COLLEGE OF SOCIAL SCIENCE AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

PRIORTIZATION OF MICRO-WATERSHEDS FOR CONSERVATION INTERVENTION AND RESTORATION MEASURES USING GIS AND REMOTE SENSING TECHNOLOGIES: A CASE OF UPPER BILATE WATERSHED, SNNPR, ETHIOPIA.

By: ELIAS AREGA

MAIN ADVISOR: Ajay Babu (PhD)

CO-ADVISOR: Kiros Tsegaye (MA)

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES, JIMMA UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIRIMENT FOR THE DEGREE OF MASTER OF SCIENCE IN GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING.

October, 2019

Jimma, Ethiopia

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Declaration

I hereby declare that **"Prioritization of micro-watersheds for conservation intervention and restoration measures using GIS and Remote sensing technologies: A case of Upper Bilate watershed, SNNPR, Ethiopia"** is in partial fulfillment of the requirement for the degree of master of science in Geographic Information System and Remote sensing is an original work carried out by me under the guidance of Dr. Ajay Babu and Mr. Kiros Tsegaye and has not been submitted to any other University/Institution for the award of any other degree or diploma.

Signature ………………………

By: ELIAS AREGA

Place: Jimma University

Date: …………………………

Table of Contents

Table of Contents I
ACRONYMS III
LIST OF TABLE IV
LIST OF FIGURES V
ACKNOWLEDGMENTS VI
ABSTRACT VI
CHAPTER ONE 1
1. INTRODUCTION 1
1.1. Background of the study 1
1.2. Statement of the Problem 3
1.3. Objectives 5
1.3.1. General Objective 5
1.3.2. Specific Objectives 5
1.4. Research Questions 5
1.5. Scope of the study 5
1.6. Significance of the Research 5
1.7. Limitation of the study 5
CHAPTER TWO 6
2. LITERATURE REVIEW 6
2.1. Management of Natural Resources on Watershed Basis 6
2.2. Land Degradation 6
2.3. Land degradation in Ethiopia 7
2.4. RUSLE Model 8
2.5. Priority Areas in a Watershed 9
2.6. Role of GIS and remote sensing in Assessing Land Degradation 10
CHAPTER THREE 12
3. METHODS AND MATERIALS 12
3.1. Description of the Study Area 12
3.1.1. Location 12
3.1.2. Geology 13
3.1.3. Soil 13
3.1.4. Topography 13
3.1.5. Climate 13
3.2. Methodology 14
3.2.1. Research Design 14

3.2.2. Data types and Sources ... 14
3.3.2. RUSLE Model ... 17
3.3.3. Morphometric Analysis ... 21
3.3.4. Multi-Criteria Analysis factor generation and reclassification ... 28
3.3.5. Pairwise comparison for weighting ... 28
3.3.6. Erosion Risk in the Watershed based on Multi-Criteria Evaluation ... 30
CHAPTER FOUR ... 32
4. RESULTS AND DISCUSSION ... 32
4.1. Factors of RUSLE Model ... 32
4.1.1. Land Use Land Cover Data ... 32
4.1.2. Accuracy Assessment ... 33
4.1.3. Cover(C) factor ... 34
4.1.4. Rainfall Erosivity (R-factor) ... 36
4.1.5. Soil vulnerability to soil erosion (Erodibility) ... 37
4.1.6. Topographic (LS) factors ... 39
4.1.7. Conservation practice (P) factor ... 42
4.1.8. Estimated soil loss from the watershed ... 43
4.2. Factors of Morphometric analysis: ... 46
4.2.1. Basic Parameters ... 46
4.2.2. Linear Parameters ... 49
4.2.3. Shape Parameters ... 53
4.3. Prioritization of Micro-watersheds ... 55
4.3.1. Priority area based on RUSEL model ... 55
4.3.2. Erosion Risk in the Watershed based on MCE ... 58
4.3.3. Priority area based on morphometric analysis: ... 60
4.3.4. Conservation priority area ... 63
CHAPTER FIVE ... 65
5. CONCLUSION AND RECOMENDATION ... 65
5.1. CONCLUSION ... 65
5.2. RECOMMENDATION ... 66
REFERENCES ... 66
APPENDEX : ... **Error! Bookmark not defined.**

ACRONYMS

ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
GIS	Geographical information system
GLCF	Global Land Cover Facility
GPS	Global Positioning System
Ha	Hectare
Km	kilometer
LS	Slope Length and Slope Steepness
LULC	Land Use Land Cover
m.a.s.l	meter above sea level
MCA	Multi Criteria Analysis
Mm	Millimeter
MoARD	Ministry of Agriculture and Rural Development
MW	Micro-Watershed
NMA	National Meteorological Agency
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
SRTM	Shuttle Radar Topographic Mission
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WEPP	Water Erosion prediction project
WGS	World Geodetic System

LIST OF TABLE

Table 1: Source, type, description and purpose of the data used in the study 15
Table 2: Average annual Rainfall (mm) of the Five stations from 1997-2018..18
Table 3: Soil type, Color and Soil Erodibility factor (K) (Hurni, 1985 and Hellden 1987)....................19
Table 4: Conservation practice factor (P) value 20
Table 5: Micro-watersheds basin length value 22
Table 6: Micro-watersheds Bifurcation Ratio value 22
Table 7: Micro-watersheds Drainage Density value...23
Table 8: Micro-watersheds Stream frequency value 23
Table 9: Micro-watersheds Texture Ratio value..24
Table 10: Micro-watersheds Length of Overland Flow value 24
Table 11: Micro-watersheds Form Factor value..25
Table 12: Micro-watersheds Shape Factor value...25
Table 13: Micro-watersheds Elongation Ratio value...26
Table 14: Micro-watersheds based Compactness Coefficient value 27
Table 15: Micro-watersheds based Circularity Ratio value...27
Table 16: Continuous Rating Scale of Pairwise Comparison 28
Table 17: Area and percent of Land-use land-cover types 32
Table 18: Error matrix showing classification accuracy of the true land cover 34
Table 19: Land cover C-values used in different studies...35
Table 20: Annual precipitation and erosivity value 36
Table 21: Soil types and their erodibility factor 38
Table 22: LS-factor classes and their distribution in the watershed 41
Table 23 : Land Use/Land Cover types and the corresponding P values 42
Table 24: Micro-watershed wise Priority Rank based on potential soil loss..45
Table 25: Number of Stream within each Micro watershed 47
Table 26: Basic parameter of each Micro-watershed 49
Table 27: Stream number and Bifurcation ratio in different orders..50
Table 28: Micro-watershed based Computed Value for Linear parameters 53
Table 29: Micro-watershed based Computed Value for shape parameters 55
Table 30: Priority rank of micro-watersheds 56
Table 31: weight derived from pairwise comparison of criteria...58
Table 32: Areal proportion of the study area based on CEI classes 59
Table 33: Final prioritization based on compound Morphometric parameter 61
Table 34: Priority class based on morphometric analysis...62
Table 35: Conservation priority area 64

LIST OF FIGURES

Figure 1: Location and Topography map of the study area 12
Figure2: Upper Bilate Micro Watersheds 16
Figure 3: weight for pairwise comparison 29
Figure4: Flow chart of the overall methodology 31
Figure 5: Land use Land cover map of Upper Bilate watershed (2019) 33
Figure 6: The cover factor (C-values) in the study area 35
Figure 7: Rain fall and R-factor map of the study area 37
Figure 8 : Map of K-factor 39
Figure 9: Slope map of Upper Bilate watershed 40
Figure 10: LS-factor Map of upper bilate watershed 41
Figure 11: P factors map of upper bilate watershed 42
Figure 12: Soil loss map of Upper Bilate watershed 44
Figure 13: Stream Order map of the study area 48
Figure 14: Drainage density Map of the study area 51
Figure 15: Micro-watershed Prioritization map of soil loss severity rank 57
Figure 16: Composite Erosion Index map 59
Figure 17: Micro-watershed Prioritization map based on morphometric analysis 62
Figure 18: Micro-watershed Prioritization map based on RUSEL model and morphometric analysis ... 63
Figure 19: Conservation priority area map 64

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ABSTRACT

Watershed prioritization has gained importance in natural resources management, especially in the context of watershed management. RUSEL model and Morphometric analysis has been commonly applied to prioritization of micro watersheds. In the present study, prioritization on the basis of RUSEL model and morphometric analysis of watersheds has been performed for the Upper Bilate watershed. Eighteen micro-watersheds were delineated and designated as MWSD-1 to MWSD-18 for prioritization purposes. A particular micro-watershed may get top priority due to various reasons but often, the severity of land degradation is taken as the basis. A methodology, based on RUSLE and Morphometric analysis, has been applied using remotely sensed data, ASTER DEM together with other ancillary data in a ArcGIS10.3 environment. The analysis shows that RUSLE model and Morphometric analysis helps to categorize micro-watersheds into different levels of erosion risk and identify areas that require priority to conservation measures in relative to others. In both RUSEL model and morphometric analysis, and the resultant ranks, the micro-watersheds have been classified into five categories in relation to their priority for soil conservation measures: very high, high, moderate, low and very low. Based on the RUSLE model, the potential average annual soil loss of each micro-watershed in the watersheds ranges from 0.15-2985 t/ha/year with a mean annual soil loss of 16.08t/ha/year. The result showed that Micro-watersheds (MWSD-3, 6, 8 and 16) estimated very high soil loss (16.03-44.17t/ha/year) and fell under high soil erosion classes. About 21.03% of the micro-watersheds fall in below the annual average soil loss of the entire watershed. Based on Morphometric analysis, different prioritization ranks were ascribed following the computation of compound factors. It is found that micro-watersheds (MWSD-8 and 6) and micro-watersheds (MWSD- 10) are categorized in the class of very high and very low priority respectively and about 38.47% of micro-watersheds are classified in the categories of very high and high priority. With reference to the integration of the two methods of prioritization, micro-watersheds (MWSD-3, 6, 8 and 16), and (MWSD- 5, and 11) can be classified in the class of very high and high priority class respectively. By contrast, micro-watersheds (MWSD- 13, 17 and 18) and micro-watersheds (MWSD- 10) are categorized in the class of low and very low priority respectively. About 40.22% of the watershed falls in the categories of very high and high priority. As a result the critical micro-watersheds which are under very high and high category were selected and prioritized to be intervened for conservation and other rehabilitation measures.

Key Words: Prioritization, Micro-watershed, GIS and RS, RUSLE, Morphometric analysis

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Land degradation is increasing in severity and extent in many parts of the world, seriously affecting more than 20% of all cultivated areas, 30% of forests and 10% of grasslands (Bai et al., 2008). It is especially widespread in Sub-Saharan Africa (SSA), affecting 20-50% of the land and some 200 million people (Snel and Bot, 2003). An estimated 65% of Africa's agricultural land is degraded due to erosion and/or chemical and physical damage (FAO, 2005; UNEP, 2008).

Ethiopia, one of the developing countries in sub- Saharan Africa, depends on agriculture to satisfy the demand for food, fibre and other goods. Nevertheless, diminishing productivity, resulting from degradation of agricultural land induced by soil erosion, has been and is still a major concern (Admasu, 2005).

The Ethiopian government has for a long time recognized the serious implications of continuing soil erosion to mitigate environmental degradation and as a result large national programs were implemented in the 1970s and 1980s. However the efforts of these initiatives were seen to be inadequate in managing the rapid rate of demographic growth within the country, widespread and increasing land degradation, and high risks of low rainfall and drought. Since 1980, the government has supported rural land rehabilitation, this aimed to implement natural resource conservation and development programs in Ethiopia through watershed development (MOARD, 2005).

More recently, rapid population growth, cultivation on steep slopes, clearing of vegetation and overgrazing are the main factors that accelerate soil erosion (Hurni, 2002).In the Ethiopian highlands, the population has grown very fast on the limited land area and every possible piece of land is put into cultivation to produce food which results soil erosion (Hwado, 1997). Similarly, as stated by (Paulos,2001), the unique topography, type of soil, deforestation, i ntensive rainfall and low level of land management and the type of land use practiced all have resulted in heavy runoff that induced soil erosion particularly in the northern and central highlands. A study by Tilahun et al. (2001) also accounted that declining vegetative cover and increased levels of farming on steep slopes in Ethiopian highlands have eroded and depleted soils, so that soil degradation is now a widespread environmental problem. Thus understanding watershed characteristics and watershed management is very important part to maintaining healthy productive rivers.

In Ethiopia, cultivation on steep slopes and clearing of vegetation has accelerated erosion. The soil loss from different land categories is very high. In Ethiopia, the soil formation rate is very low which was compared to soil erosion rates (Hurni, 1993). In addition, Hurni states that annually Ethiopia loses over 1.5 billion tons of topsoil from the highlands by erosion. This could have added about 1-1.5 million tons of grain loss to the country's harvest. This catastrophic phenomenon has been mainly attributable to rapidly increasing human population, the limited area of fertile soils on flat lands, deforestation, and excessive livestock population. The demands of a rapidly expanding population has set up pressures on the study's area natural resources and these in turn have resulted in a high level of environmental degradation. The most important manifestations are heavy soil losses; high sediment yields; soil fertility decline and reduction in crop yields; marginalization of agricultural land; gullies formation; landslides and deforestation and forest degradation.

At national level, the overall soil loss from the whole land is estimated about 1.5 billion tons per year (FAO, 1986) with a mean of 42 t ha^{-1} accompanied with land loss of 25,000 ha $year^{-1}$, of which 45% initiated from cultivated land solely. On the other hand, soil loss in the high lands of Ethiopia was estimated about 200–300 t ha^{-1} $year^{-1}$ which makes a total soil loss of 23,400 million ton per year (Bewket, 2003).

Bilate watershed, that transects the central zones of the southern region of Ethiopia, is among the most degraded highland plains in Ethiopia. The watershed area is exposed to various physical and biological forms of land degradation. Besides, overgrazing, improper cultivation practices, mismanagement of land resource are the main causes for land degradation in the study area. Among the various forms of land degradation, soil erosion is the most serious problem, which results in soil nutrient depletion and loss of fertility of farm land (Wagayehu, 2005).

Prioritization of sub-watersheds for soil and water conservation is conducted recently in several areas. Such studies confirm the role of geographic information system (GIS), remote sensing (RS), and morphometric analysis as efficient tools in ranking different sub-watersheds according to the order in which they have to be taken for treatment and for soil conservation measures (Sureh. et. al., 2004).

Therefore, this study is to prioritize micro-watersheds based on morphometric analysis and RUSLE methods using remote sensing and GIS technology. A priority map for micro-watersheds was generated based on both methods, then; a final priority map has been developed by integrating the results achieved from the two methods of prioritization. Prioritizing micro watersheds based on hot-spot areas of erosion and strictly degraded areas is crucial to intervene on conservation measures in a cost effective and well-timed manner, rather than general implication of land degradation in a large watershed level. Having the above discussion in mind, the aim of this research is to identify conservation priority areas for intervention and Restoration measures in Upper Bilate Watershed using GIS and remote sensing technology.

1.2. Statement of the Problem

In Ethiopia, heavy dependence of people's livelihoods on agriculture and inappropriate use of natural resources resulted in fast and vast land degradation. On the other hand, development of agricultural sector partly depends on land productivity. However, this resource is seriously threatened by land degradation and aggravates the food insecurity problems in the country through its adverse impact on crop yield (Genene, 2006).

Land degradation particularly soil degradation has significant negative impact on productivity of land. This is because soil degradation and soil productivity are inversely related. It is manifested by a reduction in the actual or potential productivity of soils. Thus productivity of soil is significantly affected in Ethiopia due to the serious soil degradation in the country. It is indicated that the soil in cropping land of Ethiopia is not sufficiently fertile to support the required level of crop production. (Desta, 2009).

Mismanagements and misuse of natural resources, which is also related with traditional farming, use of Forests, use of primitive technology and the likes, are among the major problems in the country. These days, the most recommended approach to overcome problems related with environmental degradation is that of watershed based planning and management. Watershed based development programs, plans and conservation practices are related with the objective of prioritizing based on its severity and give solution for watershed related problems, proper land management, environmental protection, conservation practices, sustainable development Planning and the likes (Wagayehu, 2005).

Different researchers have conducted studies on land degradation in different parts of Ethiopia. These researchers have mainly focused on: nature of land degradation; traditional farmers' land management practices, ongoing soil and water conservation by government and other actors; farmers' perception on soil fertility change and on causes of land degradation (Yeraswork, 2000; Eyasu, 2002; Taffa, 2002; Aklilu, 2006; Genene, 2006).

Bilate watershed has tremendous land use land cover change and vegetation loses in relation with the increase of the rural population. Expansion of farmlands including the river bank is very common especially in the upper and middle courses. Although it needs further analysis by other researches, some of the tributaries are on the transformation from perennial to intermittent. At the mouth and around Lake Boyo in the middle course area the sedimentation area is increasing from time to time. Such problems are directly related with biomass Degradation followed by land degradation (Degelo, 2007).

Most of these researchers generally found out that there is high degree of land degradation in Ethiopia in general and in the highland areas in particular. In addition, limited financial resources as well as restrictions on land often exclude the application of conservation measures to all areas experiencing land degradation (Tamene and Vlek, 2007).

Concerning to the study area that identification of hot-spot areas of erosion and prioritizing areas of intervention in a micro watershed level is extremely important for reducing further degradation, reclaiming the degraded areas based on severity rank and improving the land productivity in a cost effective and well-timed manner in the watershed, the main one is that of the community were intervene on conservation measures without prioritizing strictly degraded area. Therefore, to fill this research gap the present study was attempted to identify conservation priority areas in Upper Bilate Watershed based on morphometric analysis and RUSLE models.

1.3. Objectives

1.3.1. General Objective

The overall objective of this study is to prioritizing micro-watersheds for conservation intervention and Restoration measures in Upper Bilate Watershed using GIS and Remote sensing.

1.3.2. Specific Objectives

This study is designed to realize the following specific objectives

- To identify high erosion hotspots using RUSLE model in the watershed,
- To make a comparative analysis among micro-watersheds on the basis of morphometric analysis,
- To prioritize and rank micro-watersheds based on magnitude of severity in land degradation ,

1.4. Research Questions

- Which micro-watershed having potential soil erosion in Upper Bilate Watershed?
- Where does most severe land degradation occur in the watershed?
- Which micro-watersheds need to be given highest priority for conservation measures?

1.5. Scope of the study

The scope of this study was limited in terms of space, time and subject. Spatially this study was delimited to Upper Bilate watershed and temporally study was conducted in a single time. In subject wise, the study was focused on identifying conservation priority area using GIS and Remote sensing in of Upper Bilate watershed as a decision making tool.

1.6. Significance of the Research

To undertake corrective measures and prevent further degradation of many watersheds, timely information on the extent and spatial distribution of erosion areas is of paramount importance. This information is necessary for cost effective soil conservation planning. In a watershed management program, however, it may not be possible to restore all degraded areas at once due to spatial variability in erosion severity and financial constraints. Therefore, it is necessary to focus watershed restoration efforts on selected watershed priority areas which need immediate attention and where there is hope of making a meaningful difference.

1.7. Limitation of the study

In the study area, since the soil loss are not measured manually using soil loss measuring materials, it only shows the vulnerability of the micro-watersheds spatially and it needs a deep study in a micro-watershed level. Moreover, to maximize the representativeness of the result of the soil erosion rate map relatively dense metrological stations were required to spatially represent rainfall over the study area, but only three stations were available within the watershed. Thus, in the study additional two rainfall data were taken from the stations nearby. Finance and time were also identified as real constraints in assessing the study area fully and buying appropriate imageries.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Management of Natural Resources on Watershed Basis

Soil, water and vegetation are the most vital natural resources for sustainable development and management, and hence should be handled and managed effectively, collectively and simultaneously. Managing the natural resource with sustainable approach is a rational phenomenon in its natural region. In this approach, the natural regions are invented to be in terms of the flow of water, which influences almost all fields of the environment, where the regions are diversified as basin, catchment, sub-catchment, macro watershed (50,000 ha), sub-watershed (10,000–50,000 ha), milli-watershed (1,000–10,000 ha), micro watershed (100–1,000 ha), mini watershed (1–100 ha) (Nair, 2009). However, a particular extent/size of a region is imperative with regard to the aim of its development. Size will also be affected by the possible major components of a development such as afforestation, cultivation practices, etc. Keeping in view the local conditions and completion of the project within a reasonably short time, an average size of 2,000 ha is considered rational for agricultural development with regard to ease of surveys and investigations and effective planning. In the present research work, a watershed has been taken as the smallest planning unit, as it conveniently and efficiently represents continuum of three vital natural resources i.e. soil, water and vegetation (Nair, 2009).

Watershed management programmers has emerged as a sustainable strategy to conserve the natural resources i.e. water, forest and soil in an integrated manner particularly in the rain fed and drought areas (Roy, 2005). Planning and management of natural resources at micro level of the watershed where there is a high spatio-temporal variability in Geo-physical and socio-economic variables, particularly in the fragile arid and semi-arid tropics (SATs), are the crucial need of the hour. The real challenge on water resources planning at a micro level is to assess the quantum of water demand and availability caused due to unavailability of adequate database. Watershed based planning through augmentation of modern techniques such as remote sensing (RS) and Geographic Information System (GIS), for modeling the availability of water resources and sectorial demand is being considered as the most appropriate approach (Aher et al. 2012).

2.2. Land Degradation

Land degradation problem has been addressed by a number of researchers. Land degradation is one of the consequences of mismanagement of land and results frequently from a mismatch between land quality and land use (Beinroth et al., 1994, in Reich et al., 2001). Most of works indicated that human induced land degradation is a critical problem in sub Saharan Africa including Ethiopia. This is attributed to increasing population pressure leading to cultivating marginal lands already susceptible or vulnerable to various forms of degradation (FAO, AGL, 2000), poverty and lack of agricultural intensification (lack of mechanized farming activities) (Nyssen et al., 2004) or soil erosion and deteriorations of soil structure due to heavy grazing (Tekle, 1999). Drainage practices on farm fields, inappropriate land use system and inappropriate land tenure policies aggravate land degradation processes in Ethiopia (Taddesse, 2001).

Degradation of agricultural land by soil erosion is a worldwide phenomenon leading to loss of nutrient rich surface soil, increased runoff from more impermeable subsoil and decreased water availability to plants. Thus, estimation of soil loss and identification of critical area for implementation of best management practice is central to success of a soil conservation program. The total land area subjected to human-induced soil degradation is estimated at about 2 billion hectares. By this, the land area affected by soil degradation due to erosion is estimated at 1100 million ha by water erosion and 550 million ha by wind erosion (Saha, 2003).

2.3. Land degradation in Ethiopia

The Ethiopian highlands, with an altitude of above 1600 Mts. above sea level, occupy only 44% of the area but host about 90% of the total population. The highland includes 95% of the cropped area and 75% of the countries livestock. Ethiopian Highlands have been facing repeated environmental crises associated with mainly drought, deforestation and soil degradation, which in turn caused food shortage and degradation of natural resources (EHRS- FAO 1986).

In accordance with various studies taken about land degradation issues at the national level in Ethiopia, land degradation has become more acute and major problem threatening phenomenon particularly in agricultural sector. As listed in Berry (2003), these include the Highlands Reclamation Study: Ethiopia Highland reclamation Study (EHRS- FAO 1986); studies by the National Conservation Strategy Secretariat, the Ethiopian Forestry Action Plan, and Soil Conservation Research Project.

Ethiopian Highlands Reclamation Study which was conducted on the Ethiopian highlands that is above 1500m a.m.s.l and associated valley has been an important source of information written in a series of working papers produced in 1984. It was intended to analyze and explain the types of soil degradation processes, their causes, severity and extent and estimate the soil loss rates in the highlands. One of the outputs of this study was a production of soil loss rate map at 1: 1,000,000 scales. The methodology used to produce the map was by superimposing the soil erodibility, rainfall erosivity, and land use/ land cover maps of the country. It in general produced erosion hazard and the present severity of erosion generalized maps in the high lands at scale of 1: 4000000. According to this study the study area categorized within none to slight to very high class, since the scale of the study area is small, it may not reflect exactly the real condition of the watershed under study (FAO, 1986).

On the other hand, Soil Conservation Research Project also made an important contribution to scientific understanding of the erosion processes in Ethiopia, since 1981.This project had six regional research units covering different climate zones in the Ethiopian highlands. From each site climate, run off, sediment loss and land use data were collected, some conservation measures have been tested, and results are available. Several research progress reports were produced. The conclusion from the researches indicate that in mid1980's 27 million ha or almost 50% of the highland area was significantly eroded, 14 million hectare seriously eroded and over 2 million hectare beyond reclamation. Erosion rates were estimated at 130 tons /ha /yr for cropland and 35 tons/ha/yr average for all land in the high lands. Forests in general have shrunk from covering 65% of the country and 90% of the highlands to 2.2% and 5.6% respectively (lbid).

On the basis of Ethiopian Highland Reclamation Study, the Ethiopian highlands, highly intersected by deep gorges and valleys, are suffering from serious forms of degradation. The inevitable human-induced land degradation through the persistent need for food, firewood and building poles has, over the centuries, led to the cutting down of forests on the mountain slopes and reduced the carrying capacity of parts of the highlands. With a population steadily increasing, putting more pressure on an already fragile environment, considerable damage has been done to the ecology. Fuel wood is already scarce, and many rural, inhabitants of the highlands now depend on animal dung as an alternative source of energy supply, consequently the situation reduces soil fertility (EHRS- FAO 1984).

In Ethiopian condition many environmentalists' policy makers and researchers agree that land degradation caused by soil erosion has been one of the chronic problems. For instance, majority of the farmers in rural areas are subsistence oriented, cultivating impoverished soils on sloppy and marginal lands that are generally highly susceptible to soil erosion and other degradation forces. These farmers constitute the poorest and the largest segment of the population whose livelihood depends directly on exploitation of natural resources. Most of the agricultural lands of south Ethiopia are known to be located in the humid tropical zone where the problem is witnessed. Land degradation in southern region occurs mainly in the form of soil erosion, deforestation and overgrazing. Depending on climate, soil type, topography of the land, vegetation cover, the highlands of the region including the study area catchments have experienced very serious land degradation (Tsegaye, 2007).

2.4. RUSLE Model

The Revised Universal Soil Loss Equation (RUSLE) is an empirically based model that has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practices (Renard*et al.*, 1997). It retains the factors of the USLE by including improved means of computing soil erosion factors. The RUSLE model in GIS environment can predict erosion potential on a cell-by-cell basis, which is effective when attempting to identify the spatial pattern of soil loss present within a large watershed area (Shi *et al.*, 2004). GIS can then be used to isolate and query these locations to identify the role of individual variables in contributing to the observed erosion potential value (Saavedra, 2005). In spite of this advantage, RUSLE does not estimate remote deposition and gully erosion. RUSLE computes average annual erosion as (Renard*et al.*, 1997):

$$A = R * K * LS * C * P$$

Where: A = computed average annual soil loss in tons/acre/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.

2.5. Priority Areas in a Watershed

Numerous studies have indicated that a few areas of the watershed are critical and responsible for high amount of soil erosion and sediment delivery because of differences in environmental attributes across landscapes (Tamene and Vlec, 2007; Tripathi*et al*., 2003). Moreover, as resources for conservation are often limiting, there will be a need to define priorities so that conservation action can be targeted where it is needed most. As a result, identification of priority areas is essential for the effective and efficient implementation of watershed management programmes.

According to UNEP (2003), conservation priorities can be defined in terms of either species or areas. Priority species for conservation are generally those most threatened with extinction, are restricted to small areas (endemics) or have few remaining individuals. Priority areas in a watershed, on the other hand, are those areas that are either sources of priority pollutants in the watershed or are most susceptible to changes that would result in increased input of priority pollutants, resulting in degradation of habitat and water quality (UNEP, 2003).

Priority areas in a watershed for conservation measures can be identified by considering physical hazards like drought, soil erosion, sedimentation and excessive percolation under irrigation (Khan *et al*., 2001; Tripathi*et al*., 2003). For instance, a watershed with a higher rate of erosion needs to be given higher priority for soil conservation measures to be adopted. Priority area identification in a watershed requires considering various factors since watershed is the natural integrator of variables such as precipitation, runoff, erosion and sediment discharge as they relate to input and output in an open hydrological system (Deore, 2005).

Keeping this in view, various studies used climatological, pedological, topographic and morphometric parameters to identify and map critical areas, which are proposed as high priority areas for conservation. For example, Deore, (2005) in his PhD thesis, used multi-criteria analysis to determine priority categories of micro-watersheds in Bhama basin by integrating such factors as slope, erosivity, erodibility, and drainage density and elongation ratio.

Using concepts of Similar Erosion Risk Potential Units (SERPUs), integrated landscape parameters such as slope, lithology, land use/cover, gully and fraction of surface cover to assess soil erosion and their delivery potential of two catchments of Northern Ethiopia. They also used Transformed Soil Adjusted Vegetation Index (TSAVI) as additional criterion to assess the fractional degree of surface cover and its relative level of degradation. For such input data generation and thereby priority area identification (or micro-watershed prioritization) activities, GIS and RS techniques together with various erosion prediction models have been successfully used in many studies (Lulseged and Vlek, 2005).

2.6. Role of GIS and remote sensing in Assessing Land Degradation

Soil erosion is spatial phenomenon, thus geo-information techniques play an important role in modeling (Yazidhi, 2003). Information regarding soil erosion status is vital for affecting soil conservation planning. Remotely sensed data both in the form of aerial and satellite data have potential utility for mapping and assessing soil erosion conditions. Visual interpretation of analog satellite images and digital analysis of remote sensing satellite digital data are employed in soil erosion mapping by studying soil, land cover and drainage characteristics (Rao, 1999).

The potential utility of remotely sensed data in the form of aerial photographs and satellite sensors data has been well recognized in mapping and assessing landscape attributes controlling soil erosion, such as physiographic, soils, land use/land cover, relief, and soil erosion pattern. Remote Sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Multi-temporal satellite images provide valuable information related to seasonal land use dynamics. Satellite data can be used for studying erosional features, such as gullies, rainfall interception by vegetation and vegetation cover factor (Pande et al., 1992).

Geographic Information System (GIS) has emerged as a powerful tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output, and for interaction with models. A fundamental characteristic of GIS is its ability to handle spatial data i.e. the location of object in geographic space, and the associated attributes. There is considerable potential for the use of GIS technology as an aid to the soil erosion inventory with reference to soil erosion modeling and erosion risk assessment. Erosional soil loss is most frequently assessed by RUSLE in GIS environment.

2.7. Morphometric analysis for watershed prioritization

Watershed prioritization is the ranking sub watersheds of a watershed according vulnerability to soil erosion. This analysis can be achieved through measurement of linear and shape aspects of basins with the aid of Geographic Information System (GIS). GIS techniques are currently used for assessing various terrain and morphometric parameters of the drainage basins, as they provide a flexible environment and powerful tool for the manipulation spatial information (Mohammed et. al., 2018). A quantitative morphometric characterization of a drainage basin to be the most satisfactory method planning of watershed management because it enables the user to understand the relationship among different aspects of the drainage the basin, and also to make evaluation of different drainage basins developed in various geologic and climatic regimes (Zende et al., 2013).

In specific terms, results morphometric analysis yield useful information pertinent to the ruggedness irrigation potential of the basin, flood and above all, it provides an input for understanding the role of the characteristics of the terrain in development of the drainage basin (Vandana, 2013

CHAPTER THREE
3. METHODS AND MATERIALS

3.1. Description of the Study Area

3.1.1.Location

Upper Bilate watershed is the sub watershed of major Bilate River Basin. It is located mainly in between Hadiya zone (Misha, Lemo, Ani-Lemo and Shashogo woreda) and Kembata zone (Angech Woreda) and Gurage zone (Gumer Woreda). It covers a total area of 1608.52 Km^2 and geographically positioned between latitude 7^0 05' 45" to 8^0 08' 48" N and longitude 37^0 40' 52" to 38^0 06' 11" E (Fig.1). Upper Bilate watershed is located to South West of Addis Ababa 230km away via Alemgena-Butajira route, 280km from via Wolkite route, and also located 168 km away via Halaba-Angeca and 203km via Halaba-Durame from Hawassa a capital of SNNPR (Sintayehu, 2009).

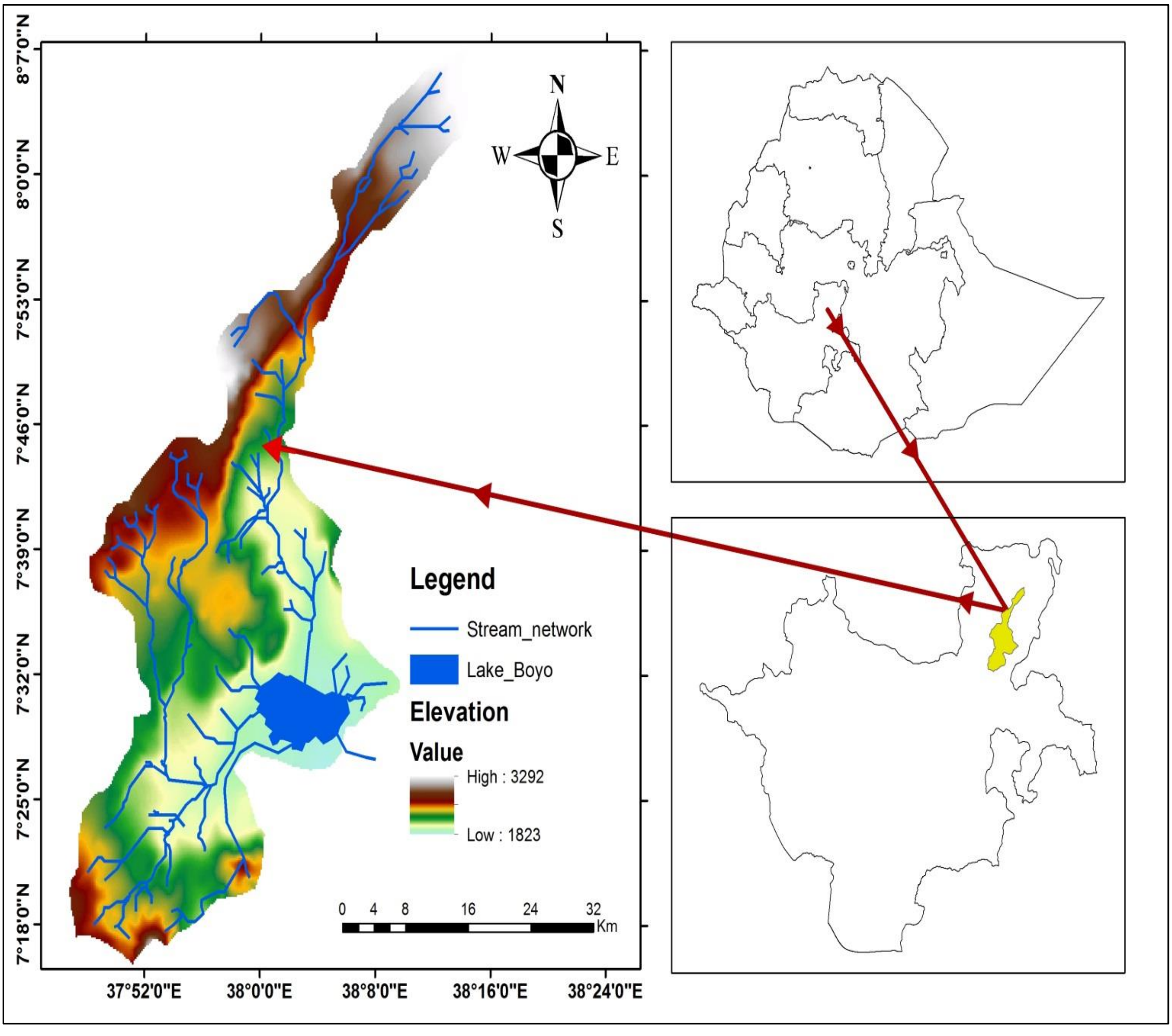

Figure 1 : Location and Topography map of the study area

3.1.2. Geology

As described in SNNPR regional map (2004), the study area is geologically part of the magdala shield group of Cenozoic era of tertiary volcanic predominate by acidic rocks including acid tuffs, mostly ignimbrites, pentelleritic rhyolites and trachytes. These rocks are bedded with lava and agglomerates of basaltic composition. The volume of acidic rocks tends to decrease away from the rift valley.

3.1.3. Soil

As to the distribution of soil, FAO / UNESCO classification of soil of the world taken in to consideration, accordingly, there are 5 types of soils in Upper Bilate catchment, Of which, Chromic Luvisol accounts for 821.9 Km^2 (49.1%) of the entire study area. The rest Eutric Vertisols, Lithic Leptosols, Humic Nitosol and Vertic Andosols constitute the remaining areal share of the study area (UNESCO /FAO, 1984).

3.1.4. Topography

The main land form of the catchment is steep slope having 10%-30% with small relatively gentled slope. As seen from the Fig.1 more than 75 % of the study area lies within the slope range of 15%-25% which is generally steep slope undulating topographic feature. The elevation of the area in general ranges from 1800 – 3000 a.m.s.l in Gurage Zone Arikit becomes the highest and water divide between the study's area drainage and those rivers empty in to major Omo River (Shafi, 2013).

3.1.5. Climate

Rain fall which plays a great role in the formation of soil at the same time making the soil more readily removable varies in the study area within the range of 929.9 mm to (Shashogo) and 1481.3mm (ARIKIT). Though some part of the study area along Upper Bilate River lies on relatively low rainfall, the largest part of the study area fall in areas where rain fall receiving above 1200mm. This in general made the area to have experienced above Weyina Dega to Dega type of climate. It could also be grouped as an area in the country getting bimodal rain fall. Despite the fact that bimodal rain fall would allow two growing seasons for the area the probability of removing soil and aggravating mass movement (wasting) is so high. As most part of Ethiopia experience the study's area climate is also governed by the north-south oscillation of ITCZ (Inter tropical Convergence Zone) (NMA, 2018).

3.2. Methodology

3.2.1. Research Design

This study was conducted based on partially mixed sequential dominant status quantitative cross sectional research design. It was relied more on quantitative or technical logical procedures while concurrently recognizing qualitative procedures (Burke et al., 2007). Powell et.al, (2008), also indicated that quantitative and qualitative phases occur one after the other, with the quantitative or technical phase being given higher priority and mixing occurring at the data interpretation stage as a triangulation. The technical phase of this research was associated with the prioritization of highly degraded land (area).

3.2.2. Data types and Sources

3.2.2.1. Data Sources

To achieve the objective of the present study primary and secondary data were obtained from different sources. Primary source of data was from Garmin Handheld global positioning system (GPS) to collect ground control truth points and field observation. Whereas Secondary data sources were from, internet, reports, books, journals, governmental institutions, like Ethiopian Mapping Agency (EMA), Central Statistical Agency of Ethiopia, National geological survey of Ethiopia, Ministry of agriculture.

3.2.2.2. Data Type and Method of collection

3.2.2.2.1. Satellite Data

Cloud free 2019 Sentinel image covering the study area was downloaded from USGS for LULC classification. 30m*30m resolution ASTER DEM was downloaded from USGS and it was used for watershed delineation, micro-watershed, slope and flow accumulation generation. Additionally random sample of erosion susceptible area polygons were generated from Google earth for the verification of erosion potential map.

3.2.2.2.2. Field Data

Field work was carried out during the sunny season in 2019. Prior to the fieldwork, a detailed examination of False Color Composite of a Sentinel image and a topographic map of the study area was conducted to get an overall view and to systematically identify and select sampling areas depending on the accessibility of each site. A GPS was used to locate and define the sampling areas. Meanwhile, Information was collected about physical aspects of vegetation cover and erosion features of the area.

3.2.2.2.3. Ancillary data

Ancillary data was collected from different reports and departments in the study area. Soil data was collected from Ministry of Water Resource and Geological Survey of Ethiopia and it was used to analysis and interprets the data. Climatic data such as 22 years mean annual rainfall from (1997-2018) were also gathered from National Meteorological Agency of Ethiopia. The study will be tried to use the optimum availability of ancillary data to achieve the objectives of the study.

Table 1: Source, type, description and purpose of the data used in the study

No.	Types of data	Source	Description	Purpose
1	DEM	USGS	❖ ASTER 30m x 30m resolution	For Watershed delineation and slope & flow accumulation generation
2	Sentinel	USGS	❖ 10m*10m spatial resolution	For supervised LULC classification
3	Digital Soil map	Ministry Of Water Resources (MoWR)	❖ FAO (1986)	To generate soil map for the model
4	Rainfall	National Meteorological Agency, Ethiopia	❖ 22 years RF data from 5 stations near the study area	To extract the R-map from mean annual RF data
5	GCPs		❖ Random coordinates from each LU/LC using Garmin GPS 72 model device	For accuracy assessment of the supervised classification
6	Informal interview	Natural resource experts and Development Agents who work in the study area	❖ Rank the contribution of erosion factors	Input for the Multi- criteria analysis

3.3. DATA ANALYSIS

3.3.1. Micro-watershed Delineation

The micro watersheds under study area were delineated using the automatic delineation option available in ArcHydro Tools 9.1 Extension. Patched DEM derived from 30m x 30m ASTER DEM was used in the delineation procedures. Any areas of internal drainage are filled in so as to create depression less elevation grid. From filled DEM, flow direction then flow accumulation was generated. Based on an iterative process to find the best stream threshold value, 18 micro-watersheds were delineated as shown in Figure 2. Area of the micro-watersheds ranges between 48 km^2 (MWS14) and 169 km^2 (MWS1).

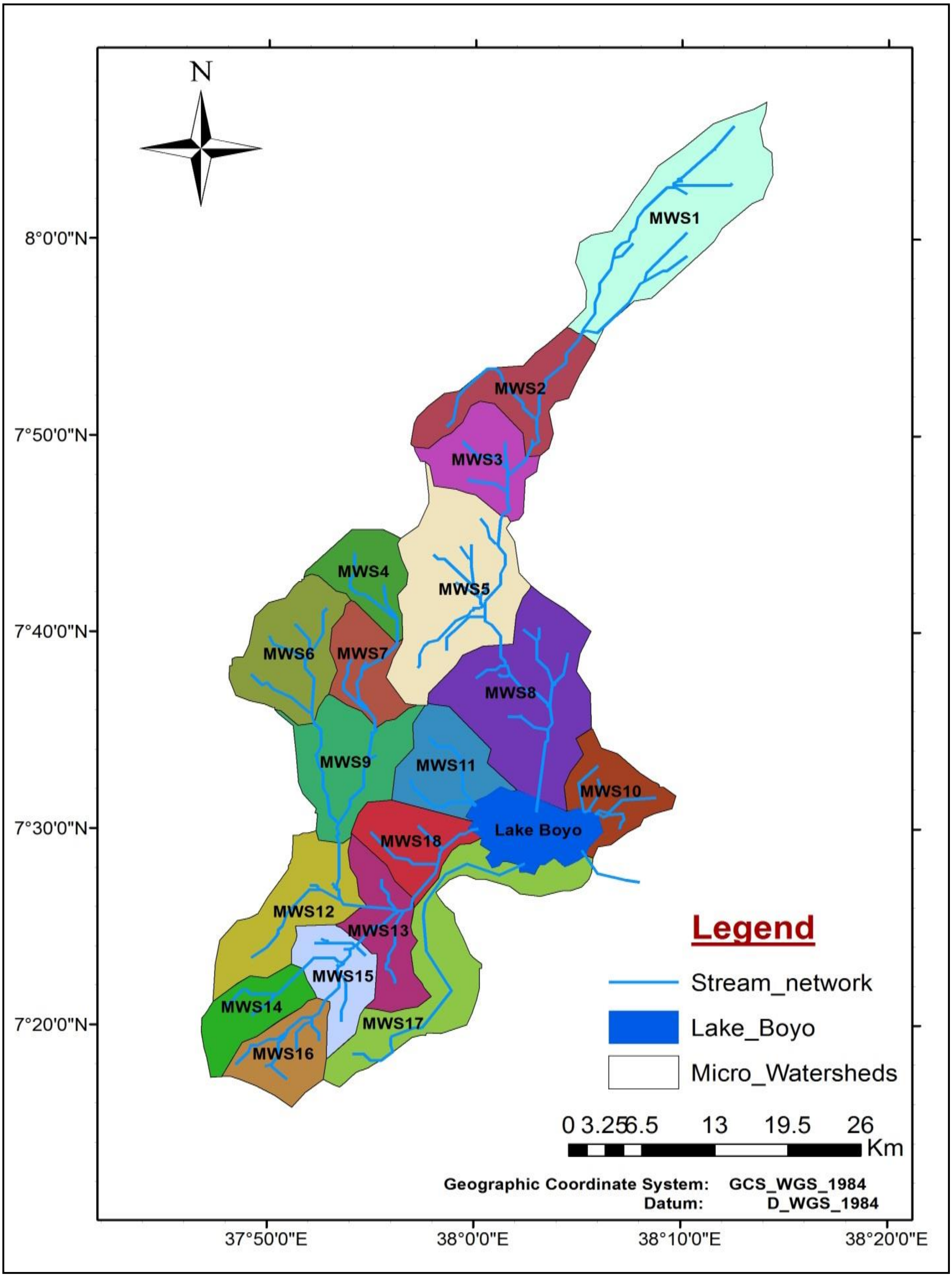

Figure2: Upper Bilate Micro Watersheds

3.3.2. RUSLE Model

3.3.2.1. Image Classification

From the downloaded 13 bands of Sentinel by subtracting the two bands (the panchromatic band and the thermal band) 11 bands were combined by layer stack in ERDAS imagine 2015. Then combined bands of the image data were classified. Next to this; the LULC classes were considered in the image classification process were identified. This was done by using field survey and visual image interpretation of the source image. The FAO (2011) land LULC classification system was used to define the LULC classes. The overall objective of image classification procedures is to automatically categorize all pixels in an image into LULC classes (Lillesand and Kiefer, 1994). For this study supervised LULC classification was undertaken by ERDAS Imagine 2015 software using the maximum likelihood image classification to obtained crop cover factor (C-factor).

Accuracy assessment were undertaken to validate and compare the classified image with geographical data that are assumed to be true. The accuracy assessment of the LULC maps has been undertaken by comparing the field data collected by GPS with the classified images in ERDAS imagine 2015 software. Six LULC classes were recognized using visual image interpretation and field survey. Thus from the supervised digital image classification and 83.5% accuracy was recorded from the collected ground truth information. These include forest, farm land, bare land, settlement, water body and grass land.

3.3.2.2. Cover (C) factor

From the Supervised digital image classification six LULC classes were recognized. These include water body, settlement, forest, grass land, farm land and bare land. The crop cover factor *C* measures the combined effect of all the interrelated cover and management variables.
The cover (C) factor corresponding to each land use land cover was estimated from different literature listed in Table 6. After getting the classified image, format has been changed into vector format and the corresponding C-value which was obtained from different literature listed in Table-6 was assigned and C - factor map was produced (Figure-5).

3.3.2.3. Rainfall Erosivity (R)

Due to rainfall characteristics and absence of automatic hourly rain intensity records in many rainfall stations in Ethiopia, it is difficult to apply erosivity equation proposed by Renard *et al.,* (1997) for Ethiopia condition (Nyssen,2001). Therefore, 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 based on the easily available mean annual rainfall (P).

R = - 8. 1 2 + (0. 5 6 2 x P)……………………………. (Hurni H, 1985)

Where **P** is mean annual rainfall in mm.

In this study, historic rainfall data of 22 years (1997-2018) was collected from five rain gauge stations (Alaba, Angach, Fonko, Hosanna, and Walberg) shown in Table: 2. Based on this the average rainfall of the study area which has been ranges from 929 mm to 1482mm. A rainfall map with cell size of 30m*30m was generated from the average rainfall data of the five stations using IDW interpolation technique in Arc GIS 10.3. The R-value was calculated using the rainfall map with a cell size of 30m*30m in raster calculator function of ArcGIS 10.3.

Table 2: Average annual Rainfall (mm) of the Five stations from 1997-2018

		Annual RF data of five Stations				
		Angech	Alaba	Hossana	Foniko	Wulibarg
X- Coordinate		37.571626	38.096111	37.856235	37.960258	38.118042
Y-Coordinate		7.253148	7.299239	7.567737	7.643853	7.741520
Years	1997	1600.6	796	1163.7	946.1	1464.9
	1998	1442.7	941.1	1173.2	1375.4	1190.3
	1999	1503.3	992.7	1429.5	1664.9	1266.7
	2000	1345.1	856.1	1305.3	1367.7	1416.8
	2001	1026.7	873.8	1003.6	1154	1525.7
	2002	1399.5	1051.6	991.9	1184.6	1377.4
	2003	2407.6	950.3	1093.9	1417	1027.2
	2004	1668.5	850.3	1250.9	1406.1	1198.3
	2005	1922.5	1105.8	1146.3	1466.6	1431.75
	2006	1714.2	956	1162.5	1195.8	1152.4
	2007	1934.8	710.2	1175	1225.5	1381.8
	2008	1830.3	1177.9	1197.7	1200.1	1136.4
	2009	1892.8	1057.75	1178.9	1110.7	1663
	2010	1443.6	531.3	1210.6	1269.2	1228.9
	2011	1259.9	1211.9	1170.4	1009	1183.6
	2012	1234.3	786.3	1121.59	1253.3	1176.5
	2013	1290.5	901.9	1004.5	1064.4	931.5
	2014	1092.3	1092.7	1109.3	1082.8	1060.2
	2015	1316.1	756.1	1164.6	1169.8	1530.8
	2016	1076.4	837.8	1499.1	1134.7	1143.6
	2017	732.1	1211.6	748	1218.95	1227.5
	2018	1455.4	809.3	1275.7	1359.4	987.7
MAP of each stations		**1481.32**	**929.93**	**1162.5**	**1239.82**	**1259.2**

Sorce: National Meteorological Agency of Ethiopia

3.3.2.4. Soil Erodibility Factor (K) Index

The Soil Erodibility (K-factor) refers to the liability of the soil to "suffer" erosion due to the forces causing detachment and transport of soil particles (Hellden, 1987). For Ethiopian condition an attempt was made to classify the soil types of the study area based on their color by referring the FAO soil database.

Table 3: Soil type, Color and Soil Erodibility factor (K) (Hurni, 1985 and Hellden 1987)

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

No.	Soil type	Soil Color	Erodibility factor (K)
1	Andosols	Brown	0.2
2	Leptosols	Brown	0.2
3	Luvisol	Red	0.25
4	Nitosol	Red	0.25
5	Vertisols	Black	0.15
6	Water body	Blue	0

3.3.2.5.Topographic (LS) factors

In using RUSLE, the effects of topography on soil erosion are estimated by the slope length (L) and slope steepness (S). It has been demonstrated that increases in slope length and slope steepness can produce higher overland flow velocities and correspondingly higher erosion (Han*et al*., 1994).The upslope drainage area for each cell in a Digital Elevation Model (DEM) was calculated with multiple flow algorithms. Multiple flow algorithms can divide flow between several output cells (Desmet & Govers, 1996).

The LS-factor has been derived from slope and flow length. Slope was generated from 30m*30m resolution DEM using ArcGIS 10.3. To generate flow length which is the unit contributing area first, any spurious single-cell sinks within the DEM were filled to produce a depression less DEM. In this process, individual sink elevations were flattened. Then by using filled DEM the flow directions of each DEM cell was calculated. From flow directions Flow length was determined in ArcGIS 10.3. Then the LS factor grid was estimated with the following equation using raster calculator in which is proposed by (Wischmeier and Smith 1978).

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

Where LS is slope steepness-length factor, the cell value is the resolution of DEM which is 30and S is slope in percent generated from DEM.

3.3.2.6.Conservation practice (P) factor

The management practice factor P indicates the effect of conservation practices on soil erosion, wherein the land which has adequate conservation interventions. Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff (Renard and Foster, 1983). Studies conducted by Hurni (1985) have found P values for various support practices and land use cover. Hurni used P value range between zero and one. This means the P value indicates reduced erosion potential, with a range between 0 to 1 because of farming practices or soil and water conservation measures. With no erosion control practice, P is equal to one.

The data related to management or support practices situations of the study area were collected during the field work through different techniques. The techniques deployed includes interview of the local community, site observation by transect walk and secondary information collected from wereda and local agricultural offices. Therefore, values for this factor were assigned considering local management practices and based on values suggested in Hurni (1985). Management factors were obtained by assessing the different supporting practices in the study area and it was taken the weighted value for similar land use types.

Table 4: Conservation practice factor (P) value

No.	LULC type	P value
1	Grass Land	0.63
2	Forest/Woody Land	0.53
3	Farm Land	0.9
4	Settlement	0.65
5	Bare Land	0.75
6	Water body	-

3.3.2.7.Soil Erosion Risk Analysis using RUSEL model

The five erosion factors (Cover factor (C), Rainfall Erosivity (R), Soil Erodibility Factor (K), slope steepness- length factor (LS) and Conservation practice (P) factor) which are estimated in the above was used for the estimation of average annual erosion in RUSLE. Each factor grid had a cell size of 30 m and all the layers were projected with Adindan_UTM_Zone_37N datum. All the five factors were multiplied by applying the following equation in Arc GIS10.3 using raster calculator (Renard et al., 1997).

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

Where: - A is the computed spatial average soil loss rate (t/ha /year),

R is the rainfall-runoff erosivity factor [MJ mm/ (ha h year-1)],

K is the soil erodibility factor [t ha h/ (ha MJ mm)],

L is the slope length factor,

S is the slope steepness factor,

C is the cover management factor, and

P is the conservation support practice factor.

The factors L, S, C, and P are all dimensionless.

3.3.3.Morphometric Analysis

Morphometric analysis was employed for prioritizing of watersheds at different scales including sub-watersheds, mini-watersheds, and micro-watersheds. Hydrologic investigation extension in ArcGIS offers a system to define the physical features of a surface using a Digital Elevation Model (DEM) as input. Hydrological model analyses were used to determine the behavior of where the water comes from and where it is going is important for morphometric characterization through watersheds delineation. This quantitative analysis of micro-watersheds in Upper Bilate watershed was performed to assess the characteristics and properties of the drainage networks. Morphometric parameters of watershed which represent basic, linear, areal, shape and relief aspects of the watershed were considered for analysis to characterize the entire watershed. Whereas, five basic parameters, five linear parameters, and five shape parameters were computed for the micro-watersheds to prioritize them for soil conservation.

3.3.3.5. Basic Parameters

Basic parameters which were computed for each micro-watershed are: the area (A), perimeter (P), stream order (u), basin length (Lb), and stream length (Lu).

I. Micro-watershed area (A) and perimeter (P)

The drainage area that was considered as the most significant hydrological characteristics of a watershed. It reflects the volume of water that can be generated from precipitation. The present study was computed that the area coverage of each micro-watersheds and the watershed perimeter which represents the length of the line that demarcates the surface divide of the micro-watershed using in Arc- toolbox geometric calculator in GIS software analysis (as shown in Table-11).

II. Stream order (Nu)

Based on Strahler (1964) method; the streams were given order designation. The smallest finger-type tributaries were designated order 1, where two first order channels join, a channel segment of order 2 where forms; where two channels of order 2 join a segment of order 3 is forms; and so forth. In this paper, the whole drainage in the watershed was strewn in five orders (as shown in Table-10).

III. Total length of streams (Lu)

The number of streams of various orders for each micro-watershed were measured their lengths geometric calculator in GIS software analysis based on the formula which formulated by (Horton, 1945) (as shown in Table-11).

IV. Basin length (Lb)

(Patel *et al*., 2012,) stated that the (Lb) parameter is crucial in hydrological computation and increases as the drainage increases and vice versa. It is defined as the distance measured along the main channel from the watershed outlet to the basin divide. Thus, the basin length is measured along the principal flow path, and constitutes a basic input parameter to calculate the major shape parameters. In this study a variation of each micro-watershed basin length were calculated using a formula:

$$L_b = 1.321 \times A^{0.568}$$ .... (Nooka, 2005)

Where: - L_b= basin length

A = area of basin

Table 5: Micro-watersheds basin length value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km²)	**195.2**	**99.89**	**79.64**	**51.22**	**162.27**	**91.13**	**50.53**	**164.96**	**93.2**	**54.4**	**68.33**	**89.9**	**64.3**	**49.7**	**54.4**	**56.4**	**124.2**	**58.7**
$A^{(0.568)}$	**19.99**	**13.7**	**12.02**	**9.35**	**18.01**	**12.97**	**9.28**	**18.17**	**13.1**	**9.68**	**11.02**	**12.9**	**10.6**	**9.2**	**9.68**	**9.88**	**15.47**	**10.1**
L_b	**26.41**	**18.1**	**15.9**	**12.4**	**23.79**	**17.1**	**12.3**	**24**	**17.4**	**12.8**	**14.6**	**17**	**14.1**	**12.2**	**12.8**	**13.1**	**20.44**	**13**

3.3.3.6. Linear Parameters

Linear parameters include bifurcation ratio, drainage density, stream frequency, texture ratio, and length of overland flow.

I. Bifurcation Ratio (Rb)

Bifurcation Ratio (Rb) is the ratio of the number of the streams of a given order to the number of streams of the next higher order (Horton, 1945). The bifurcation ratio is introduced by Horton (Horton, 1945) as an index of relief and topographic dissection. Bifurcation ratios vary between 2 for flat or rolling catchments, and 6 for watersheds distorted remarkably by geological structure (Table-12).

$$R_b = Nu/Nu + 1$$ …………………………….. (Horton, 1945).

Where: -N_u = no. of segments

N_u + 1 = no. of segments of the next higher order

Table 6: Micro-watersheds Bifurcation Ratio value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Nu	**13**	**4**	**7**	**7**	**17**	**9**	**4**	**11**	**6**	**10**	**7**	**6**	**13**	**7**	**11**	**7**	**4**	**6**
R_b=Nu/Nu+1	**3.25**	**0.57**	**1**	**0.41**	**1.89**	**2.25**	**0.36**	**1.83**	**0.6**	**1.43**	**1.17**	**0.46**	**1.86**	**0.64**	**1.57**	**1.75**	**0.7**	**-**

II. Drainage Density (D_d)

Drainage Density (D_d) refers to the closeness of spacing of channels. It is a measure of the total length of streams in a watershed per unit area, and therefore, it is a measure of topographic dissection and runoff potential of the catchment. A high value of D_d would indicate a relatively high density of streams, high runoff, a quick stream response, and consequently a low infiltration rate. Whereas,low drainage density of a basin implies low runoff and high infiltration (Table-13).

$$D_d = Lu/A$$ …………………………(Horton, 1945).

Where: - Dd = Drainage Density
Lu = total stream length of all orders (km)

A = area of the watershed (km2)

Table 7: Micro-watersheds Drainage Density value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km^2)	**195.19**	**99.89**	**79.64**	**51.22**	**162.27**	**91.13**	**50.53**	**164.96**	**93.2**	**54.38**	**68.33**	**89.91**	**64.27**	**49.72**	**54.42**	**56.44**	**124.24**	**58.7**
L_u	**70.28**	**34.02**	**38.31**	**20.98**	**83.83**	**38.00**	**22.33**	**57.57**	**34.03**	**26.08**	**22.16**	**43.41**	**26.90**	**18.47**	**38.69**	**28.49**	**41.69**	**26.94**
D_d =Lu/A	**0.36**	**0.34**	**0.48**	**0.41**	**0.52**	**0.42**	**0.44**	**0.35**	**0.37**	**0.48**	**0.32**	**0.48**	**0.42**	**0.37**	**0.71**	**0.50**	**0.34**	**0.46**

III. Stream Frequency (F_u)

Stream frequency (F_u) denotes the ratio of total number of streams (N_u) in a catchment to the catchment area (A). It is recognized as the number of streams per unit of area. The F_u value is positively correlated with D_d values of the watershed, which means that the increase in stream population is connected to that of drainage density. The values of D_d and Fu for small and large drainage basins are not directly comparable because they usually vary with the size of the drainage area. High stream frequency means more percolation with respect to drainage density, and thus, more groundwater potential (Horton, 1945) (Table-13).

Fu = Nu/A …………………………………………… (Horton, 1945)

Where: - Nu = total no. of steams of all orders
A = area of the basin (km2)

Table 8: Micro-watersheds Stream frequency value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km2)	**195.19**	**99.89**	**79.64**	**51.22**	**162.27**	**91.13**	**50.53**	**164.96**	**93.2**	**54.38**	**68.33**	**89.91**	**64.27**	**49.72**	**54.42**	**56.44**	**124.24**	**58.7**
Nu	**13**	**4**	**7**	**7**	**17**	**9**	**4**	**11**	**6**	**10**	**7**	**6**	**13**	**7**	**11**	**7**	**4**	**6**
Fu =Nu/A	**0.07**	**0.04**	**0.09**	**0.14**	**0.11**	**0.10**	**0.08**	**0.07**	**0.06**	**0.18**	**0.10**	**0.07**	**0.20**	**0.14**	**0.20**	**0.12**	**0.03**	**0.10**

IV. Texture Ratio (T)

Texture Ratio (T) refers to the ratio of the total number of streams of first order (N_u1) to the perimeter (P) of the basin. It is an important feature in drainage morphometric study and is reliant on the principal lithology, infiltration capability of the material below earth's surface and relief features of the terrain. It is calculated as the ratio between total streams number and perimeter of the basin. High texture ratio of designates great runoff and small infiltration capacity (Table-13).

T = Nu/P…………………………………………. (Horton, 1945)

Where: - Nu = total no. of streams of all orders

P = perimeter (km)

Table 9: Micro-watersheds Texture Ratio value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
P	64	52	36	33	61	41	33	59	50	37	37	50	46	32	34	31	92	34
Nu	13	4	7	7	17	9	4	11	6	10	7	6	13	7	11	7	4	6
T= Nu/P	0.20	0.08	0.19	0.21	0.28	0.22	0.12	0.19	0.12	0.27	0.19	0.12	0.28	0.22	0.32	0.23	0.04	0.18

V. Length of Overland Flow (Lo)

Length of Overland Flow (Lo) represents the length of water over the ground before it gets concentrated into definite stream channels, and is equal to half of drainage density (Horton R., 1945). The length of overland flow relates inversely to the average channel slope (Patel et.al., 2012) and is considered one of the most important independent parameters influencing both hydrologic and hydrographic development of drainage basins (Table-13).

Lo = ½ D_d …………………………………………. (Horton R., 1945)

Where: - D_d = drainage density

Table 10: Micro-watersheds Length of Overland Flow value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km^2)	195.19	99.89	79.64	51.22	162.27	91.13	50.53	164.96	93.2	54.38	68.33	89.91	64.27	49.72	54.42	56.44	124.24	58.7
D_d	0.36	0.34	0.48	0.41	0.52	0.42	0.44	0.35	0.37	0.48	0.32	0.48	0.42	0.37	0.71	0.50	0.34	0.46
Lo=1/2D_d	0.18	0.17	0.2	0.21	0.26	0.21	0.22	0.175	0.19	0.24	0.2	0.2	0.21	0.19	0.36	0.3	0.17	0.23

3.3.3.7. Shape Parameters

Shape parameters include form factor, shape factor, elongation ration, compactness coefficient (ratio), and circularity ratio.

I. Form Factor (R_f)

Form Factor (R_f) can be defined as the ratio of the area of the basin to the square of the basin length (Strahler A., 1957). R_f parameter has been elaborated to predict the intensity of a basin of a defined area. The value of R_f would always be less than 0.79, for a perfectly circular basin (Chopra R. et.al., 2005). The smaller the value of form factor (<0.45), the more the basin is elongated. The basins with high form factor are characterized with high peak flow of shorter duration, whereas an elongated sub-basin with a low form factor, indicate a low peak flow of longer duration. (Table-14).

$$\mathbf{R_f = A/L_b^2}$$ ……………………………………… (Horton, 1945)

Where: - A = area of the basin (km2)

L_b = basin length (km)

Table 11: Micro-watersheds Form Factor value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km^2)	**195.2**	**99.89**	**79.64**	**51.22**	**162.3**	**91.13**	**50.53**	**165**	**93.2**	**54.4**	**68.33**	**89.9**	**64.3**	**49.7**	**54.4**	**56.4**	**124.2**	**58.7**
L_b	**26.41**	**18.1**	**15.9**	**12.4**	**23.79**	**17.1**	**12.3**	**24**	**17.4**	**12.8**	**14.6**	**17**	**14.1**	**12.2**	**12.8**	**13.1**	**20.44**	**13**
L_b^2	**697.5**	**327.6**	**252.8**	**153.8**	**565.9**	**292.4**	**151.3**	**576**	**302.8**	**163.8**	**213.2**	**289**	**198.8**	**148.8**	**163.8**	**171.61**	**417.79**	**169**
$R_f=A/L_b^2$	**0.28**	**0.31**	**0.32**	**0.33**	**0.29**	**0.31**	**0.33**	**0.29**	**0.31**	**0.33**	**0.32**	**0.31**	**0.32**	**0.33**	**0.33**	**0.33**	**0.29**	**0.35**

II. Shape Factor (Bs)

Shape Factor (Bs) represents the square of the basin length to the area of the basin. This morphometric parameter is in inverse proportion to form factor. Shape factor affords a notion regarding the circular character of the catchment. The greater the circular character of the basin, the greater in the fast response of the catchment following a rainfall storm event (Horton, 1945) (Table-14).

$$\mathbf{B_s = L_b^2/A}$$ ………………………………… (Nooka Ratnam, K. et.al., 2005)

Where: - L_b = basin length (km)

A = area of the basin (km2)

Table 12: Micro-watersheds Shape Factor value

MWSD	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
A(km2)	195.2	99.89	79.64	51.22	162.27	91.13	50.53	164.96	93.2	54.4	68.33	89.9	64.3	49.7	54.4	56.4	124.2	58.7
L_b	26.41	18.1	15.9	12.4	23.79	17.1	12.3	24	17.4	12.8	14.6	17	14.1	12.2	12.8	13.1	20.44	13
L_b^2	697.5	327.6	252.8	153.8	565.9	292.4	151.3	576	302.8	163.8	213.2	289	198.8	148.8	163.8	171.6	417.8	169
$Bs=L_b^2/A$	3.57	3.28	3.17	3.00	3.49	3.21	3.00	3.49	3.25	3.01	3.12	3.22	3.09	3.00	3.01	3.04	3.36	2.88

III. Elongation Ratio (Re)

Elongation Ratio (Re) is the ratio between the diameters of the circle of the same area as presented by the drainage basin to the maximum basin length **(**Schumm, 1956). Strahler(1964) reported that the values of elongation Ratio generally vary between 0.6 and 1.0 over a wide range of climatic and geological environments. Values close to 1.0 are characteristic of areas with very low relief, whereas values in the range of 0.6 - 0.8 are representative of catchments described with high relief and steep slopes (Table-14).

$$R_e = \frac{2\sqrt{A/\pi}}{L_b} \quad \text{.................................} \quad \text{(Schumm, 1956)}$$

Where: - A = area of the basin (km2)
L_b = basin length (km)

Π= 3.14

Table 13: Micro-watersheds Elongation Ratio value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km2)	195.2	99.89	79.64	51.22	162.3	91.13	50.53	165	93.2	54.4	68.33	89.9	64.3	49.7	54.4	56.4	124.2	58.7
L_b	26.41	18.1	15.9	12.4	23.79	17.1	12.3	24	17.4	12.8	14.6	17	14.1	12.2	12.8	13.1	20.44	13
A/π	62.13	31.79	25.35	16.3	51.65	29.01	16.08	52.51	29.7	17.3	21.75	28.6	20.5	15.8	17.3	18	39.53	18.7
2√A/π	15.8	11.3	10.1	8.08	14.4	10.8	8.02	14.5	10.9	8.3	9.33	10.7	9.05	8	8.3	8.5	12.6	8.6
Re=(2√A/π) / Lb	0.597	0.623	0.633	0.651	0.604	0.63	0.652	0.61	0.63	0.65	0.639	0.63	0.64	0.65	0.65	0.65	0.615	0.67

IV. Compactness Coefficient (Cc)

Compactness Coefficient (Cc) is also known as the Gravelius index (GI). According to Gravelius (Gravelius, 1914), the compactness coefficient of a watershed is the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed. The Cc is independent of size of the watershed and dependent only on slope (Horton, 1945). A circular basin yields the shorter time of concentration before peak flow occurs in the basin. Cc > 1.0 indicates more deviation from the circular nature (Altaf, et.al, 2013). Lower values of this parameter denote more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion (Table-14).

$$Cc = \frac{P}{2\sqrt{\pi A}} \quad \text{..} \quad \text{(Horton, 1945)}$$

Where: - P = perimeter of the basin (km)

A = area of the basin (km2)

Π= 3.14

Table 14: Micro-watersheds based Compactness Coefficient value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km^2)	195.2	99.89	79.64	51.22	162.3	91.13	50.53	165	93.2	54.4	68.33	89.9	64.3	49.7	54.4	56.4	124.2	58.7
P(km)	64	52	36	33	61	41	33	59	50	37	37	50	46	32	34	31	92	34
A*π	613	313.8	250	161	509.8	286	159	518.2	293	171	215	282	202	156	171	177	390	184
2√Aπ	49.5	35.43	31.6	25.4	45.16	33.8	25.2	45.53	34.2	26	29.3	33.6	28.4	25	26	27	39.5	27
Cc=P/(2√Aπ)	1.29	1.5	1.14	1.3	1.35	1.21	1.31	1.296	1.46	1.4	1.26	1.49	1.62	1.3	1.3	1.2	2.33	1.3

V. Circularity Ratio (Rc)

Circularity Ratio (Rc) refers to the ratio of basin area (A) to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). Rc is affected by the length and frequency of the streams, geological structures, land use/land cover, climate, relief, and slope steepness of the watershed. Drainage basins with a range of circularity ratios of 0.4 to 0.5, were described by Miller (Miller, 1953), denoting that they are strongly elongated. If the circularity in the main watershed is low, then the discharge will be slow as compared to the others, and so the possibility of erosion will be less (Patel, 2012) (Table-14).

$$R_c = 4 \times \pi \times A/P^2 \text{...} \text{ (Miller, 1953)}$$

Where: - π= 3.14

A = area of the basin (km2)

P = perimeter (km)

Table 15: Micro-watersheds based Circularity Ratio value

MWSD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km^2)	195	99.9	79.6	51.2	162	91.1	50.5	165	93.2	54.4	68.3	89.9	64.3	49.7	54.4	56.4	124	58.7
P(km)	64	52	36	33	61	41	33	59	50	37	37	50	46	32	34	31	92	34
P2	4096	2704	1296	1089	3721	1681	1089	3481	2500	1369	1369	2500	2116	1024	1156	961	8464	1156
A/P2	0.05	0.04	0.06	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.03	0.05	0.05	0.06	0.01	0.05
Rc = 4 × π× A/P2	0.6	0.46	0.77	0.59	0.55	0.68	0.58	0.6	0.47	0.5	0.63	0.45	0.38	0.61	0.59	0.74	0.18	0.64

3.3.4. Multi-Criteria Analysis factor generation and reclassification

With the help of certain criteria Multi-criteria analysis compares various alternatives. These criteria are often a translation of the project objectives. The outcomes are more often in the form of selection, classification or ranking of alternatives. MCA can help to prioritize a watershed's tendency to erosion using easily available data. To perform MCA for the prioritizing of erosion porn micro-watershed in upper bilate watershed, four criteria which are slope, soil, rainfall and LULC have been used. On the basis of the range (Minimum and maximum) of their values, are reclassified and ranked 1 to 5 sub-classes. Then, weights were given to the four criteria (slope, soil, rainfall and LULC) as per their contributions to soil losses using Pairwise comparison.

3.3.5. Pairwise comparison for weighting

Weighting is used to assess the relative importance of one evaluation criterion from other criteria under consideration (Jankowski, 1995). Pairwise comparison method was used in this study. This is important to reduce the complexity of decision making. In Pairwise comparison method the step is development of a comparison matrix then computation of weights for each element of the hierarchy and finally estimation of consistency ratio. IDRISI Andes 17 software was used to generate the weight for pairwise comparison by using informal interview of Development agents and natural resource experts and development agents who work near the study area. The range of given weight can be from extremely less important to extremely important depending on the objective.

Table 16: Continuous Rating Scale of Pairwise Comparison

Intensity of importance	Definition
1/9	Extremely less important
1/7	Very strongly less important
1/5	Strongly less important
1/3	Moderately less important
1	equally important
3	Moderately more important
5	Strongly more important
7	Very strongly important
9	Extremely important

Source : IDRISI User Guide

Using the above approach the IDRIS data entry and editing programs are applied. The following matrix is prepared in such a way that the data can be processed. The output of Figure-3 is acceptable because the eigenvector matrix weights consistency ratio is 0.05.

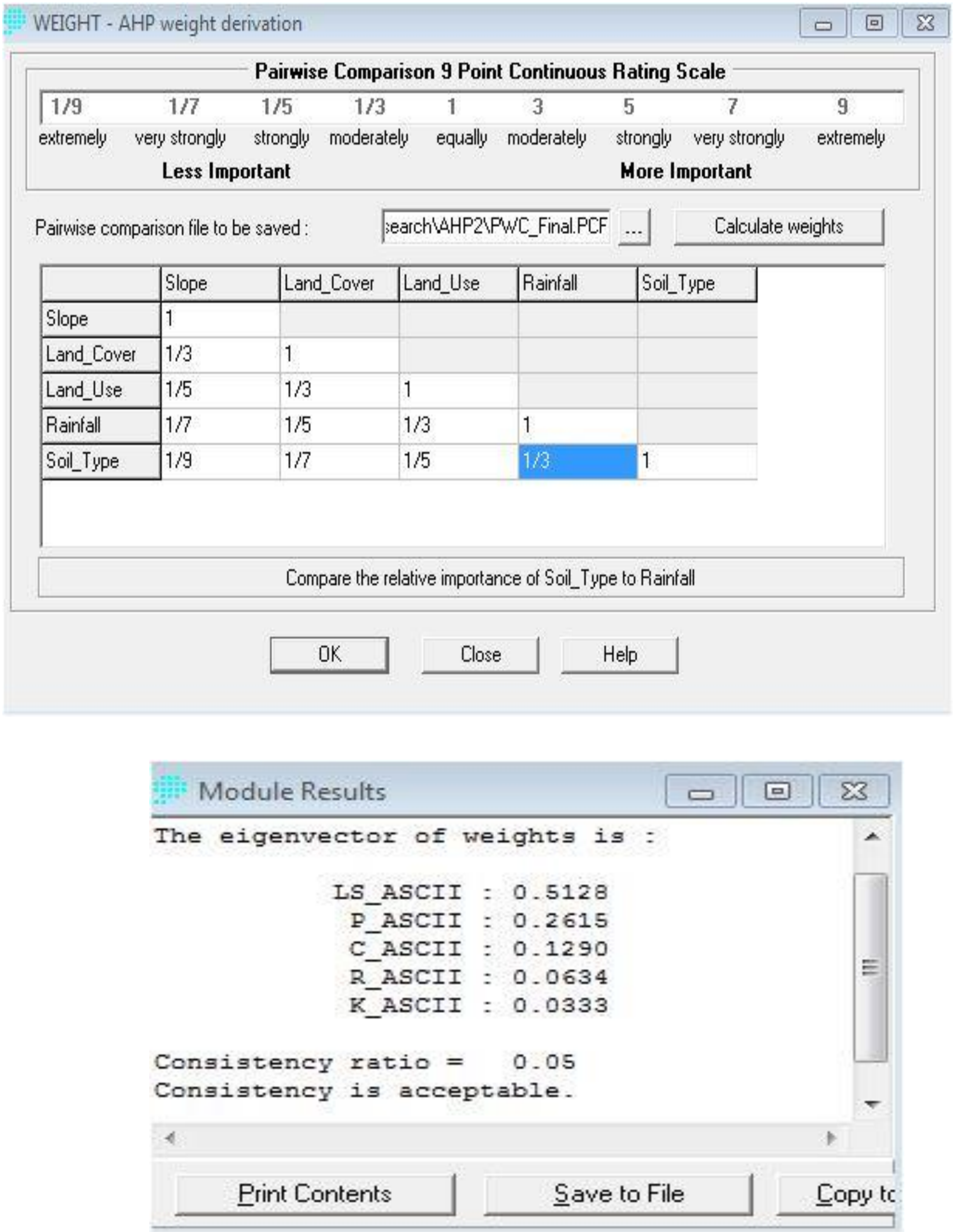

Figure 3: weight for pairwise comparison

3.3.6. **Erosion Risk in the Watershed based on Multi-Criteria Evaluation**

3.3.6.5.**Composite Erosion Index (CEI)**

The four reclassified craiteria layers (slope, soil, rainfall and LULC) were multiplied by an appropriate weight derived from pairwise comparison of criteria (Kiflu, 2010). Then added by Weighted Linear Combination (WLC) equation using raster calculator operation in ArcGIS10.3. The final output map indicates micro-watershed wise CEI that relates to the erosion intensity of the area under the relative contribution of the given criteria. The algebraic operation performed on five layers is as follow:

CEI = (W1*LS) + (W2*C) + (W3*P) + (W4* R) + (W5*K)

Where CEI is Composite Erosion Index;

W1, W2----W4 are pairwise weights derived from IDRISI; and

LS, P, C, R, and K are reclassified slope, Land use, Land cover, rainfall, and soil type.

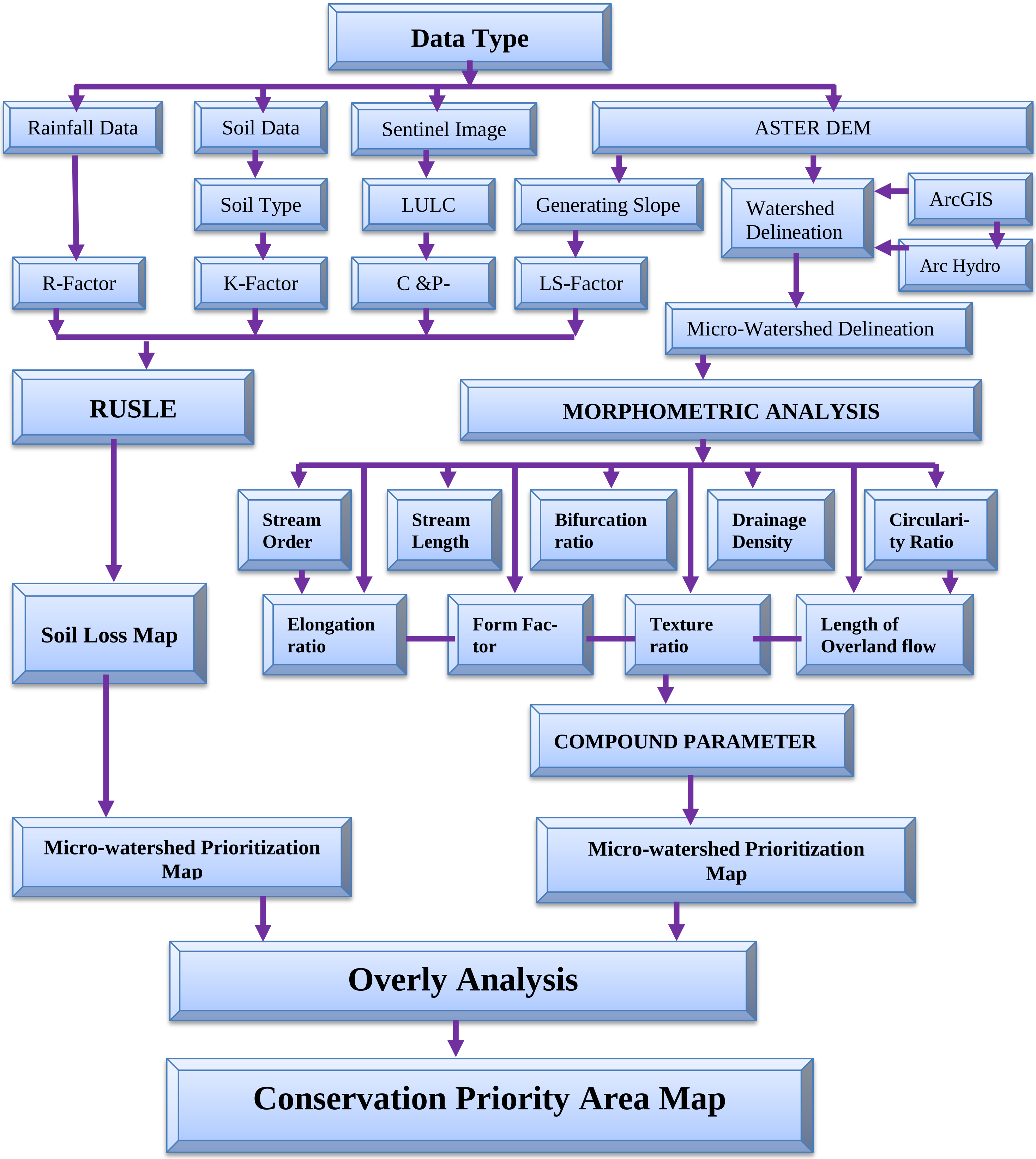

Figure4: Flow chart of the overall methodology

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Factors of RUSLE Model

4.1.1. Land Use Land Cover

Land use refers to the human employment of the land while land cover denotes the physical and biotic character of the land surface (Meyer and Turner, 1992).The most spatially and/or economically important human uses of land globally include cultivation in various forms, livestock grazing, settlement and construction, reserves and protected lands, and timber extraction. These and other land uses have cumulatively transformed land cover at a global scale (Turner *et al*., 1994).

In this study identified six land use and land cover types which are indicated in Table: 17, the largest portion of the study area is covered by three land uses (Farm land 40.1%, Forest 29.4%, Settlement 14.9%) and the remaining area by, bare land 2.45% and Grass land 9.39%. As shown in table: 18 the overall accuracy of the classification is 83.3%.

Table 17: Area and percent of Land-use land-cover types

Micro-water-sheds	**Land use and Land cover type**												**Total**	
	Grass land		**Farm land**		**Forest /woody land/**		**Settlement**		**Bare land**		**Water**			
	Area (Km2)	**Area (%)**	**area (Km2)**	**Area (%)**	**Area (Km2)**	**Area (%)**	**Area (Km2)**	**Area (%)**	**Area (Km2)**	**Area (%)**	**area(Km2)**	**Area (%)**	**Area (Km2)**	**Area (%)**
MWSD 1	40.34	27.4	55.04	8.31	55.18	11.4	17.23	7.3	0	0	0	0	195.19	11.65
MWSD 2	33.4	22.7	2.62	0.4	40.22	8.34	0.96	0.4	0	0	0	0	99.89	5.96
MWSD 3	18.85	12.8	4.37	0.66	39.68	8.22	3.94	1.67	0	0	0	0	79.64	4.75
MWSD 4	2.33	1.58	23.86	3.61	21.2	4.39	3.83	1.62	0	0	0	0	51.22	3.06
MWSD 5	24.46	16.6	50.75	7.67	60.06	12.4	27	11.5	0	0	0	0	162.27	9.69
MWSD 6	2.2	1.49	52.32	7.91	15.51	3.21	21.1	8.95	0	0	0	0	91.13	5.44
MWSD 7	0.87	0.59	29.26	4.42	12.46	2.58	7.94	3.37	0	0	0	0	50.53	3.02
MWSD 8	14.45	30.8	79.96	12.1	21.24	4.4	44.4	18.8	4.89	26.36	0	0	164.96	9.85
MWSD 9	3.38	2.3	43.84	6.63	25.84	5.36	19.92	8.45	0.22	1.19	0	0	93.2	5.56
MWSD 10	0.52	0.35	49.4	14.3	0.82	0.17	3.35	1.42	0.29	1.56	0	0	54.38	3.25
MWSD 11	1.1	0.75	42.24	6.39	15.65	3.24	7.32	3.1	2.02	10.9	0	0	68.33	4.08
MWSD 12	1.58	1.07	39.35	5.95	35.64	7.39	12.19	5.2	1.15	6.2	0	0	89.91	5.37
MWSD 13	0.38	0.26	37.42	5.66	18.78	3.89	5.34	2.26	2.35	12.7	0	0	64.27	3.84
MWSD 14	0.58	0.39	12.65	1.9	21.01	4.35	15.44	6.55	0.04	0.22	0	0	49.72	2.97
MWSD 15	0.3	0.2	23.77	3.59	24.21	5.01	5.58	2.4	0.56	3.02	0	0	54.42	3.25
MWSD 16	0.55	0.37	13.77	2.08	23.49	4.87	18.61	7.89	0.02	0.11	0	0	56.44	3.37
MWSD 17	0.49	0.33	66.94	10.1	37.66	7.8	16.84	7.14	2.31	12.4	0	0	124.24	7.42
MWSD 18	1.42	0.97	33.94	5.13	13.83	2.87	4.77	2.02	4.7	25.3	0	0	58.7	3.50
Total LULC	**147.2**	**9.39**	**661.5**	**40.1**	**482.5**	**29.4**	**235.8**	**14.9**	**18.55**	**2.45**	**62.89**	**3.76**	**1675.1**	**100**
Total Area (Km2)													**1675.09**	

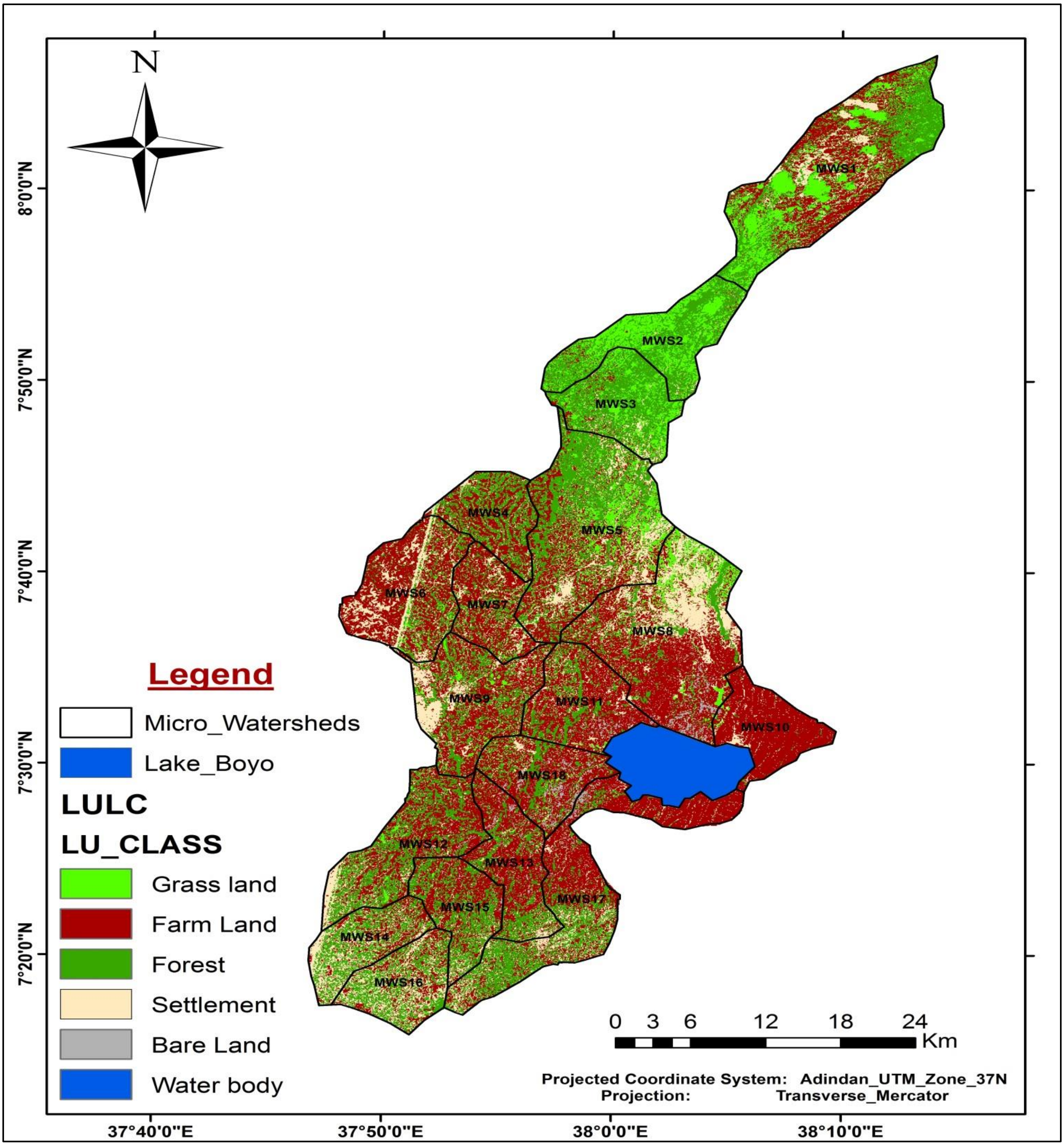

Figure 5: Land use Land cover map of Upper Bilate watershed (2019)

4.1.2. Accuracy Assessment

The overall accuracy index is produced by dividing all the pixels correctly classified by the total number of pixels in the matrix. The producer accuracy index is produced by dividing the number of correctly classified pixels that belong to a class by the sum of the values of the column of the same class. The user accuracy index is produced by dividing the total number of correctly classified pixels that belong to a class by the sum of the values of the rows of the same class. By having this, in this study the overall classification accuracy is (6+7+10+8+9+10) / 60 which is equal to 0.833 or 83.3% (Table 18).

Table 18: Error matrix showing classification accuracy of the true land cover

	Grass Land	Farm Land	Forest	Settlement	Bare Land	Water body	Total(user)
Grass Land	6	3	-	-	-	-	9
Farm Land	-	7	-	3	-	-	10
Forest	-	-	10	-	-	-	10
Settlement	-	-	-	8	2	-	10
Bare Land	-	-	-	1	9	-	10
Water body	-	-	1	-	-	10	11
Total(producer)	6	10	11	12	11	10	60

$$\text{Overall Accuracy} = \frac{\text{total number of correctly classified pixels}}{\text{Total number of reference pixels}} \text{ X } 100$$

$$50/60 \text{ X } 100 = \mathbf{\underline{83.3\%}}$$

$$\text{Kappa coefficient} = \frac{(\text{TS X TCS}) - \sum (\text{col.tot X row.tot})}{\text{TS}^2 - \sum (\text{col.tot X row.tot})}$$

$$\text{Kc} = \frac{(60 \text{ X } 50) - \sum ((6\text{x}9)+(10\text{x}10)+(11\text{x}10)+(12\text{x}10)+(11\text{x}10)+(10\text{x}11))}{(60)^2 - \sum ((6\text{x}9)+(10\text{x}10)+(11\text{x}10)+(12\text{x}10)+(11\text{x}10)+(10\text{x}11))} \text{ X } 100$$

$$= \frac{3000 - 604}{3600 - 604} = \frac{2396}{2996} = \mathbf{\underline{0.799}} \text{ X } 100$$

The overall classification accuracy of 83.3 and overall Kappa statistics of 0.799 was achieved, which is feasible for further application. The kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give percentage measure of classification accuracy. Kappa value is characterized in to three grouping: value greater than 0.8 represents strong agreement, 0.4 - 0.8 represents moderate agreement and that of less than 0.4 is considered as poor agreement (Congleton, 1991). The reasons for the errors may include the similarity of reflectance of settlement, grazing land and cultivated areas. In addition, the fast land use land cover dynamic nature of the area may also introduce the classification error.

4.1.3. Cover(C) factor

The cover and management factor (C) reflects the effect of cropping and management practices on soil erosion rates (Renard*et al.*, 1997). The C-factor is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith, 1978). Land use classification is often used to map vegetation types that differ in their effectiveness to protect the soil. After classification, a qualitative ranking of vegetation types is made, or C-factors are assigned from reported values in different literature described in table 19. It can be seem in figure 5 higher values indicating more bare soil (high susceptibility to erosion) and low values corresponding to high vegetation (no soil erosion).

Table 19: Land cover C-values used in different studies

No.	LULC type	C factor value	MWSDs	Area (%)	References
1	Forest	0.01	1,2,3	9.39	Hurni , 1985
2	Grassland	0.01	4,5,15	29.4	Hurni, 1985
3	Farm land	0.25	9,10,11, 12,17,18	40.1	Hurni ,1985
4	Bare land	0.05	11,18	14.9	Asmamaw et al., 2012
5	Settlement	0.05	6,7,8,14	2.45	Asmamaw et al., 2012
6	Water body	0	-	3.76	-

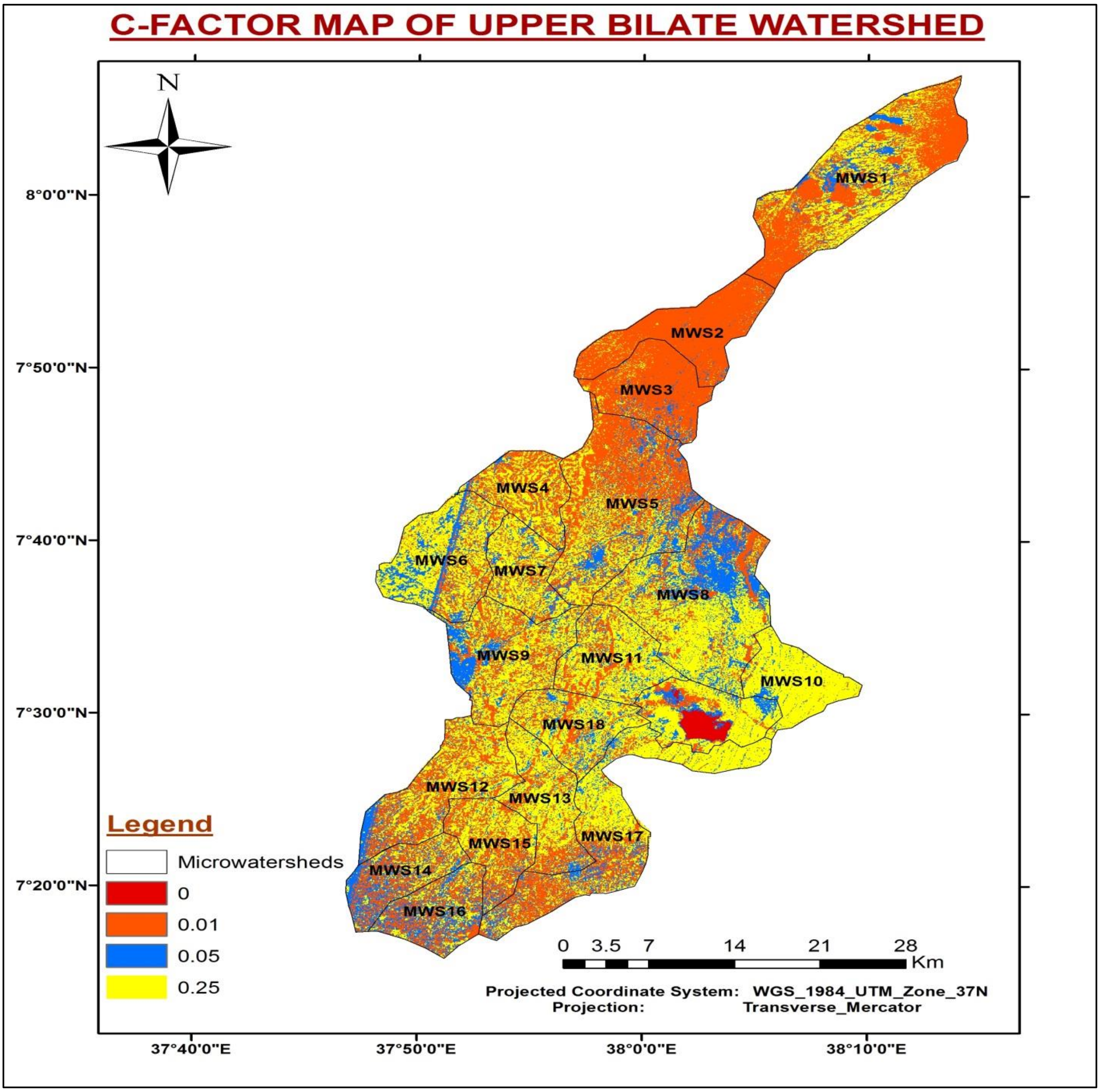

Figure 6: The cover factor (C-values) in the study area

4.1.4. Rainfall Erosivity (R-factor)

RUSLE was designed to account for the effects of raindrop impact and subsequent overland flow on soil erosion .Within the RUSLE, rainfall erosivity is estimated using the EI30 measurement (Renard et al., 1996). However, rainfall kinetic energy and intensity data are not available in our cases. Therefore, the erosivity factor R was calculated according to the equation given by Hurni (1985), derived from a spatial regression analysis for Ethiopian conditions. The model adapted by Hurni for Ethiopian conditions is based on the available mean annual rainfall data.

In order to compute R factor using such formula for the project watershed five metrological stations (Hosanna, Fonko, Angech, Alaba kuluto and Wulbarag) with mean annual rainfall of 22 years were used. After having the averaged 22 years rainfall data for each metrological station, IDW interpolation was done in ArcGIS 10.3 spatial analysis using map algebra tool to generate an estimated surface from these scattered set of point data into surface.

Table 20 shows the mean annual precipitation and erosivity value of the study. The value of R-factor ranges from 628– 805. From this result shown in figure: 7, the higher value which is 805 found in the upper part of the study area showing high rainfall erosivity. Thus based on R-factor value it is more vulnerable to erosion. The lower value of R-factor in the lower part of the study area indicates that this part of the watershed is less vulnerable to erosion.

Table 20: Annual precipitation and erosivity value

RF_Class	Mean annual precipitation	R_factor
1	1180-1210	628-671
2	1220-1270	672-698
3	1280-1340	699-728
4	1350-1400	729-761
5	1410-1480	762-805

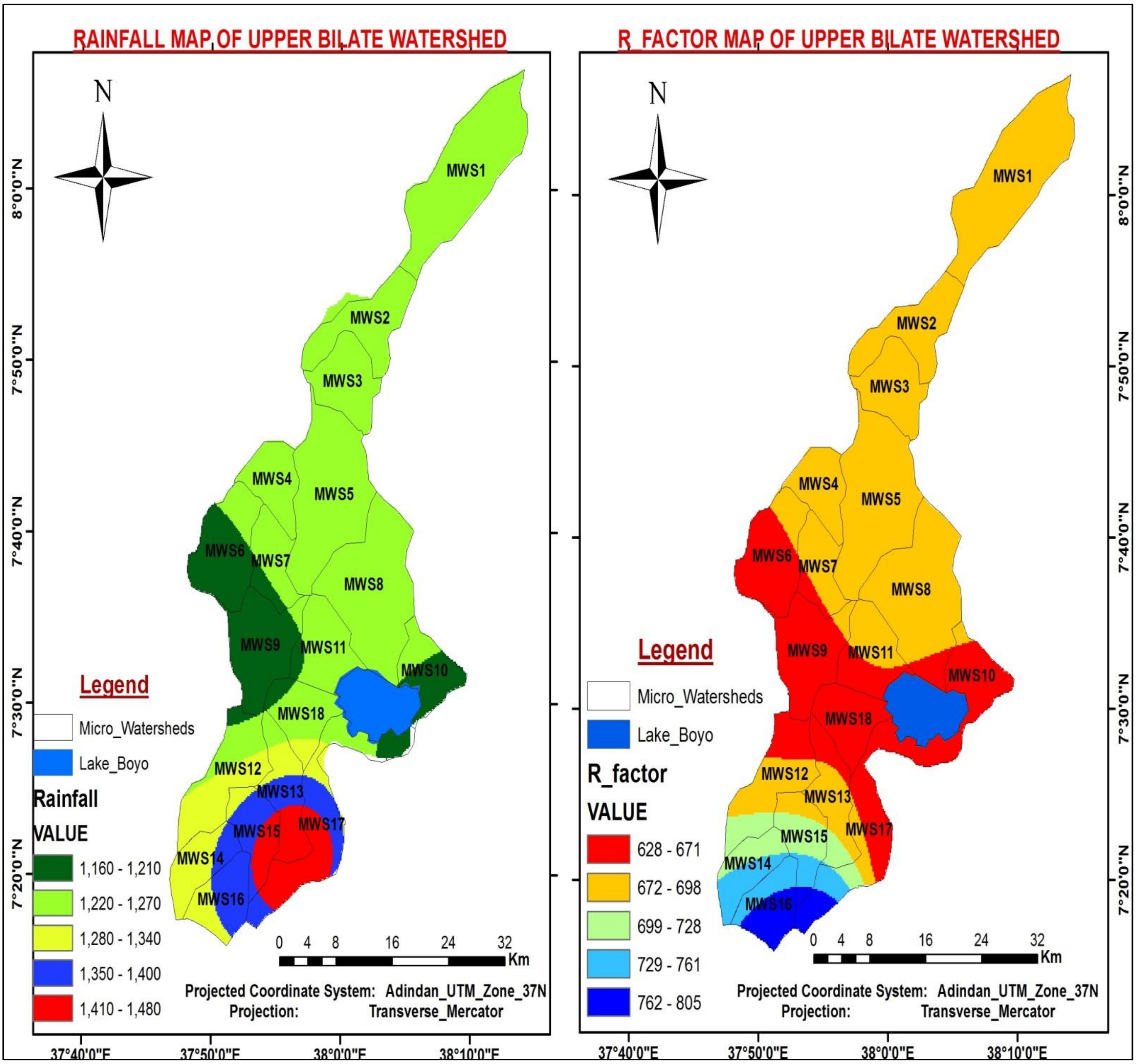

Figure 7: Rain fall and R-factor map of the study area

4.1.5. Soil vulnerability to soil erosion (Erodibility)

Soil erodibility is related to the integrated effect of rainfall, runoff, and infiltration on soil loss and is commonly called the soil erodibility factor (K). Soil erodibility factor (K) in RUSLE accounts for the influence of soil properties on soil loss during storm events on upland areas. Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic matter and chemical content of the soil (Morgan, 1995).

The K value can be calculated with the use of soil nomograph for soils where the silt fraction does not exceed 70%, derived by Wischmeier and Smith (1978), when all the values of K influencing factors are available.

Though in reality, especially at local level, these data are often difficult to find and may not be suitable for extrapolation from one area to another. The erodibility of soils as defined by Hurni (1985), in the adaptation of USLE to Ethiopian considers the soil color to have relation with erodibility even though others consider soil texture and structure so as to determine the value of soil erodibility factor. Therefore, the 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 color of the soil.

According to FAO soil classification (1986) and visual interpretation of the area, upper bilate watershed is covered by five soil types. After assigning values for each soil types the soil map was reclassified with a grid map of 30m x 30 m cell size using adopted K values (Hellen, 1987). From fig: 8 the largest portion of the study area covered by Chromic Luvisols (49.1%) types of soil. And 14.06% of the study area is covered by Humic Nitosol.

Based on soil color the value of k-factor in the study area ranges from 0.15 to 0.25. The high k-factor value indicates more vulnerable soil type to soil erosion and the smaller value shows less vulnerable soil type to erosion. As it is shown in table 21: the high k-factor value is shown in Humic Nitosol soil type which is found the middle side of the watershed and the largest portion of low value where shown in the upper side of the watershed which is Luvisols and Vertisols major soil type. Thus, result the high k-factor value indicates more vulnerable soil type to soil erosion and the smaller value shows less vulnerable soil type to erosion.

Table 21: Soil types and their erodibility factor

No.	Soil type	Color	K-factor value	Micro-watersheds	Area in %
1	Vertic Andosols	Brown	0.16	8,10,11,13,17,18	13.7
2	Lithic Leptosols	Brown	0.2	1,2,3,5,8	10.13
3	Chromic luvisol	Red	0.2	2,3,4,5,6,7,8,9,11,12,14,15,16,17	49.1
4	Humic Nitosol	Red	0.25	9,12,13,15,17,18	14.02
5	Eutric Vertisols	Black	0.15	1	9.3
6	Water body	Blue	-		3.75
	Total				100

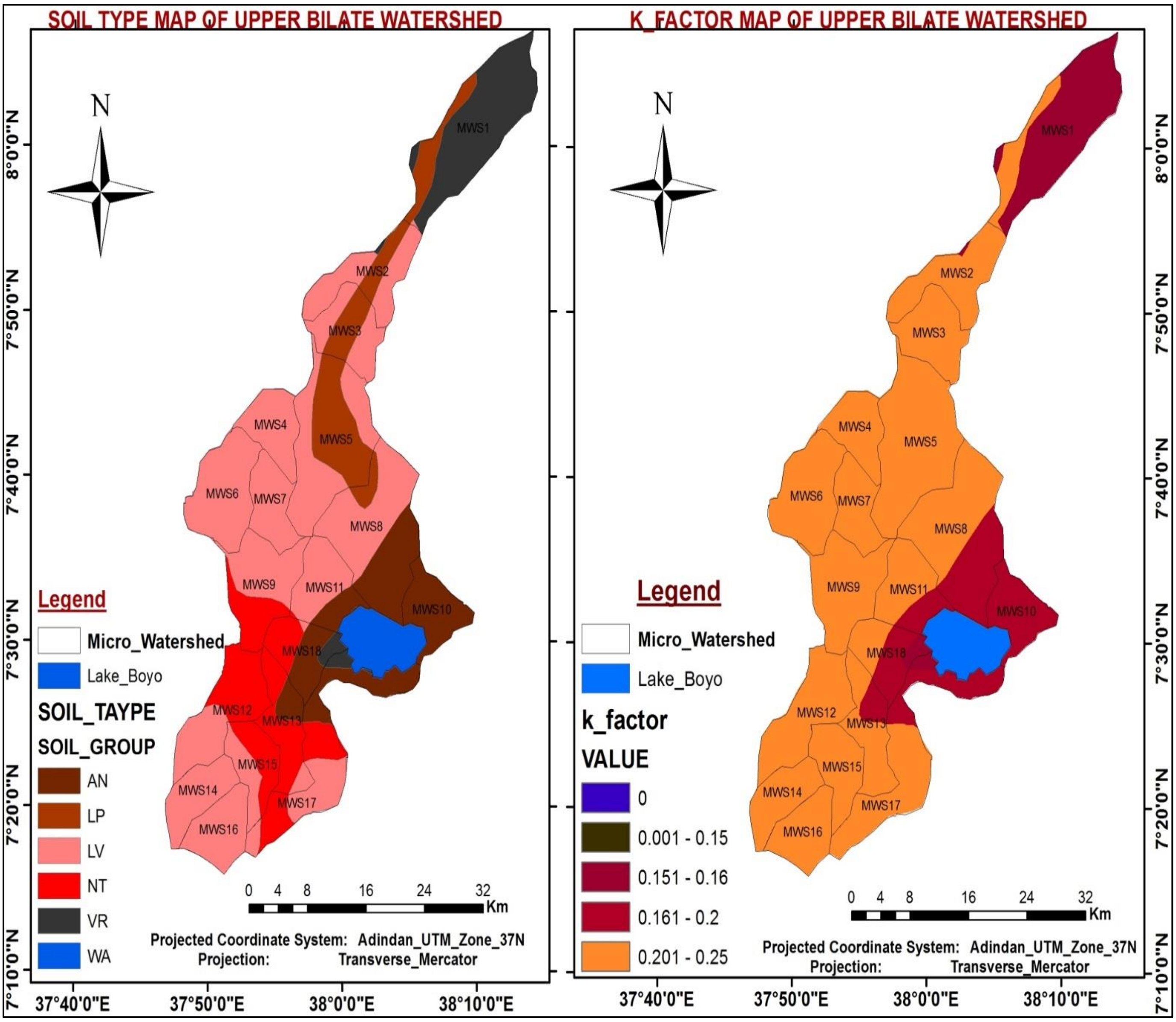

Figure 8 : Map of K-factor

4.1.6. Topographic (LS) factors

Erosion increases as slope length increases, and is considered by the slope length factor (L). Slope length is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel (Wischmeier and Smith, 1978). The slope steepness factor (S) reflects the influence of slope gradient on erosion. Both slope length and steepness substantially affects sheet and rill erosion estimated by RUSLE. In erosion prediction, the factors L and S are usually evaluated together. In this study, the slope gradient was determined from digital elevation model (DEM) of 30 meter resolution. The slope gradient determined for the study area is used for generating the LS factor as determined by (SCRP, 2000) for Ethiopian condition. Erosion is influenced both by the slope gradient and length of the slope, the potential erosion on uniform slopes increases as these parameters increase.

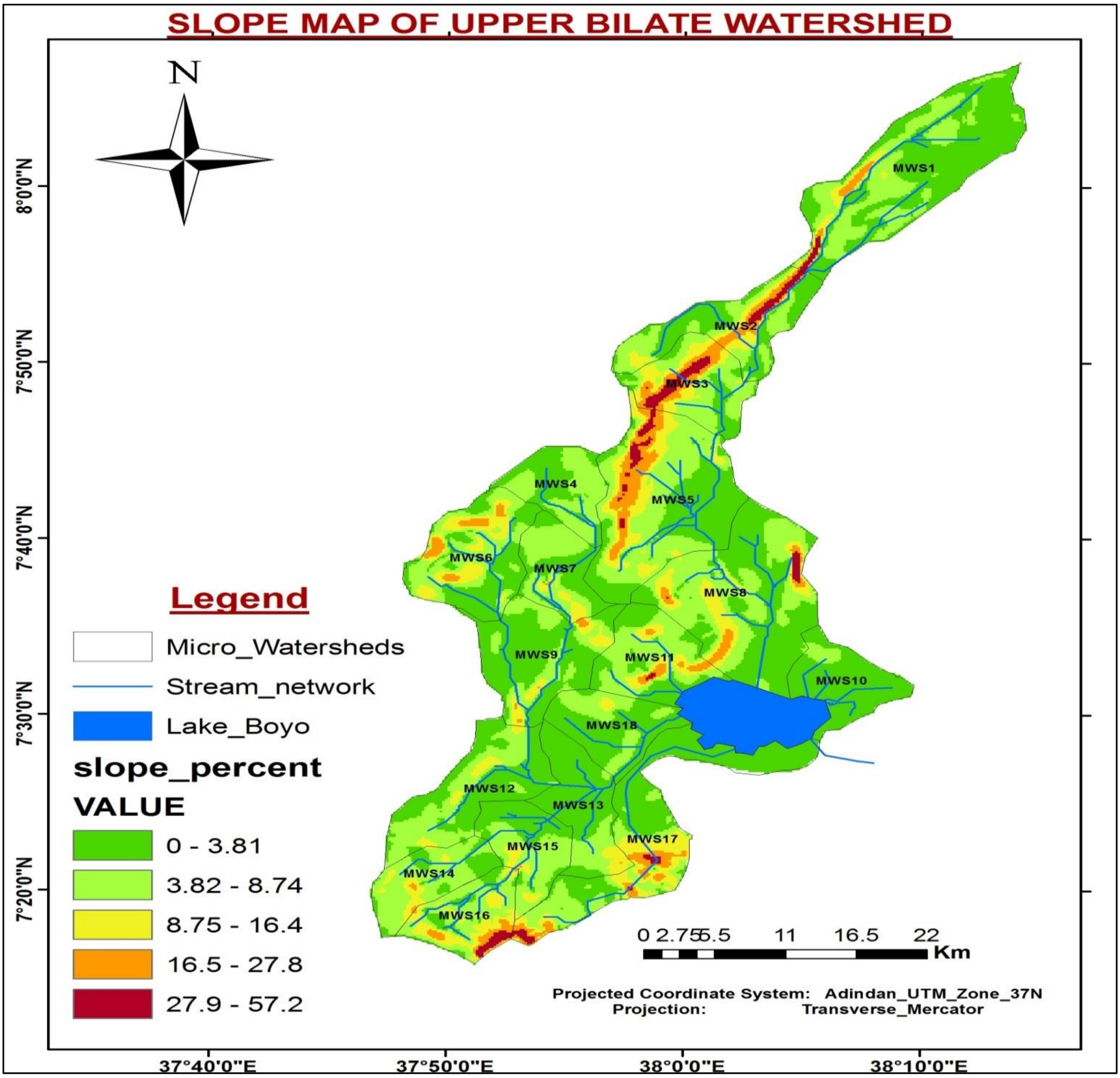

Figure 9: Slope map of Upper Bilate watershed

The values of LS factor ranges from 0.01- 14. As it is shown in Table: 22 and Figure :11 based on the mean and standard deviation the LS-factor was classified into five LS factor classes four micro-watersheds (MWSD-2,3,6,16) covering 19.6% of the watershed are in very high class of LS-factor. Micro watersheds (MWSD – 1,5,8,11, and 14) covering 38.2% of the study area are in the class of high LS-factor. These two LS factor classes found in the Upper part (specifically Kemibata Zone) and Middle part of the watershed more vulnerable to soil erosion. The very low and low class of LS-factor covering 10.98% and 21.9% of the watershed respectively in the south-eastern part are relatively less vulnerable.

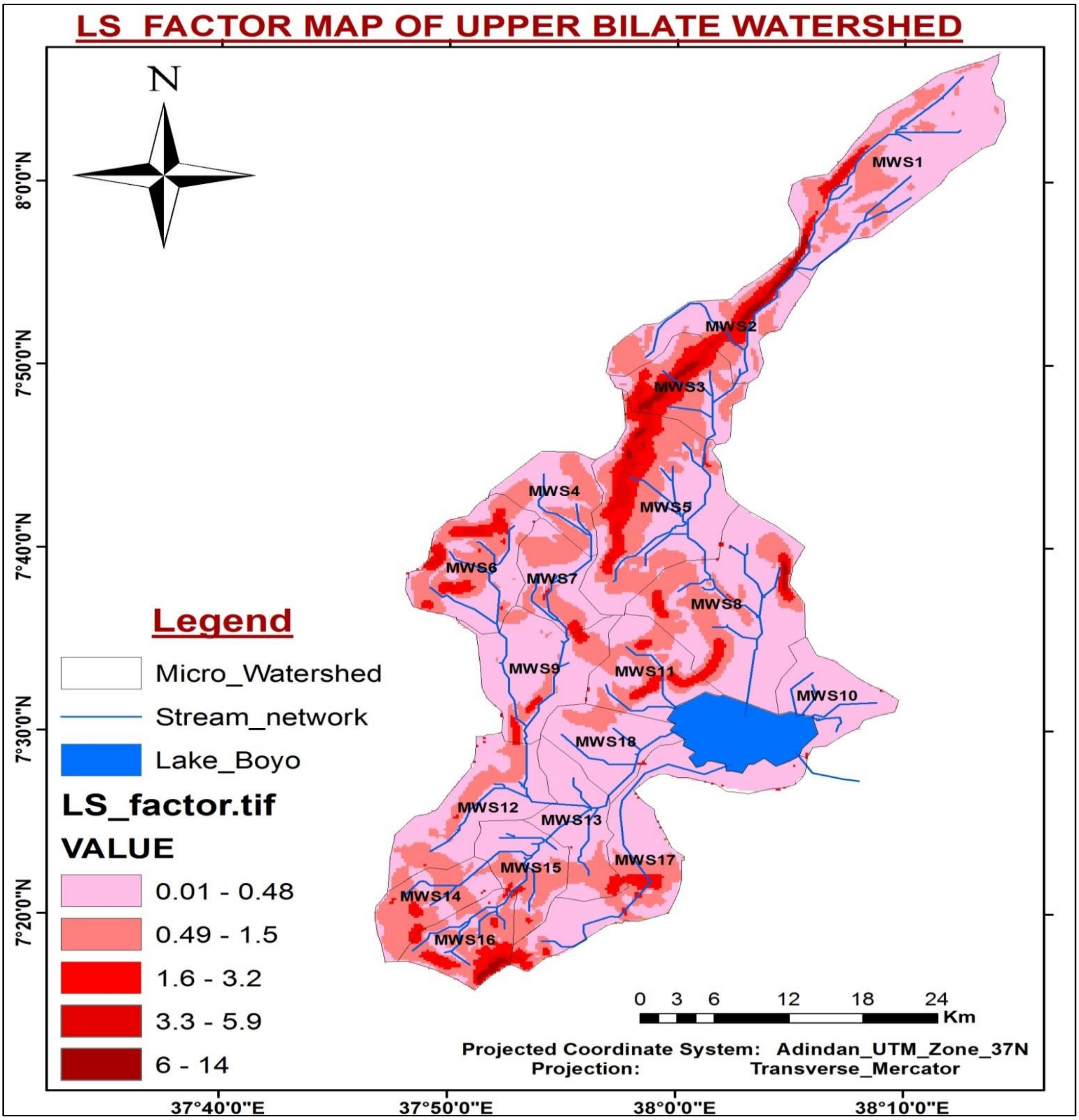

Figure 10: LS-factor Map of upper bilate watershed

Table 22: LS-factor classes and their distribution in the watershed

No.	LS-factor class	LS-class range	Micro-watersheds	No. of Micro-watersheds	% total
1	Very High	6 - 14	2,3,6,16	4	19.6
2	High	3.3 – 5.9	1,5,8,11,14	5	38.2
3	Moderate	1.6 -3.2	4,7,15	3	9.32
4	Low	0.49 – 1.5	9,12,17,18	4	21.9
5	Very Low	0.01- 4.8	10,13	2	10.98

4.1.7. Conservation practice (P) factor

The p value assigned for different land use types presented in Table 23. As a result the classified LULC map format has been changed into vector format and the corresponding P values were assigned to each land use/land cover classes and the P factor map was produced Figure 12.

Table 23 : Land Use/Land Cover types and the corresponding P values

No.	LULC type	Area in Km2	Area in %	P value
1	Grass Land	147.2	9.39	0.63
2	Forest/Woody Land	661.5	40.1	0.53
3	Farm Land	482.5	29.4	0.9
4	Settlement	235.8	14.9	0.65
5	Bare Land	18.55	2.45	0.75
6	Water body	62.89	3.76	-

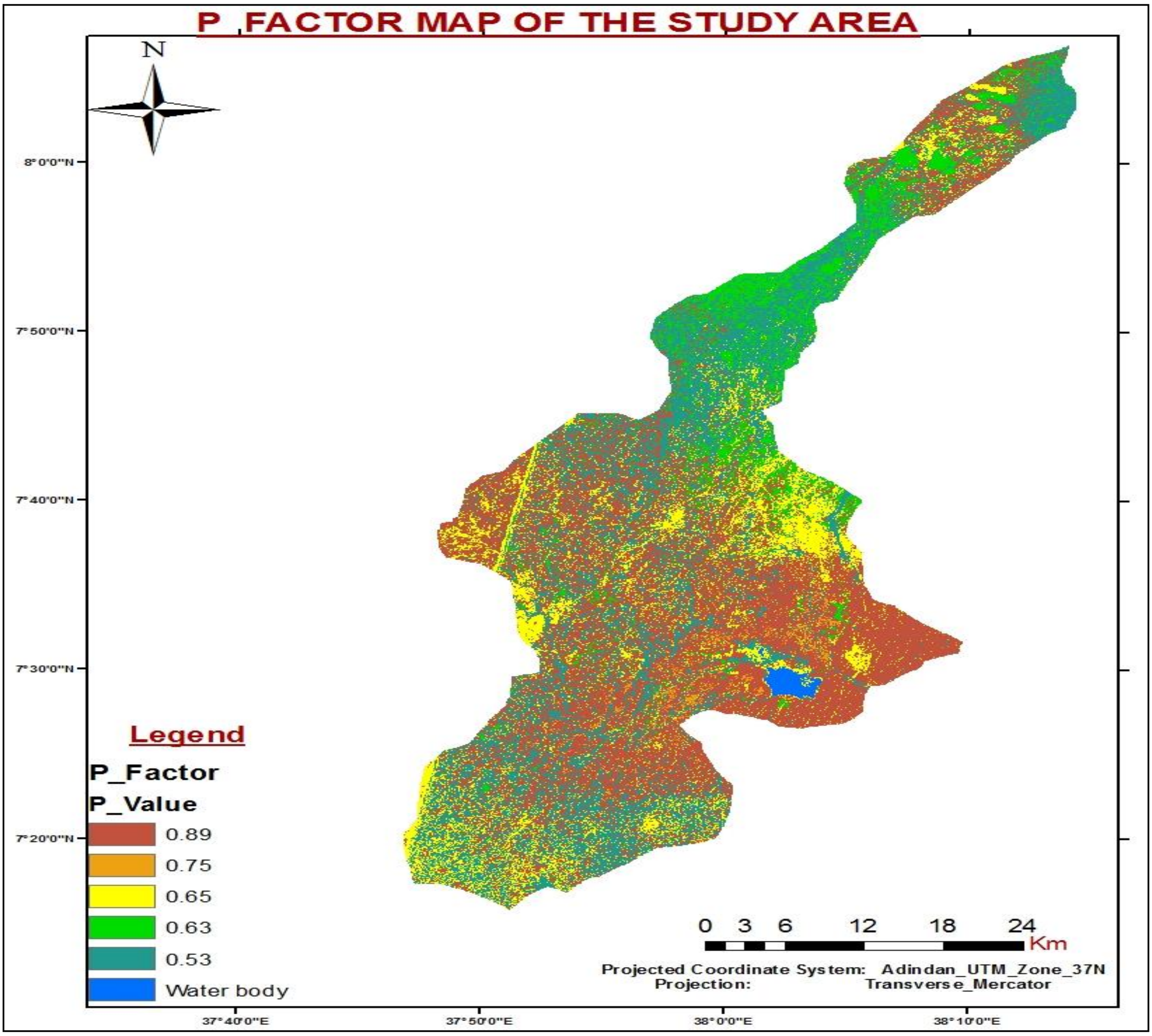

Figure 11: P factors map of upper bilate watershed

4.1.8. Estimated soil loss from the watershed

The annual soil loss rate of the study area was determined by multiplying the respective RUSLE factor (erosivity (R), erodibility (K), topographic(LS), cover management (C) and conservation support practice (P) factor) values interactively in ArcGIS 10.3,raster calculator using Equation;

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

The result showed that the potential annual soil loss of the Upper Bilate watershed ranges from 0.15 to 2985 ton/ha/year. The average annual soil loss rate is 16.08t/ha/year, which is much greater than the tolerable level 10 ton/ha/year (Hurni, 1983). The result of study falls within the ranges of the findings of FAO (1984). 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. In order to obtain a better view and understanding and at the same time be able to compare areas, the quantitative output of potential soil erosion rate for Upper Bilate watershed resulted from the current farming practice and land use/land cover were computed and grouped into five ordinal classes. The soil loss map also further classified into five soil losses severity classes in ArcGIS environment Figure 12.

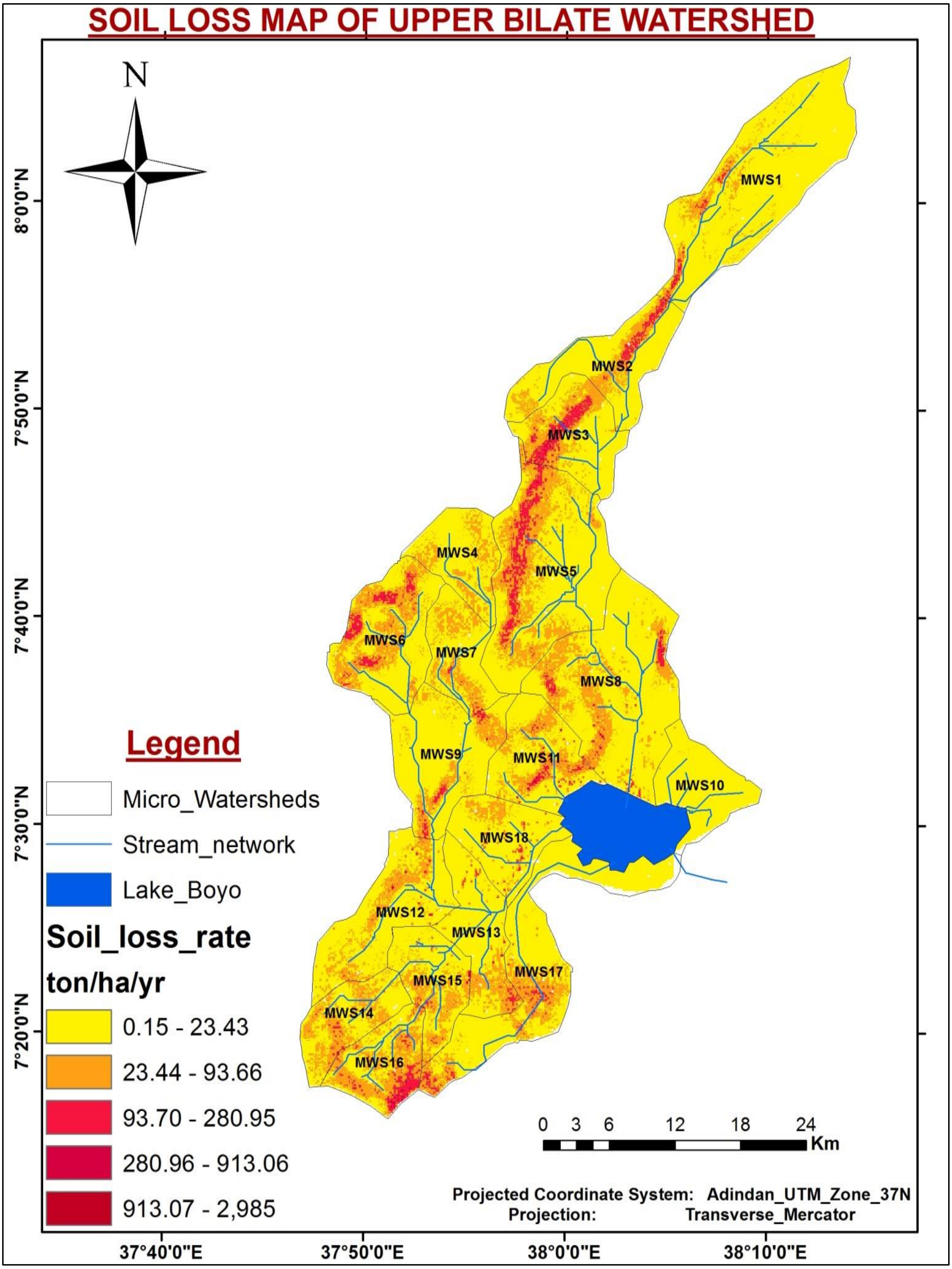

Figure 12: Soil loss map of Upper Bilate watershed

Table 24: Micro-watershed wise Priority Rank based on potential soil loss

Micro-watersheds name	Area (A) Km2	Mean Soil loss t/ha/yr	Priority Rank
MWSD 1	195.19	10.04	17
MWSD 2	99.89	18.85	8
MWSD 3	79.64	36.78	2
MWSD 4	51.22	15.49	12
MWSD 5	162.27	28.52	4
MWSD 6	91.13	31.23	3
MWSD 7	50.53	18.19	9
MWSD 8	164.96	16.03	10
MWSD 9	93.2	14.9	15
MWSD 10	54.38	2.6	18
MWSD 11	68.33	20.71	7
MWSD 12	89.91	15.42	13
MWSD 13	64.27	14.64	14
MWSD 14	49.72	23.95	5
MWSD 15	54.42	21.5	6
MWSD 16	56.44	44.17	1
MWSD 17	124.24	15.99	11
MWSD 18	58.7	13.32	16
Total	1675.09		

4.2. Factors of Morphometric analysis:

4.2.1. Basic Parameters

4.2.1.1. Micro-watershed area (A) and perimeter (P)

The drainage area is considered the most significant hydrological characteristics of a watershed. It reflects the volume of water that can be generated from precipitation. The present study shows that micro-watershed no.1 covers the maximum area of 195.19 km^2, while micro-watershed no.14 has a minimum area of 49.72 km2. The basin perimeter represents the length of the line that demarcates the surface divide of the micro-watershed. The maximum and minimum values are 92 km for micro-watershed no.17, and 31 km for micro-watershed no.16.

4.2.1.2. Stream order (u)

The stream order parameter was elaborated by Strahler (1964) and Horton R. (1945), to describe the drainage network in a quantitative manner. The first order stream has no tributary, and its flow depends totally on the surface overland flow to it. Similarly, the second-order stream is formed by the junction of the two first-order streams and thus, has a higher surface flow and the third-order streams receive flow from two second-order streams.

In the present study, all selected eighteen micro-watersheds are of third-order, and the number of first-order streams (Nu) varies from one watershed to another. It ranges from 12 first-order streams (MWSD 5) to 2 first-order streams (MWSD 2). The total number of stream ranges here between 1 to 90 streams. Similarly, the number of streams (Nu) for each micro-watershed range from 4 to 17. It is expected therefore, that micro-watershed near to Lake Boyo is receiving a higher surface flow than other micro-watersheds. Thus, it is expected that soil erosion susceptibility, flooding and siltation are higher due to high amount of over land flow and discharge than that of the upper part of the micro watersheds.

Table 25: Number of Stream within each Micro watershed

Micro-watersheds name	Stream number in different orders					
	1st	2nd	3rd	4th	5th	Total
MWSD 1	8	3	2	-	-	13
MWSD 2	2	1	-	1	-	4
MWSD 3	4	2	-	1	-	7
MWSD 4	4	2	1	-	-	7
MWSD 5	12	3	1	1	-	17
MWSD 6	6	2	1	-	-	9
MWSD 7	2	1	1	-	-	4
MWSD 8	8	2	1	-	-	11
MWSD 9	3	-	2	1	-	6
MWSD 10	7	2	1	-	-	10
MWSD 11	5	2	-	-	-	7
MWSD 12	4	1	-	1	-	6
MWSD 13	6	2	-	4	-	13
MWSD 14	4	2	1	-	-	7
MWSD 15	4	1	2	4	-	11
MWSD 16	4	2	1	-	-	7
MWSD 17	3	1	-	-	-	4
MWSD 18	4	1	-	-	1	6
Total	90	30	14	13	1	149

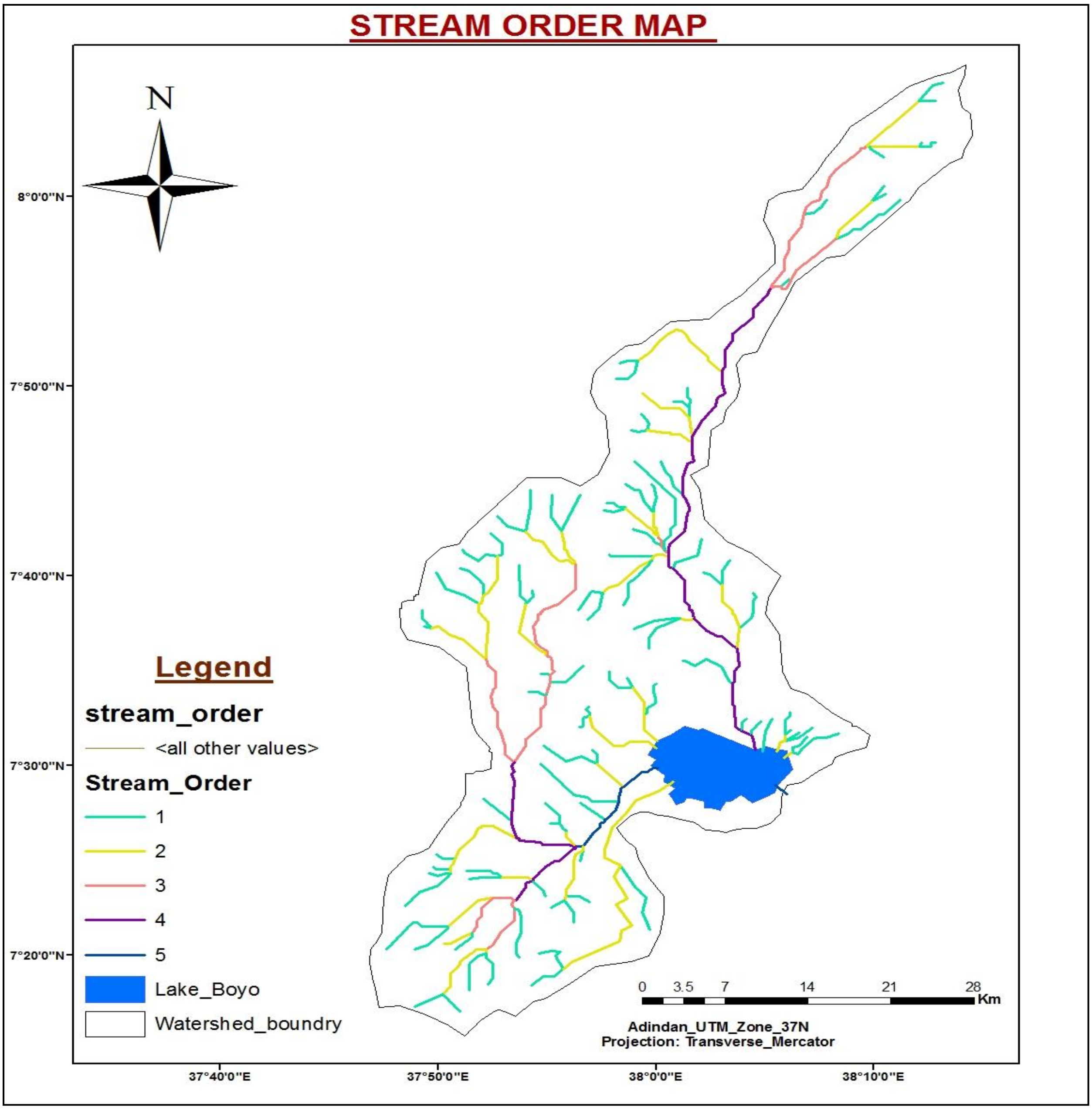

Figure 13: Stream Order map of the study area

4.2.1.3. Stream length (Lu)

Stream order wise stream length has computed in GIS environment and Horton's stream length law has employed for the same. Stream order wise stream length exhibits that total stream length decreases with increasing order. The total stream length of all order segments in Upper Blate Watershed is 672.2 km. and highest length of stream observed in MWSD 5 it was computed 83.83Km. Accordingly, basin length in the eighteen micro-watersheds varies between 83.83 km (MWSD5) and 18.447(MWSD14) km.

Table 26: Basic parameter of each Micro-watershed

Micro-watersheds name	Basic parameter of each Micro-watersheds				
	Area (A) in km^2	Perimeter (P) in km	Stream order(Nu)	Stream length (Lu)	Basin length (Lb) Km
MWSD 1	195.19	64	13	70.28	26.42
MWSD 2	99.89	52	4	34.02	18.06
MWSD 3	79.64	36	7	38.31	15.87
MWSD 4	51.22	33	7	20.98	12.35
MWSD 5	162.27	61	17	83.83	23.78
MWSD 6	91.13	41	9	38	17.14
MWSD 7	50.53	33	4	22.35	12.26
MWSD 8	164.96	59	11	57.57	24.01
MWSD 9	93.2	50	6	34.03	17.36
MWSD 10	54.38	37	10	26.08	12.78
MWSD 11	68.33	37	7	22.16	14.55
MWSD 12	89.91	50	6	43.41	17.01
MWSD 13	64.27	46	13	26.9	14.05
MWSD 14	49.72	32	7	18.47	12.15
MWSD 15	54.42	34	11	38.69	12.79
MWSD 16	56.44	31	7	28.49	13.06
MWSD 17	124.24	92	4	41.69	20.44
MWSD 18	58.7	34	6	26.94	13.35
Total	1675.09	822	149	70.28	

4.2.2. Linear Parameters

Linear parameters include bifurcation ratio, drainage density, stream frequency, texture ratio, and length of overland flow.

4.2.2.1. Bifurcation Ratio (Rb)

Bifurcation Ratio is the ratio of the number of the streams of a given order to the number of streams of the next higher order (Horton, 1945). The bifurcation ratio is introduced by (Horton, 1945) as an index of relief and topographic dissection. Bifurcation ratios vary between 2 for flat or rolling catchments, and 6 for watersheds distorted remarkably by geological structure. On the contrary, low values of Rb are indicative of structurally less disturbed watersheds, or alternatively without any clear distortion of drainage pattern (Horton, 1945). It is postulated that a small range of variation in Rb values exists between different geomorphic environments, except where geological control prevails. Table 12 shows a prominent variation in the bifurcation ratio (Rb) of Upper Bilate micro-watersheds. Micro-watershed 2 and 3 has a minimum Rb of 2.0, whereas micro-watershed no.12 has maximum ratio of 6. The Rb value for the entire Upper Bilate is 3.98. It is obvious that the values of Rb are relatively high, especially for the micro-watershed affected largely the lower part of the watershed.

Table 27: Stream number and Bifurcation ratio in different orders

MWSD name	Stream number and Bifurcation ratio in different orders											
	Nu	R_b	Nu	R_b	Nu	R_b	Nu	R_b	Nu	R_b	Total	
	1st		2nd		3rd		4th		5th	-	Nu	Rb
MWSD 1	8	2.67	3	1.5	2	-	-	-	-	-	13	4.7
MWSD 2	2	2	1	-	-	-	1	-	-	-	4	2
MWSD 3	4	2	2	-	-	-	1	-	-	-	7	2
MWSD 4	4	2	2	2	1	-	-	-	-	-	7	4
MWSD 5	12	4	3	1	1	1	1	-	-	-	17	6
MWSD 6	6	3	2	2	1	-	-	-	-	-	9	5
MWSD 7	2	2	1	1	1	-	-	-	-	-	4	3
MWSD 8	8	4	2	2	1	-	-	-	-	-	11	6
MWSD 9	3	2	-	-	2	2	1	-	-	-	6	4
MWSD 10	7	3.5	2	2	1	-	-	-	-	-	10	5.5
MWSD 11	5	2.5	2	-	-	-	-	-	-	-	7	2.5
MWSD 12	4	4	1	-	-	-	1	-	-	-	6	4
MWSD 13	6	3	2	-	-	-	4	-	-	-	13	3
MWSD 14	4	2	2	2	1	-	-	-	-	-	7	4
MWSD 15	4	4	1	0.5	2	0.5	4	-	-	-	11	5
MWSD 16	4	2	2	2	1	-	-	-	-	-	7	4
MWSD 17	3	3	1	-	-	-	-	-	-	-	4	3
MWSD 18	4	4	1	-	-	-	-	-	1	-	6	4
Total	90	3	30	2.14	14	1.08	13	-	1	-	149	

4.2.2.2. Drainage Density (Dd)

Drainage density is the stream length per unit area in a region (Horton, 1945, Strahler, 1952). It is vital element of drainage morphometry to study the landscape dissection, runoff potential, infiltration capacity of the land, climatic condition and vegetation cover of the basin. The authors have calculated drainage density of whole Upper Bilate watershed, indicating moderate density, which are 2.13 Km/Km^2 .In this study drainage density ranges between 2.13 to 3.2 Km/ Km2.

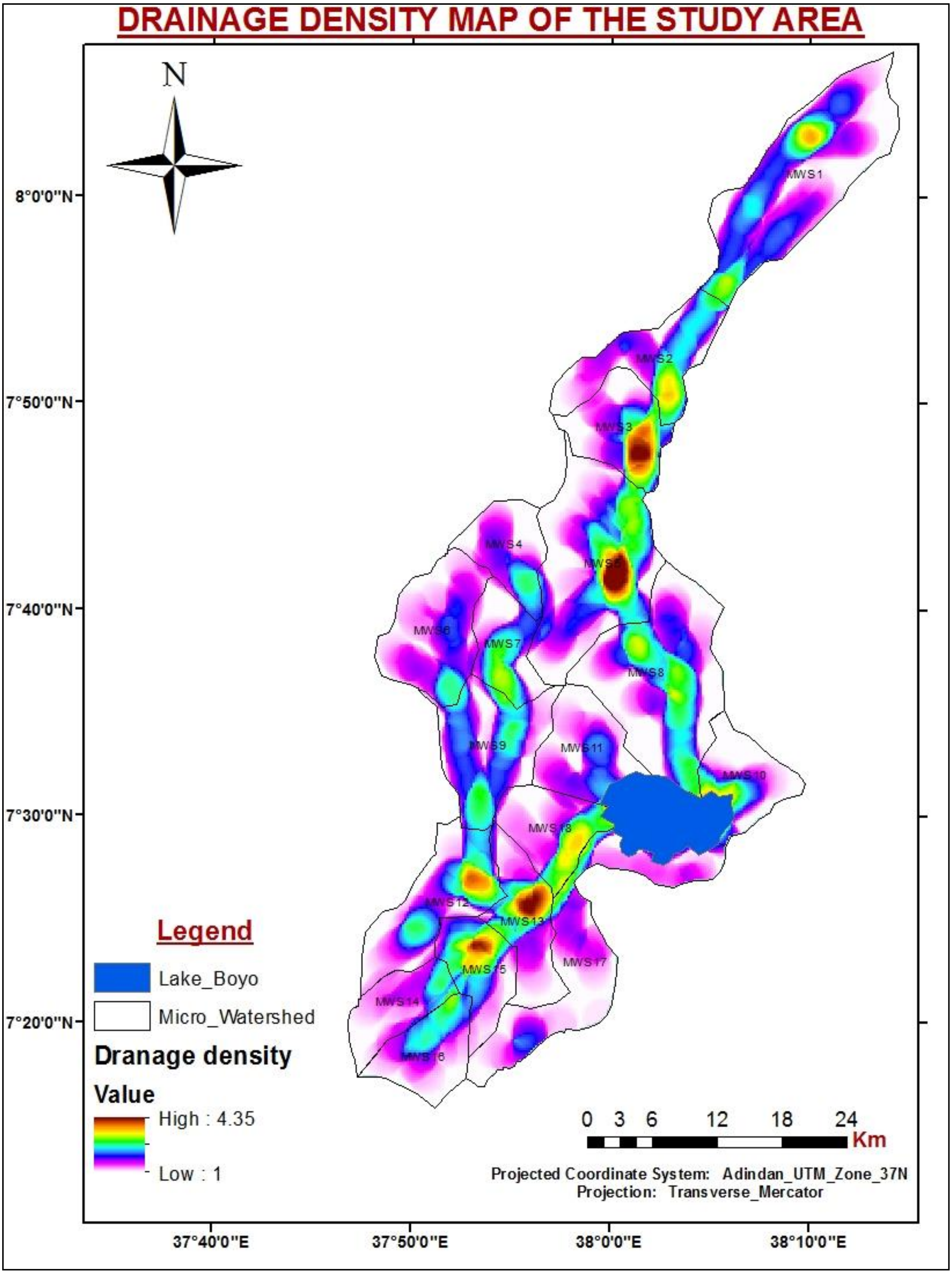

Figure 14: Drainage density Map of the study area

4.2.2.3. Stream Frequency (F_u)

The stream frequency is defined as the total number of stream segment of all order per unit area (Horton, 1932**)**. Generally high stream frequency is related to impermeable sub surface material, sparse vegetation, high relief and low infiltration capacity of the region. Upper Bilate watershed has 1.90 stream frequency and it varies from one micro watershed another. The highest and lowest stream frequency occurred in MWSD 10 and MWSD 17 respectively.

4.2.2.4. Texture Ratio (T)

Texture Ratio (T) refers to the ratio of the total number of streams of first order (N1) to the perimeter (P) of the basin. It is one of the most significant factors in drainage basins morphometry. Texture ratio depends on the underlying lithology, infiltration capacity, and relief aspect of the terrain (Altaf, F. et.al., 2013). The value of the texture ratio for Upper Bilate watershed is 3.46, and for the micro-watersheds ranges from 0.043 (MWSD 17) to 0.28 (MWSD 5 &13). Such figures indicate that the catchment is of moderate runoff.

4.2.2.5. Length of Overland Flow (Lo)

It is the length of water over the ground before it gets concentrate into definite stream channels and is one of the most important independent variables affecting hydrologic and physiographic development of drainage basin (Horton, 1945). This factor depends on the rock type, permeability, climatic regime, vegetation cover and relief as well as duration of erosion (Schumm, 1956). The average length of overland flow is approximately half the average distance between stream channels and is therefore approximately equals to half of reciprocal of drainage density (Horton, 1945). Length of overland flow (Lo) relates inversely to the average channel slope (Patel et. al., 2012). The higher values of Lo infer the longer flow paths, less surface runoff and low relief with gentle slopes whereas lower Lo values indicate the shorter flow paths, high surface runoff and high relief with steep slopes. The computed values of Lo for all micro-watersheds range from 0.16 km (MWSD 11) to 0.36 km (MWSD 15) (Table 13) show lower Lo values, indicating short flow paths having less infiltration and areas of high relief with steep slopes.

Table 28: Micro-watershed based Computed Value for Linear parameters

MWSDs	A	P	Nu	Lu	Rb	Dd	Fu	T	Lo
MWSD 1	195.19	64	13	70.28	4.71	0.36	0.07	0.20	0.18
MWSD 2	99.89	52	4	34.02	2	0.34	0.04	0.08	0.17
MWSD 3	79.64	36	7	38.31	2	0.48	0.09	0.19	0.24
MWSD 4	51.22	33	7	20.98	4	0.41	0.14	0.21	0.2
MWSD 5	162.27	61	17	83.83	6	0.52	0.10	0.28	0.26
MWSD 6	91.13	41	9	38	5	0.42	0.1	0.22	0.21
MWSD 7	50.53	33	4	22.35	3	0.44	0.1	0.12	0.22
MWSD 8	164.96	59	11	57.57	6	0.35	0.07	0.19	0.17
MWSD 9	93.2	50	6	34.03	4	0.36	0.06	0.12	0.18
MWSD 10	54.38	37	10	26.08	5.5	0.48	0.18	0.27	0.24
MWSD 11	68.33	37	7	22.16	2.5	0.32	0.10	0.19	0.16
MWSD 12	89.91	50	6	43.41	4	0.48	0.07	0.12	0.24
MWSD 13	64.27	46	13	26.9	3	0.42	0.20	0.28	0.21
MWSD 14	49.72	32	7	18.47	4	0.37	0.14	0.22	0.18
MWSD 15	54.42	34	11	38.69	5	1.01	0.20	0.32	0.36
MWSD 16	56.44	31	7	28.49	4	0.5	0.12	0.23	0.25
MWSD 17	124.24	92	4	41.69	3	0.33	0.03	0.043	0.18
MWSD 18	58.7	34	6	26.94	4	0.46	0.10	0.18	0.23
Total	1675.09	822	149	672.2	4.71	7.77	1.90	3.46	3.88

4.2.3. Shape Parameters

4.2.3.1. Form Factor (R_f)

Horton (1932) stated that form factor is the ratio of basin area to square of the basin length. This is an important dimensionless property which enumerates the shape of the basin. Form factor of Upper Bilate watershed is 0.19. In short the shape of the watershed is quite elongated in watershed; the smaller value of the form factor shows maximum elongation of the watershed. The high value of form factor shows high peak in short duration and vice versa. In this study, it was found that the value of form factor varies 0.036 to 0.139, which indicates that the MWSD-15 is more elongated as compared to MWSD-11 (Table.14). However, the MWSD-15 will be generating the high peak in short duration.

4.2.3.2. Shape Factor (Bs)

Shape Factor represents the square of the basin length to the area of the basin. This morphometric parameter is in inverse proportion to form factor (Nooka R et. al., 2005). Shape factor affords a notion regarding the circular character of the catchment. The greater the circular character of the basin, the greater in the fast response of the catchment following a rainfall storm event (Tuker G. and Bras R., 1998). The shape factor value of the eighteen micro-watershed ranges from 1.15 (MWSD-2, 13) - 9.85 (MWSD-7) (Table 14), which indicates that the elongated shapes dominate the micro-watersheds.

4.2.3.3. Elongation Ratio (Re)

Schumm (1956) defined elongation ratio (Re) as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. According to Strahler (1964), the values of elongation ratio generally varies from 0.6 to 1.0 over a wide variety of climate and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are associated with high relief and steep ground slope. Lower value of Re infers more elongated basin whereas larger value indicates more circular in shape of the basin. The elongation ratio values of all the micro-watersheds range from 0.12 to 0.77 (Table 14), indicating that the micro-watersheds are more or less elongated or oval shape, characterized by high relief and steep slopes.

4.2.3.4. Compactness Coefficient (Cc)

Cc parameter is independent on size of the catchment and depends mainly on slope. Low Cc values imply greater elongation and high erosion rates (Horton R., 1945). The Cc value of upper bilate watershed is 6.09, while the Cc values for the eighteen micro-watershed vary from 0.961 (MWSD-16) to 8.62 (MWSD-13); thus, high surface erosion is characteristic.

4.2.3.5. Circularity Ratio (Rc)

Circularity ratio (R_C) is dimensionless quantity which is defined as the ratio of the basin area to the area of a circle having the same circumference as the perimeter of the basin and expresses the degree of circularity of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/cover, climate, relief and slope of the basin (Chopra et. al., 2005). The high R_C value indicates that the micro-watersheds are more circular and are characterized by high to moderate relief and drainage system is structurally controlled while the lower Rc values of micro-watersheds indicate an elongated shape.In the present study, the Rc values for all micro-watersheds range from 0.77 to 0.18 (Table 11) which show that the micro-watersheds are almost elongated.

Table 29: Micro-watershed based Computed Value for shape parameters

MWSD name	A	P	Nu	Lb	Rf	Bs	Re	Cc	(Rc)
MWSD 1	195.19	64	13	70.28	0.039	2.53	0.66	2.9	0.60
MWSD 2	99.89	52	4	34.02	0.086	1.15	0.72	6.0	0.50
MWSD 3	79.64	36	7	38.31	0.054	1.83	0.41	1.0	0.77
MWSD 4	51.22	33	7	20.98	0.116	8.93	0.55	3.0	0.59
MWSD 5	162.27	61	17	83.83	0.023	4.30	0.35	3.9	0.55
MWSD 6	91.13	41	9	38	0.063	1.54	0.53	1.4	0.68
MWSD 7	50.53	33	4	22.35	0.101	9.85	0.48	3.2	0.58
MWSD 8	164.96	59	11	57.57	0.049	2.09	0.59	2.9	0.59
MWSD 9	93.2	50	6	34.03	0.080	1.22	0.55	5.8	0.47
MWSD 10	54.38	37	10	26.08	0.079	1.20	0.41	5.0	0.5
MWSD 11	68.33	37	7	22.16	0.139	7.1	0.77	2.3	0.63
MWSD 12	89.91	50	6	43.41	0.047	2.05	0.71	6.3	0.45
MWSD 13	64.27	46	13	26.9	0.088	1.15	0.53	8.62	0.38
MWSD 14	49.72	32	7	18.47	0.145	6.81	0.54	2.6	0.61
MWSD 15	54.42	34	11	38.69	0.036	2.70	0.12	3.0	0.59
MWSD 16	56.44	31	7	28.49	0.069	1.48	0.37	0.96	0.74
MWSD 17	124.24	92	4	41.69	0.071	1.38	0.73	1.2	0.18
MWSD 18	58.7	34	6	26.94	0.080	1.26	0.45	2.1	0.64
Total	1675.09	822	149	672.2					

4.3. Prioritization of Micro-watersheds

4.3.1. Priority area based on RUSEL model

Some micro-watersheds may get highly vulnerable to soil erosion due to various reasons. One of the major reasons for this is the intensity of land degradation (Trimphati, *et al.*, 2003). In this study, identification of vulnerable micro-watersheds on the basis of soil loss rate was done.

As it is shown in Table: 15, based on the values of wise soil loss rate micro-watershed are classified in to 5 classes (Very high, high, moderate, Low and Very low). As shown in figure: 16, out of the 18 micro-watersheds, four micro-watersheds (MWSD-3,6,8, and 16) covering 16.6% of the watershed shows very high soil loss rate it may be due to high contribution of LS factors. These very high values found in the upper and middle part of the watersheds. In the high soil erosion classes there are four micro-watersheds (MWS-5, 7, 11 and 12) and it covers 24.5% of the study area. And 27.4% of watershed categorized on moderate erosion class. About 21.1% of the watershed (MWSD-1, 13, and 17) are found in the low erosion classes which is below the annual average soil loss of the entire watersheds. Very low soil loss category includes two micro-watersheds (MWSD-10) which are located in the lower reach of the study area and it covers 10.4% of the study area. The micro-watershed under this class is not immediate area of action plan.

Based on the annual soil losses, erosion vulnerable micro-watersheds are identified and ranked in ascending order. The micro –watershed that comes first is more erosion vulnerable micro-watershed. Thus priority is given for developing the management plan to reduce the exposed land degradation. Based on this – MWSD-3, MWSD-6, MWSD-8, and, MWSD-16 are the most vulnerable micro-watersheds and immediate attention can needs to rehabilitation and restoration.

Table 30: Priority rank of micro-watersheds

no.	Priority rank class	MWSDs	no. of MWSD	A(Km2)	% from total
1	Very High	3,6,8,16	4	459	16.6
2	High	5,7,11,12	4	411	24.5
3	Moderate	2,4,9,14,15,18	6	278	27.4
4	Low	1,13,17,	3	352.09	21.1
5	Very Low	10	1	175	10.4

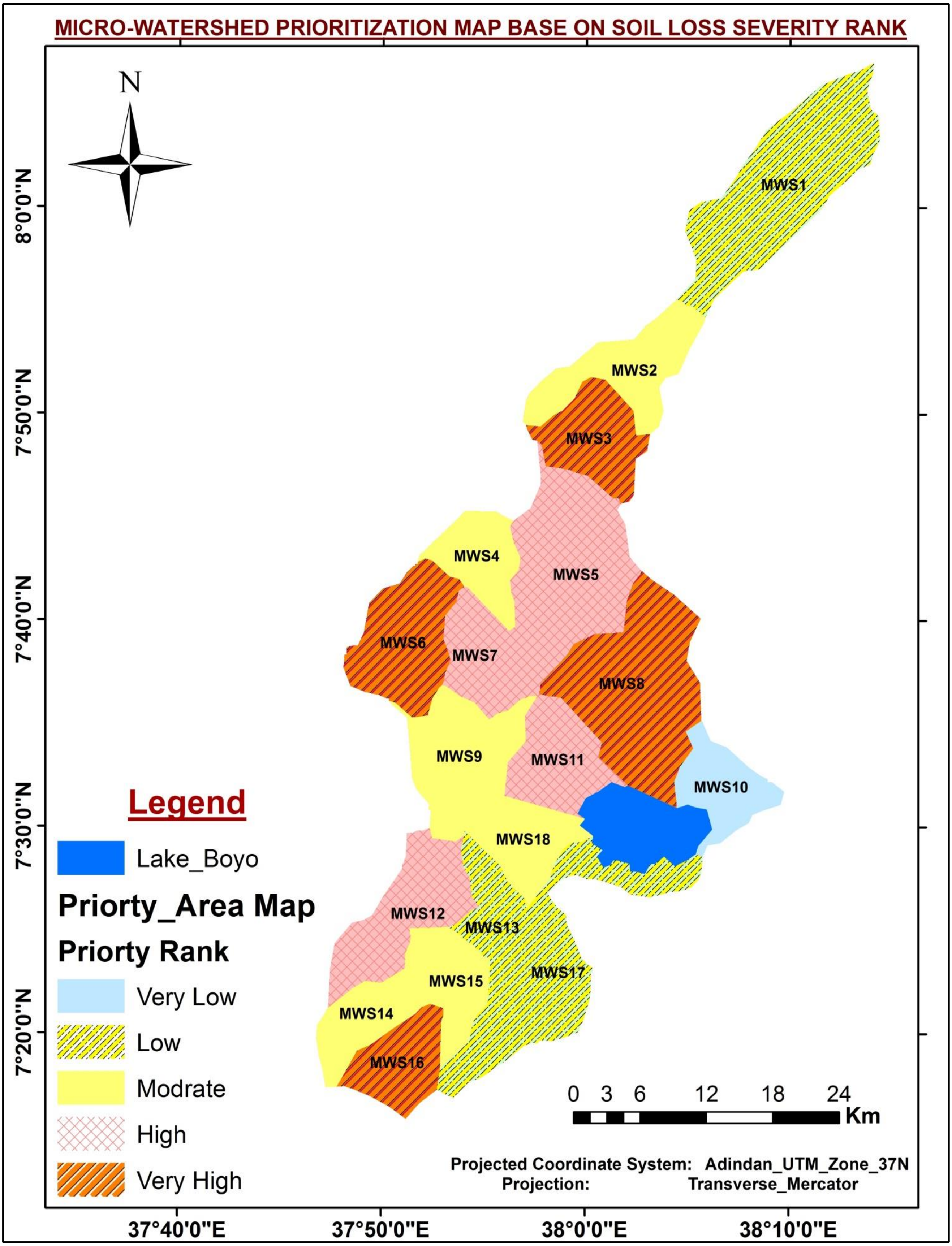

Figure 15: Micro-watershed Prioritization map of soil loss severity rank

4.3.2. Erosion Risk in the Watershed based on MCE

4.3.2.1. Composite Erosion Index (CEI)

All criteria layers obtained in section 3.3.5 were multiplied by an appropriate weight derived from pair-wise comparison of criteria (Table: 31) and then added by Weighted Linear Combination (WLC) equation in raster calculator operation in ArcGIS10.3.

The algebraic operation performed on four layers is as follow:

CEI = (W1*S) + (W2*P) + (W3*C) + (W4*R) + (W4*K)

Where CEI is Composite Erosion Index;

W1, W2----W4 are pairwise weights derived from AHP; and

S, P, C, R and K are reclassified slope, land use type, land cover, rainfall and.

The final output map indicates micro-watershed wise CEI that relates to the erosion intensity of the area under the relative contribution of the given criteria. Values of CEI range between 0.89 and 4.52 (Figure17).

Table 31: weight derived from pairwise comparison of criteria

No.	criteria	Weights (%)
1	Slope (S)	51.28
2	Land use type (P)	26.15
3	land cover (C)	12.90
4	Rainfall (R)	6.34
5	Soil (K)	3.33

Figure 17: showed the influence of topography on erosion potential in the study area. Minimal and low erosion potential was present under dense vegetation when the slope gradient was also low, but increased with higher slope values. There were few cells with extreme erosion potential, and these were usually restricted along stream channels and ridges with very high slope values. Table 32 shows area and proportion of the study area categorized in a classified CEI map. Most of the study area (64.5%) lays on CEI class values between 1.09 and 2.10.

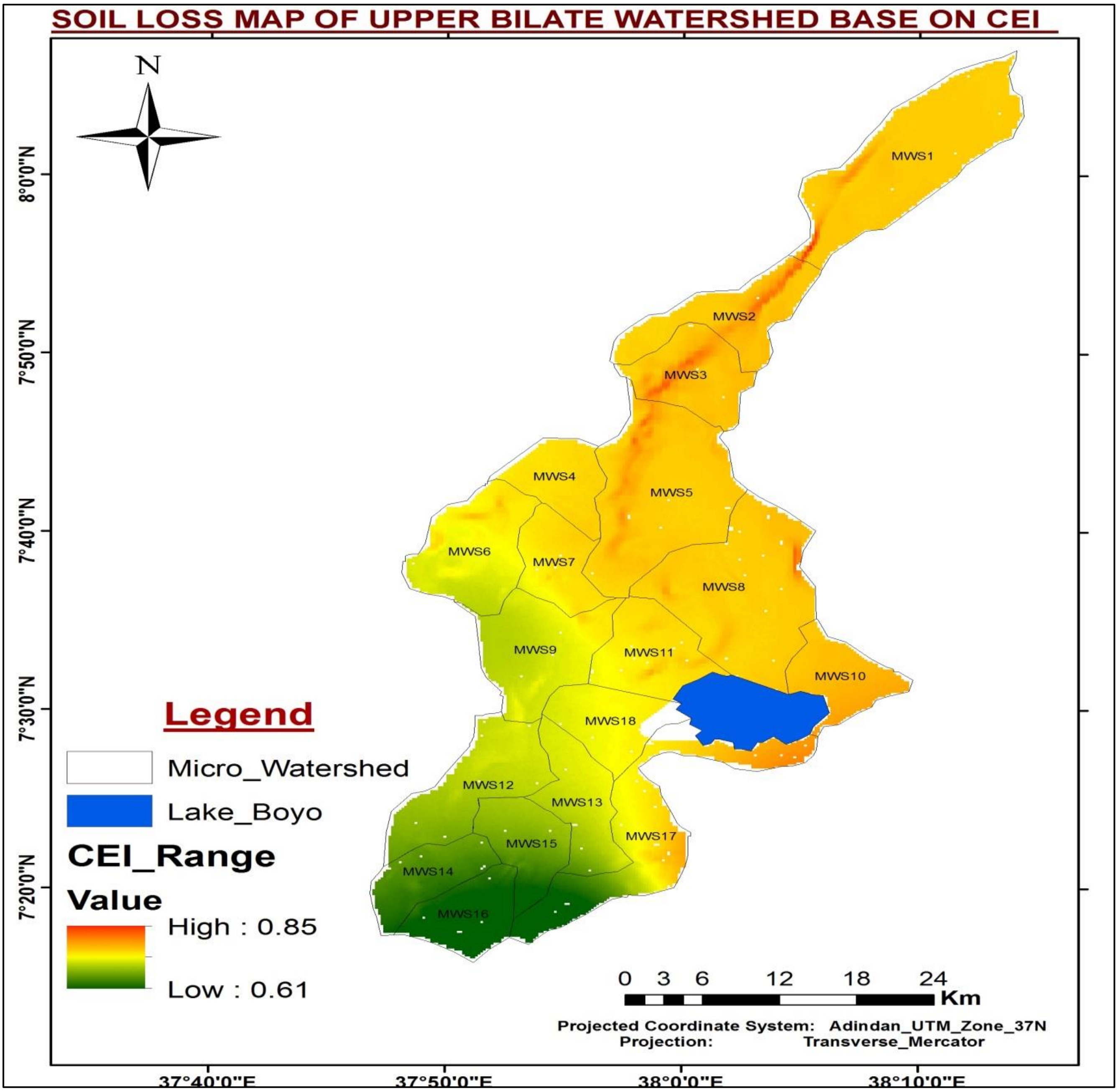

Figure 16: Composite Erosion Index map

Table 32: Areal proportion of the study area based on CEI classes

no.	Priority class	MWSDs	A(Km2)	% from total
1	Very High	3,5,6	160.45	9.58
2	High	2,9,12,14	332.72	19.86
3	Moderate	8,11,17, 7,18	383.03	26.85
4	Low	1,13,15	374.78	22.37
5	Very Low	10	357.46	21.34

4.3.3. Priority area based on morphometric analysis:

The morphometric parameters i.e., bifurcation ratio (Rb), compactness coefficient (Cc), drainage density (Dd), stream frequency (Fs), drainage texture (Dt), form factor (Ff), circularity ratio (Rc), and elongation ratio (Re) are also termed as erosion risk assessment parameters and have been used for prioritizing watersheds (Horton R.,1945). The linear parameters such as drainage density, stream frequency, bifurcation ratio, drainage texture have a direct relationship with erodibility, higher the value, more is the erodibility. Hence for prioritization of watersheds, the highest value of linear parameters was rated as rank 1, second highest value was rated as rank 2 and so on, and the least value was rated last in rank. Shape parameters such as elongation ratio, compactness coefficient, circularity ratio, and form factor have an inverse relationship with erodibility (Horton R., 1945), lower the value, more is the erodibility. Thus the lowest value of shape parameters was rated as rank 1, next lower value was rated as rank 2 and so on and the highest value was rated last in rank.

Hence, the ranking of the watersheds has been determined by assigning the highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters. After the ranking has been done based on every single parameter, the ranking values for all the linear and shape parameters of each watershed were added up for each of the 18 micro watersheds to arrive at compound value (Cp) (Table 33). Based on average value of these parameters, the watersheds having the least rating value was assigned highest priority, next higher value was assigned second priority and so on.

The watershed which got the highest Cp value was assigned last priority. The watersheds were then categorized into five classes as very high, high, moderate, very low and low priority on the basis of the range of Cp value. Hence, on the basis of morphometric analysis, micro-watershed (MWSD-8, 6) fall in the very high priority, micro-watershed (MWSD-3,5,11,16) high priority micro-watershed (MWSD-1,2,4,7,9,12,13,14,15) fall in moderate priority, micro-watershed (MWSD-17 and 18) low priority and micro-watershed (MWSD-10) in the very low priority category (figure-16)

Table 33: Final prioritization based on compound Morphometric parameter

Basic parameters value of micro watersheds																		
MWSDs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A(km^2)	195.2	99.89	79.64	51.2	162.3	91.13	50.53	165	93.2	54.4	68.33	89.9	64.3	49.7	54.4	56.4	124.2	58.7
P	64	52	36	33	61	41	33	59	50	37	37	50	46	32	34	31	92	34
Nu	13	4	7	7	17	9	4	11	6	10	7	6	13	7	11	7	4	6
L_u	70.28	34.02	38.31	20.98	83.8	38	22.3	57.57	34.03	26.08	22.2	43.41	26.9	18.47	38.7	28.49	41.7	26.94
$L_b=1.321*A^{(0.568)}$	26.4	18.1	15.9	12.4	23.8	17.1	12.3	24	17.4	13	14.6	17	14.1	12	13	13	20.4	13
Linear and Shape Parameters of micro watersheds																		
R_b=Nu/Nu+1	3.25	0.57	1	0.412	1.89	2.25	0.36	1.83	0.6	1.43	1.17	0.46	1.86	0.64	1.57	1.75	0.67	-
D_d=Lu/A	0.36	0.54	0.48	0.41	0.52	0.32	0.44	0.35	0.37	0.34	0.32	0.48	0.42	0.37	0.71	0.5	0.34	0.56
Fu =Nu/A	0.07	0.06	0.09	0.15	0.11	0.1	0.08	0.07	0.16	0.18	0.1	0.07	0.2	0.14	0.2	0.12	0.03	0.14
T= Nu/P	0.2	0.09	0.19	0.21	0.28	0.12	0.12	0.19	0.12	0.17	0.19	0.14	0.28	0.22	0.32	0.23	0.04	0.28
Lo=1/2D_d	0.18	0.17	0.2	0.25	0.26	0.15	0.25	0.14	0.19	0.34	0.29	0.24	0.21	0.19	0.36	0.3	0.17	0.23
$R_f=A/L_b^2$	0.28	0.31	0.32	0.33	0.29	0.21	0.33	0.29	0.31	0.33	0.32	0.35	0.32	0.33	0.33	0.33	0.29	0.35
$Bs=L_b^2/A$	2.57	3.28	3.17	3.31	3.49	2.61	3.47	2.81	3.65	3.01	3.12	3.25	3.09	3.38	3.01	3.04	3.36	2.88
$Re=(2\sqrt{A/\pi})/L_b$	0.597	0.65	0.733	0.651	0.60	0.33	0.65	0.3	0.63	0.25	0.64	0.63	0.64	0.65	0.65	0.65	0.62	0.67
$Cc=P/(2\sqrt{A\pi})$	1.29	1.468	1.14	1.47	1.35	1.21	1.31	1.02	1.56	1.74	1.66	1.59	1.62	1.3	1.3	1.2	2.33	1.3
$Rc = 4 \times \pi \times A/P^2$	0.399	0.56	0.321	0.591	0.55	0.24	0.58	0.39	0.47	0.62	0.63	0.45	0.38	0.61	0.59	0.74	0.18	0.64
Cp	0.839	0.769	0.764	0.778	0.92	0.75	0.76	0.739	0.806	0.941	0.79	0.766	0.90	0.783	0.91	0.886	0.93	0.935
Rank	10	6	3	7	15	2	4	1	11	18	9	5	13	8	14	12	16	17

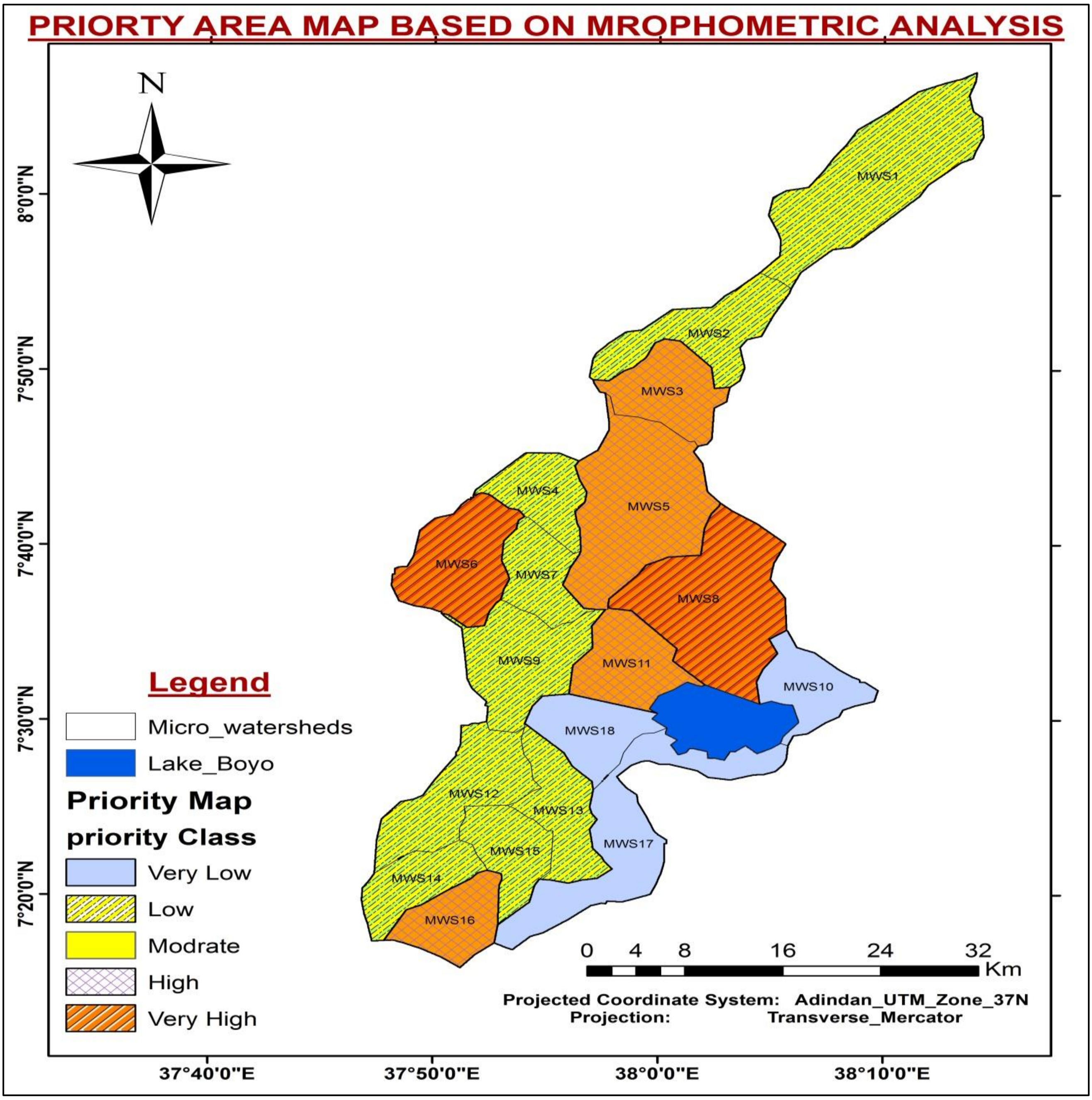

Figure 17: Micro-watershed Prioritization map based on morphometric analysis

Table 34: Priority class based on morphometric analysis

no.	Priority class	MWSDs	no. of MWSD	A(Km2)	% from total
1	Very High	8, 6	2	256.09	15.29
2	High	3,5,11,16	4	388.33	23.18
3	Moderate	1,2,4,7,9,12,13,14,15	5	793.35	47.36
4	Low	17,18	4	182.94	10.92
5	Very Low	10	2	54.38	3.25

4.3.4. Conservation priority area

An integration of the results achieved from the morphometric analysis method, and soil erosion susceptibility (RUSLE) method was conducted through superimposition of the two produced maps. Such a process makes it possible to identify the common micro-watersheds falling under each category of priority. The result reveals four micro-watersheds (MWSD-5, 8, 11, and 18) as the common micro-watersheds ranked under very high, micro-watersheds (MWSD-, 2, 9, and 14) under high, micro-watersheds (MWSD-, 1, 4,7, 12, and 13) under moderate, micro-watersheds (MWSD-, 6, 16, and 17) under low and micro-watersheds (MWSD-3, 10 and 15) very low priority(Figure 17). Accordingly, it can be concluded that a reasonable number of micro-watersheds are classified in the categories of moderate, high, and very high priority based on both morphometric and soil erosion susceptibility analysis. Therefore, they should be prioritized for soil and water conservation measures.

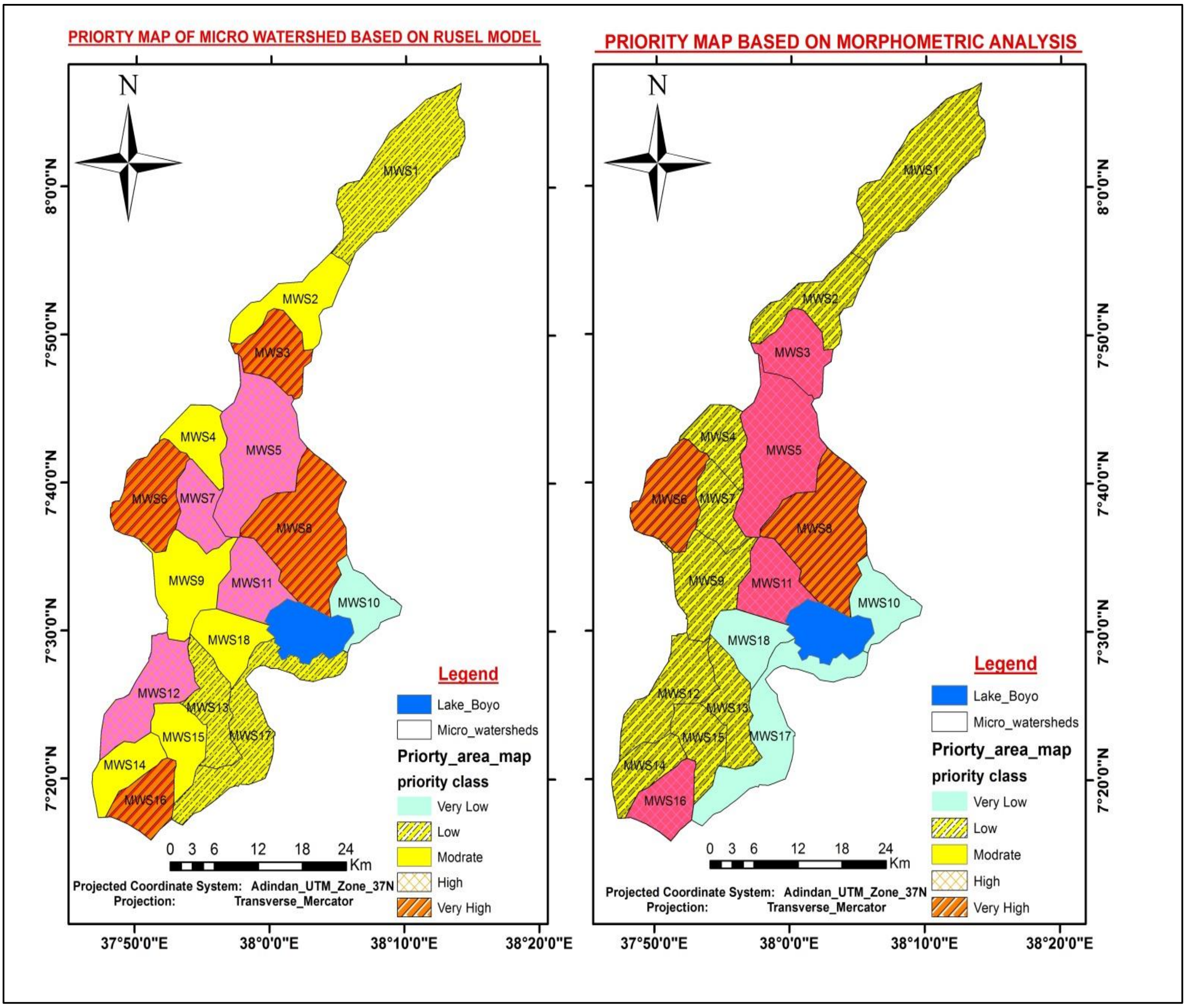

Figure 18: Micro-watershed Prioritization map based on RUSEL model and morphometric analysis

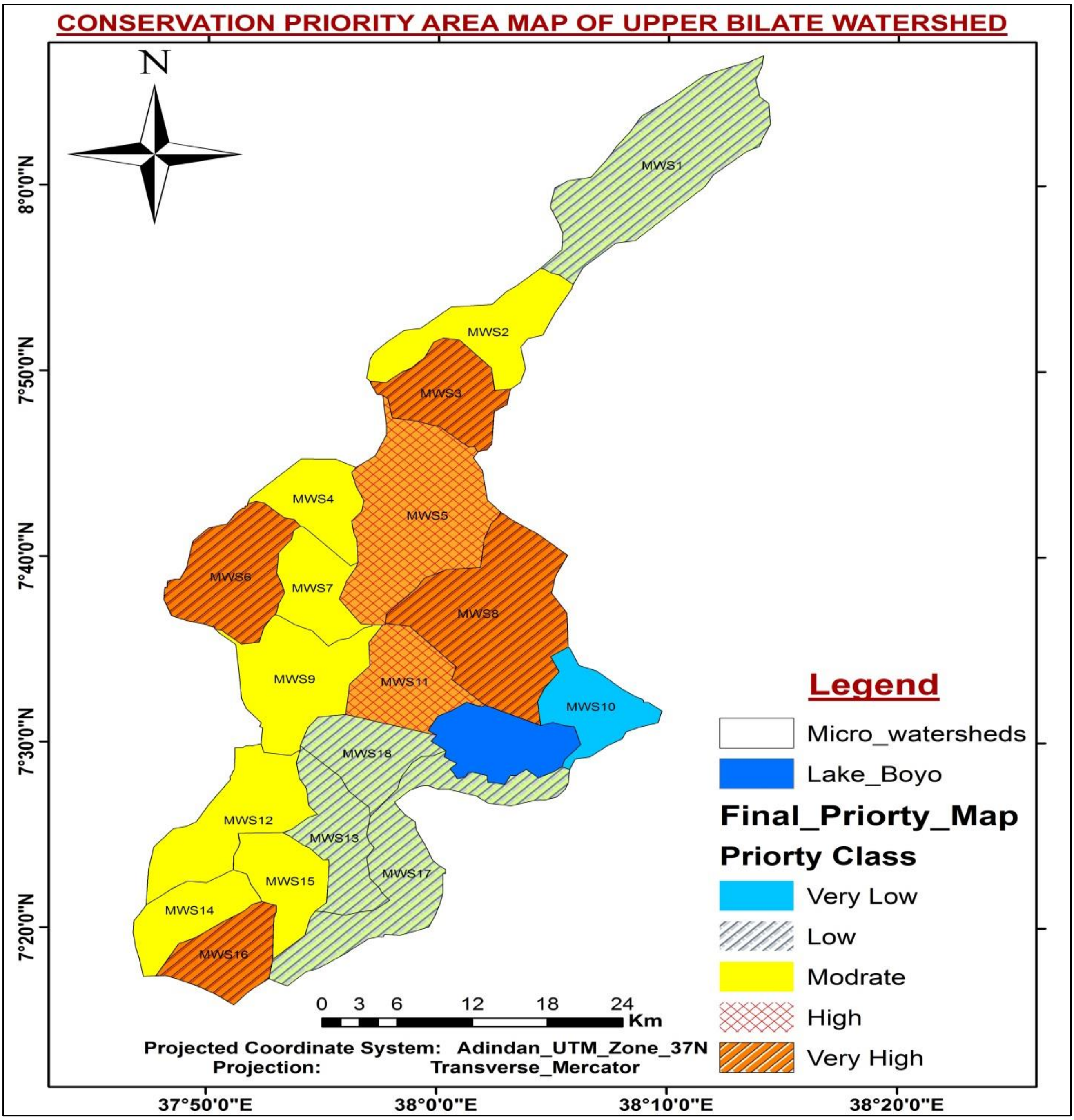

Figure 19: Conservation priority area map

Table 35: Conservation priority area

no.	Priority rank class	MWSDs	no. of MWSD	A(Km2)	% from total
1	Very High	3,6,8,16	4	392.17	23.47
2	High	5,11	2	280.6	16.75
3	Moderate	2,4,7,9,12,14,15	7	649.9	38.75
4	Low	13,18,17	3	297.21	17.74
5	Very Low	10	1	55.21	3.29

CHAPTER FIVE

5. CONCLUSION AND RECOMENDATION

5.1. CONCLUSION

The main objective of this study is to prioritizing micro-watersheds for conservation intervention and Restoration measures in Upper Bilate Watershed. The study demonstrates that an empirically based erosion assessment model, the RUSLE, integrated with morphometric analysis using GIS and remote sensing can provide useful information for conservation decision-making. The important results of the study include soil erosion value map of the watershed and the prioritization of micro-watersheds into conservation priority categories, which can be used for preparation of a conservation plan for management of the watershed.

Based on Soil erosion susceptibility analysis the total amount of soil loss in Upper Bilate watershed is about 27,262,478.8 tons per year from a total area of 1675.09 Km^2. The average annual soil loss from each micro-watersheds ranges from 2.6 to 44.17t/ha/yr. The mean annual soil loss of the entire watershed is 16.08t/ha/yr. Of the 18 micro-watersheds, 9 (MWSDs-2, 3, 5, 6, 7, 11, 14, 15, 16) were predicted to experience annual soil loss of more than the watershed's average (16.08t/ha/yr), whereas five micro-watersheds (MWSDs-1, 4, 9, 10, 12, 13, 17, 18) estimated annual soil losses were less than the average. The result showed that four micro-watersheds (MWSDs- 3, 6, 8, and 16) fell under very high soil erosion classes (16.03–44.17t/ha/yr) covering an area of 392.17 Km2 which contributed 23.47% of the total area. Micro-watersheds MWSDs- 5 & 11 fell under high soil erosion classes (28.52-20.71 t/ha/yr) covering an area of 280.6 Km^2 contributed the 16.75% of the total area. The micro-watersheds (MWSDs-2, 4, 7, 9, 12, 14, 15) fell under moderate soil erosion classes (14.9-23.95 t/ha/yr) covering an area of 649.9 Km^2 contributed the 38.75% of the total area. The micro-watersheds (MWSDs- 10, 13, 18, 17) that are predicted to experience very low to low soil loss together cover about 352.42km^2 contributed 21.03% of the watershed area.

Based on morphometric analysis, the results of prioritization indicate that (MWSDs- 8, 6) 256.09km2 (15.29%) of the area are classified as very high priority, whereas, micro-watersheds (MWSDs- 3, 5, 11, 16) 388.33Km^2 (23.18%) of the area are categorized as high priority. Micro-watersheds (MWSDs- 1, 2, 4, 7, 9, 12, 13, 14, 15) 793.35Km^2 (47.36%) of the area are categorized as moderate priority. And Micro-watersheds (MWSDs- 17, 18, 10) 237.32Km^2 (14.17%) of the area are categorized as moderate priority.

Through integration of the results or the RUSEL model and morphometric analysis method, the micro-watersheds (MWSDs- 3, 6, 8, 16) & (MWSDs- 5,11) are the common micro-watersheds that come under very high priority and high priority respectively. Seven micro-watersheds (MWSDs- 2, 4, 7, 9, 12, 14,

15) are classified in the category of moderate priority. Similarly, micro-watershed (MWSDs- 13, 18, 17) & (MWSDs- 10) comes under the category of low and very low priority respectively.

When prioritizing for conservation intervention, micro-watersheds (MWSDs- 3, 6, 8, 16) can be considered in the first stage and micro-watersheds (MWSDs- 5, 11) can be considered in the second stage. The micro-watersheds in the erosion severity class of moderate (MWSDs- 2, 4, 7, 9, 12, 14, 15) and low (MWSDs- 13, 18, 17) can be considered third and fourth for conservation priorities in order of sequence respectively.

5.2. RECOMMENDATION

The findings of the study showed that the study area is prone to soil erosion and there is change on the land use land cover trend of the area. The unsustainable use of resources and soil erosion risk may result in land degradation that can put the sustainability of agriculture of the area at risk in a long run. If this trend is continued it might influence the life time of the Lake Boyo and the lower part of the watershed especially rural kebeles of Shashogo woreda those near to Lake Boyo are vulnerable to siltation and flood risk problems. As a result, the following recommendations were forwarded depending on the findings of the study.

- ❖ Based on the result of the study, the areas which have fallen under very high and high severity classes need immediate attention in their order of soil erosion potential.
- ❖ The vegetation cover of the land (biological conservation) should be improved to reduce the removal of soil (soil detachments).
- ❖ Creating awareness among the society concerning sustainable use of natural resources and conservation methods.
- ❖ Responsible bodies in the woreda and including Regional level should incorporate during land use planning and soil and water conservation and management practices.

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APPENDIECES:

1. Five stations 22 years Annual rain fall

		Annual RF data of five Stations				
		Angech	Alaba	Hossana	Foniko	Wulibarg
X- Coordinate		37.571626	38.096111	37.856235	37.960258	38.118042
Y-Coordinate		7.253148	7.299239	7.567737	7.643853	7.741520
Years	1997	1600.6	796	1163.7	946.1	1464.9
	1998	1442.7	941.1	1173.2	1375.4	1190.3
	1999	1503.3	992.7	1429.5	1664.9	1266.7
	2000	1345.1	856.1	1305.3	1367.7	1416.8
	2001	1026.7	873.8	1003.6	1154	1525.7
	2002	1399.5	1051.6	991.9	1184.6	1377.4
	2003	2407.6	950.3	1093.9	1417	1027.2
	2004	1668.5	850.3	1250.9	1406.1	1198.3
	2005	1922.5	1105.8	1146.3	1466.6	1431.75
	2006	1714.2	956	1162.5	1195.8	1152.4
	2007	1934.8	710.2	1175	1225.5	1381.8
	2008	1830.3	1177.9	1197.7	1200.1	1136.4
	2009	1892.8	1057.75	1178.9	1110.7	1663
	2010	1443.6	531.3	1210.6	1269.2	1228.9
	2011	1259.9	1211.9	1170.4	1009	1183.6
	2012	1234.3	786.3	1121.59	1253.3	1176.5
	2013	1290.5	901.9	1004.5	1064.4	931.5
	2014	1092.3	1092.7	1109.3	1082.8	1060.2
	2015	1316.1	756.1	1164.6	1169.8	1530.8
	2016	1076.4	837.8	1499.1	1134.7	1143.6
	2017	732.1	1211.6	748	1218.95	1227.5
	2018	1455.4	809.3	1275.7	1359.4	987.7
MAP each stations		**1481.32**	**929.93**	**1162.5**	**1239.82**	**1259.2**

2. Land use class ground points

Id	X_Coordnat	Y_Coordina
1	411060	891469
2	409384	891855
3	410390	888066
4	411764	894420
5	403114	885183
6	405930	884411
7	410306	888250
8	400868	880858
9	400935	879483
10	408646	882634
11	410272	884210
12	403902	829794
13	403332	833097
14	399828	835846
15	391413	829040
16	379795	832745
17	382511	825318
18	379208	824262
19	386803	820373
20	375906	805553
21	381455	809493
22	385059	853733
23	386451	856969
24	387339	859517
25	392486	854706
26	390491	865435
27	392720	866558
28	391782	868217
29	396174	873247
30	389594	857519
31	390229	859599
32	392015	858694
33	392634	856186
34	392316	847343
35	395475	845311
36	395618	847764
37	385998	845676
38	375062	833045
39	375599	834671
40	397368	830708
41	395728	832388
42	394564	833016
43	395278	832104
44	394339	832315
45	388723	832778
46	389107	832924
47	388108	832071
48	390059	832851
49	391078	832534
50	392447	831250
51	392467	830999
52	393327	829094
53	394471	828982
54	396026	826713
55	394207	827057
56	393373	828221
57	394795	827864
58	396681	827804
59	393909	828558
60	395152	826755

3. Field pictures Gallery