional Administration. Administratively, water shade which the reservoir of dam is in stretches over fourteen woredas namely Sibu Sire, Billa Seyou, Chelia, Bako Tibe, Wama Boneya, Tikur, Dano, Nonno, Limu Seka, Limu Kosa, Sekoru,Tiro Afeta, Kersa and Gorro. The study area location extends from latitude 8°40'32"–9°22'01" N and longitude 36°52'13"–37°17'50" E covering a total area of 7197.8 km^2 (Fig.3.1).

As its name implies, the Halele - Werabesa Stage I scheme is the first development in a cascade. The second stage development is located some 35 km downstream on the same Gibe River at Werabesa. The Halele - Werabesa stage I development include dam and huge reservoir, with a total storage of about 3300 Mm^3 and a total surface area of about 280 km^2, will provide the capacity to regulate the Gibe River flows. It will have a total capacity 500 Gwh/y.

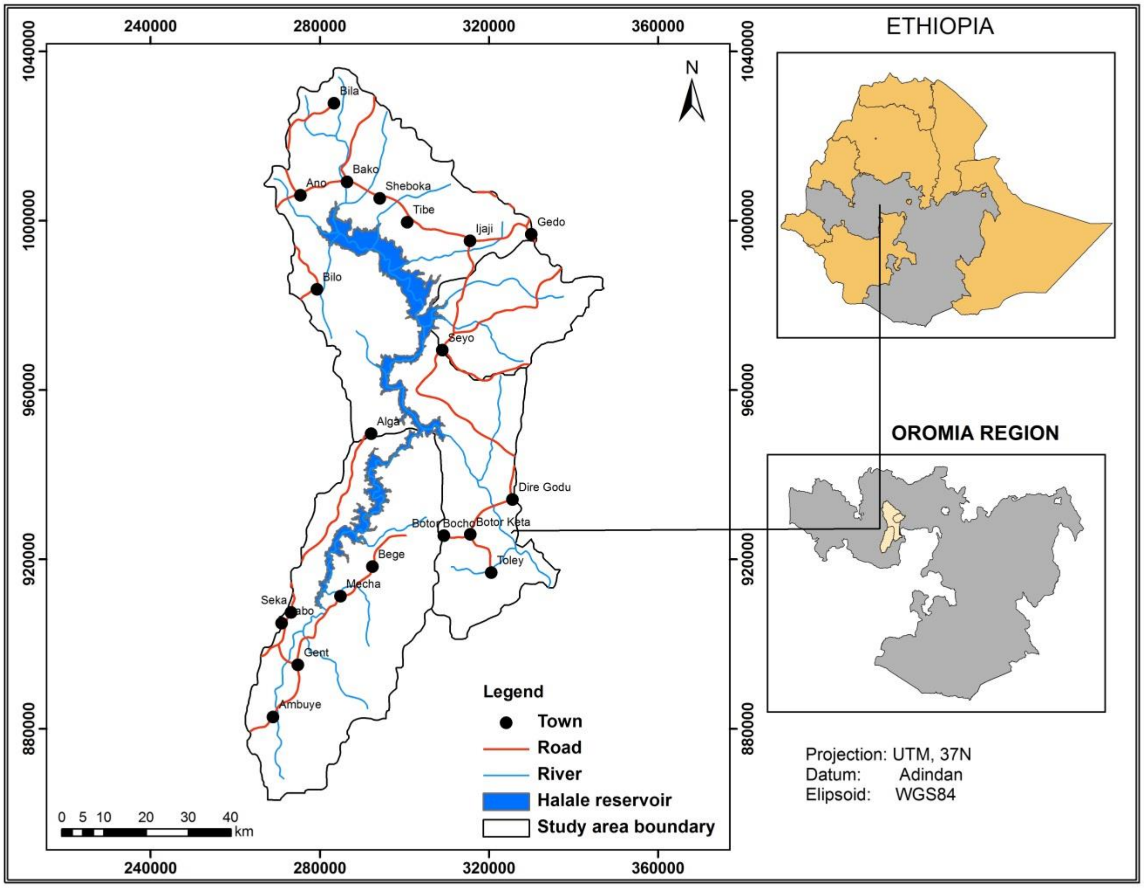


Figure 3. 1 Location map of the study area.

3.1.1 Topography

The study area and its surrounding are characterized by large basins enclosed by mountain ranges up to 3200 m asl. The slopes in the catchments are mostly gentle and only in the highest parts steep slopes are found. The Gilgel Gibe River, which flows through Jimma zone from south-west to north-east, is a tributary of the Great Gibe River (known as the Omo River further downstream) and is extremely variable in course and gradient. The lowest area in the study area is about 1,080 m asl whereas the highest area is 3,129 m above sea level (Fig 3.2).

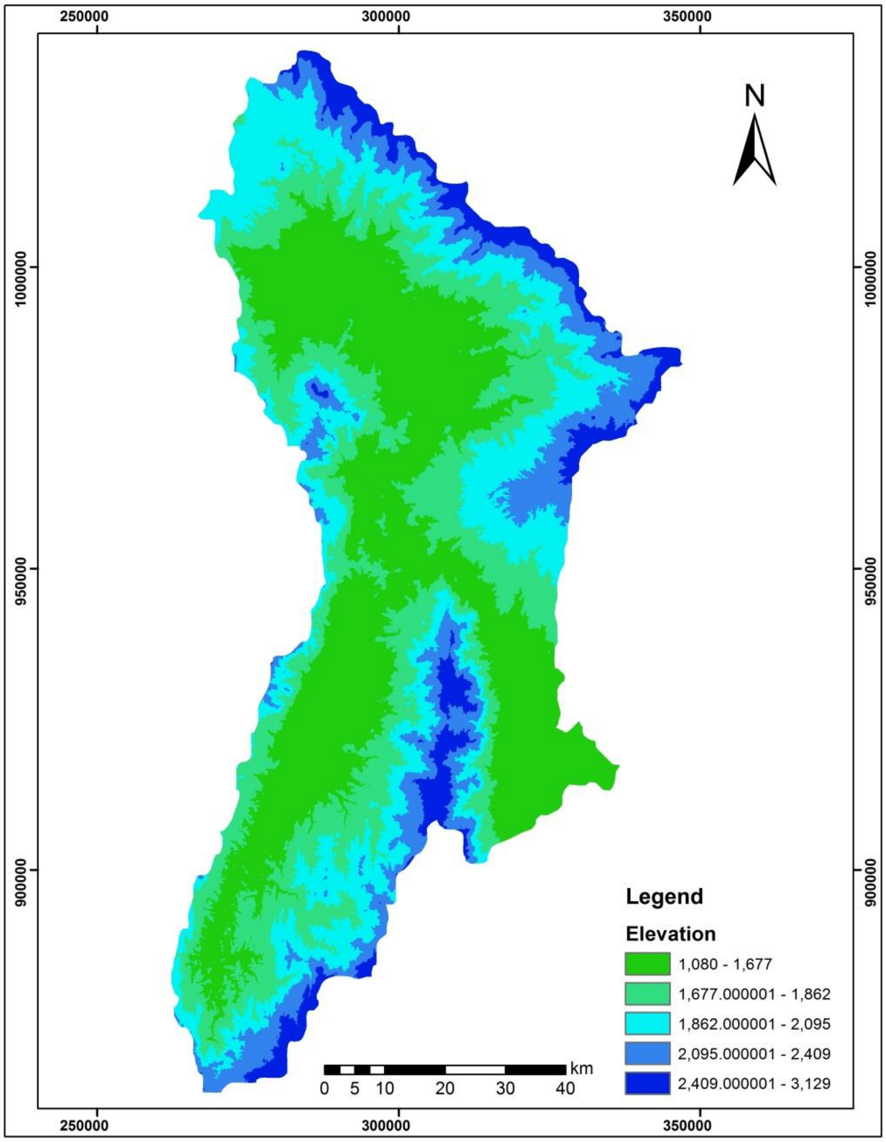


Figure 3. 2 Topographic map of the study area.

3.1.2 Climate

The amount of rainfall decrease with respect to change in elevation minimum of 1,200 mm annually, occurs in the lower reaches, and increases to 1,800 mm at some locations at higher elevations approaching 2,000 m asl and above. The mean annual rainfall calculated over the whole project area is about 1,460 mm. 75% to 80% of annual rainfall occurs during a five months period from May to September. The mean annual temperature around the study area is 20°C.

3.1.3 Hydrology

The Halele – Werabesa River is one of the tributaries of gibe river basin. At the dam site, the catchment area is some 6,126 km². The long term mean flow at Halele - Werabesa dam and reservoir is estimated to be 78.4 m^3/s. Seasonal variations are extreme, with monthly mean flow ranging from around 8.2 m^3/ S in March and more than 217.9 m^3/s in August.

Estimated inflows to the reservoirs were derived from mean annual rainfall-runoff relationships founded on available rainfall and stream flow data for the period 1963-1996. The resulting estimates of monthly average flows at the dam sites under current conditions are presented in Table 3.1 (EEPCO, 2000).

Table 3. 1 Estimated Monthly Average Flows at Dam Sites (m^3/s).

Month	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Halele	10.9	9.1	8.2	10.1	13.4	32.7	159.8	271.9	232.9	129.0	36.0	20.7	78.4

Source: EEPCO, 2000.

3.1.4 Population and Settlement

In 2007, an estimated 1,021,168 people were living in the surrounding weredas of around Halele - Werabes stage I hydropower plant of which 49.9% were females and 50.1% were males. There are about 214442 households in the study area. Different ethnic groups live around the future project area and the major ethnic groups are including Oromo, Amhara, Sodo Gurage, and Sebatbet Gurage. The population density is estimated to be about 63 people per km^2. Most settlement patterns are restricted to the highlands leaving the lower areas very sparsely inhabited. The degree of urbanization in the catchment area is still negligible with only 6% of the population living in urban centers while 94% of the population lives in a rural setting.

3.1.5 Geology

Both abutments of the dam consist of rhyolite, a basically competent volcanic rock. This rhyolite, however, overlies partly weaker agglomerates. These pyroclastic rock fill a paleo-channel, about 50 m deep, and forms the bottom of the river valley. The weak agglomerates are prone to slides as observed on the downstream left abutment. The existence of this paleo-channel and the weakness of the agglomerate will have a significant impact on the selection of the dam type and its layout (EEPCO, 2000).

The oldest rocks exposed in the area, the Jimma Volcanics, occur both as a lower part consisting mainly of flood basalts and as an upper part consisting mainly of rhyolites and trachytes (Fig. 3.3).

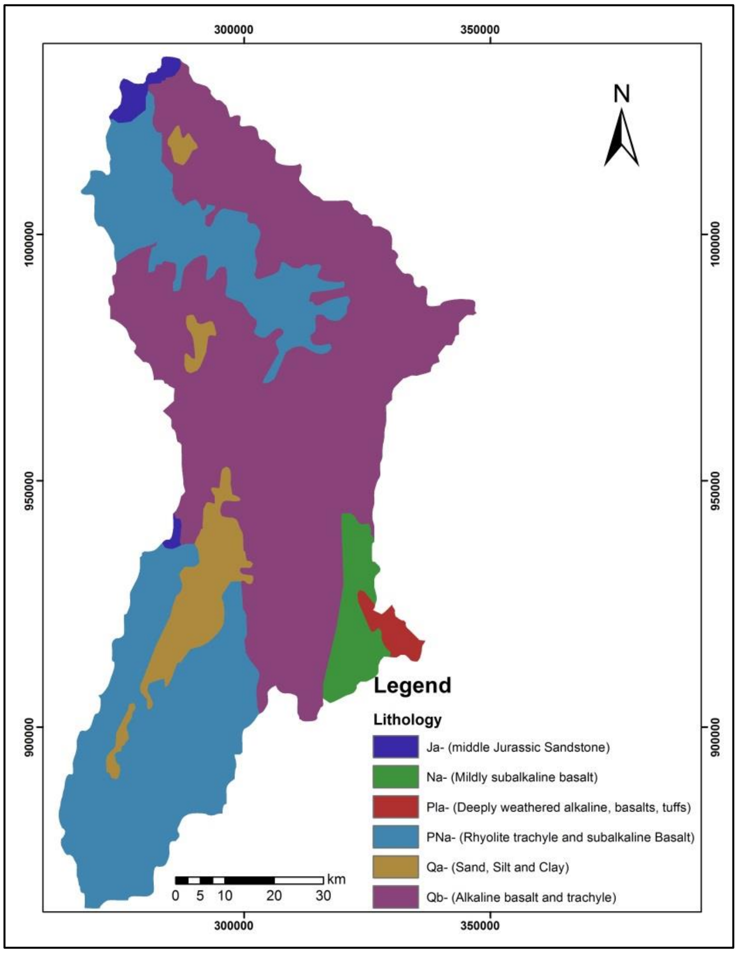


Figure 3. 3 Geological map of the study Area.

3.1.6 Soil

Soil composition within the project area is determined principally by the area's geology, which are predominantly volcanic rocks in mountains and alluvial material in the flood plains. The volcanic rocks are partly easy weathering especially the tuff types. The soils are characterized by a high clay part with a sufficient to high nutrient content.

The main soil types in the Halele – Werabesa stage I reservoir area are different forms of heavy Vertisols. Along the old river terraces mostly Vertisols and some Nitosols can be found whereas in the river valley mostly younger Fluvisols are dominant. In the rest of the study area we also found Leptosols and Alisols.

Nitosols is the major soil type found in the study area, generally occur on steeper hillslopes and are well drained. Nitosols are distinguished from other soils by migration of clay to a great depth, while at the same time a strong angular blocky structure is formed. These soils contain more than 35% clay but are commonly influenced by intensive biological activities, resulting in a homogenization of the upper meter of the soil.

On the other hand, Vertisols the second dominant soil type in the study area. It occurs on the flood plains along the Gibe River and its tributaries and in the lower hills. They have in general good natural fertility and are characterized by their high clay content. Due to clay mineralogy they are very hard and crack when dry, and sticky and plastic when wet. These are chemically rich soils, having a large reserve of nutrients and generally moderate amount of organic matter. Vertisols have a great agricultural potential and are outside of the flood areas important agricultural soils in the project area. Vertisols are dominantly found in plains of the Halele reservoir (Fig 3.4).

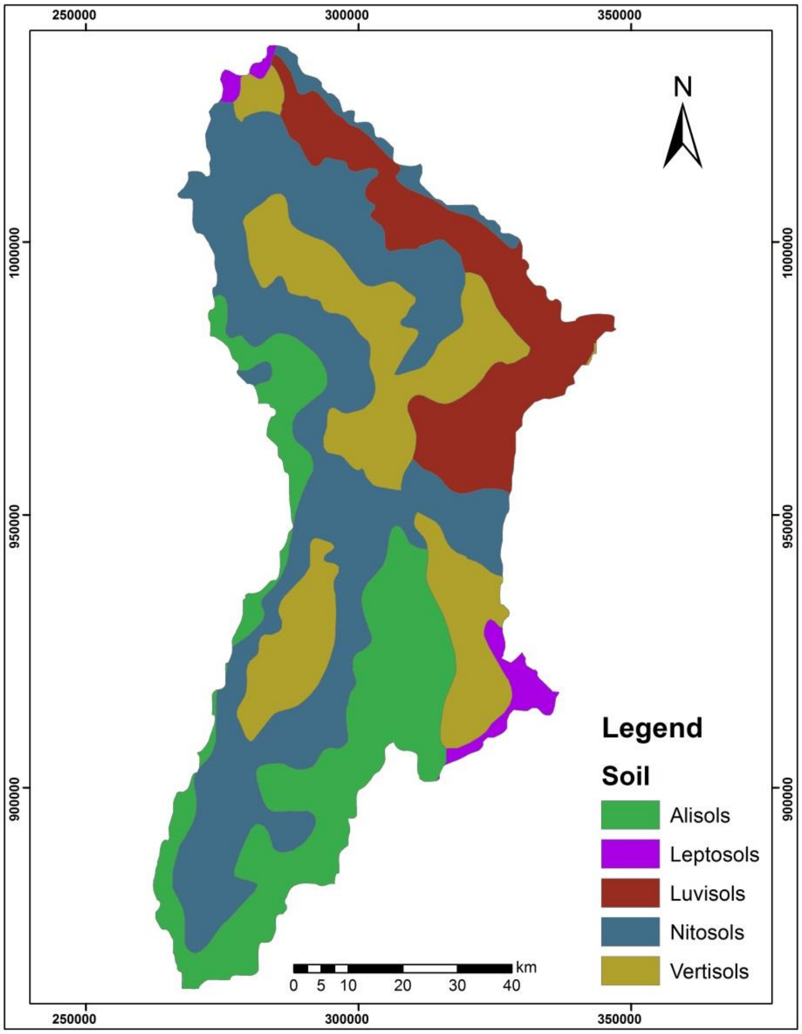


Figure 3. 4 Soil map of the study Area.

3.1.7 Vegetation Cover

The reservoir area is covered with scattered trees and a mixture of shrubs, bushes and moderately dense riverine forest. The status of the forest is degraded at many locations along the riverbanks and many of the taller trees are cut leaving only bushes and shrubs. Burning, felling and encroachment of the woodland for agriculture are a common practice. As a result, there is a decline in forest area and the forest quality both in stocking density and species composition. Currently there are no regulatory mechanisms by which this destruction of the woodland resources could be stopped (EEPCO, 2000).

3.2 Methodology and Data Source

In the present study both spatial and temporal data are gathered. These data were collected from both primary and secondary data sources. Primary data were generated from the analysis of Remote sensing data such as satellite images and DEM data and also field data verifications. On the other hand, secondary data were obtained about the study area from different sources (Table 3.2). Besides, published materials including books, journals, research articles, Meteorological data and census reports were reviewed. All this data were integrated in GIS environment.

3.2.1 Data Type and Source

Table 3. 2 Data type and Source.

No.	Data Type	Source
1.	Topographic sheets: 1:50,000 0837- A1, A2, A3, A4, C1, C2, C3, C4 0937- C3, C4	EMA(Ethiopian Mapping Agency)
2.	Satellite Imageries • Landsat 8 (2013) (30m resolution) P169, R054, P169,R055 and P170, R054	Down loaded from Internet site http://glovis.usgs.gov/
3.	Soil Type	FAO, 1998
4.	Demographic Data	Central Statistical Agency
5.	Annual Temperature and Rainfall (1980-2013)	NMSA(National Meteorological System Agency)
6.	Geological Map	EIGS (Ethiopia Institute of Geological Survey)
7.	ASTER DEM (15m Resolution)	
8.	EIA and Feasibility Document	Ethiopian Electric Power
9.	Halele-WerabesaReservoir Shape file	Ethiopian Electric Power
10.	Ground Truth	Study Area

3.2.2. Material and Software

The materials and software that are necessary for the research were used to conduct the research:

- ArcGIS 10.0- Used for spatial analysis and mapping
- ERDAS 9.3- Used for Image analysis and interpretation
- STATA- Used to calculate logistic regression
- IDRISI- to map landslide Susceptibility
- Other software such as MS Word, MS Excel, and IDM downloader are also used.
- Material such as base map, GPS (Global Positioning System) are used to collect information from the study area.

3.2.3. Method

The present study is aimed at identifying geo-environmental impacts, Landslide and Soil erosion susceptible sites in the study area and producing mass wasting map. For mapping Landslide susceptible sites factors considered in the study are essentially the preparatory factors for which pertinent data can be collected from available resources as well as from the field. These were slope, aspect, lithology, soil type, drainage density, lineament density and land use. Based on the information collected from available maps, satellite data, and field investigations, thematic data layers were generated.

Slope and aspect map of the study area generated from DEM. The lithology map and lineament maps were derived from Oromia region geological map (scale 1:1000, 000). Lineament density is also prepares using lineament map of the study area. Soil map derived from FAO Ethiopia soil map 1998. To prepare drainage density map drainage was digitized from Landsat 8 satellite image using ArcGIS 10 and drainage density map is prepared. The major input for landslide susceptibility is landslide inventory map. It was mapped from Spot 5 satellite imagery and field checked. Landslide susceptibility map (probability map) is produced using Multivariate approach: logistic regression model in STATA software.

On the other hand, for mapping Soil erosion risk site factors considered in the study are Rainfall runoff erosivity (R) factor, Soil Erodibility (K – Factor) Layer, Slope Length (LS – Factor) Layer, Land Use/Land Cover (C – Factor) Layer and Management (Support) Practice (P) Factor Layer. To map soil erosion risk map the researcher used RUSEL model in ArcGIS environment.

To come up with rainfall runoff erosivity (R–Factor) 33 years of rainfall data for 15 rain gauge station is collected from NMSE. R–factor map is prepared by using kriging method and interpolated rainfall map is produced. K–factor, C–factor and P–factor map was produced according to Harni 1985 adopted standard for Ethiopia. LS–factor map was prepared by combining slope angle (%), flow direction and flow accumulation in ArcGIS environment.

All the input datasets were georeferenced to Adindan UTM Zone 37N coordinate system new maps were generated spatial geodatabse is designed to include the input datasets, their derived data and the final result. The shape files are exported to the corresponding feature datasets and the raster files are exported as individual raster datasets in the geodatabase generated. The detailed flow chart was presented in (Fig. 3.5).

3.2.3.1 Multivariate Approach: Logistic regression (LR)

In this study the researcher will conduct the study using statistical approaches Logistic Regression model to forecast potential landslide sites using STATA 0.2 software.

The general purpose of the model is to determine the best fitting model to describe the relationship between the dependent variable (e.g., landslides) and set of independent parameters (e.g., slope, land cover, lithology). The advantage of the model is that the dependent variable can have only two values, an event occurring or not occurring, and that predicted values can be interpreted as probability since they are constrained to fall in the interval 0 and 1 (Dai and Lee, 2002). This method is very suitable for landslide prediction using GIS (Ayalew and Yamagashi, 2005).

LR model is based on the generalized linear model that can be calculated by the following equation (Eq. 1):

$$P = \frac{1}{(1+e^{z})}$$ **Equation 1**

Where P is the probability of an event (landslide and non-landslide), Z is a value from $-\infty$ o $+\infty$, defined by the following equation;

$$Z = B0 + B1X1 + B2X2 + . . . + BnXn$$ **Equation 2**

B0 is the intercept of model, n is the number of independent variables, and B1, B2, …, Bn are coefficients, which measure the contribution of independent variables (X1, X2, …, Xn) (Ayalew and Yamagishi, 2005).

For coefficient (Bn) to be acceptable for analysis, P-value must be less than 0.05. Independent variables with p-value greater than 0.05 the parameter will not be accepted or it is not significant for the analysis. Variable with higher coefficient are more significant for the occurrences of the dependent variable in this case landslide.

3.2.3.2 Soil erosion risk model

The application of RS and GIS techniques makes soil erosion estimation and its spatial distribution to be determined at reasonable costs and better accuracy in larger areas. A combination of RS, GIS, and RUSLE is an effective tool to estimate soil loss on a cell-by-cell basis (Millward and Mersey, 1999 as cited in Chen *et al*., 2010).

The expected soil loss potential (erosion hazard) expressed as tone per hectare per year for the study area was determined using the RUSLE model in a GIS environment. The Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) is the most frequently used empirical soil erosion model worldwide. More recently, Renard *et al*. (1997) has modified the USLE into a Revised Universal Soil Loss Equation (RUSLE) (Eq. 3) by introducing improved means of computing the soil erosion factors (Israel Tessema., 2011).

The RUSLE equation is:

$$A = R \times K \times L \times S \times C \times P$$ **Equation 3**

Where: A = computed average annual soil loss in tons/hectare/year; R = rainfall-runoff erosivity factor; K = soil erodibility factor; L = slope length factor S = slope steepness factor; C = cover management factor; and P = conservation practice factor.

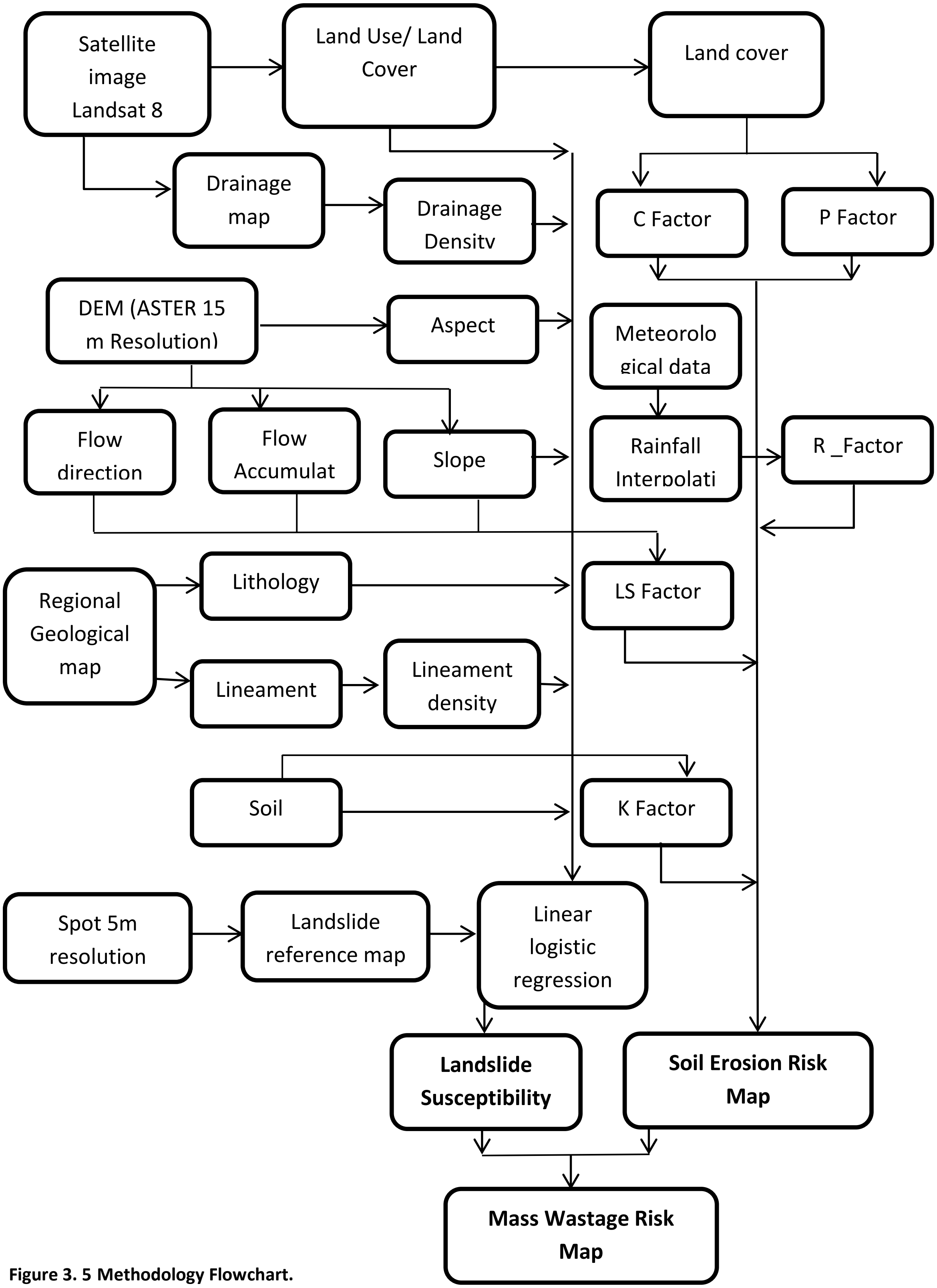


Figure 3. 5 Methodology Flowchart.

CHAPTER FOUR

DATA ANALYSIS AND INTERPRETATION

4.1 Landslide Susceptibility Mapping

Different outputs have been prepared to study and identifying landslide risk zone in the study area. Thematic maps like Slope, Aspect, drainage density, lineament density, valley buffer have prepared.

4.1.1 Slope

Slope angle is one of the most important factors controlling the stability of slopes. Slope angle is the form between any part of the surface of the earth and a horizontal datum (Kavazoglu *et al*., 2013). In most of studies slope is a major factor causing landslides (Ayalew *et al*., 2004; Sarkar and Kanungo, 2004). To obtain a slope angle map, digital elevation model (DEM) with 15 m resolution, was utilized. The resulting thematic map showed that slope angles ranged from 0° to 64° in the study area. Most of the area was occupied by the 15° to 25° and 25° to 35° slope classes, while steep slopes greater than 35° are much less frequent in the area. The slope map of the study area was categorized into 5° intervals as per slope classification of earlier researchers (Kavazoglu *et al*., 2013; Sarkar *et al*., 2006) equal intervals were applied to determine subclasses. As result eight subclasses (0–5, 5–10, 10‑15, 15‑20, 20‑25, 25‑30, 30‑35, 35‑64) were formed (Fig 4.1).

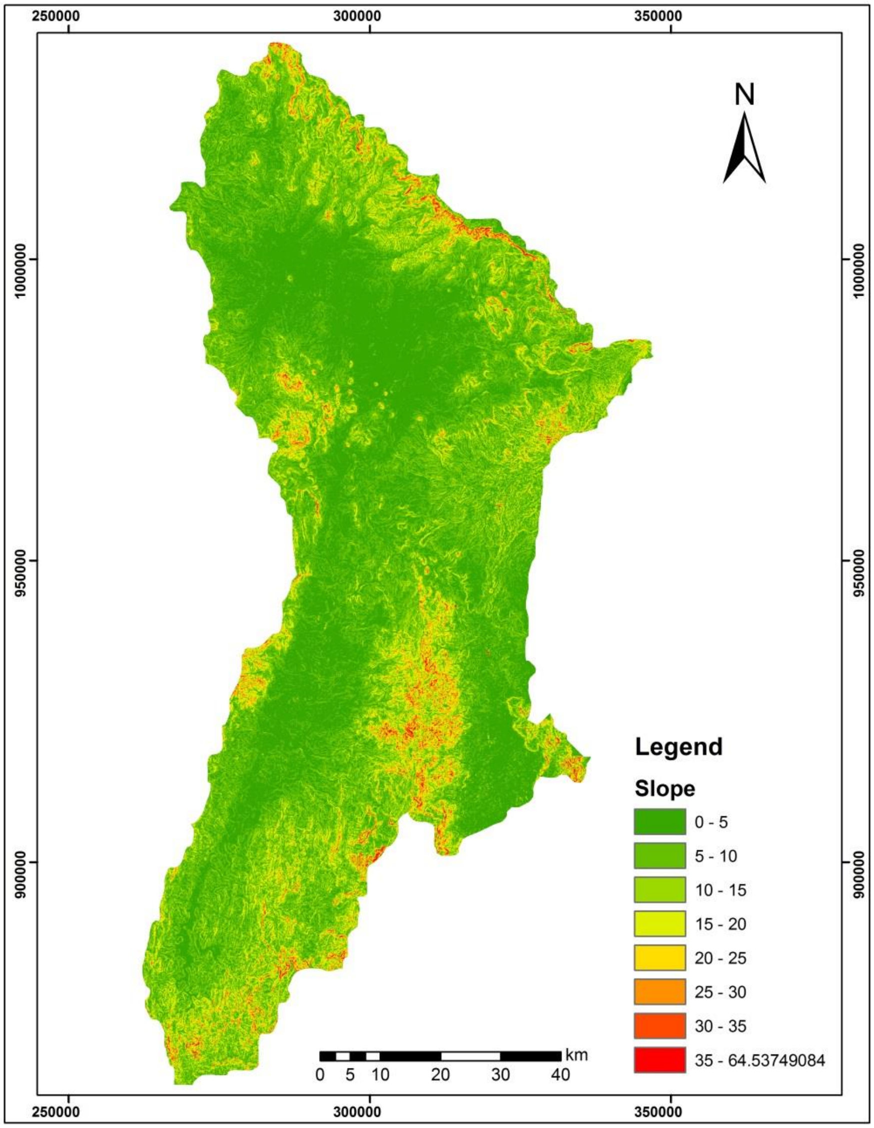


Figure 4. 1 Slope map.

4.1.2 Aspect

According to Dai *et al*., (2001 as cited in Kavazoglu *et al*., 2013) Aspect is the orientation or direction of slope that is measured clockwise in degrees from 0° to 360°, where 0° is north-facing, 90° is east-facing, 180° is south-facing, and 270° is west-facing. Aspect associated parameters such as exposure to sunlight, drying winds, rainfall (degree of saturation), and discontinuities are important factors in triggering landslides. In the present work, the DEM was used to calculate the aspect values for each pixel to construct the aspect image; and reclassified into ten categories (Fig 4.2): flat (−1°), north (0°-

22.5°) and (337.5-360), northeast (22.5°-67.5°), east (67.5°-112.5°), southeast (112.5°-157.5°), south (157.5°-202.5°), southwest (202.5°-247.5°), west (247.5°-292.5°), northwest (292.5°-337.5°).

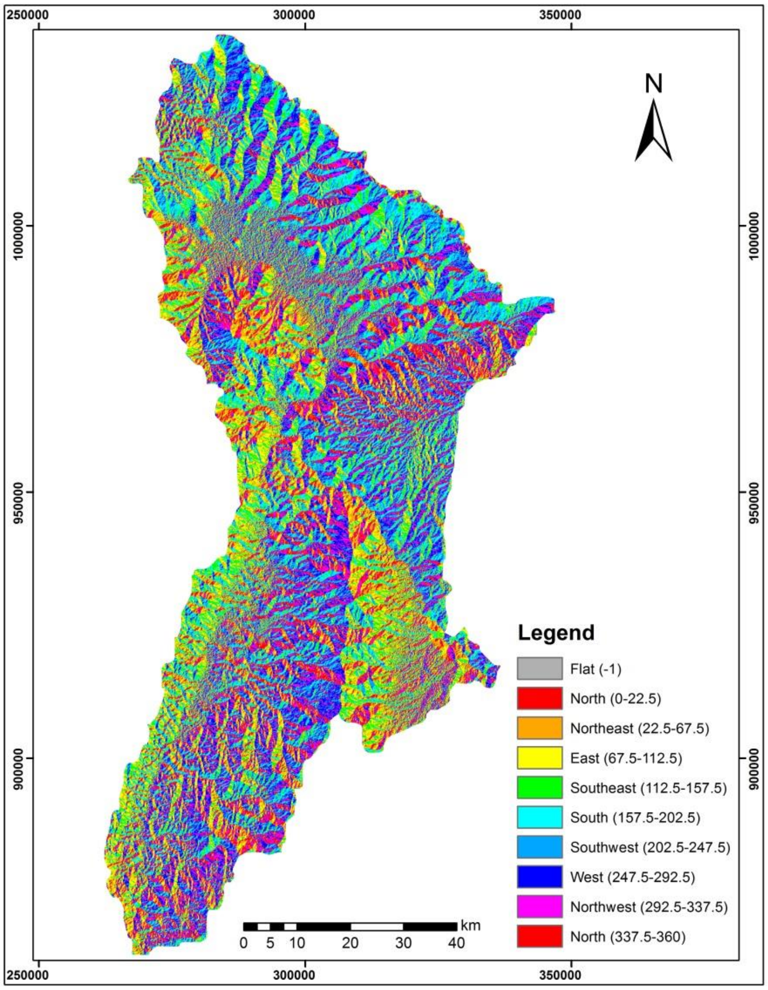


Figure 4. 2 Aspect map.

4.1.3 Lithology

Lithology is one of the main factors having a direct effect on the occurrence of landslides since lithological and structural variations often lead to changes in strength and permeability of rocks and soils (Kavazoglu *et al*., 2013). The geological map of the study area, including lithological units, was created from 1:1000, 000 scale regional geological map of Oromia.

There are six rock types present in the study area. Adigrat formation: Triassic- middle Jurassic Sandstone, Alaji formation: Rhyolite trachyle transitional and subalkaline Basalt Alluvium: Sand, Silt and Clay; Plateau basalt: Alkaline basalt and trachyle; Ashangi formation: Deeply weathered alkaline and transitional basalts, tuffs, often tilted; Na-stratoid basalt: Mildly subalkaline basalt (Fig 4.3).

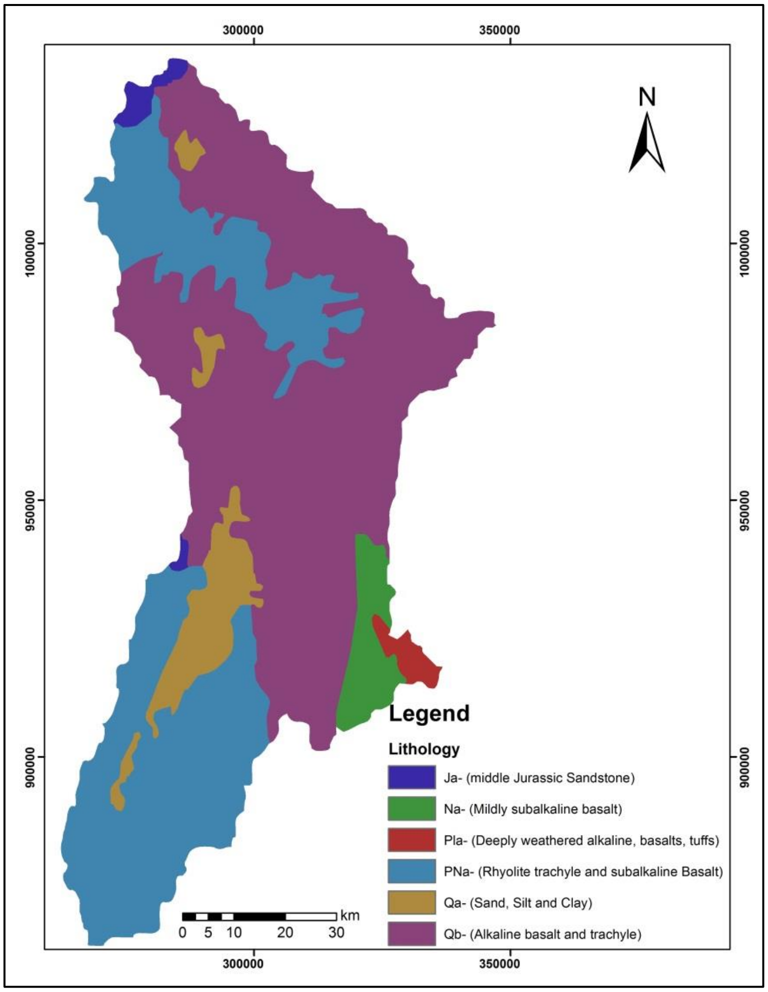


Figure 4. 3 Lithology map.

4.1.4 Soil type

The topsoil cover on a slope has an influence on landslide occurrence. FAO soil for Ethiopia is used to prepare the soil map of the study area. Clay Loam and Clay are the soil types in the study area and Clay loam is the highly concentrated whereas clay only found in the northern and eastern part of the study area (Fig 4.4). Both types of soils are vulnerable for landslide. Especially clay soil is vulnerable to landslide because of its texture and permeability. It has small pores and liberates the water gradually. It means that clay soil is easier to be saturated than sandy soil. It is also less permeable the slower the permeability represents the higher the possibility of landslide. Hence, clay soil is more susceptible to landslide because this soil can retain more water (Wati *et al*., 2010).

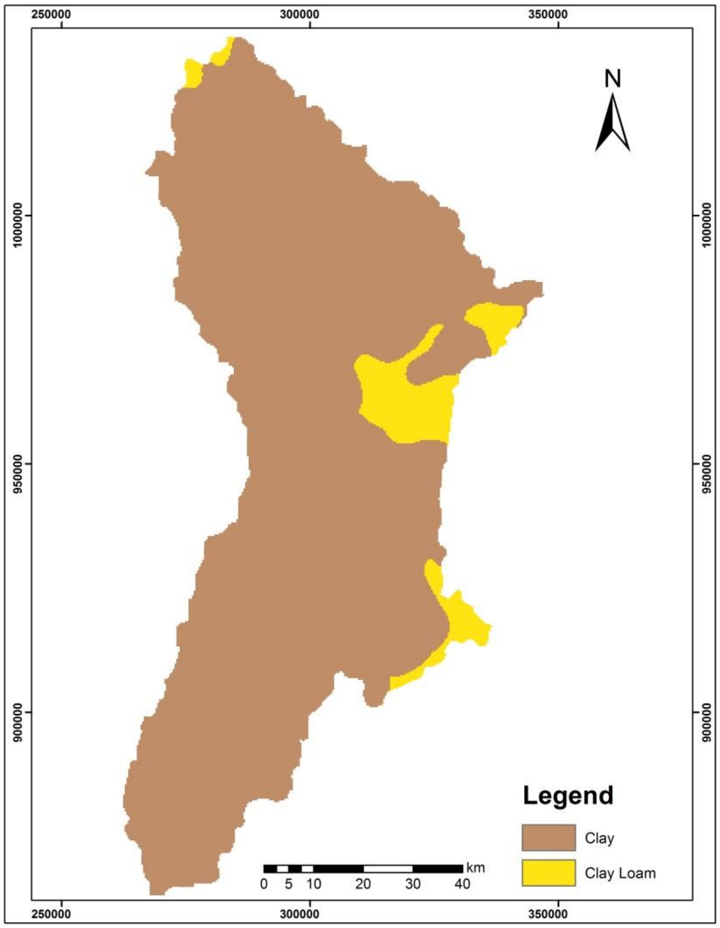


Figure 4. 4 Soil map.

4.1.5 Drainage Density

The drainage map shows the flow of water throughout the study area. As the distance from the drainage line increases the probability of occurrence of landslide also increase (Nithya and Prasanna, 2010). Drainage density is the total length of all streams and rivers in a drainage basin divided by the total area of the drainage basin. Drainage density provides an indirect measure of groundwater conditions having an important role in landslide activity (Kavazoglu *et al*., 2013). In 2004 Sarkar and Kanungo states that, there is an adverse relationship between landslides and drainage density.

Drainage density is calculated from;

$$D_y = \sum L / A$$ **Equation 4**

Where Dy is the drainage density, L is the stream length, and A is the catchment area. Drainage density map of the study area was produced from the drainage map using an appropriate algorithm in ArcGIS software. The resulting map was reclassified into four with equal intervals to be used in subsequent analyses based on previous research (Nithya and Prasanna, 2010). Drainage density is classified as < 0.004 (Low), 0.004 – 0.006 (Moderate), 0.006 -0.008 (High), >0.008(High) (Fig 4.5).

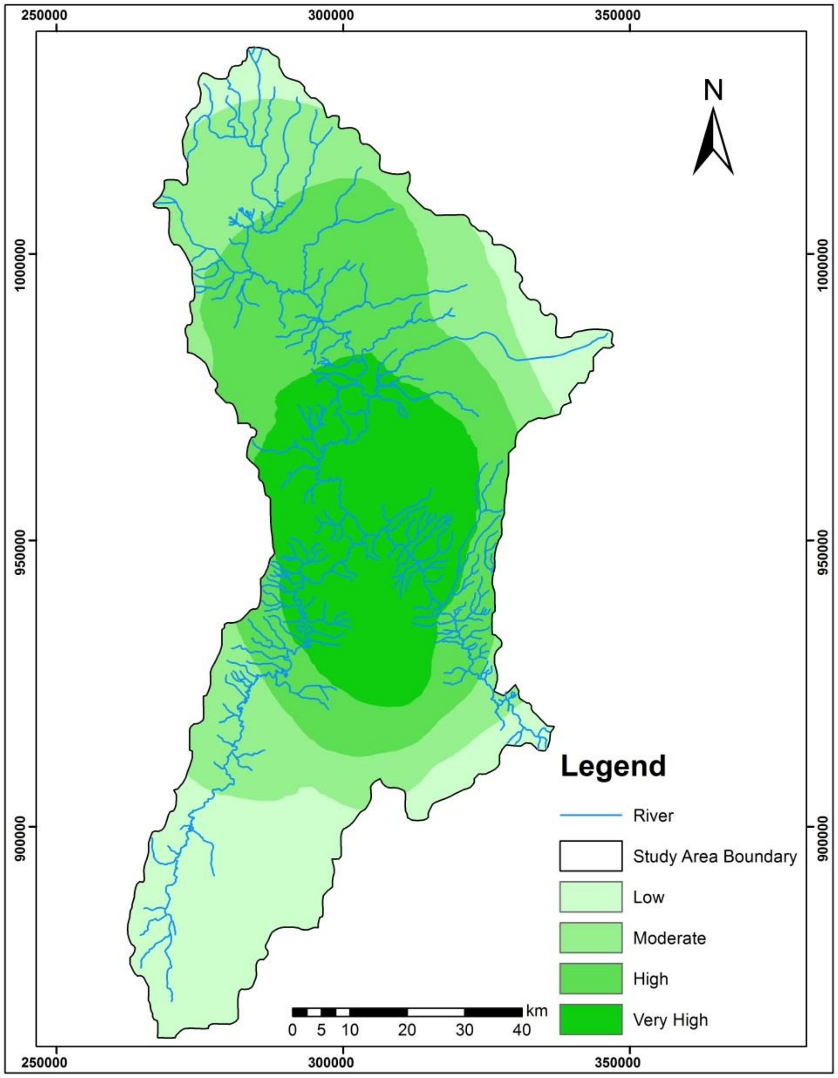


Figure 4. 5 Drainage density map.

4.1.6 Lineament Density

The lineament map shows the lineaments formed in the study area due to the geological conditions. Water flows through the cracks and the soil over this lineament would slide and hence this triggers the landslide (Nithya and Prasanna, 2010); it also helps to identify the weathered zones in an area (Bagyaraj *et al*., 2014). Lineament map is generated from regional geological map of the study area. Based on previous research (Nithya and Prasanna, 2010) the lineament density map is reclassified in to four classes as very high (> 0.008), high (0.006 – 0.008), moderate (0.002 – 0.004) and low (< 0.002) (Fig 4.6). General trend shown by the lineaments present in the study area are NNE‐SSW and NE‐SW.

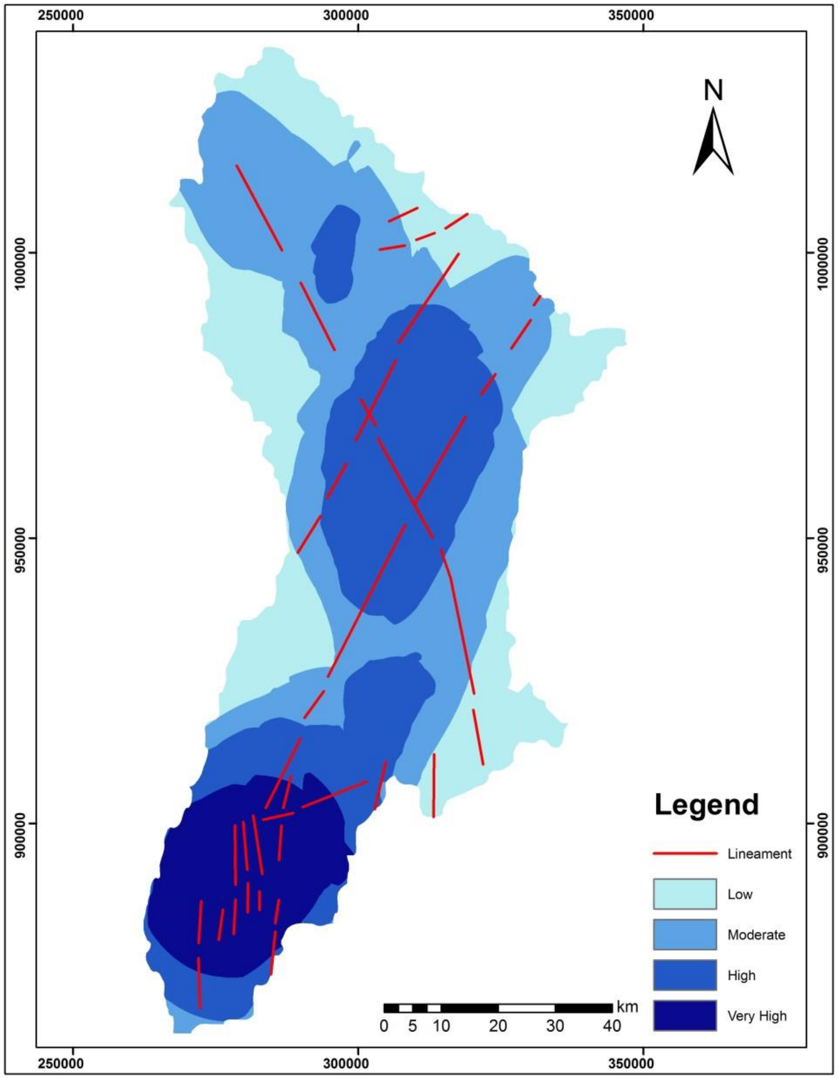


Figure 4. 6 Lineament density map.

4.1.7 Land-use/ Land-cover

A land-use/land-cover map in general shows the distribution of forest cover, water bodies, and types of land-use practices. To prepare this map, Landsat 8 2013 merged images were processed in ERDAS Imagine software using unsupervised and supervised classification techniques. An unsupervised classification is the natural grouping of pixels in the input image data. While performing the unsupervised classification, the output was generated for 20 classes. These classes were compared with different land-use types of the area based on the data from field and topographic map sheets. It was observed that the areas covered by forest, Agriculture, bare land, and grass land were correctly classified (Fig 4.7).

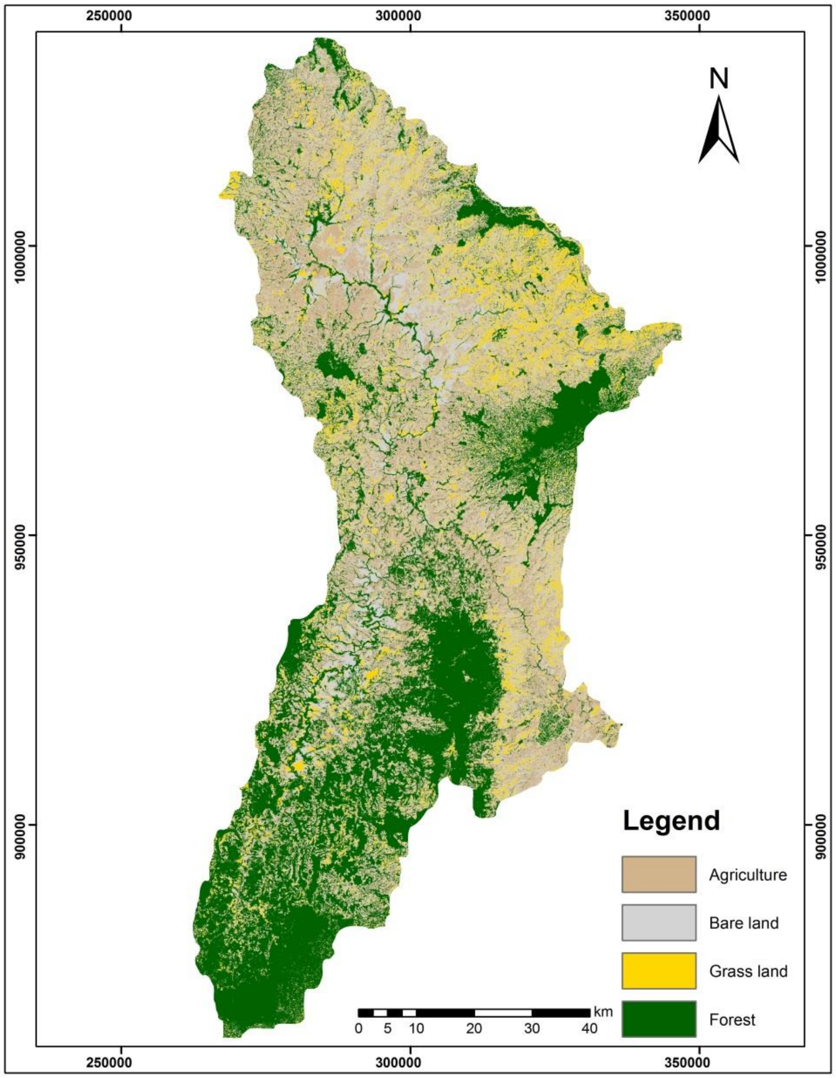


Figure 4. 7 Land-Use and Land- Cover map.

4.1.8 Landslide distribution

In this study SPOT 5m resolution was used for landslide distribution mapping. The important aspects for detecting landslides in satellite imagery are spectral characteristics, size, shape, contrast, and morphological expression. A few of the landslide sample points were confirmed in the field and the map was modified accordingly. Finally, I have inventoried 51 landslides sample points (Fig. 4.8).

Non landslide fields determined by applying technique used by Gómez and Kavzoglu in (2005 as cited in Kavzoglu *et al.*, 2013) ; it is based on two basic facts : Landslide activity is not likely to happen on river channels and on terrains with slope angles lower than 5°. Based on these view total number of 103 sample points were selected, from this 52 of them are non-landslide were as 51 points were selected as landslide sample points.

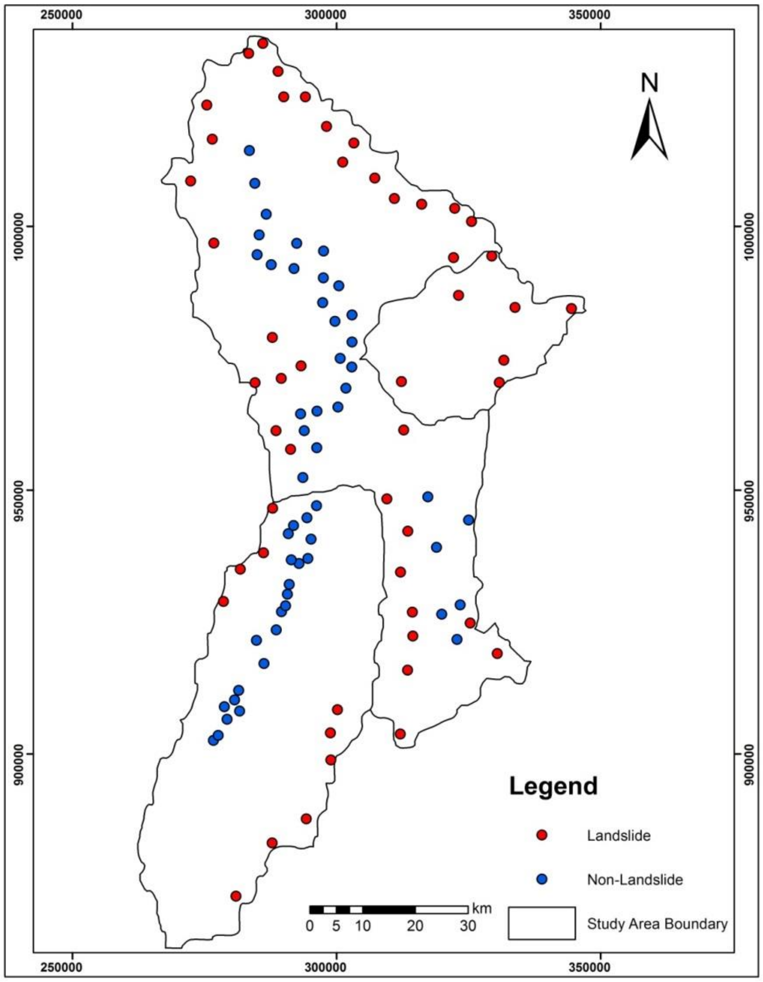


Figure 4. 8 Landslide Distribution map.

4.2 Soil Erosion Susceptibility mapping

To identify the spatial pattern of potential soil erosion in the study area, all the considered erosion factors (R, K, LS, C and P) had been surveyed and calculated depending on the recommendations of Hurni (1985) to Ethiopian context and other related studies. The following thematic layers were formed in raster format as input for the RUSLE model.

4.2.1 Rainfall runoff erosivity (R) factor

Rainfall runoff erosivity is an index of rainfall erosivity which is the potential ability of the rain to cause erosion. A storm’s maximum 30-min precipitation intensity must be known to compute the storm’s erosion index. If a station has not recorded 30-min intensities and only monthly and annual rainfall, the 30-min intensity of the nearest station was assumed to be representative. In this case, the erosivity factor R was calculated according to the equation given by Hurni (1985), derived from a spatial regression analysis (Hellden, 1987) for Ethiopian conditions. The model adapted by Hurni for Ethiopian conditions is based on the available mean annual rainfall data.

Rainfall data were obtained from National Meteorological System Agency. The monthly average rainfall data of 24 years (1980 –2014) fifteen stations in the watershed namely Ejaji, Bako, Sibu sire, Bilo Boshe, Ifa biya, Seyo, Limu Genet, Atnago, Limu Seka, Abelti, Ambuye, Babu, Busa, Gunjomariam and Jimma (Table 4.1) was used to calculate the R factor(Equation 5) .

$$\mathbf{R = -8.12 + (0.562 \times P)} \qquad \text{Equation 5}$$

Where P is mean annual rainfall in mm.

After having the averaged 24 years rainfall data for each metrological station, kriging interpolation by ArcGIS 10.0 was done to generate an estimated surface from these scattered set of point data into surface (Fig 4.9).

Table 4. 1 Calculated R_ factor and rainfall values of the rainfall stations.

Station Name	**Easting**	**Northing**	**ALT**	**Mean_Rf**	**R_factor**
Ejaji	37.316667	8.983333	1731	122.37	60.65
Bako	37.053333	9.120333	1680	106.91	51.90
Sibu sire	36.871833	9.039667	1826	114.21	64.18
Bilo Boshe	36.988000	8.889167	1726	121.03	59.89
Ifa biya	37.106500	9.268167	2387	136.61	68.65
Seyo	37.275833	8.767833	1772	119.01	58.76
Limu Genet	36.950000	8.066667	1766	154.41	78.56
Atnago	36.983333	8.300000	1847	141.31	71.29
Limu Seka	37.100000	8.300000	1711	143.14	72.32
Abelti	37.633333	8.166667	1968	93.50	44.42
Ambuye	36.900000	7.966667	1686	145.60	73.70
Babu	36.783333	7.883333	1707	153.56	78.18
Busa	37.200000	7.933333	1993	209.87	109.83
Gunjomariam	36.937167	9.017667	1844	117.56	57.95
Jimma	36.816667	7.666667	1718	125.00	62.13

Source: NMA (National Meteorological Agency)

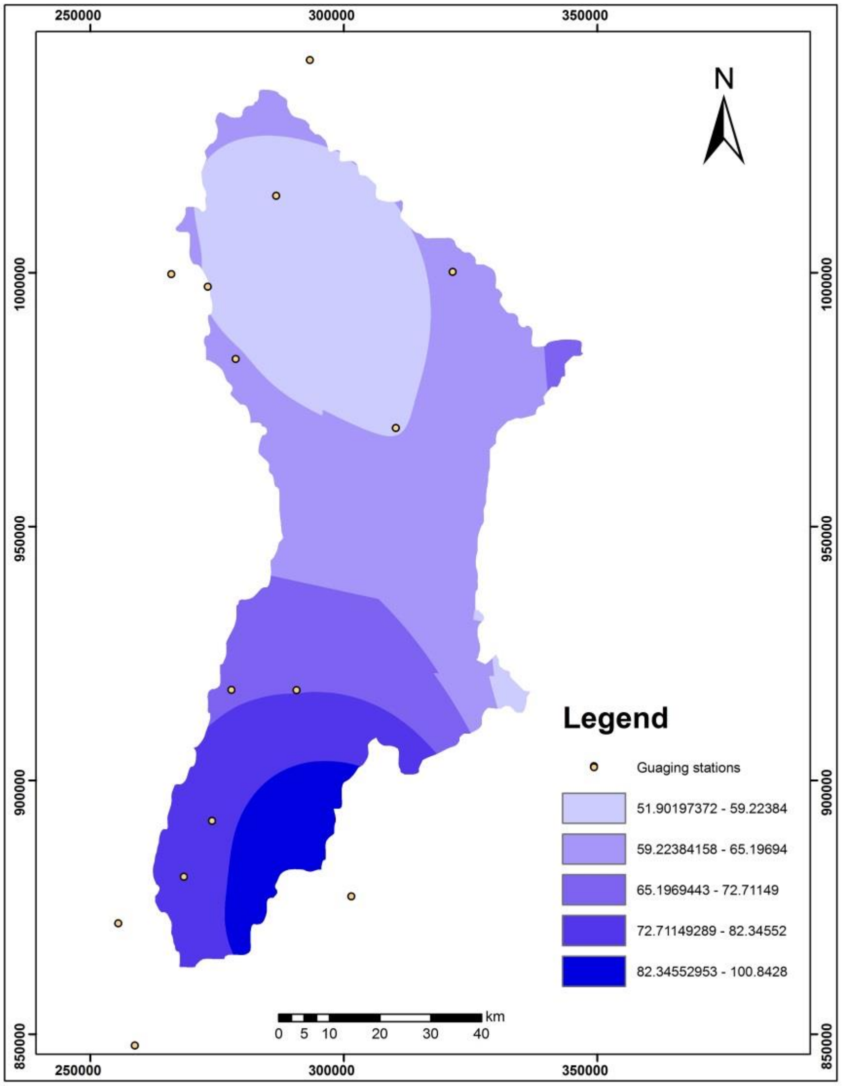


Figure 4. 9 R_factor map.

4.2.2 Soil Erodibility (K – Factor) Layer

The soil erodibility factor (K), represents both susceptibility of soil to erosion and the amount and rate of runoff, as measured under standard plot conditions (Chen *et al*., 2010). It depends on a lot of biological and chemical soil characteristics such as its mineralogical composition, particle size, permeability and the presence of organic matter. The soil data used in this study were collected and derived from the FAO Ethiopia soil map (Fig 4.10).

According to Wischmeier and Smith (1978 as cited in Israel Tesema., 2011) the physical, chemical and mineralogical soil properties and their interactions that affect K values are many and varied. It is therefore unlikely that a relatively few soil characteristics will accurately describe K values for each soils. Most studies widely used and frequently cited relationship is the soil erodibility nomograph. The nomograph comprises five soil and soil profile parameters: percent modified silt; percent modified sand; percent organic matter; classes for structure and permeability. The K value can be calculated with the use of soil nomograph for soils where the silt fraction does not exceed 70%, derived when all the values of K influencing factors are available.

But in Ethiopia finding this kind of detailed information is very difficult and time taking. To solve this problem soil erodibility (K) factor for the study area was estimated as a qualitative index that was adapted to Ethiopia by Hurni (1985) based on the soil color. According to FAO soil classification the study area is covered by six soil types and respective K values: Alisols (0.1), Leptosols (0.2), Luvisols (0.25), Nitosols (0.2) and Vertisols (0.15). K value is assigned for all soil types they have different soil erodability value (Table 4.2).

Table 4. 2 land use and land cover type and corresponding K_value

No.	**Soil Type**	**K_FACTOR**
1	Alisols	0.1
2	Leptosols/Nitosols	0.2
3	Luvisols	0.25
4	Vertisols	0.15

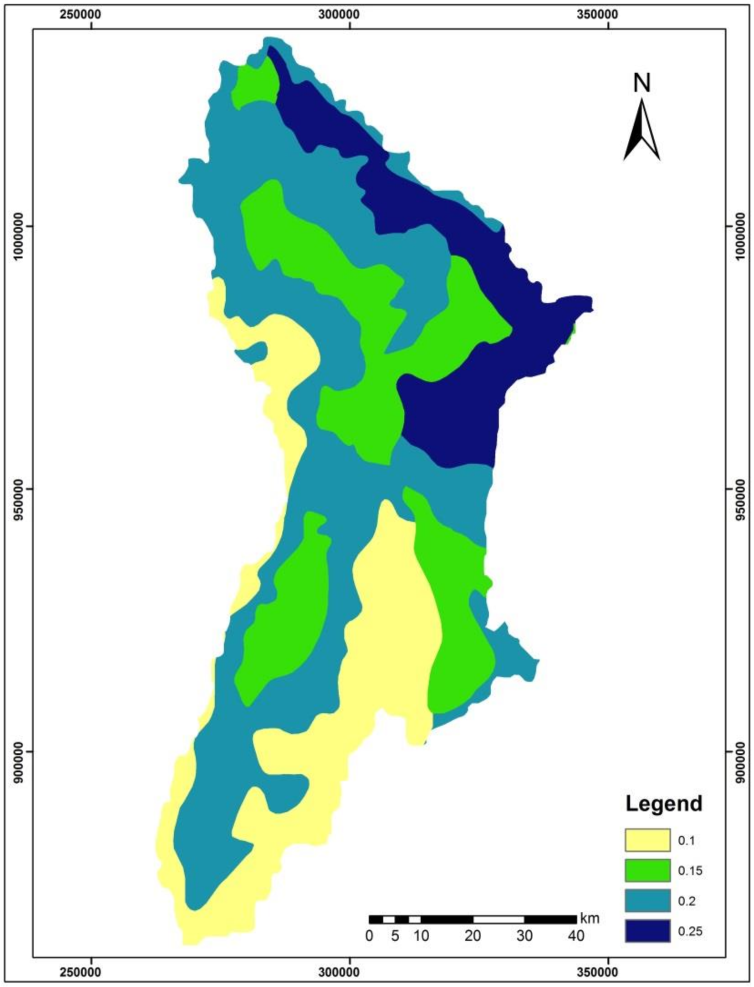


Figure 4. 10 K_factor map

4.2.3 Slope Length (LS – Factor) Layer

According to Wischmeier and Smith, (1978 as cited in Israel Tesema., 2011) the effect of topography on erosion in RUSLE is accounted for by the LS factor. Erosion increases as slope length increases, and is considered by the slope length factor (L). Slope length is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel.

The specific effects of topography on soil erosion are estimated by the dimensionless LS factor as the product of the slope length (L) and slope steepness (S). In this study, LS-factor map was derived from the DEM map of the region after preparing flow direction map and flow length map. LS map prepared using equation:

LS = (λ0.3/22.1) * (S/9)1.3

LS = (pow(flow length, 0.3)/22.1) * pow(slope/9,1.3) **Equation 6**

Where λ = Flow length

S = Slope in percent

Two steps in raster calculator:

1. Determination of (λ0.3) * (S/9)1.3
2. Division of the result of step one by 22.1

The LS map was further reclassified based on value given by SCRP for Ethiopian conditions (Israel Tesema., 2011). Then, the LS factor value was assigned to each slope class and the LS map was derived (Fig 4.11).

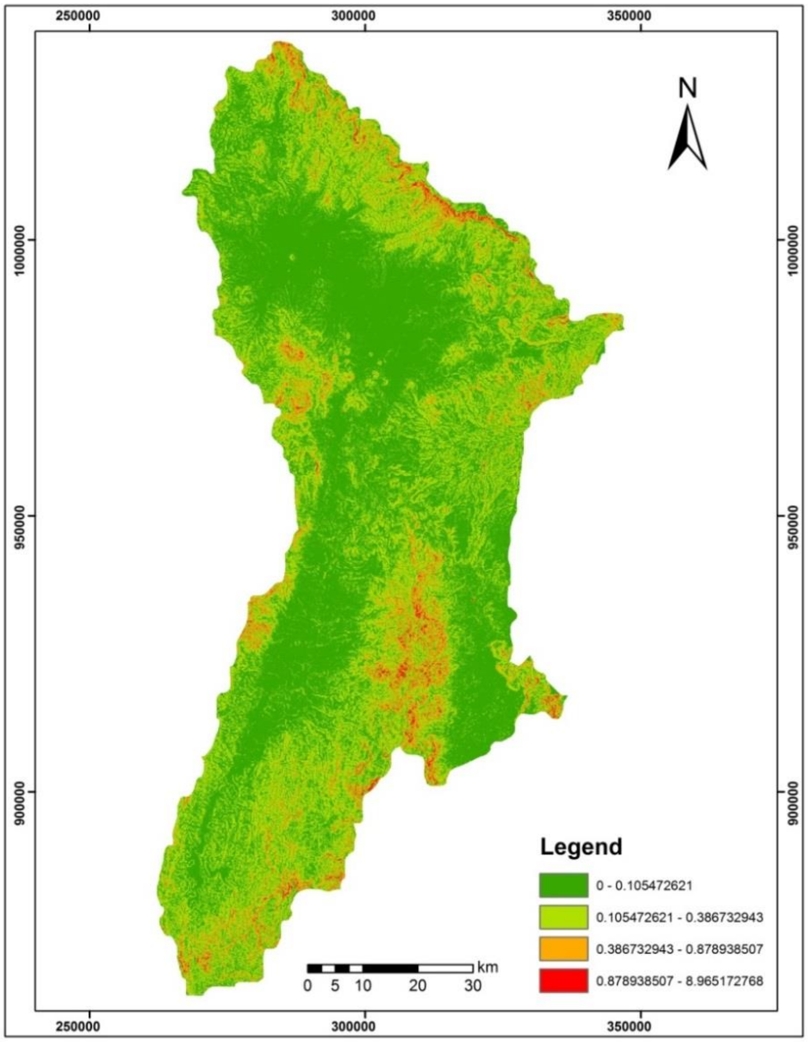


Figure 4. 11 LS map.

4.2.4 Land-use/Land-cover (C – Factor) Layer

The C factor represents the effect of cropping and agricultural management practices as well as the effect of ground, tree and grass covers on reducing soil loss in non-agricultural situation (Kouli *et al*., 2009).

To obtain the C factor dataset, supervised classification were carried out on the Landsat ETM 2013 images which cover the study area. Major land cover classes (forest, agriculture, bare land and grass land), as shown in Figure 4.12.

Assessment of the type of land-use/land-cover was made separately for each land unit and the corresponding value for land-use/land-cover was obtained from Hurni (1985) which was adapted to Ethiopian condition (Table 4.3).

Table 4. 3 land use and land cover type and corresponding C_value.

No.	Land-use/ Land-cover Type	C_FACTOR
1	Agriculture	0.18
2	Bare land/Grass land	0.05
3	Vegetation	0.02

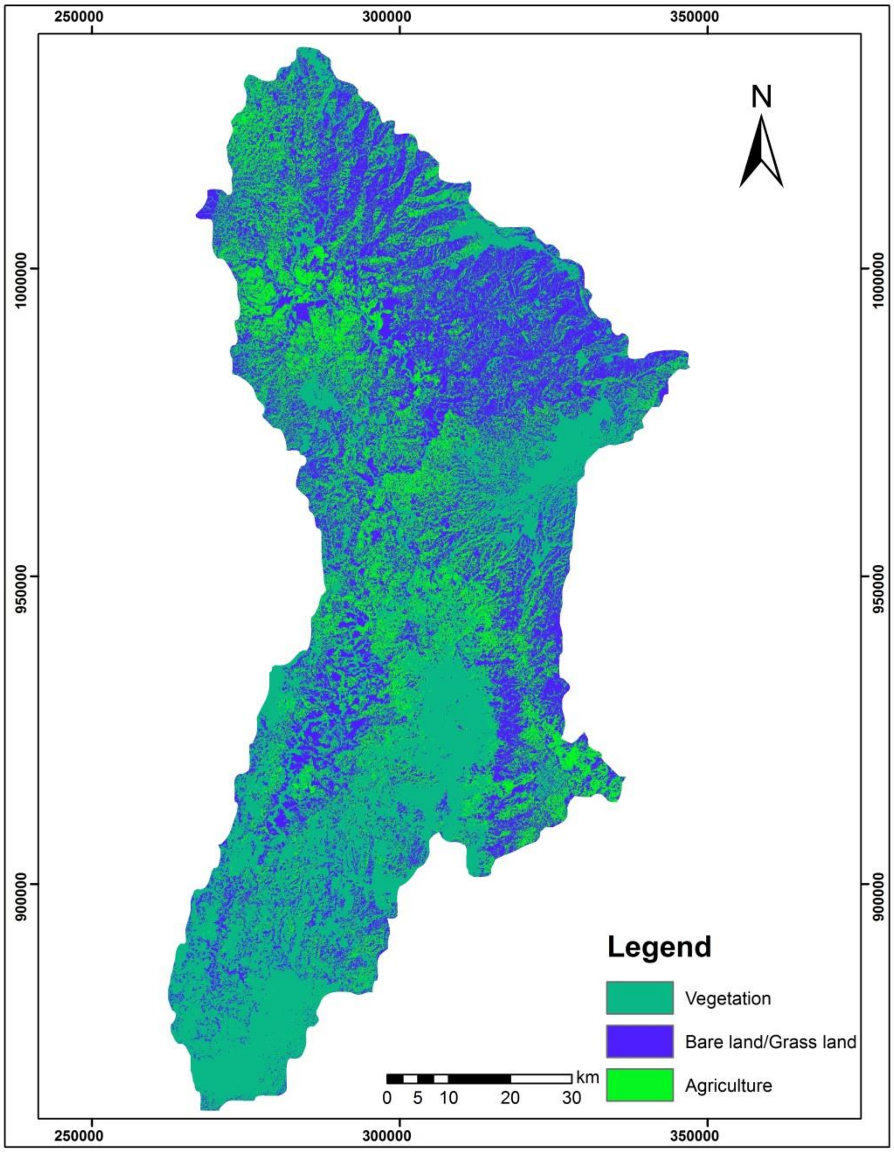


Figure 4. 12 C_factor map.

4.2.5 Management (Support) Practice (P) Factor Layer

P factor reflects the impact of support practices dealing with the average annual erosion rate. It is the ratio of soil loss with contouring and/or strip cropping to that with straight row farming up and- down slope. The lower the P value, the more effective the conservation practice is deemed to be at reducing soil erosion. As with the other factors, the P-factor differentiates between cropland and rangeland or permanent pasture (Arekhi *et al*., 2012).

P-factor value estimations were made by different researchers at different locations. In any case, the values were obtained from tables of the ratio of soil loss where the practice is applied to the soil loss where it is not. The P-factor values ranges from 0 – 1 and are required for agricultural land only. Unlike agricultural lands, other land uses, were found with no any control practice measures and hence P-values were assumed as one. Hurni (1985as cited in Israel Tesema., 2011) adapted and assigned the P-values to the cultivated highlands of Ethiopia.

About 4 class image data has been assigned with P- Factor values (Table 4.3) based on the estimation made by Hurni (1985), cited in Israel Tesema. 2011) as displayed in Figure 4.12).

Table 4.3 Land use/cover and the associated support practice (P) factor values.

No.	Land-use/ land-cover Type	P_FACTOR
1	Agriculture	0.9
2	Bare land	0.73
3	Grass land	0.63
4	Forest	0.53

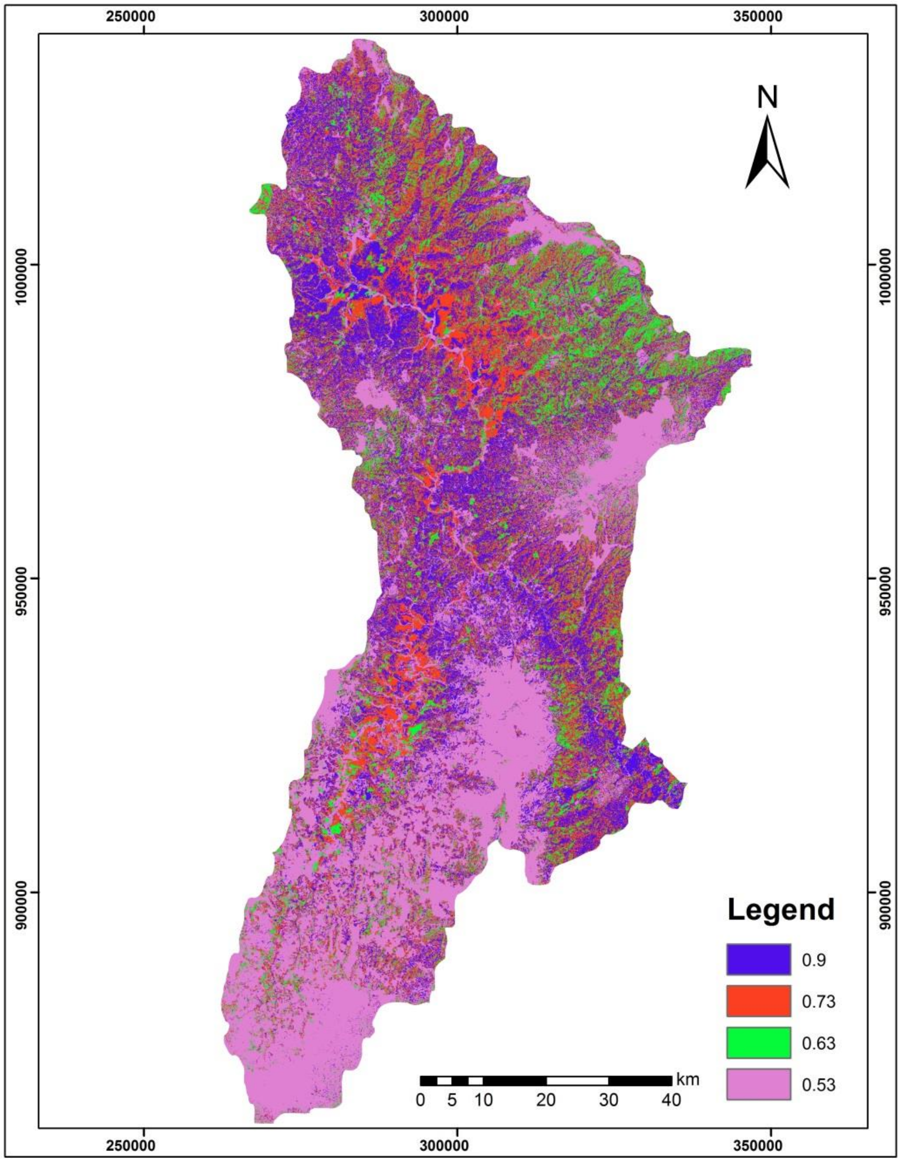


Figure 4. 13 P_factor map.

CHAPTER FIVE

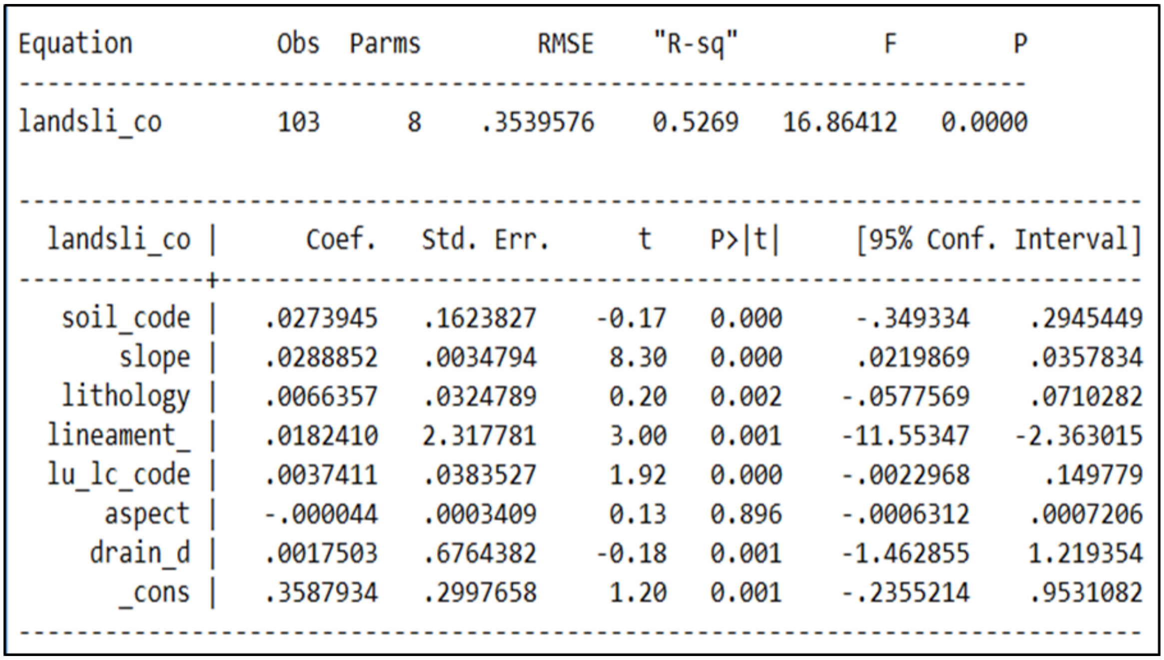
RESULTS AND DISSCUSION

5.1 Landslide Susceptibility

The spatial relationship between landslide occurrence and landslide-related parameters was determined through the coefficients of the logistic regression model. While the positive values of the logistic regression coefficient imply that the occurrence of landslides is positively related (i.e., the independent variable increases the probability of a landslide), negative values of the coefficients have a negative relationship with the landslide occurrence considering the P value less than 0.05 to be accepted.

Based on the regression result, slope, soil and lineament were highly correlated with land slide occurrence in the study area where as lithology, LULC and drainage density had a positive relation but with a relatively small in comparison with the previous parameters. In contrast, aspect had a negative coefficient value which indicates that it has a negative relation with the dependent variable (Table 5.1).

Table 5. 1 Logistic regression–landslide probability.



```
Equation          Obs  Parms        RMSE    "R-sq"          F        P
----------------------------------------------------------------------
landsli_co        103      8    .3539576    0.5269   16.86412   0.0000


------------------------------------------------------------------------------
  landsli_co |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   soil_code |   .0273945   .1623827    -0.17   0.000     -.349334    .2945449
       slope |   .0288852   .0034794     8.30   0.000     .0219869    .0357834
   lithology |   .0066357   .0324789     0.20   0.002    -.0577569    .0710282
  lineament_ |   .0182410   2.317781     3.00   0.001    -11.55347   -2.363015
  lu_lc_code |   .0037411   .0383527     1.92   0.000    -.0022968     .149779
      aspect |   -.000044   .0003409     0.13   0.896    -.0006312    .0007206
     drain_d |   .0017503   .6764382    -0.18   0.001    -1.462855    1.219354
       _cons |   .3587934   .2997658     1.20   0.001    -.2355214    .9531082
------------------------------------------------------------------------------
```

The derived coefficients were applied in the LR model in order to produce a land slide susceptibility map.

$$P = \frac{1}{(1+e^{z})}$$

$$Z = B0 + B1X1 + B2X2 + . . . + BnXn$$

Z =0.36+0.027(soil code) + 0.028 (slope) + 0.0066(lithology) + 0.018(lineament) + 0.0037(LU/LC) + 0.0017(drainage density)……….. (Eq 2).

Landslide susceptibility map generated by using logistic regression model was reclassified into four susceptibility classes based on their probability value using equal interval classification approach in Arc GIS environment (Fig. 5.1). In addition to the model statistics and coefficients, the final result of the regression process was carried out in IDRISI to predict map of probability defined by numbers those are constrained to fall between 0 and 1. The more these numbers are close to 1, the better they indicate the likelihood of finding the mapped landslides.

The results of the entire analyses and evaluation allowed us to divide the study area into four zones of susceptibility, namely low (69.1%), moderate (21.5%), high (7.8%) and very high (1.6%) (Table 5.2).

Table 5. 2 landslide susceptibility category.

Probability range	Class name	Coverage (%)
0 – 0.09	Low	69.1%
0.1–0.16	Moderate	21.5%
0.17–0.23	High	7.8%
0.24–1	Very High	1.6%

Source: Ayalew, L. and Yamagishi, 2005.

The result of the analysis revealed that the north east, north, south of the study area is highly susceptible to landslides, while the west was determined as having low susceptibility to landslides. Most of foothills of mountains fall in either very low or low susceptible zones indicating that elevation and slope gradient played an important role. As expected, flatlands such as river channels and interfluves are designated to be extremely low susceptible. The result also shows there is high probability of landslide in areas with clay soil type.

In general, by honoring what was observed in some sectors of the study area, the map given in Fig. 5.1 is believed to reflect the situation for landslide in Halele-Werabesa stage I reservoir and surrounding watershed.

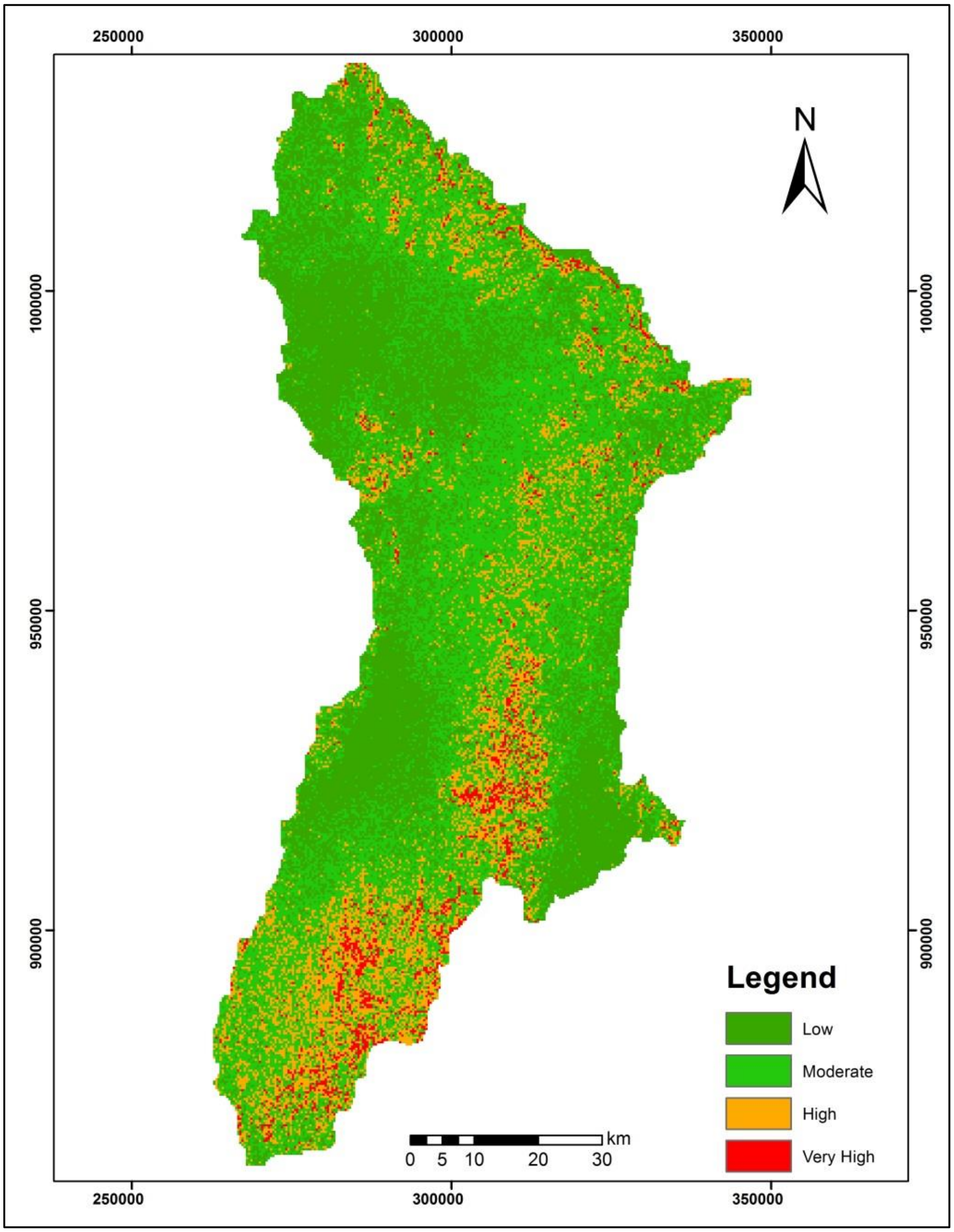


Figure 5. 1 Landslide Susceptibility map.

5.2 Accuracy Assessment for land slide susceptibility map

The landslide susceptibility map was integrated with the landslide inventory map to check its accuracy (Fig 5.2). Overall predicted accuracy of landslide susceptibility is 89 %. This shows that accuracy of the produced landslide susceptibility map is acceptable (Kavzoglu *et al*, 2013). Furthermore 86 % of the collected landslide points fell in the high risk areas where as 96 % of the non-land slide sample points also matches to the analysis.

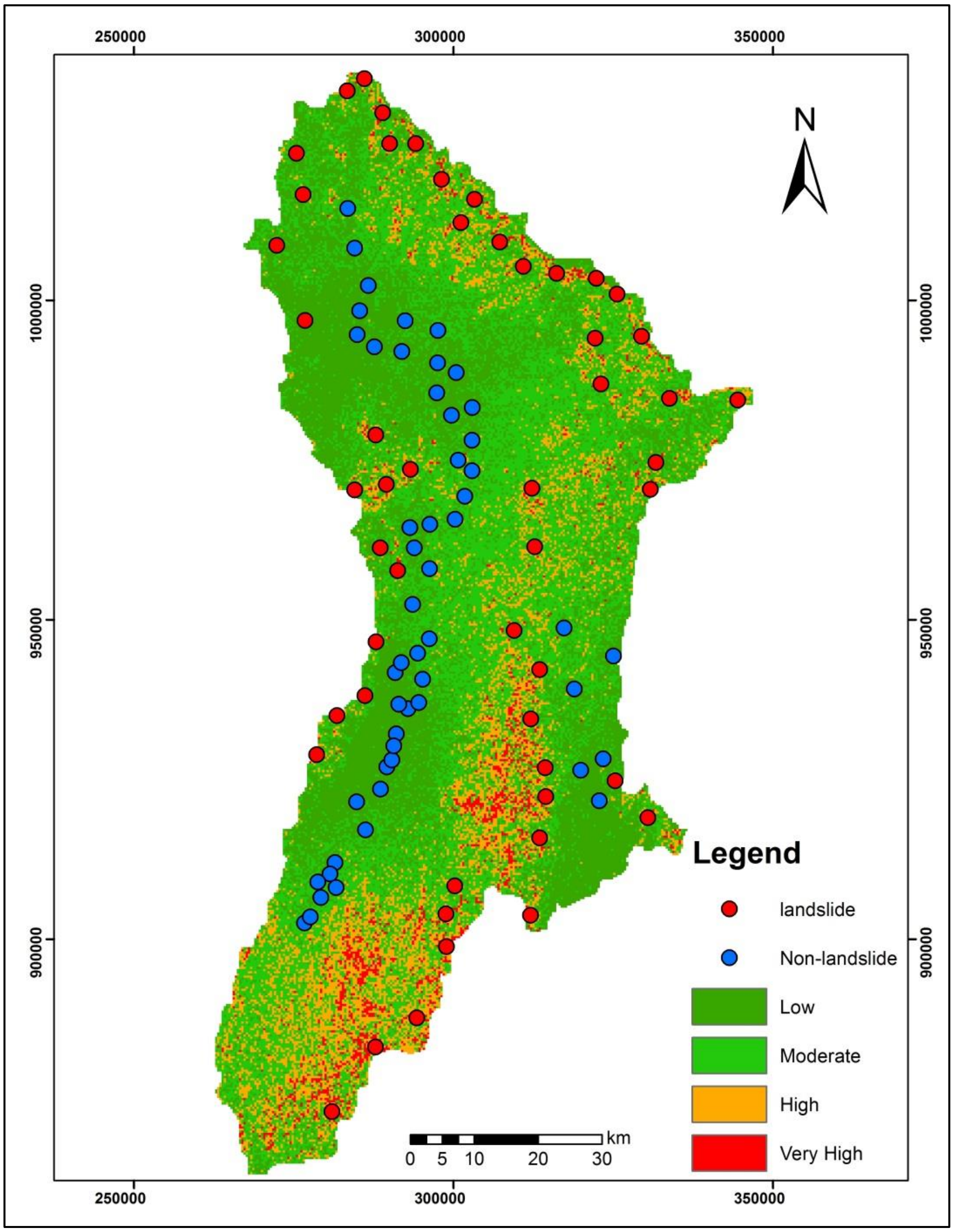


Figure 5. 2 Landslide Susceptibility *vs* landslide inventory map.

5.2 Estimated Soil Loss from the Watershed

Average annual soil loss was estimated by multiplying R, K, LS, C and P factors with use of ArcGIS software environment. The result showed that the potential annual soil loss of the Halele-Werabesa stage I Hydropower plant watershed ranges from 0.0 to 263.25 ton/ha/year (Fig. 5.3). The average annual soil loss rate is 64.3 ton/ha/year; which is much greater than the tolerable level 10 ton/ha/year (Hurni, 1983 as cited in Israel Tesema., 2011).

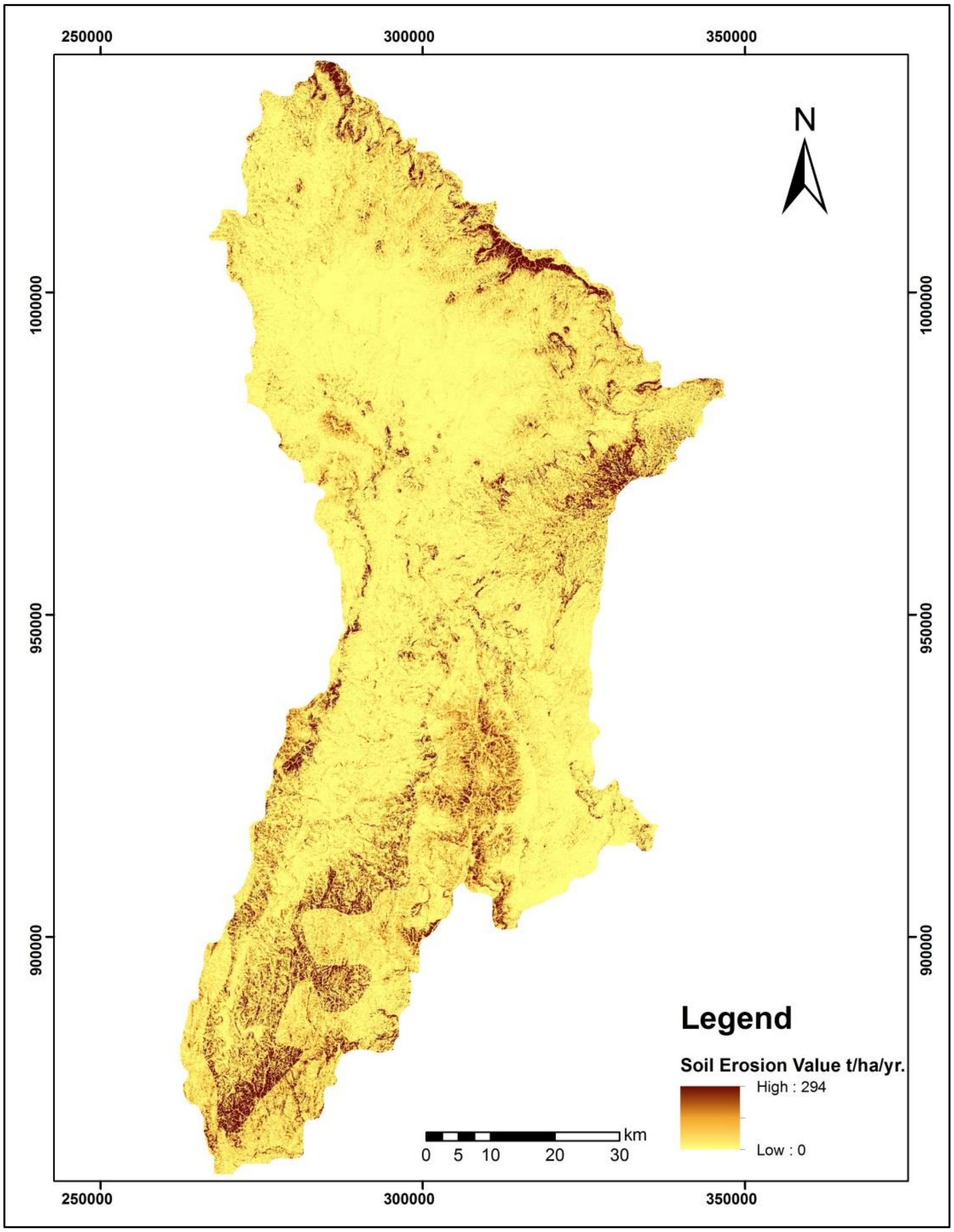


Figure 5. 3 Soil erosion map.

In order to obtain a better view and understanding potential soil erosion rate for Halele-Werabesa stage I Dam watershed result , the soil loss map also further classified into four soil loss severity classes were generated (Fig 5.4).

Table 5. 3 Area Coverage and Proportion of Soil Erosion Risk Classes

No.	**Soil Erosion Risk Class**	**Numerical Range of Soil Loss Potential (ton/ha/y)**	**Area**	
			km^2	**%**
1	Low	0 – 10	5471	76.1
2	Moderate	10 – 20	1348.5	18.7
3	High	20 – 50	334	4.6
4	Very High	50 – 294	44.3	0.6
		Total	7197.8	100

Source: Israel Tesema, 2011

The potential soil erosion risk map of the study watershed have been divided in to four classes of severity, i.e., soil loss less than 10 ton/ha/year which is described as low soil erosion risk class; between 10 and 20 ton/ha/year described as moderate soil erosion risk class; between 20 and 50 ton/ha/year described as high soil erosion risk class; and above 50 ton/ha/year described as very high soil erosion risk class. The area coverage and relative percent of each class has been derived from the soil erosion map of the study watershed.

The result indicate that, most areas of the watershed fall within the low erosion category (76.1%) which is mostly seen in the west and central parts of the watershed. About 4.6 % and 0.6 % of the watershed is categorized from high to very high erosion risks respectively. Which are found in southeast, east and northeast parts of the region (Fig 5.4). The reason for this high soil loss is related to its close relationship with the slope length (L) and slope steepness (S). In this area, priority must be given to protection of forest and afforestation of bare lands to reduce soil loss.

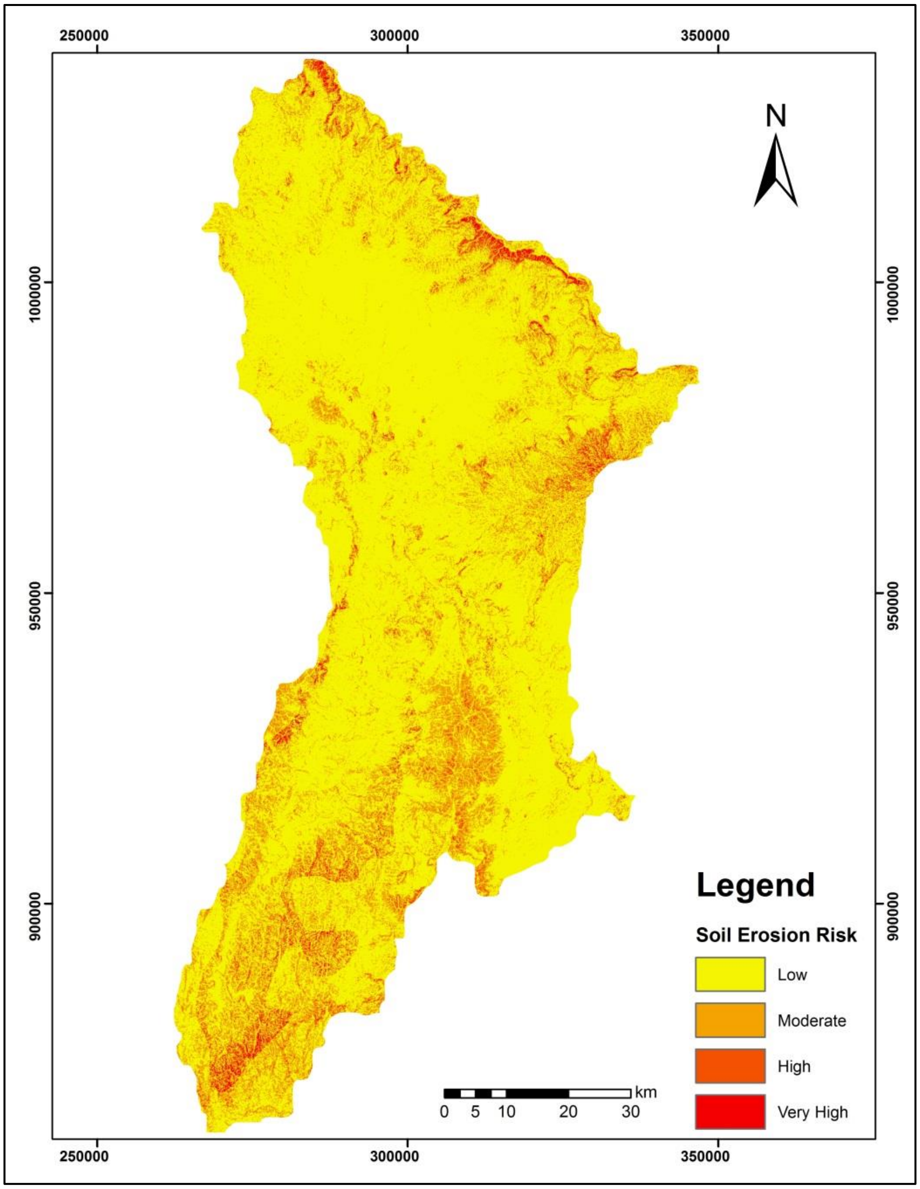


Figure 5. 4 Soil Erosion Risk Class Map of Halele-Werabesa stage I Dam Watershed.

The spatial locations of the high spot area for soil erosion in the study revealed that the potential soil loss is typically greater along the steeper slope banks of tributaries. Other high soil erosion areas are dispersed throughout the watershed and are typically associated with high erosion potential land use.

Soil erosion in agricultural fields and the surrounding watershed affects not only land productivity but also water bodies in the downstream. Because it is expected that these materials will in the future be deposited in the Halele-Werabesa stage I dam reservoir.

5.3 Mass Wastage

Finally by combining, landslide and soil erosion risk maps, mass wastage map were prepared to show mass wastage prone areas. Using equal interval based classification the mass wastage risk map was classified as very high mass wastage, High mass wastage, Moderate mass wastage and Low mass wastage.

According to mass wastage classification result (0.4%) of the study area fall under very high mass wastage area; (4.3%) of the study area is high mass wastage; (16.2%) of the watershed is moderate mass wastage whereas, (78.8%) of the study area were classified less vulnerable to mass wastage. When prioritizing for conservation intervention, areas with very high and high mass wastage risk can be considered in the first stage based on their vulnerability to mass wastage (Fig. 5.5).

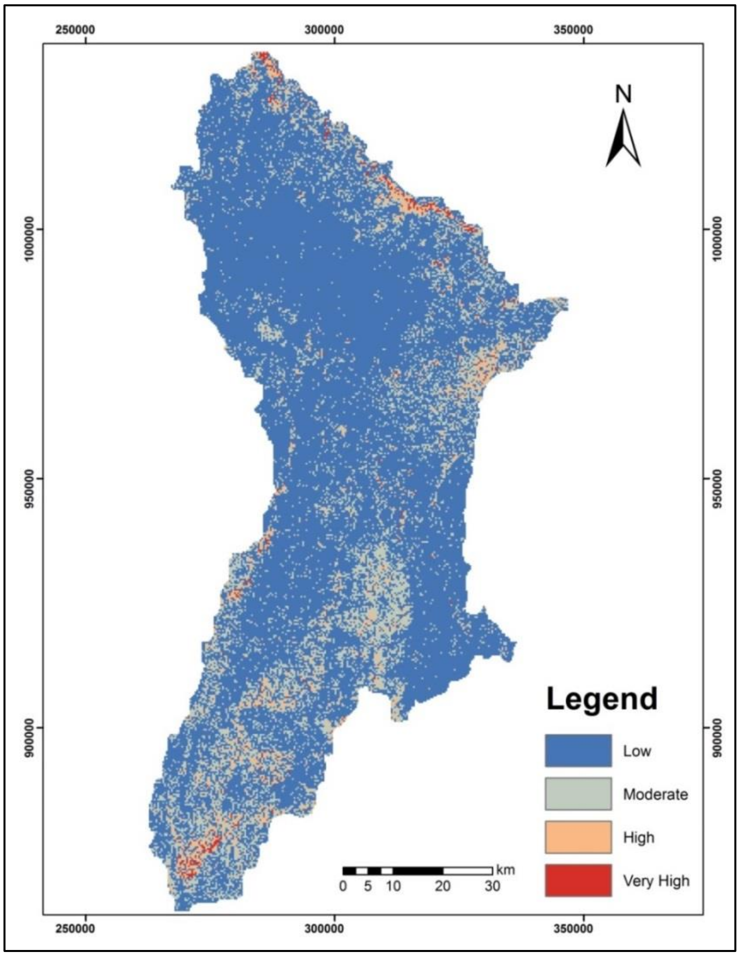


Figure 5. 5 Mass wastage risk map.

5.4 Discussion

In this study geo-environmental impact, which will affect the life span of the Halele-Werabesa stage I dam reservoir, was studied using remote sensing and GIS techniques. To end up with mass wastage risk map of the study area two models were devised namely landslide susceptibility and soil erosion risk. For landslide susceptibility researcher used logistic regression model whereas RUSEL model was employed to study soil erosion risk of the study area. As a result by combining the soil erosion risk map and landslide susceptibility map researcher have prepared mass wastage map which shows area which needs conservation priority.

The parameters used in this study to prepare landslide susceptibility are similar to Sarkar and Kanungo (2004). The variation is that they used weight index overlay mechanism to prepare landslide susceptibility map of the study area; which was proved as subjective. Where as in this research, logistic regression analysis was employed which is more scientific and enables to avoid subjectivity.

Ayalew *et al*. (2005) has also used logistic regression to predict the occurrence of landslide based on information on the geology, and topographic parameters and inventoried past landslides of Sado Island in Japan. Similarly, Kavzoglu *et al*. (2013) and Lei and Jing-feng (2006) have also used the same methodology to predict landslide occurrence in Turkey and China respectively. The variations are only the factors taken into consideration which vary depending on the target areas setting. When we compare these results with Halele-Werabesa stage I result, even though we used the same regression approach, the factors used in the model did not match with the afore mentioned researches, because the parameters used in this research are accepted based on their probability value.

To assess soil erosion risk Israel Tessema (2011) used RUSEL method in ArcGIS environment. When we compare the output of this research with Halele-Werabesa stage I, it supports the result. According to the estimate of FAO (1984), the annual soil loss of the highlands of Ethiopia ranges from 1248 – 23400 million ton per year from 78 million of hectare (16 to 300t/ha/yr.) of pasture, ranges and cultivated fields throughout Ethiopia.

This is equivalent to 16 to 300t/ha/yr. This finding of FAO aligns with this research in that the calculated loss from the watershed is around 294t/ha/yr.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1Conclusion

The objective of this study was to assess geo-environmental impact in the Halele-Werabesa stage I dam watershed which is located in the Omo-Gibe Basin 170km south east of Addis Ababa. Geo-environmental impact assessment is often evaluated systematically in order to assess the nature of hazards and their potential damage to human life, land, buildings and other property. In the study to assess the geo-environmental impact in the study area three parameters were selected; landslide, soil erosion and mass wastage.

Identification of landslide-prone regions and determining their locations according to given susceptibility levels play an important role for the success of planning activities. Many methods have been suggested in the literature to produce landslide susceptibility maps. In this study, logistic regression model was implemented to study landslide probability of the study area. This method was employed using independent variables lithology, Slope, land-use/ land-cover, aspect, drainage density, aspect, and soil factors and dependent variable is landslide reference map.

When the logistic regression model was applied to the study area, the east of the study area was generally identified as highly susceptible to landslides that are mainly located in areas with high slope angle. It shows that slope is significance parameter which control landslide probability in the study area.

Accuracy assessment results showed that the map produced by logistic regression model have 89 % accuracy in terms of overall accuracy considering landslide reference map. The results of the entire analyses and evaluation allowed us to divide the study area into four zones of susceptibility, namely low (69.1%), moderate (21.5%), high (7.8%) and very high (1.6%). The landslide susceptibility map is believed to be useful for identifying slope sectors liable to landslide on relative basis.

To be more specific about the future landslide occurrence in the region, more detailed investigations were required. Further, any change in the natural environment by human interference, may change the existing landslide susceptibility of the area. Hence, such maps need to be updated periodically. It was always better to avoid the highly susceptible zones, but if not possible, corrective measures need to be worked out. The risk maps prepared were of immense use for disaster management/planning.

The second parameter the study considers as geo-environmental impact is soil erosion. The study demonstrate that an empirically based erosion assessment model, the RUSLE, integrated with satellite remote sensing and geographical information systems can provide useful information for conservation decision-making.

The total amount of soil loss in Halele-Werabesa stage I Dam watershed is about 294 tons per year from a total area of 7197.8 Km^2. Average soil loss was calculated as the product of each pixel value multiplied by pixel area.

In the study area, the mountainous area has more erosion risk due to its soil erodibility. More than half of the Halele-Werabesa stage I reservoir watershed (76.1%) falls into low erosion risk class, where soil loss is lower than 10 t ha^{-1} ya^{-1}. Soil loss increases from north east to the south east of the watershed.

The spatial distribution of erosion risk classes was 76.1% low, 18.7 % moderate, 4.6 % high and 0.6 % very high. Soils susceptible to erosion with a soil loss more than 10 t ha^{-1} ya^{-1} are found primarily in the eastern part of watershed. In this area, priority must be given for protection of forest and afforestation of steep bare lands and maximize plant coverage by rotation practices in the agricultural lands. Generated soil loss map is also able to indicate high erosion risk areas to soil conservationists and decision makers.

By combining the first two geo-environmental impacts in the study area, Mass wastage map result (0.4%) of the study area fall under very high mass wastage area; (4.3%) of the study area is high mass wastage; (16.2%) of the watershed is moderate mass wastage and (78.8%) of the study area is less vulnerable to mass wastage. When prioritizing for conservation intervention, areas with very high and high mass wastage risk can be considered in the first stage based on their vulnerability to mass wastage.

6.2 Recommendations

Any strategy which will be used for mitigation of geo-environmental impacts must focus on the changes of the values in landslide susceptibility and soil erosion risk factors. In this regard, the following points are forwarded as a recommendation:

- Based on the result of the study, the areas which falls under high and very high mass wastage class needs immediate attention in their order of vulnerability.
- Further, any change in the natural environment by human interference, such as implementation of the project, deforestation, etc., may change the existing geo-environmental condition. Hence, such studies should be conducted periodically.

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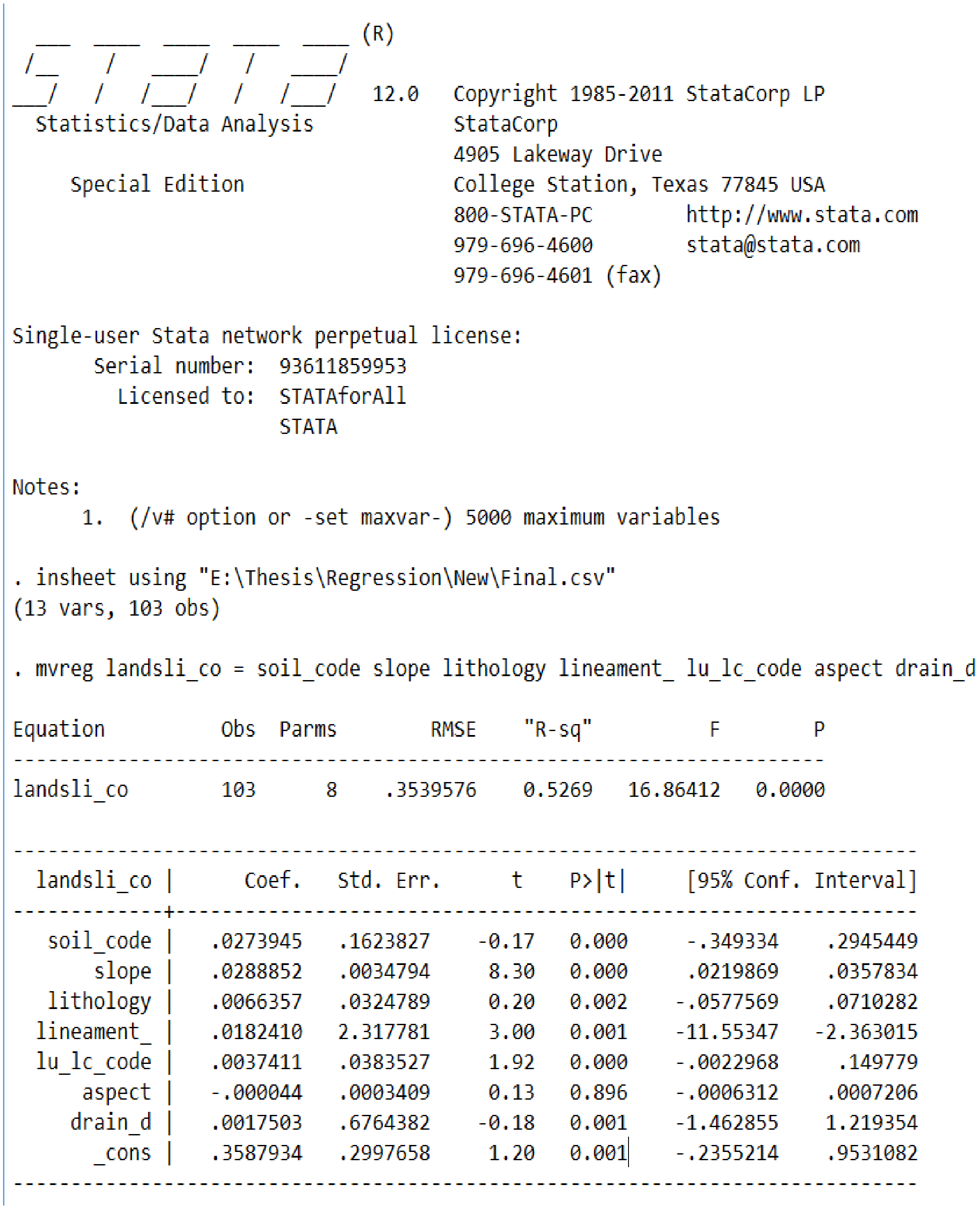
APPENDEX 1

Multivariate approach: Logistic Regression model result



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     Special Edition                  College Station, Texas 77845 USA
                                      800-STATA-PC        http://www.stata.com
                                      979-696-4600        stata@stata.com
                                      979-696-4601 (fax)

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Notes:
      1.  (/v# option or -set maxvar-) 5000 maximum variables

. insheet using "E:\Thesis\Regression\New\Final.csv"
(13 vars, 103 obs)

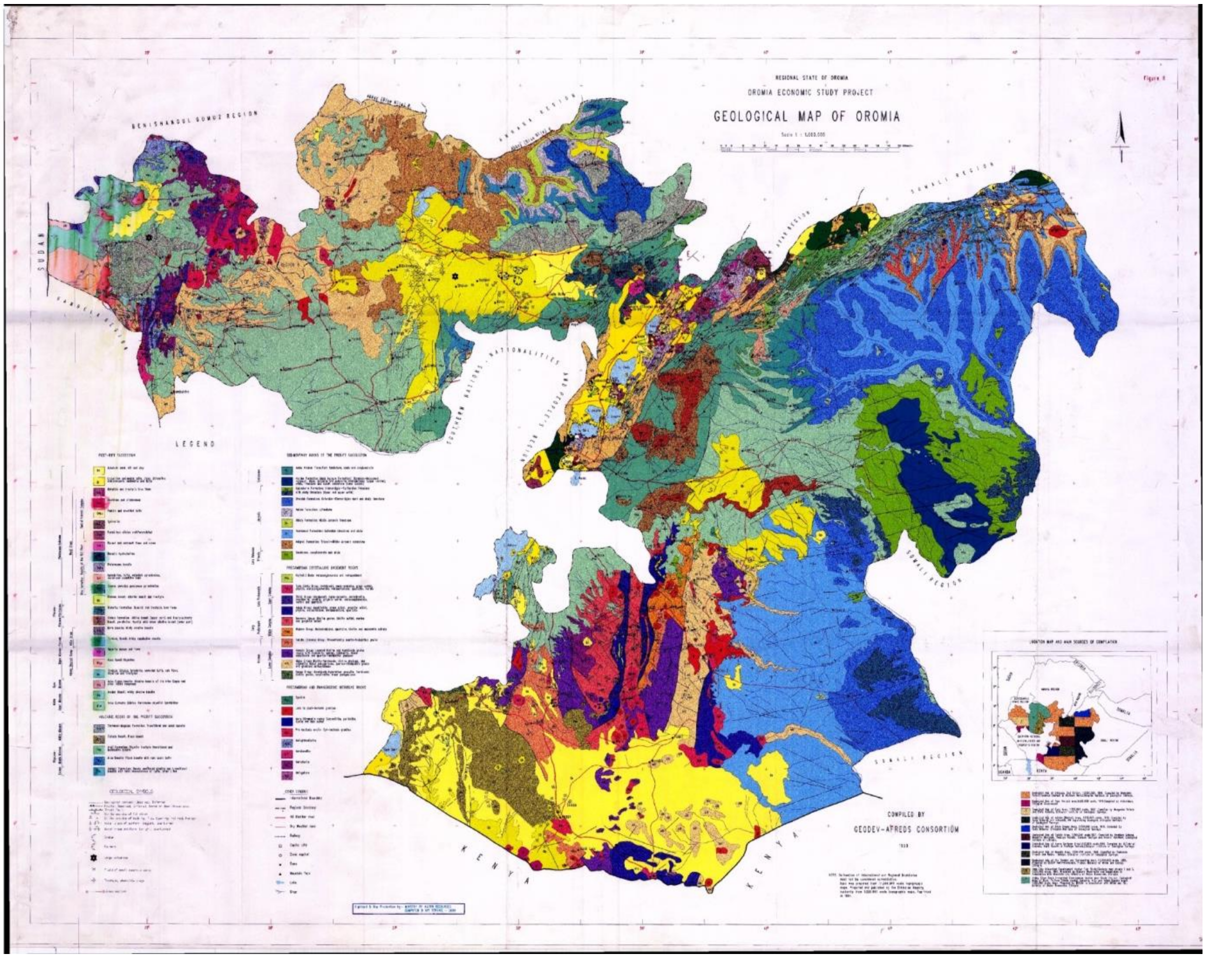
. mvreg landsli_co = soil_code slope lithology lineament_ lu_lc_code aspect drain_d

Equation          Obs  Parms        RMSE    "R-sq"          F        P
----------------------------------------------------------------------
landsli_co        103      8     .3539576    0.5269   16.86412   0.0000

------------------------------------------------------------------------------
  landsli_co |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   soil_code |   .0273945   .1623827    -0.17   0.000     -.349334    .2945449
       slope |   .0288852   .0034794     8.30   0.000     .0219869    .0357834
   lithology |   .0066357   .0324789     0.20   0.002    -.0577569    .0710282
  lineament_ |   .0182410   2.317781     3.00   0.001    -11.55347   -2.363015
  lu_lc_code |   .0037411   .0383527     1.92   0.000    -.0022968     .149779
      aspect |   -.000044   .0003409     0.13   0.896    -.0006312    .0007206
     drain_d |   .0017503   .6764382    -0.18   0.001    -1.462855    1.219354
       _cons |   .3587934   .2997658     1.20   0.001    -.2355214    .9531082
------------------------------------------------------------------------------
```

APPENDEX 2

Geological map of Oromia region.



APPENDEX 3: Rainfall Data for stations

Station Name	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug.**	**Sep**	**Oct**	**Nov**	**Dec**
Abelti	19.78	29.67	63.94	75.02	95.96	169.85	243.46	224.78	125.75	50.40	11.23	12.17
Ambuye	25.68	27.55	83.45	127.31	204.19	261.42	291.97	267.37	236.04	143.80	40.43	38.06
Atnago	16.29	40.48	82.71	117.85	188.43	253.46	298.81	302.13	215.05	124.03	35.53	20.96
Babu	34.75	36.64	99.08	125.05	231.96	251.83	270.03	282.36	261.19	152.29	56.06	41.50
Bako	10.18	8.64	52.23	66.08	140.77	246.95	257.46	211.98	192.41	65.44	19.78	11.03
Biloboshe	13.39	15.06	55.28	69.57	146.37	260.83	294.91	288.37	189.99	85.07	22.92	10.55
Busa	35.52	62.39	105.79	158.08	167.65	347.35	606.19	694.50	263.01	47.47	14.69	15.81
Ejaji	9.9	14.73	59.61	57.25	161.69	255.04	255.83	307.40	205.10	88.69	41.30	11.87
GebreGuracha	10.19	13.34	41.53	71.47	71.43	160.97	350.67	334.72	161.53	29.06	15.17	9.74
GunjoMariam	12.58	16.29	46.43	75.80	151.49	245.77	278.41	276.46	170.32	92.15	28.13	16.86
Ifabiya	28.13	29.20	73.50	78.59	176.85	272.04	329.47	305.47	191.23	87.78	39.81	27.28
Limu genet	21.50	30.51	94.29	130.99	211.29	273.16	302.77	296.00	257.57	164.09	42.11	28.62
Limu seka	19.09	39.44	83.26	112.53	188.08	236.18	294.44	302.73	257.14	130.56	35.33	18.89
Seyo	15.04	7.7	21.9	54.64	175.93	195.13	389.80	227.8	178.20	0	3.8	39.2
Sibusire	10.48	13.39	53.65	76.63	164.29	233.06	264.10	243.29	185.77	83.13	30.09	12.66

Source: NMSA(1980-2013)

APPENDEX 4

The Universal Soil Loss Equation (USLE) adapted for Ethiopia

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

1. R = Rainfall Erosivity

Annual rainfall	100	200	400	800	1200	1600	2000	2400
Factor R	48	104	217	441	666	890	1115	1340

2. K = Soil Erodibility factor

Soil color	Black	Brown	Red	Yellow
Factor K	0.15	0.20	0.25	0.30

3. L = Slope length

Length (m)	5	10	20	40	80	160	240	320
Factor L	0.5	0.7	1.0	1.4	1.9	2.7	3.2	3.8

4. S = Slope Gradient

Slope (%)	5	10	15	20	30	40	50	60
Factor S	0.4	1.0	1.6	2.2	3.0	3.8	4.3	4.8

5. C = Land Cover Factor

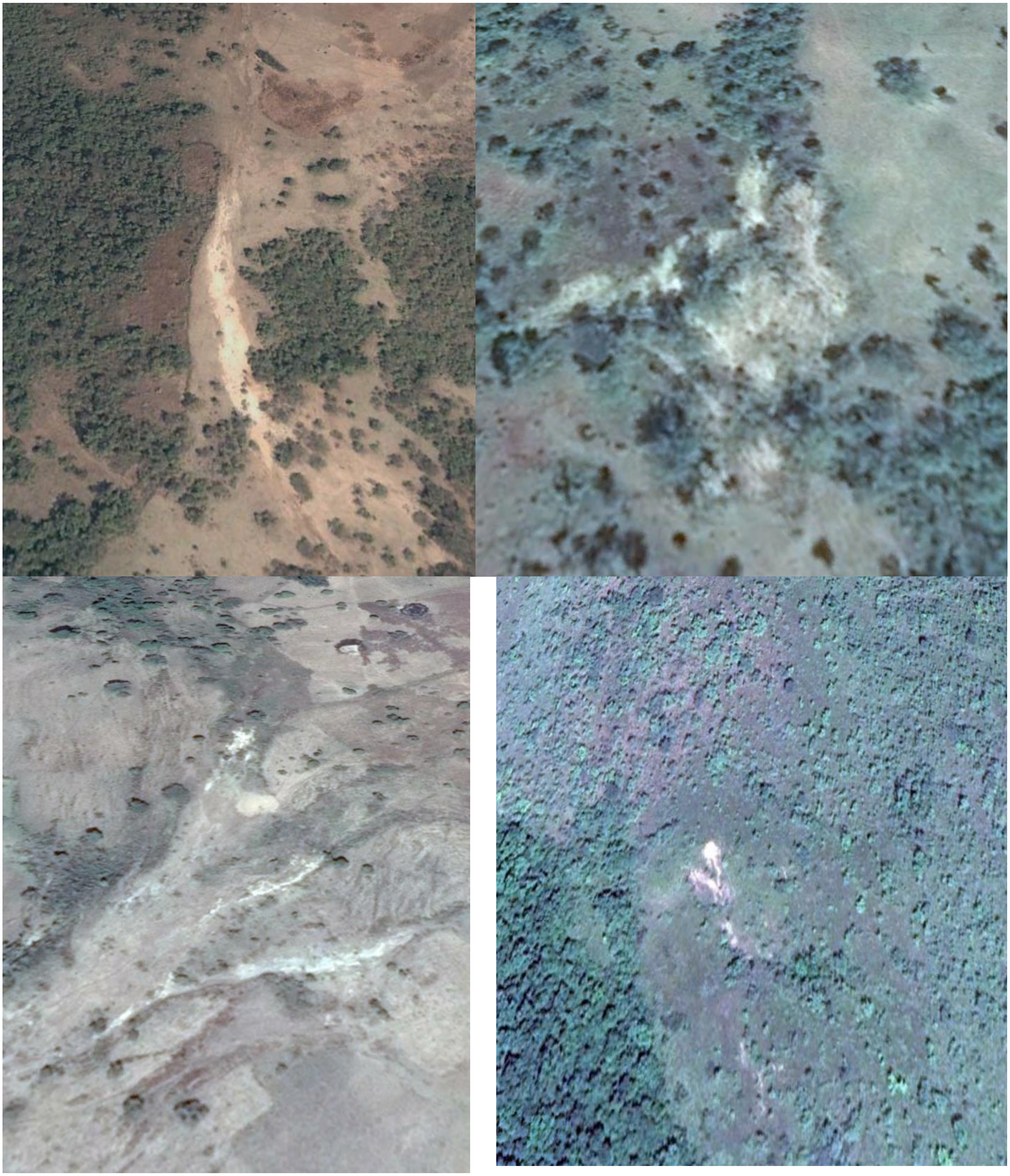
Dense forest	0.001	Dense grass	0.01
Other forest	0.01 – 0.05	Degraded grass	0.05
Bad land hard	0.05	Fallow hard	0.05
Bad land soft	0.04	Fallow ploughed	0.60
Sorghum, maize	0.10	Ethiopian Teff	0.25
Cereals, pulses	0.15	Continuous fallow	1.00

6. P = Management factor

Ploughing up and down	1.00	Ploughing on contour	0.90
Strip cropping	0.80	Intercropping	0.80
Applying mulch	0.40	Dense intercropping	0.70
Stone cover (80%)	0.50	Stone cover (40%)	0.8

Source: Hurni (1985), Hellden (1987)

APPENDEX 5: Landslide samples on satellite image



CERTIFICATE

This is certified that the thesis entitled "*Geo-Environmental Impact Assessment Using Integrated GIS and Remote Sensing Technique: A Case Study on the Halele-Werabesa Stage I Hydropower Plant, West Showa, Jimma Zone, Oromia, Ethiopia*" is a bonafied work carried out by Mekdes Zenebe under my guidance and supervision. This is the actual work done by Mekdes Zenebe for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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DECLARATION

I hereby declare that the dissertation entitled "*Geo-Environmental Impact Assessment Using Integrated GIS and Remote Sensing Technique: A Case Study on the Halele-Werabesa Stage I Hydropower Plant, West Showa, Jimma Zone, Ethiopia*" has been carried out by me under the supervision of Dr. K. V. Suryabhagavan and Dr. Trufat H/Mariam School of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2013-2014 as a part of Master of Science program in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date: May 30, 2014

(Mekdes Zenebe Ketema)