PRIORITIZATION OF NAZERO WATERSHED FOR SOIL AND WATER CONSERVATION PLANNING USING GEOSPATIAL TECHNIQUES IN EFERTANA GIDEM DISTRICT; CENTRAL LOWLANDS OF ETHIOPIA

MSc. Thesis

Zemenu Alamawu

April 2021
Debre Berhan, Ethiopia

PRIORITIZATION OF NAZERO WATERSHED FOR SOIL AND WATER CONSERVATION PLANNING USING GEOSPATIAL TECHNIQUES IN EFERTANA GIDEM DISTRICT; CENTRAL LOWLANDS OF ETHIOPIA

A Thesis Submitted to the Department of Natural Resources Management
College of Agriculture and Natural Resource Sciences
School of Graduate Studies

DEBRE BERHAN UNIVERSITY

In partial Fulfillment of the Requirements for the Degree of Master of Science in Soil and Water Conservation

Zemenu Alamawu

Major Advisor: Estifanos Lemma (Ph.D.)
Co-Advisor: Tesfaye Mebrate (Ph.D.)

June 2021
Debre Berhan, Ethiopia

DEBRE BERHAN UNIVERSITY

EXAMINERS' APPROVAL SHEET-I

(Submission Sheet-1)

We, the undersigned, members of the Board of Examiners of the final open defense by having read and evaluated his/her thesis entitled "**Prioritization of Nazero Watershed For Soil and Water Conservation Planning Using Geospatial Techniques in Efertana Gidem District, Central Lowlands of Ethiopia** "and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree **Masters of Science** in Natural resources management with Specialization in **Soil and Water Conservation.**

Estifanos Lemma (Ph.D)	____________	_________
Name of Major Advisor	Signature	Date
Tesfaye Mebrate (Ph.D)	__________	_________
Name of Co-Advisor Advisor	Signature	Date
Yitea Sineshaw (Ph.D)	___________	_________
Name of Internal Examiner	Signature	Date
Hassen Mohammed (Ph.D)	____________	_________
Name of External Examiner	Signature	Date
_____________________	__________	__________
Associate Dean, College Res/CS & Post Graduate	Signature	Date
_____________________	_________	__________
Dean, College of Graduate Studies (CGS)	Signature	Date

Final approval and acceptance of the thesis are contingent upon the submission of the final copy of the thesis to the College of Graduate Studies (CGS) through the Department Graduate Committee (DGS) of the candidates.

Stamp of CGS   Date ___________________

DEBRE BERHAN UNIVERSITY

College of Agriculture and Natural Resource Science

Department of Natural Resource Management

(Submission Sheet-2)

As members of the Board of Examiners of the final Master's open defense, we certify that we have read and evaluated the thesis prepared by **Zemenu Alamawu** under the title "**Prioritization of Nazero Watershed For Soil and Water Conservation Planning Using Geospatial Techniques in Efertana Gidem District, Central Lowlands of Ethiopia"**, and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in **Natural resources management** with Specialization in **Soil and Water Conservation.**

____________________	____________	____________
Name of the Chairman	Signature	Date
Estifanos Lemma (Ph.D)	____________	____________
Name of Major Advisor	Signature	Date
Tesfaye Mebrate (Ph.D)	____________	____________
Name of Co-Advisor Advisor	Signature	Date
Yitea Sineshaw (Ph.D)	____________	____________
Name of Internal Examiner	Signature	Date
Hassen Mohammed (Ph.D)	____________	____________
Name of External Examiner	Signature	Date

Final approval and acceptance of the thesis are contingent upon the submission of the final copy of the thesis to the College of Graduate Studies (CGS) through the Department Graduate Committee (DGS) of the candidate's major department.

DEBRE BERHAN UNIVERSITY

College of Agriculture and Natural Resource Science

Department of Natural Resource Management

(Submission Sheet-3)

As members of the Board of Examiners of the final Master's open defense, we certify that we have read and evaluated the thesis prepared by **Zemenu Alamawu** under the title "**Prioritization of Nazero Watershed For Soil and Water Conservation Planning Using Geospatial Techniques in Efertana Gidem District, Central Lowlands of Ethiopia"**, and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in **Natural resources management** with Specialization in **Soil and Water Conservation.**

Yitea Sineshaw (Ph.D)	________________	______________
Name of Internal Examiner	Signature	Date
Hassen Mohammed (Ph.D)	________________	______________
Name of External Examiner	Signature	Date

Final approval and acceptance of the thesis are contingent upon the submission of the final copy of the thesis to the College of Graduate Studies (CGS) through the Department.

Thesis approved by

________________________________	________________	______________
DGS	Signature	Date

Certification of the Final Thesis

I hereby certify all the correction and recommendations suggested by the board of Examiner are incorporated in the final thesis "**Prioritization of Nazero Watershed for Soil and Water Conservation Planning Using Geospatial Techniques in Efertana Gidem District, Central Lowlands of Ethiopia" by**

________________________________	________________	______________
Name of the Designate	Signature	Date

Stamp of CGS Date ____________________

STATEMENT OF THE AUTHOR

I declare that this thesis is my genuine work and that all sources of materials used for this thesis have been profoundly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Master of Science (MSc) at Debre Berhan University and it is deposited at the University library to be made available for users under the rule of the library. I intensely declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author and advisors of this thesis.

Name: Zemenu Alamawu Signature: ---------------------

Place: College of Agriculture and Natural Resource Sciences, Debre Berhan University.

Date of Submission: ----------------------------------

BIOGRAPHICAL SKETCH

The author was born in Menth Gera Woreda North Shewa Administrative zone, Amhara-Region (280 km Northern from Addis Ababa, the capital city of Ethiopia) on June 04, 1984. He attended Sinamba Primary and Elementary School and completed his secondary and preparatory school education at Mehal Meda. Then he joined University of Gondar in 2006 and graduated with a BSc degree in Natural Resource Management in July 2008.

Finally, he was employed by Ataye Technical, Vocational, Educational and Training Collage as a trainer of Natural Resource conservation and utilization management department for the past three years. And now he joined Debrebrehan University to pursue his Master of Professional Study degree in soil and water conservation program.

ACKNOWLEDGEMENT

Primarily I would like to extend my unshared thanks to the Almighty God for helping me with the success and accomplishment of this research. Then my appreciation goes to my Major Advisor: Dr. Estifanos Lemma for his insightful professional guidance of the overall research work and my Co-Advisor: Dr. Tesfaye Mebrate for his professional guidance and suggestion in writing this research I learned many things and I believe which would be of great help for my future work. Also, my appreciation goes to Natural Resource Management Department Coordinator Abrha Yibeyn for his support by calling and emailing all the necessary information as well as coordinating from the beginning up to now and I would also like to thank all the staff members of the natural resource management department for their support in organizing, preparing and teaching relevant courses for the past two years.

ABBREVIATIONS and ACRONYMS

DEM	Digital Elevation Model
DSMW	Digital Soil Map of World
EUROSEM	European Soil Erosion Model
FAO	Food and Agricultural Organizations
GCPs	Ground Control Point
GIS	Geographical Information System
GPS	Global Positioning System
IDW	Inverse Distance Weight
ISRIC	International Soil Reference and Information Centre
LISEM	Limburg Soil Erosion Model
LU/LC	Land Use Land Cover
RS	Remote Sensing
RUSLE	Revised Universal Soil loss Equation
SWAT	Soil and Water Assessment Tool
SWC	Soil and Water Conservation
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project

Contents

LIST OF TABLE

LIST OF FIGURES

ABSTRACT

Ethiopia is one of the severely affected countries of the world by soil erosion. Soil and water conservation (SWC) measures have been implemented to minimize soil erosion since the 1980s without priority-based and scientifically quantified state of soil erosion in the study watershed. Therefore, this study was aimed to estimate spatially distributed potential soil loss in the Nazero watershed and prioritize its sub-watersheds ready for SWC planning, using Revised Universal Soil Loss Equation (RUSLE) and Geospatial techniques. Input parameters were derived from FAO and open access geospatial database. The result indicated that the mean annual estimated soil loss rate in the district was 17 t $ha^{-1}y^{-1}$ *with a standard deviation of 62 t* ha^{-1} y^{-1}*. Priority sub-watersheds, based on soil loss SW4, SW8. SW10, and SW9, were labeled as a high priority while, SW5, SW6, and SW7 were categorized under medium priority, and SW3, SW2, and SW1 were categorized under least priority based on the average degree of severity of drainage density and bifurcation ratio SW9, SW7, SW5, SW6, and SW8 were the first priority of sub-watershed but for Soil and water conservation planning and implementation use priority of soil loss. The soil erosion process in the study area was not as damaging. Reduction of the present soil erosion status of Nazero watershed by prioritizing at sub-watershed level can provide on-time responses to sub-watersheds exposed to potential erosion and help use limited resources. , Integration application of geospatial technics with the RUSLE model could be vital in other parts of the country for soil loss severity level-based watershed partitioning.*

Keywords: Drainage density, Nazero, geospatial technique, soil loss, RUSLE, watershed prioritization

1. INTRODUCTION

1.1. Background and Justification

Land degradation is the process of losing or declining the productive capacity of the land to sustain life (Temesgen et al., 2017). It is any form of deterioration of the natural potential of land that affects ecosystems integrity, either in terms of reducing its ecological sustainability or in terms of reducing its biological richness and maintenance of its resilience due to the cause of soil loss (Temesgen et al., 2014). Soil loss is mainly influenced in two ways. They are soil degradation and impoverishment of the vegetative cover. Soil degradation is a reduction in soil fertility caused by soil erosion and exploitative cropping. While impoverishment of the vegetative cover is, a reduction in the available biomass caused by climatic factors, overutilization of vegetation, and reduced soil fertility (Ananda et al., 2019).

Globally soil degradation is affecting 1.9 billion hectares and is increasing at a rate of 5 to 7 million hectares each year (Haillemarkos et al., 2018). Soil erosion is a worldwide environmental problem that treats the lives of most smallholder farmers (Temesgen et al., 2014). The average rate of soil loss in the world was estimated to be approximately 12 to 15 t/ha/year (Latifa and Mhamed, 2020). This rate of soil loss implies a topsoil loss of 0.90–0.95 mm every year (Temesgen et al., 2014). It has been estimated that 11 million km^2 areas were affected by erosion caused by water (Mengie et al., 2019). Furthermore, climate change and intense agricultural practices are among the problems that cause soil erosion similarly in African countries (Temesgen et al., 2014).

In most of the African countries including Ethiopia, the amount of soil loss on average is estimated from 30 to 40 t/ha/year (Rubianca. et al., 2018). Most tropical developing nations, challenged by unsustainable and exploitative land-use practices have accelerated soil erosion in many parts of Africa (Latifa and Mhamed, 2020). In sub-Saharan country soil erosion leads to declining soil fertility, brings about a series of negative impacts of environmental problems (Mengie et al., 2019). It has become a challenge for sustainable agricultural production and water quality in tropical and semi-arid regions of Ethiopia (Prasannakumar et al., 2012). In the highlands of Ethiopia, annual soil loss is estimated to be up to 300 tons ha^{-1} $year^{-1}$ (Ebrahim et al., 2019). Other studies in the north, south and south-eastern part of Ethiopia indicated that the annual soil loss of the Ethiopian highlands ranges between 200 to 300 tons ha^{-1} year^{-1}, for examples in Agewmariam northern Ethiopia (Gebrehana et al., 2020) in the southern part of Ethiopia (Rediet et al., 2020) in south-eastern Sissay et al., 2019). In the Amhara region, the situation is more prevalent and determinant for example in North Shewa Zone studies Andit Tid, watershed the mean soil loss 25 tons ha^{-1} year^{-1} (Ayele et al., 2018) and Ajema watersheds, the mean soil loss 22.3 tons ha^{-1} year^{-1} (Haillemarkos, 2018).

Overall, soil erosion is the most common environmental and economic problem in Ethiopia in general and in the highlands of Ethiopia (including the current study district) in particular. And it is the most challenging and continuous environmental problem resulting in both on-site and off-site effects in the world particularly in Ethiopia. Due to this Ethiopia faces different problems such as reduction of land cover, reduction soil fertility and productivities of crops, reduction of water and air quality, and overall challenges for ecological substances are some the problems (Yared et al., 2020).

The major causes of soil loss in Ethiopia are due to poor soil conservation planning, intensive farming, cultivation on steep slopes, clearing of vegetation problems, and high rainfall erosivity (Yared et al., 2020). Several studies in the highlands of Ethiopia indicate that reducing the protective plant cover can expose the topsoil to high-intensity rainfall (Fazzini et al. 2015; Mengie et al., 2019). As a consequence, these problems contributed to soil fertility loss, soil resource quality degradation, and dam siltation.

The needs of soil and water conservation technologies at the district level in different studies indicate that it is useful to enhance the productive capacity of land in areas affected by soil erosion (Tamrat et al., 2018). It includes the prevention, reduction, and control of soil erosion and velocity surface runoff (Yared et al., 2020). The mechanisms such as, maintaining good soil cover through mulching and canopy, retention of soil moisture, protecting of raindrop impact, maintaining favorable soil structure for reducing crusting, re-shaping the slope to reduce its steepness and slope length (Ebrahim et al., 2019). According to Efrtana gidim wereda Agricultural offices, In the study district soil and water conservation has been practiced for the past two decades but the approach has not been supported with prioritization of the most severely affected watersheds. Therefore, the identification and prioritization of erosion susceptible areas for planning soil conservation measures at the sub-watershed level are quite essential.

A watershed is any surface area from which runoff resulting from rainfall is collected and drained through a common confluence point (Wani et al. 2008). It is an ideal part of land and water resource management (Juliet and Brigitta 2020). Hydrologically watershed is an area, from which the runoff flows to a common point on the drainage system every stream, tributary, or river has an associated with a single outlet or common confluence point (Meshram and Sharma 2015). Micro watersheds are aggregated together to become larger watersheds (Umair and Syed, 2014). A large watershed may be split into two or more micro-watersheds where soil and water conservation (SWC) practices will be implemented and integrated within the watershed for the development and sustainable use of resources.

Watershed development is applying the holistic approach of integrated watershed management (IWM) that enables different actors to protect and restore the physical, and biological integrity of ecosystems and to preserve the base for sustainable economic growth (Juliet and Brigitta 2020). It is vital management of natural resources and mitigation of the impact of natural disasters for achieving sustainable development (Umair and Syed 2014). IWM is an effective tool for addressing many land and water resource problems and is recognized as a potential engine for agriculture growth and development (Suhas and Kaushal 2009).

Watershed prioritization is important for the planning and implementation of effective SWC measures (Sissay et al., 2019, Latifa and Mhamed 2020). Furthermore, it is critical to undertake proper intervention measures on the characteristics and features of the land (Gezahegn. et al., 2018). Watershed characteristics are generally defined as general biophysical natures or groups of features that distinguish one watershed from others (Sissay et al., 2019). It provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Umair and Syed 2014). Various watershed physiographic characteristics parameters such as stream order, drainage density & bifurcation ratio were computed based on watershed characteristics. Hence, in this study, such parameters and erosion severity values were used for the priority analyze the result of soil loss of watersheds.

The recently available geospatial technologies such as Remote Sensing(RS), Geographic Information Systems (GIS), and Global Positioning Systems (GPS) play a vital role in collecting, analyzing, and mapping eroded or degraded lands (Elzbieta 2020). Geospatial techniques for erosion assessment and watershed characterization have been proved to be a reliable tool when combined with empirical/semi-empirical soil erosion models (Wischmeier and Smith 1978, Ganasri and Ramesh 2016).

There are various soil erosion models, e.g., the European soil erosion model (EUROSEM), the water erosion prediction project (WEPP), the Limberg soil erosion model (LISEM), the chemical runoff and erosion from agricultural management system (CREAMS), the universal soil loss equation (USLE) and its revised version (Renard et al.(1997). Revised Universal Soil Loss Equations (RUSLE) model is the most commonly used empirical model in coordination with geospatial techniques to calculate potential soil loss based on soil types, rainfall, slope, and land cover factors of the watershed (Latifa and Mhamed 2019). Therefore, the GIS-based soil erosion model is a cost-effective method to estimate soil erosion, to identify and prioritize watersheds for sustainable natural resource conservation practices.

Several studies have been done to estimate soil loss and prioritize watersheds for SWC planning by using geospatial techniques and RUSLE everywhere across the globe such as in India (Umair and Syed 2014, Firoz and Laxmi 2017), in Nigeria (Babatude et al., 2016), in China (Long-Fei and young 2014), and Italia (macro et al., 2019). Similarly, there have been many related studies conducted in Ethiopia such as in Dembecha District Northwestern Ethiopia (Mengesha et al.2018), in East Hararghe (Gezahegn. et al., 2018), in Northwestern (Habtamu and Amare 2016), and Andit Tid watershed (Ayele et al., 2018). The overall conclusions of these studies indicate that geospatial technologies coupled with an erosion model have been used to estimate the average soil losses with varying scales of spatial resolutions. Therefore, this study focused on estimating soil erosion and prioritizing watersheds for SWC based on the severity of soil loss in the study watershed. Besides, there has been no specific study for SWC work.

1.2. Statement of the Problem

Land degradation and soil erosions is a major factor affecting the sustainability of agricultural production in Ethiopia (Temesgen et al., 2017). Soil erosion is one of the most dynamic factors in nature even if varied in centimeters extent (Yared et al., 2020). In SWC programs, soil erosion is considered to be a problematic issue for many countries including Ethiopia impacting various sectors of economic and environmental problems (Nigussie et al., 2015). To solve soil erosion problems in Ethiopia including the present study area, particularly following the famines of the period of the th1970s and 1980s many conservation programs were launched (Bewket & Teferi, 2009; Legas & Assen 2019; Yared et al., 2020). Thus, large areas have been covered with various soil and water conservation practices and millions of seedlings have been planted (Legas & Assen 2019; Yared et al., 2020). However, the success rate has been very low. If the soil erosion continues consistently, huge areas of agricultural land may be rendered economically unproductive (Teferi, 2009).

In Ethiopia, many large basin level studies have been reported on the amount of soil loss and its effects such as in the Blue Nile Basin (Temesgen et al.,2017, Mengie et al., 2019), in the Awash River basin (Atesmachew et al., 2015) and Omo-gibe river basin (Rediet and Eshetu 2020). However, micro-watershed level soil loss studies are more relevant than mega-scale studies for planning and implementing soil and water conservation measures at smaller land units like the Nazero watershed (Mengie et al., 2019). Since no watershed prioritization was made to help the SWC planning and implementation, every year resources are being dispatched to almost all watersheds irrespective of their differences. Besides, in the study area, no attempt was seen to analyze the different physiographic characteristics of the watersheds and identifying the critical feature of the site. Therefore, the soil erosion problem is being tackled by developing micro-watershed-based ideal conservation plans (Yared et al., 2020).

Overall the study attempts to identify and prioritize sub-watersheds based on the estimated soil loss and existing watershed physiographic characteristics such as drainage density, for soil and water conservation planning.

1.3. Objective of the study

1.3.1. General Objective

To prioritize and identify erosion affected Sub-watersheds for soil and water conservation planning using RUSLE and geospatial techniques in Nazero watershed Efertana Gidem, North Shewa Zone, Ethiopia

1.3.2. Specific Objectives

- To estimate average annual soil losses of the sub-watersheds using RUSLE and geospatial technologies
- To analyze the sub-watersheds physiographic characteristics based on selected watershed characteristics (drainage density and bifurcation ratio)
- To prioritize sub-watersheds for SWC planning based on their soil loss status and physiographic characteristics

1.4. Research Questions

- ✓ How much soil was lost annually from each micro watershed?
- ✓ Which physiographic characteristic did influence most soil loss to the greater extent?
- ✓ Which watershed was severely affected by erosion and did need urgent SWC planning and implementation?

1.5. Significance of the study

Understanding the dynamic nature of erosion and associated processes is critical for computing and mapping erosion risk. It will produce information that is essential for designing soil and water conservation plans in the study watershed. in the study watershed, the research will provide some insights about how to estimate the amount of soil loss and determine the physiographic characteristics of the sub-watershed at the district level for SWC planning and implementation. Moreover, the study will provide scientific information and be used as a reference for future study, monitoring, and management of soil and water resources at the district level. It will help experts, planners, district land managers, agricultural offices, natural resource conservation sectors, and NGOs. Furthermore, the study will use as a springboard to conduct further study to further enrich the area of investigation.

1.6. Scope of the study

This study focused mainly on issues related to soil loss by erosion and Sub-watershed physiographic characteristics that influence soil loss within the study watershed at the sub-watershed level. The study also focused on the prioritization of sub-watersheds for SWC planning and sustainable management in Nazero watershed Efratana Gidim.

2. LITERATURE REVIEW

2.1. Soil erosion

Erosion involves both the losses of the soil itself and the loss of organic and material nutrients found in the soil (Semu, 2018). Soil erosion results in the loss of soil organic matter and plant nutrients removal of soil from one part to another usually downhill by the action of water is known as water erosion (Semu, 2018). It refers to the removal of topsoil by the natural physical forces of water and wind at a greater rate than it is formed or through forces associated with farming activities such as tillage (Safdar et al., 2017).

2.1.1. Type of soil erosion

Soil erosion can be classified into two major types, i.e., accelerated and geological erosion (Neha and Shivakumar, 2018). The normal process of weathering is geological erosion that usually happens as a part of natural soil-forming mechanisms at low rates in all soils (Semu, 2018). While accelerated soil erosion occurred due to disturbance in natural equilibrium by the activity of human and animal through land mismanagement, destruction of forests, overgrazing, etc (Safdar et al., 2017). Gradually when the soil is removed under normal conditions of physical, biotic, and hydrological equilibrium, it is called normal erosion. Sometimes, it is also called geological erosion it takes place steadily but a long time slowly which developed the present topographic feature like valleys, plains, streams, channels, etc (Telkar et al., 2017).

2.1.2. Mechanism of soil erosion

2.1.2.1. Water erosion

Soil erosion caused by water is the application of energy from two distinct sources namely the falling raindrops and the surface flow (Neha and Shivakumar, 2018). Soil erosion caused by water can be distinguished in different forms, splash erosion, sheet erosion, rill erosion, gully erosion, and stream-bank erosion (Safdar et al., 2017).

2.1.2.2. Wind erosion

The soil particles on the land surface are lifted and blown off as dust storms mostly in arid and semi-arid (Semu 2018). When the velocity of the dust-bearing wind is retarded, coarser soil particles are deposited at the low land depend on the wind force responsible for three types of soil movement in the process of wind erosion. They are known as saltation, suspension and surface creep (Neha and Shivakumar, 2018). But this study focuses on the water erosion effect on soil loss.

2.1.3. Causes of soil erosion

Soil erosion is influenced by economic, social conditions, climate, land use and management, and topography (Safdar et al., 2019). Mainly soil erosion caused by the combined effects of deforestation, overgrazing, detrimental cultivation practices with an emphasis on small-seed crops that require fine tillage, poverty, land fragmentation, expansion of cropland onto steep slopes, and unsustainable use of natural resources (Birhan and Assefa 2017). The natural factors causing soil erosion and land degradation includes the high intensity of rainfall, types of soil, topography, and steep relief (Wudu 2019). Agricultural intensification has high relation with population pressure and is the main cause for soil erosion (Haregeweyn et al., 2017; Mengie et al., 2019).

2.1.4. Impact of soil erosion on agricultural production

Soil erosion is a very serious threat to food security and has a direct impact on livelihoods among rural communities in Ethiopia (Birhan and Assefa, 2017). Poverty level directly relates to soil erosion in developing countries (Safdar et al., 2019). The agricultural impacts of soil erosion are, loss of soil nutrients, reduction of crop yield, silting up of reservoir and It also contributes to persistent poverty and results in decreasing ecosystem resilience and provision of environmental services (Wudu 2019). The main on-site impact is the reduction in soil quality which results from the loss of the nutrients in the upper layers of the soil, and the reduced water-holding capacity of much-eroded soil (Balasubramanian 2017). Though it has a high influence on agricultural productivity.

Soil loss is a major factor in causing food insecurity in Ethiopia (Yared et al., 2020). In high land Ethiopia, the annual costs of soil erosion and nutrients loss from agricultural and grazing lands is estimated at $106 million (about 3% of agricultural GDP) from a combination of soil and nutrient loss (Bekele 2019; Yared et al., 2020). Soil erosion is recognized as one of the most serious causes of soil degradation in Ethiopia and hence in highland areas of the country the crop yield and soil fertility levels are extremely low (Zenebe et al., 2013). Annually about

2 billion cubic meters of topsoil loss is reported in Ethiopia and losses over 1.5 billion tons of topsoil annually only from the highlands area due to erosion (Tefer et al., 2016). The average annual soil loss rates from cropland are estimated as 42 tonnes/ha and ranged up to 300 tonnes/ha in extreme cases (Bekele, 2019). The last impact of soil erosion increased the price of food grains and other agricultural products both in rural and urban areas which ultimately results in lowering the living standard of the population (Addisu et al., 2015). Similarly more in the study district, more than 85% of society's livelihood depends on agriculture so erosion has a big influence on agricultural productivity and the living standard of the community.

2.1.5. Estimation of soil loss

The main cause of soil erosion is the removal of soil or soil loss, many types of research have been done so far in estimating soil loss by water erosion in the Ethiopian highlands and arid and semiarid parts (e.g. Gelagay and Minale 2016; Gashaw et al. 2017; Haregeweyn et al. 2017; Miheretu and Yimer 2018; Woldemariam et al. 2018; Zerihun et al. 2018). In different districts which are located in the northern part of Ethiopia, such as northwest (Kersa), south (KurfaChele), and south-west (Girawa) watershed, prioritization has been done based on the amount of estimated soil loss and classified the erosion risk into eight conservation priority levels. As a result, about 104.78 ha (0.04% of the total study area), 1164.27 ha (0.49% of the total study area), 1963.74 ha (0.83% of the total study area).

Table 1. Watershed priority in Gelana sub-watershed. (Birhan and Assefa, 2017)

Class	Soil loss (t ha^{-1} y^{-1})	Severity class	Priority class	Area	% of the total area	Annual soil loss	% of total soil loss	Mean soil loss ha^{-1} y^{-1})
1	0-12	Low	VI	16177.5	64.8	37,208.3	6.1	23
2	12-25	Moderate	V	3303.1	13.2	60,116.4	9.9	18.2
3	25-50	High	IV	2458	9.8	88,484	14.6	36
4	50-80	Very high	III	1162.7	4.7	73,366.4	12.1	63.1
5	80-125	Severe	II	822	3.3	82,282.2	13.6	100.1
6	>125	Very severe	I	1048.7	4.2	265,321.1	43.76	253

Generally, soil loss estimation and identification of the magnitude and risk of erosion assessment have a critical role in SWC planning.

2.1.6. Erosion estimation models

On a watershed scale, various models have been developed for the assessment of soil loss risk, namely, the European Soil Erosion Model (EUROSEM), Limburg Soil Erosion Model (LISEM), Soil and Water Assessment Tool (SWAT) model, and Water Erosion Prediction Project (WEPP) model (Latifa B. and Mhamed 2019). The Universal Soil Loss Equation (USLE) or Revised USLE (RUSLE) models have been the most used methods to effectively predict soil loss in different conditions. Integrating the remote sensing, geographic information system (GIS), and USLE/RUSLE facilitates to estimate of soil loss gird wise (Boloori et al., 2019). The USLE has originally developed at the farm plot scale more accurately for soils with medium texture and slopes of less than the length of the plot are 22.1 m long, is 1.83 m wide, and has a slope of 9 % (Wischmeier and Smith 1978). Although the model accounts for rill and interracial erosion, it does not account for soil loss from gullies or mass wasting events such as landslides. The models modified in RUSLE that able to estimate complex topography supported by geospatial technology.

It has been extensively used to estimate soil loss by erosion, assess soil erosion risk, and guide development and conservation plans to control erosion. The problems of soil erosions are identifying by RUSLE and other different models most of the local SWC practice not estimating the risk magnitude and severity and also not prioritizing watershed for implement SWC measurement. Information on soil loss is essential to plan and prioritize treatments of the watershed, to understand the erosion process and their interaction.

The advantage of the RUSLE model is to be attributed to its relatively low data requirements compared to other more complex soil loss models, making it potentially easier to apply in areas with scarce data and it is flexible, time and cost-effective, and practical in areas of scarce measured data which can be used for watershed conservation. Due to this, different studies selected the model in areas where there is no enough data. RUSLE also has some limitations in terms of reliability and its spatial coverage especially for large areas (Chen et al., 2011; Prasannakumar et al., 2011) and overestimates K values (Fernández and Vega 2016; Ostovari et al., 2017). But integrating with geospatial technology is very essential for estimating soil loss.

2.2. Watershed

A watershed is a topographically delineated area that is drained by a stream system (Addisu et al., 2015, Guangyu et al., 2016). It has moved from a focus on physical water and soil utilization and conservation to the integration of social, economic, and environmental development (Guangyu et al., 2016). Watershed management practices played a crucial role in arresting runoff and help to reduce erosion hazards (Tesfa and Sangharsh, 2015). Characterization of the watershed is a necessary and important process in the planning and management of a watershed (Arbind and Madan, 2017). Delineating watershed-based characteristics is very important for management.

2.2.1. Watershed delineation

Watershed delineation is very essential for the understanding of the geo-environmental condition of an area. (Arbind et al., 2017). Now a day, digital elevation models (DEM) are being widely used for watershed delineation, extraction of stream networks, and characterization of watershed topography (Guangyu et al., 2016). Many researchers have used DEM and GIS techniques and for watershed delineation and extraction of drainage networks and various topographic characteristics of a watershed (Parmita bose et al., 2009; Arbind et al., 2017). Watershed delineation is very essential for the understanding of the geo-environmental condition of an area. Similarly delineating watersheds in different parts of Ethiopia like in south Gelana sub-watershed (Birhan and Assefa 2017), in Koga watershed, Northwestern Ethiopia (Habtamu and Amare, 2016), and Gobble Watershed, East Hararghe Zone (Gezahegn et al., 2018) conducted for soil erosion studies at watershed levels.

2.2.2. Watershed physiographic characteristics

Watersheds are the basic land unit for water resource management, their delineation, importance, variation is explained and illustrated (Pamela et al., 2015). The watershed is surrounded by ridges or the watershed boundary is a topographic high point due to this the incoming rainfall drains to the same place towards the same body of water or the same topographic low area (Gezahegn et al., 2018).

Watershed physiographic characteristics are to characterize watersheds based on the most influential variables as this provides a basis for planning of soil and water conservation issues as well as for developing water resources (Pamela et al., 2015). Stream length, stream order, and bifurcation ratio of water in watersheds depend on biophysical characteristics watersheds most commonly affected by geographical, geological, physiographical, and biological features of watershed characteristics. So features in the watershed will determine where water will accumulate and flow. After all, streams and rivers are simply low points on the land where surface flow accumulates.

Watershed is determining by geometry, soil characters, slope factors, and run-off type information and providing input data that are used in the hydrological simulation (Riad et al., 2020). DEM was used to drive the flow direction, flow accumulation, watershed boundaries, and drainage network (Gelagay and Minale 2016). The derivation of such information through using remote sensing and GIS will be very useful in site selection and planning of soil and water conservations in terms of size every watershed connected to gathers the larger watershed contain a small watershed (Gezahegn et al., 2018).

2.2.3. Watershed prioritization

Watershed prioritization is the ranking of different sub-watersheds according to the order in which they have to be taken for treatment and water conservation measures (Ashish et al., 2011). Watershed priority is the process of identifying the most soil loss or risk area using RUSLE and other models supported by geospatial data and techniques. Watershed character and their management require knowledge of topography, drainage network, water divide, and channel length, geomorphologic and geological setup of an area. Watershed linear features are directly related to erosion of the soil and the high value of linear feature reflects that the area is more erosive. Similarly, the relief feature influences erosion. Compound parameters (CP) are produced by summing all the ranks of linear, shape, and relief parameters and then dividing by the number of total parameters (Riad et al., 2020).

Different studies prioritized watersheds based on different parameters. e.g. based on the estimated rate of mean annual soil loss, in Koga watershed area was classified into eight erosion class accounts from 206,910 ha (87.02% up to 22,589 ha (9.50% of the total study area) in 2016 (Gelagay and Minale 2016). Based on soil loss, slope and land cover give priority to the study of Kersa, Kurfa Chele, and Girawa districts which are located in the north, northwest, south, and south-west of the watershed (Gezahegn et al., 2018).

2.3. Application of Geospatial Techniques for watershed priority

Geospatial technologies have a great contribution to collect and analyze both ground-based and remote sensing-based data to extract new spatial information. It has three components: geographic information systems (GIS), global position systems (GPS), and remote sensing (RS). Both spatial and attribute information of soil erosion on a micro-watershed scale contributes significantly to planning soil and water conservation, erosion control, and management of the watershed (Geetha et al., 2012). Satellite remote sensing and Geographic Information System (GIS) are ideal tools capable of identifying, locating, and mapping various landforms or land units as well as monitor and manage natural resources.

Digital elevation model (DEM) along with remote sensing data and GIS can be successfully used to enable rapid as well as a detailed assessment of erosion hazard (Firoz and Laxmi 2017). The availability of data at various resolutions makes it feasible to monitor changes at different scales and periods. Further, incorporating various thematic layers in the GIS domain, it is possible to model and achieve delineating priority areas for conservation (Firoz and Laxmi 2017). The latest advances in spatial information technology have augmented the existing methods and have provided efficient methods of monitoring, analysis, and management of earth resources. Many research studies have been done using geospatial techniques across different parts of the world e.g. soil and water conservation prioritization using Geospatial Technology in Subarnarekha Basin, Jharkhand, India (Laxmi 2017), watershed prioritization for soil and water conservation aspect using GIS and remote sensing in northern elevated tract Bangladesh (Riad et al., 2020).

As stated earlier geospatial technology is an important tool to delineate watersheds and prioritize areas for soil and water conservation. Hence, in the present study geospatial technologies have been used for analyzing the spatial dimension of land, climate, and topographical data and to reveal trends, and identifying the priority areas within the watershed for soil and water conservation planning. It also has been used to identify the magnitude and risk of erosion, different thematic layers such as watershed, slope, and drainage flow. The next diagram indicates how to process images and prioritize the watershed. the next figure 1. indicating the general methods of image processing and sub-watershed prioritization farm work of the study watershed.

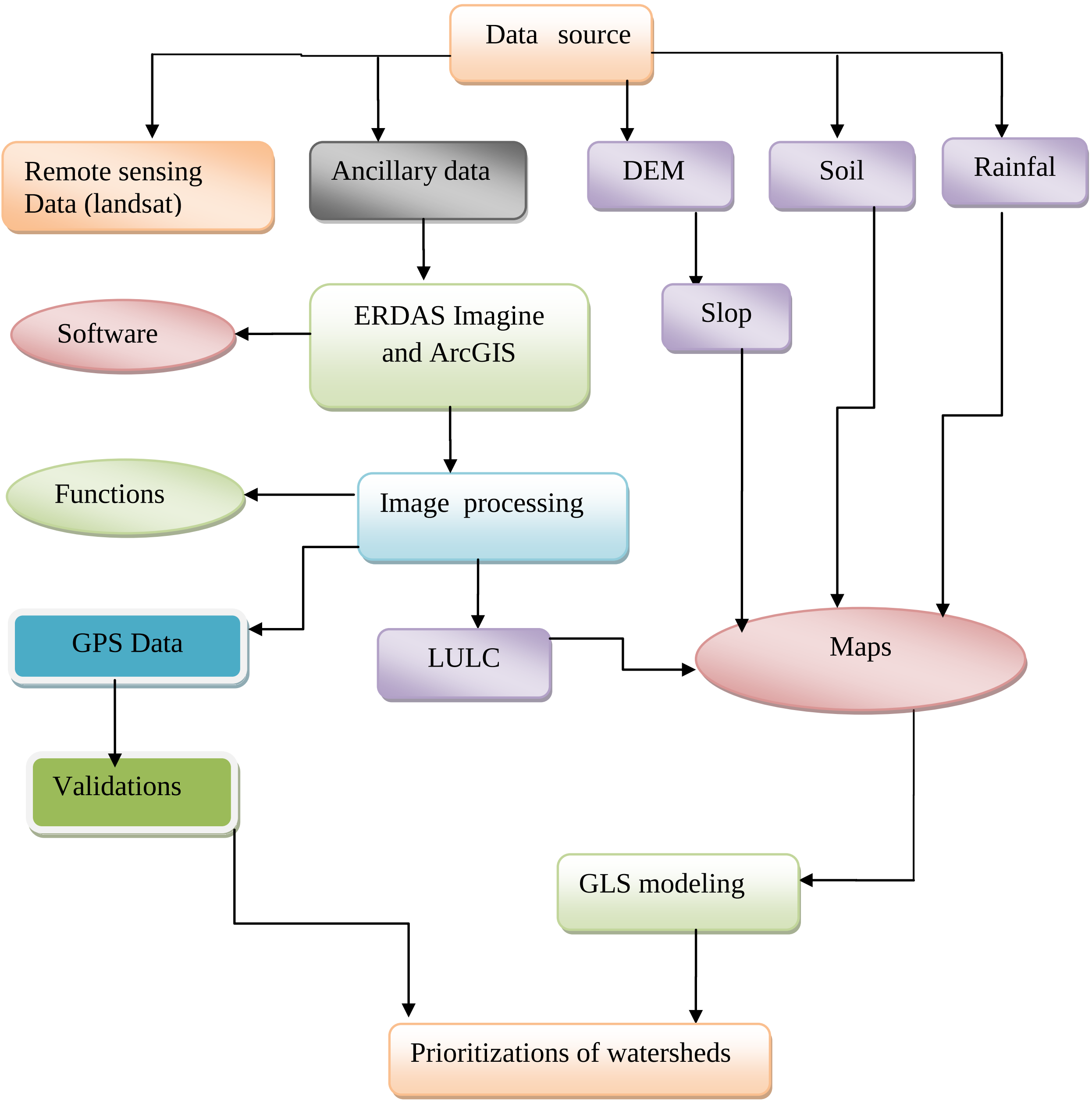

Figure 1. The methods of image processing and watershed prioritizing

2.4. Watershed based soil and water conservation planning

Soil and water conservation technologies are activities that maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion (Tesfaye and Fanuel, 2019). It includes the prevention, reduction, and control of soil erosion alongside proper management of the land and water resources (Safdar et al., 2017). Soil and water conservation practices are the primary step of watershed management they have a significant role in both in-situ and ex-situ resource management (Suhas and Kaushal 2009). Planning and implementation of effective soil and water conservation measures require, among other things, a detailed understanding of the extent, risk, and spatial distribution of soil erosion (Birhan and Assefa 2017). Soil and water conservation has been practiced in the watershed for about two decades; however, its implementation has been led without site-specific scientifically estimated soil erosion data and priority bases (Mengie et al., 2019).

Principles of effective soil and water conservation should be followed by effective erosion management. It includes reduction of the amounts and velocity of surface runoff, maintaining good soil cover through mulching and canopy cover, conservation, and retention of soil moisture. Prevention or minimizing the effects of raindrop impact on the soil, maintaining favorable soil structure for reducing crusting, re-shaping the slope to reduce its steepness and slope length to minimize runoff flows, maintenance, or improvement of soil (Tamrat et al., 2017).

Watershed logic (ridge to valley) is the most significant issue for sustainable and functional SWC practice. The drainage line contributing to the outlet many factors used to identify watershed priority like rainfall distribution soil credibility factors slope steepness and slope length is the most popular factor of identifying watershed. This research has been done watershed priorities from selecting sites using soil loss estimation using RUSLE and geospatial technology. Before implementing SWC measures it should fulfill the criteria including hydrology, the amount of water overland flow, soil type, slope class, land use land cover, and influence of wind and water erosions to understand watershed characteristics, to design layout and construction of soil and water conservations.

3. MATERIALS and METHODS

3.1. Description of the study area

3.1.1. Location and topography

Nazero watershed found Efertana Gidem wereda North Shewa Zone of the Amhara National Regional State. Geographically, it is located between 10°15’0” N to 10°25’0” N latitude and from 39°50’0” E to 40°55’0” E longitude. It is found 275 km northeast of Addis Ababa. The total area of the watershed is 12,700 ha. Efertana Gidem wereda drains to the Awash River Basin. The slope of the study area varies from flat to very steep slope. Most of the area is lowland. where its altitude ranging from 1,412m to 3,509 m .a.s.l. (above mean sea level).

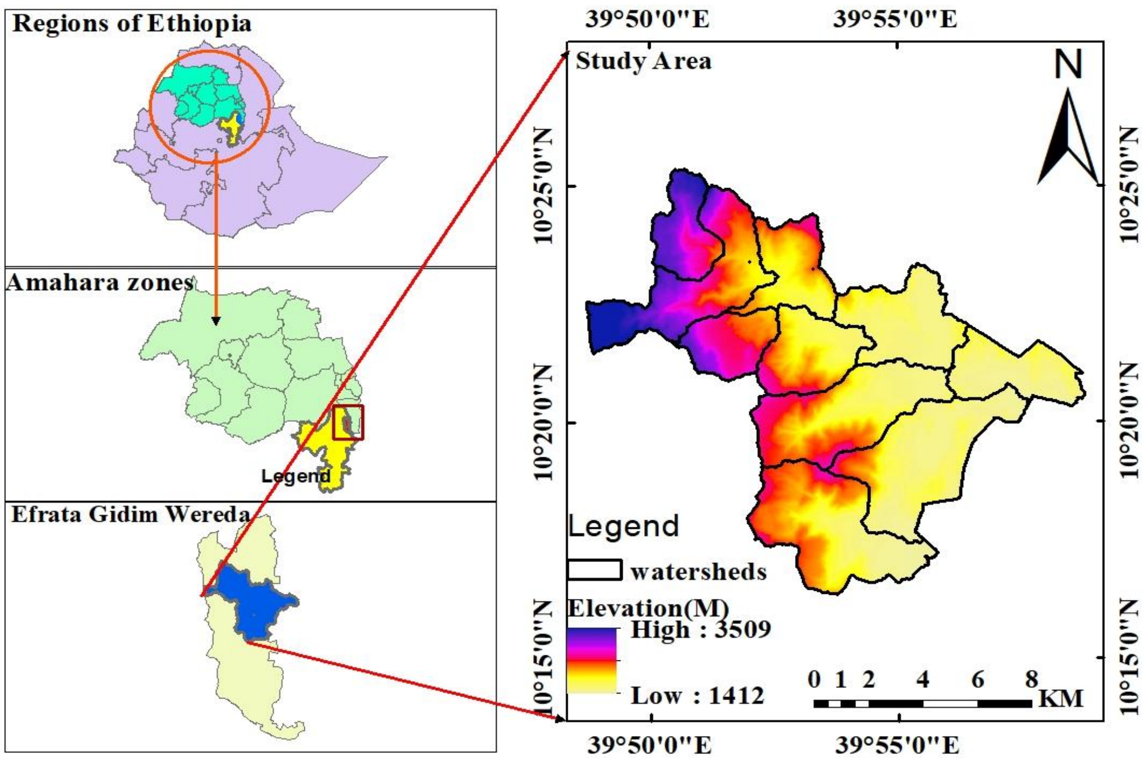

Figure 2. Description of the study watershed

3.1.2. Climate

According to Hurni and Gete (2018), Ethiopian agro-ecological classification, the study watershed has classified under dry kola up to dry dega, based on altitude and amount of rainfall distributions. The mean annual temperature of the area for 19 years (2000 – 2019) was

21.3°C and the mean monthly temperatures range from 9.2°C in December to 33.4°C in June East Amhara Metrological Agency (EAMA,). The highest average precipitation was observed during July and August. And the mean annual rainfall of the district is 1105.7mm.

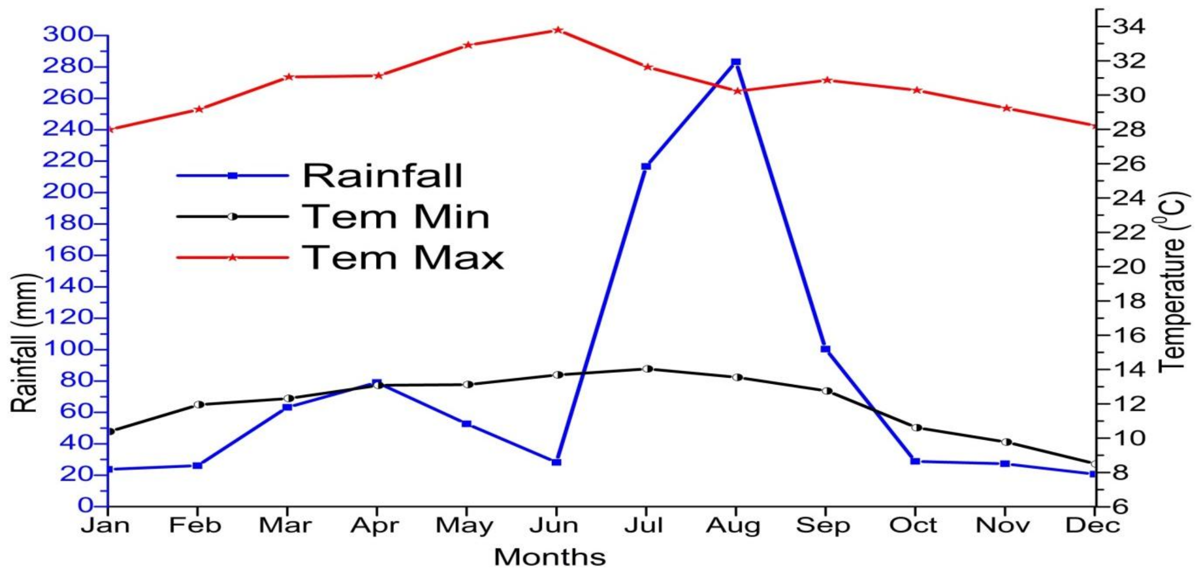

Figure 3. Rainfall and temperature of the study watershed

3.1.3. Soil and Slope

Based on the FAO, two soil types are dominant in the study watershed, which are leptosoil family and vertisols. according to the world reference book, leptosoil morphologically indicating accommodating of very shallow calcareous materials, but also deeper soil that is extremely gravelly or stone. While vertisols have high montmorillonite clay soil known for their shrink-swell properties in response to changes in soil moisture content (Okubay et al., 2015). but the erosivity factor of soil depends on the soil texture and natural characteristics of the soil. The details of the study area soil type are shown below (Table 2).

Table 2. Soil class of the nazero watershed

No	Soil class	Area (ha)	Area (%)
1	Lithic leptosoil	8560.2	67.4
2	Eutric vertisol	3106.4	23.8
3	Eutric leptosoil	145.7	6.4
4	Mollic leptosoil	887.7	2.4
	Total	12,700	100

The slope of the study area ranging from 0 to 8 % is very flat and it covers 2,264.6 ha of the area, most of the study area (8,302.2 ha) is found under the slope ranging from 8 to 45%, whereas the remaining area (2,133 ha) is found on an extremely steep slope (>45%). The details are found in Table 3 below.

Table 3. Slope class of Nazero watershed

			Area coverage	
No	Slope description	Slope class(%)	Ha	%
1	Flat	0-8	2264.8	17.8
2	Gently sloping	8-15	2020.4	15.9
3	Moderately to steep sloping	15-30	3367.8	26.6
4	Very steep sloping	30-45	2914	22.9
5	Extremely steep	>45	2133	16.8
	Total		12,700	100

3.1.4. Land use land cover

Landsat TM of 2019, downloaded from united States geological survey with row number 168 and path number 53 May 15, 2019, is used for land use land class analyzations. The land use land cover of the district was dominated by shrubland, an agricultural area, settlement, and bare land. Table 4 shows the land use and the land cover of the study area.

Table 4. Land use land cover of Nazero watershed

No	LULC	Area (ha)	Percentage (%)
1	Corpland	6,862	54
2	Shrub land	3,390	26.6
3	Forestland	938	7.51
4	Bare land	835	6.58
5	Settlement	675	5.31
	Total	12,700	100

3.2. Study watershed configuration

DEM downloaded from USGS of the district with a resolution of 12.5 m was classified by delineating into watersheds using geospatial techniques. Next, a larger basin was selected and reclassified into ten sub-watersheds using ArcGIS software of spatial analysis hydrology tools.

After delineating the main watershed, the study area has been reclassified into ten sub-watersheds and unique codes were assigned for each micro-watershed (Figure 4).

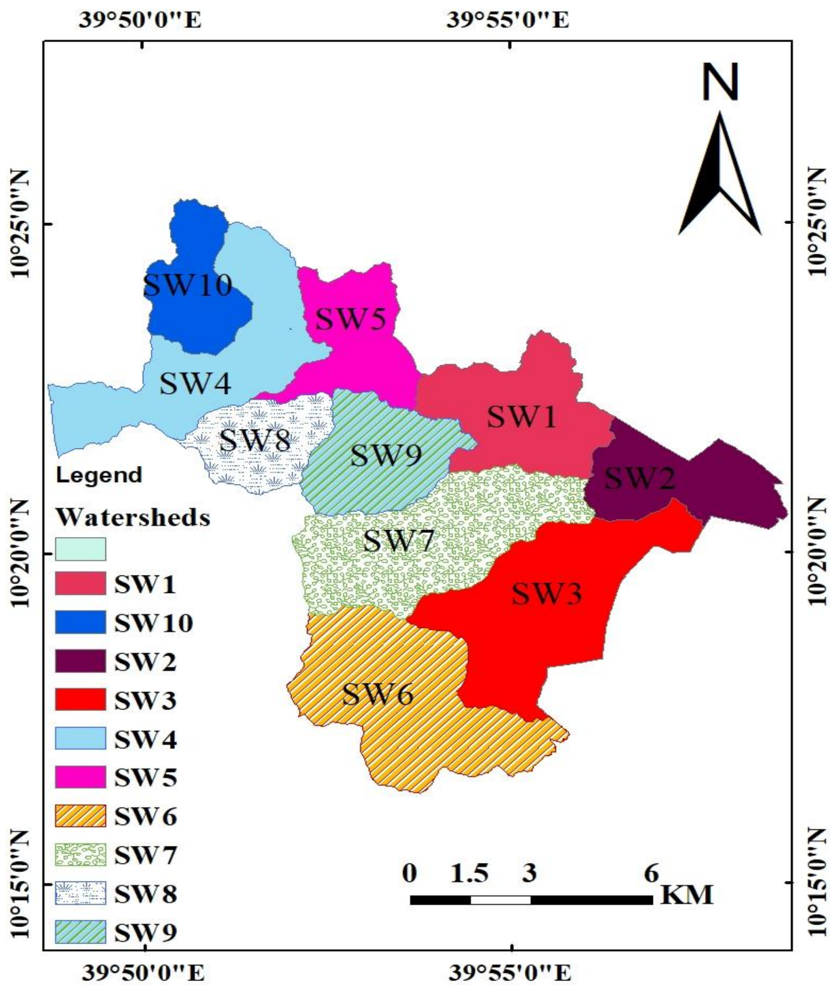

Figure 4. Micro watersheds of the nazero watershed

3.3. Method of Data Collection

For this research purpose, both primary and secondary data have been used. Some of these data were collected by geospatial technologies such as remote sensing (RS) and direct data collection using GPS. Primary data has been collected from the field using handheld GPS for ground truth authentication and observation and accuracy assessment and validation. Secondary data includes satellite images, topographic maps, Digital Elevation Model (DEM), meteorological data, soil data, and agricultural office land management documents of past reports. All the secondary data was collected from different governmental and non-governmental organizations Table 5 shows the details of data sources and types.

Table 5. Types of data and its source

No	Types of data		Source
1	Primarily data	Field survey	Direct field observation and GPS collected data
2	Secondary Data	DEM	USGS Earth Explorer
		Landsat image	USGS Earth Explorer
		Topographic map	North shewa zone agriculture office
		Soil map	Amahara region soil from soil meta catalogs (ISRIC) data goggles and Debre Brehan Agricultural research center.
		Study area shapefiles	Efrta ena Gidem agricultural office
		Meteorological data	East Amhara metrological stations

3.4. RUSLE factors

The RUSLE model estimates the mean annual soil loss per unit area for factors of erosivity of rainfall-runoff (R), erodibility of the soil (K), slope length/slope steepness (LS), cover-management (C), and support practice (P) factors of sheet and rill erosion, which can be computed using the following Equation (Rubianca. et al., 2018).

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

Where A is mean annual soil loss (t ha^{-1} yr^{-1}); R is rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}); K is soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}); C is a cover-management factor (dimensionless); LS is slope length/slope steepness factor (dimensionless), and P is the support practice factor (dimensionless). The following framework shows how to interconnect the model with geospatial techniques for the implementation of soil loss studies in one critical study area.

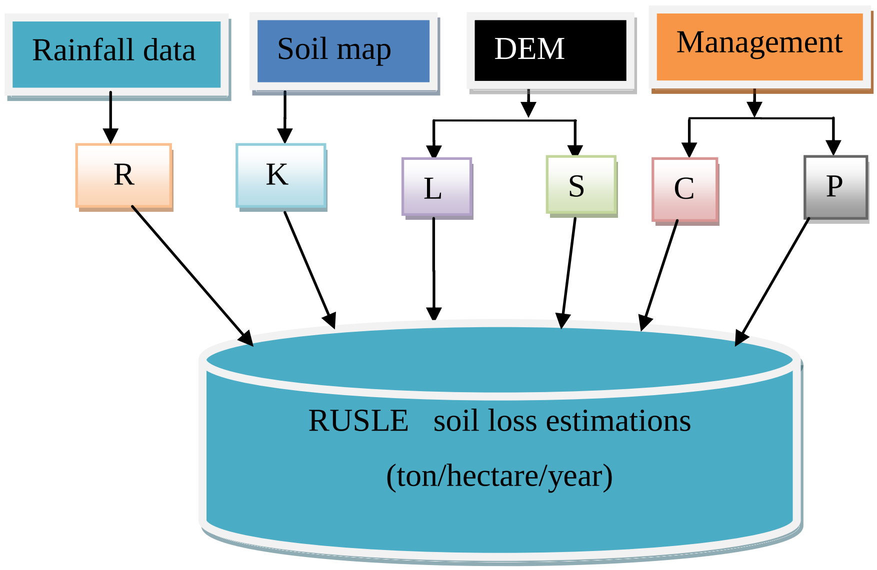

Figure 5. Conceptual framework of soil loss estimation using RUSLE

3.4.1. Rainfall erosivity factor (R)

Rainfall erosivity factor (R) is the power of rainfall to cause soil erosion by water, and a mean annual value is calculated as a summation of event-based energy intensity value for a location divided by the number of years over which the data we're collected. In the RUSLE model rainfall erosivity parameter estimation was based on the multiplication of total storm energy by 30 mint rainfall intensity; expressed as $R=EI_{30}$ (Mengie et al., 2019). However, it is difficult to apply this equation directly in data-poor areas like Ethiopia. Instead, it was modified in the real situations of Ethiopia by Hurni (1985) to be applied using easily available mean annual rainfall data. R-factor was computed by the following equation used to available mean annual rainfall data employed by Hurni (1985) empirical equation; expressed as

$$R = -4.7 + (0.55 * P) \quad (2)$$

Where R is rainfall erosivity (MJ mm ha^{-1} $h^{-1}y^{-1}$) and P is mean annual rainfall (mm). The mean annual rainfall of five stations which have 12 up to 32 years of data. The inverse distance weighted (IDW) interpolation method was used to generate an erosivity map for the watershed surface area using ArcGIS 10.5. IDW use for limited points of rainfall station and it gives the most representative interpolation result for annual rainfall with a minimum of errors (Mengie et al., 2019).

3.4.2. Soil erodibility factor (K)

The soil types of the study watershed have been classified based on their textures using the digital soil map of the world (DSMW) developed and harmonized by FAO (1974). It provides information about soil units from the legend of the soil map. The map comprises 106 soil classes grouped into twenty-six major soil groupings. For estimation of soil loss in the watershed, soil erodiblity was clipped from (DSMW) using ArcGIS 10.5. It has two generalized soil unit groupings which are BE (Eutric Cambisols) and VP (Pellic Vertisols). According to the generalized soil unit information of DSMW, both soil classes have one information about the textural and organic matter proportion in percent of both surface and subsurface ratio. Based on this information, the study area erodiblity factors were computed using William's (1995) equations as below.

$$K_{USLE} = f_{csand} . f_{cl-si} \cdot f_{\mathrm{org}}\mathrm{C} \cdot f_{hisan} \quad (3)$$

where f_{csand} is a factor that gives low K factor for soils with high coarse-sand content and high for soils with little sand; f_{cl-si} a factor that gives low soil erodibility factors for soils with a high clay-to silt ratio; f_{orgC} is a factor that reduces K factors for soils with a high organic carbon content while f_{hisand} a factor that reduces K factors for soil with high extremely high sand contents. The fraction of each also calculated as below:

$$f_{csand} = (0.2 + 0.3 * Exp[-0.256 * ms * (1 + msilt/100)]) \quad (4)$$

$$f_{fcl-si} = (\frac{msilt}{mc + msilt}^{0.3}) \quad (5)$$

$$f_{orgC} = (1.0 - (\frac{0.256 \cdot \mathrm{orgC}}{\mathrm{orgC} + \exp[3.72 - 2.95.\mathrm{orgC}\,]}) \quad (6)$$

$$f_{hisand} = \left(1.0 - \frac{0.7 \cdot (1 - \frac{ms}{100}}{(1 - \frac{ms}{100}) + Exp\,[5.51 + 22.9\,(1 - \frac{ms}{100})]\,)}\right) \quad (7)$$

where m_s is the percent sand content, m_{silt} is the percent silt content, m_c is the percent clay content, and *orgC* is the percent organic carbon content of the layer (%). the information of all contents of soil textures is derived from DSMW.

3.4.3. Slope length (L) and steepness (S) factor

The LS factor represents the effect of the slope's length and steepness in velocity and volume of runoff (Gashaw et al., 2017). It has a great influence to form sheet, rill, and inter-rill erosion by water, and it is the ratio of expected soil loss from a field slope relative to the original RUSLE unit plot (Gezahegn et al., 2018). Slope length was substituted by the upslope contributing area to take into account the flow convergence, and divergence in a three-dimensional complex terrain condition. Thus, the upstream contributing factor and slope angle were considered in the aforementioned method of slope length and gradient factor estimation (Habtamu and Amare 2016). The slope length is high in the lower part of the watershed due to high-flow accumulation (upstream contributing area), and low in the upper (inlet) and ridge part of the watershed due to the little or no flow contributing pixel upstream of the ridge (Gashaw et al. 2017). On the other hand, the slope gradient is high in the upper part (inlet) of the watershed, and vice versa in the outlet (lowest elevation) of the watershed. In this research, LS factors were determined by ArcGIS 10.5 software in Arc Toolbox surface slope factors. A 12.5 m spatial resolution DEM was used to map the flow accumulation and slope gradient of the study watershed. Finally, the map algebra- raster calculator in ArcGIS 10.5 was used to calculate the slope length and steepness (LS) factor based on the following equation.

LS = Pow[(flow accumulation) * cell size/22.1,0.6]*Pow [sin (slope) * 0.01745/0.09,1.3] (8)

3.4.4. Cover and management factor (C)

The land cover and management factor (C) is defined as the ratio of soil loss from a field with a particular cover and management to that of a field under "clean-tilled continuous fallow" (Wischmeier and Smith, 1978). The RUSLE uses a combination of sub-factors such as impacts of previous management (prior land use), canopy cover, surface cover and roughness, and soil moisture on potential erosion to produce a value for the soil loss ratio, which is used with the R factor to produce a value for the C factor (Renard et al., 1997). This method requires extensive knowledge of the study watershed cover characteristics including agricultural management and may be suitable at the field or farm-scale but in the large district it is not possible to cover all watersheds and able to determine c-factor so it needs other methods like geospatial techniques which able to cover a large area and determine C-factor.

Th study used Landsat Image. Supervised classification and cross-check through the ground truth point of the study area was collected 72 ground truth points for each land use land class type. The C factor has been taken from Table 6 below which was developed for Ethiopian highlands by Hurni (1985), and it was reclassified using Arc GIS 10.5 software.

To crosscheck, the computed result such as land use land cover classification from the satellite image, field-based observation data ground truth point were used. Besides, the data has been compared with different historical land use land covers since it has a great contribution to erosion risk. Generally, the land use land cover for this study has been extracted from Landsat images and tested with field observation for the delineated sub-watersheds.

Table 6. Land cover (C) factors

Land Cover	C- factor	Reference
Cropland	0.17	Hurni, 1988
Shrub/Bush	0.01	Wischmeier and Smith, 1978)
Forestland	0.02	Hurni, 1988
Bare Land	0.014	Eweg and van Lammeren, 1996
Settlement	0.1	(Hurni, 1988)

3.4.5. Erosion management practice factor (P-value)

The conservation practice (P) factor also known as the erosion control practice factor is the ratio of soil loss with a specific conservation practice like contouring, strip-cropping, or terracing measures to the corresponding loss with up and downslope cultivation. P-value is considered as the most important parameter for contradicting the force of erosion and resists the soil from detaching and transport by erosion agents (Gashaw et al. 2017). Some physical methods of SWC such as soil and stone bunds have been constructed in the past few years in the study area through the agricultural extension program of the government, and the results showed the structures were poorly maintained and constructed and cannot capture the soil loss. The study used the P factor introduced by Wischmeier and Smith (1978). Which considers two types of land uses (agricultural and non-agricultural) and land slopes. Thus, the agricultural lands were classified into different classes based on slope categories and different P-value was assigned for each class; while all non-agricultural lands were assigned a P-value of 1.00. Details of the P-factor value are given in Table 7 below.

Table 7. Conservation practice (p) factors Wischmeier and Smith (1978)

Land-use type	Slope (%)	P-factor
	0-5	0.1
Agricultural land	5-10	0.12
	10-20	0.14
	20-30	0.19
	30-50	0.25
	50-100	0.33
Other Land	All	1.00

3.5. Determination of watershed physiographic characteristics

3.5.1. Drainage density

The drainage density is the ratio of the total length of the stream of all order of watershed to the total area of the watershed (Horton 1945)" the stream length per unit area in a watershed. it is an essential element of drainage characteristics to study the landscape dissection, runoff potential, infiltration capacity of the land, climatic condition, and vegetation cover of the basin (Umair and Syed, 2014). The drainage density of each sub-watershed was derived from DEM by computing the flow accumulation of the watershed. Next using the map algebra raster calculator the stream length was calculated in raster format and then converted into a polyline. Drainage density is one of the best prioritizing parameters of the watershed because it depends on the permeability of subsoil material, vegetative cover, and topography of the watershed (Veera et al., 2020). Watershed with high values of drainage density is noted for the regions of weak or impermeable subsurface materials, sparse vegetation, and mountainous relief and the reverse is low drainage density (Ashish et al., 2011, Riad et al., 2020). To determine the drainage density of the study area Horton's (1932) equation was used.

$$D = Lu/A \quad (9)$$

Where Lu = Total stream length of orders, A = Area of the Basin in km^2

3.5.2. Stream order

For stream ordering computation, Horton's Law was followed, by designating un-branched streams as the first-order stream, when two first-order streams joined it was designated as second-order, two-second order joined together to form third order, and so on. It is an important physiographic characteristic used in the prioritization of watersheds (Umair and Syed 2014). It is also noted that first-order streams are the highest in number in all sub-watersheds while the highest order has the lowest number (Riad et al., 2020). This means the variation in order and size of the sub-watershed is largely due to the physiographic and structural conditions of the watershed.

3.5.3. Bifurcation ratio

Bifurcation ratio describes the branching pattern of a drainage network (Choudhari et al., 2018). It is the ratio of the number of streams in lower-order to the next order (Surendra and Mitthan 2014). If the bifurcation ratio is less it indicates plain terrain, permeable and soft bedrock where infiltrates more water makes better water holding capacity. The lower bifurcation ratio is also due to the presence of a large number of first and second-order streams in sub-watersheds (Riad et al., 2020). So bifurcation ratio is calculated from stream orders.

$$Rb = Nu/Nu+1 \qquad (10)$$

3.6. Data Analysis

Soil loss is directly related to drainage density and bifurcation ratios (Veera et al., 2020). Because drainage density is a fundamental landscape metric geomorphological parameter describing the extent of the fluvial network (Fiona et al., 2016). The soil loss and soil erodiblity are highly determined based on the textures, organic carbon, and permeability of the soil, and their physiographic characteristics of watersheds(drainage density and bifurcation ratio) depend on the geomorphological structures of a watershed (Moghadaseh et al., 2016).

Increasing of the liner parameters value such as bifurcation ratio, drainage density, similarly erodibility potential has increased; because it affects the streamflow hydrograph and peak flow. Ranking of each watershed was done depending on values of the soil loss and physiographic characteristics of watersheds (drainage density and bifurcation ratio). The highest value of each of the first soil loss parameters among 10 sub-watersheds was given a rating of 1, the next highest value was given a rating of 2, and so on. and similarly the ranking of physiographic characteristics is done based on an average of bifurcation ratio and drainage density.

For all parameters the ranking was given in ascending order, for example, number 1 indicates high soil loss, and drainage density, and bifurcation ratios. and done the average rank of physiographic characteristics of watersheds (drainage density and bifurcation ratio). This means the soil loss severity is high and it needs a priority for soil and water conservation planning. In general, the highest value of the linear parameter was ranked 1^{st}, the second-highest value ranked 2^{nd}, and so on. After the rating had been done based on every single parameter, were averaged to arrive at a compound value for each watershed physiographic characteristic. Based on the average value of these parameters, the watershed having the least rating value was assigned the highest priority number of 1, the next least value was assigned a priority number of 2, and so on. The same procedure was adopted by the researchers (Debjyoti 2014, Surendra and Mitthan 2014, Agumassie et al., 2015).

4. RESULTS and DISCUSSION

4.1. Prioritization of micro-watersheds based on the rate of soil erosion

A quantitative expression of soil erosion is a fundamental phase for any watershed management (Mengie et al., 2019). In this study, (RUSLE) model was integrated with GIS and Remote sensing techniques to conduct cell-by-cell calculation of mean annual soil loss rate (t ha^{-1} y^{-1}), and to identify and map soil erosion risk areas. A raster map of each RUSLE parameter derived from different data sources was produced and discussed as follows.

4.1.1. Rainfall erosivity factor (R)

The erosivity factor was interpolated with a cell size of 12.5 m using the IDW tool of Arc GIS software. Therefore, the R factor of each grid cell in the study area was found between 564 - 657 MJ mm ha^{-1} h^{-1} y^{-1} as estimated by Eq. (2). Table 8 shows the mean annual rainfall and R-factors of the five meteorological stations in the study area.

Table 8. Mean annual rainfall and erosivity factors at five meteorological stations

No	Station	Longitude	Latitude	Elevation	Mean annual rainfall (mm)	R-factor
1.	Effeson(Ataye)	604673	1143185	1456	1106	560
2.	Ymelewo	598684	1138212	1533	1184	621
3.	Senbetie	608069	1139644	1500	796	676
4.	Jewha	606280	1160821	1450	455	737
5.	Majete	593013	1160821	2000	1200	847

After the organization of these data, the rainfall and erosivtiy factor map were produced using a map algebra raster calculator as shown in Figure 5. The R-factor map revealed that the erosivity of rainfall in the study area ranged from 457 to 847 MJ mm ha^{-1} h^{-1}. From the result, there is a significant variation of erosivity value in the watershed the variation is directly linked with the elevation of the area the higher elevation has high erosivity than lower elevations. These means almost all erosivity value of the micro watershed is affected in different force of erosivtiy in all part of sub-watersheds. Among the five-station majete have high valves of annual rainfall but relatively far from others for the study watershed due to this the result of interpolation indicating the highest value rainfall and erosivity is between the point of high elevated stations. the next figure indicating the rainfall and erosivity force of the watershed.

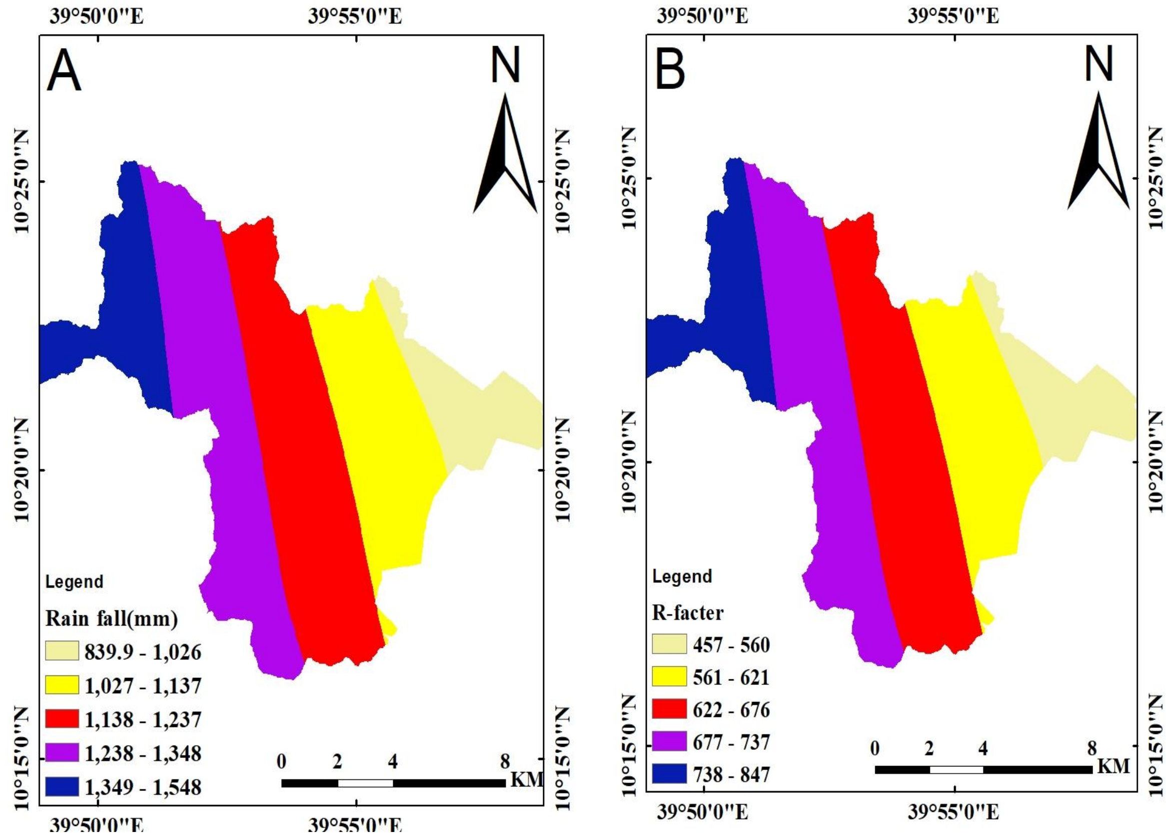

Figure 6. Rainfall Map (a) and Erosivitiy factor Map (b) in the study watershed

4.1.2. Soil erodibility factor (K)

The erodiblity of the soil (K factor) was computed in the Arc GIS raster calculator using Eq. (3). The result of the soil erodiblty factor depends on the fraction of soil textural class and organic carbon content and the detailed result is shown in Table 9. Besides, Figure 7 shows the soil map (a) and erodiblity factor (b) map of the district.

Table 9. Soil unit, soil texture, and K-factors of the study watershed (DSMW, 1974)

NO	SOIL UNIT	Sand%	Silt%	Clay%	OC%	F_{csand}	Fci-cl	F_{orgc}	F_{hisand}	K_factors
1	**BE**	36.4	37.2	26.4	1.07	0.2	0.85	0.99	1.0	0.17
2	**VP**	25.1	12.2	62.7	0.68	0.2	0.58	1.00	1.0	0.12

Based on the computed K-factor value the map of soil erodiblty of each soil unit is shown below (Figure 8a and b).

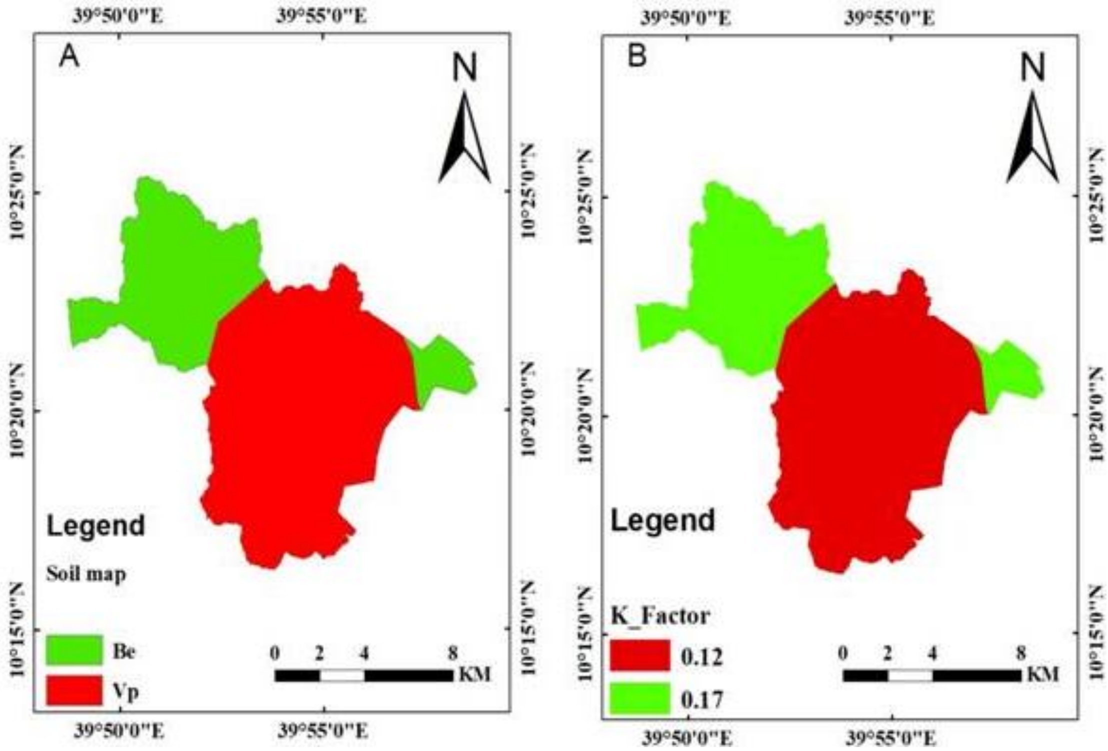

Figure 7. Soil map (a) and erodibility map (b) of the study watershed

4.1.3. Slope length (L) and steepness (S) factor

The derivation of the topographic factor (LS) for the study area was calculated from the DEM with 12.5m spatial resolution using Eq. (8). Flow accumulation and slope steepness was computed from the DEM using ArcGIS 10.5 software. The results were multiplied by using 'Spatial Analyst Tool, Map Algebra Raster Calculator in ArcGIS software to produce a combined slope length and slope steepness factor (LS) map. Figure 9 shows the LS factor map and slope class map of the study area. The value of the Sub-watershed length and steepness (LS) factor ranges between 0 to 87.7. The mean LS_factor of the watershed is 0.28. The lower LS factor revealed minimal contribution for soil erosion and runoff generation, the highest values contribute high soil loss, high runoff and less time of concentration, and low infiltration rate in the micro watershed. The result as shown below in Figure 9 b, most of the LS factor is above 15 and it needs to reduce both steepness and length by constructing different SWC physical structures and integrating different plantation methods to reduce the factor of LS within the specific watershed. Figures 8a and b show the slope map and LS factor map of the study watershed.

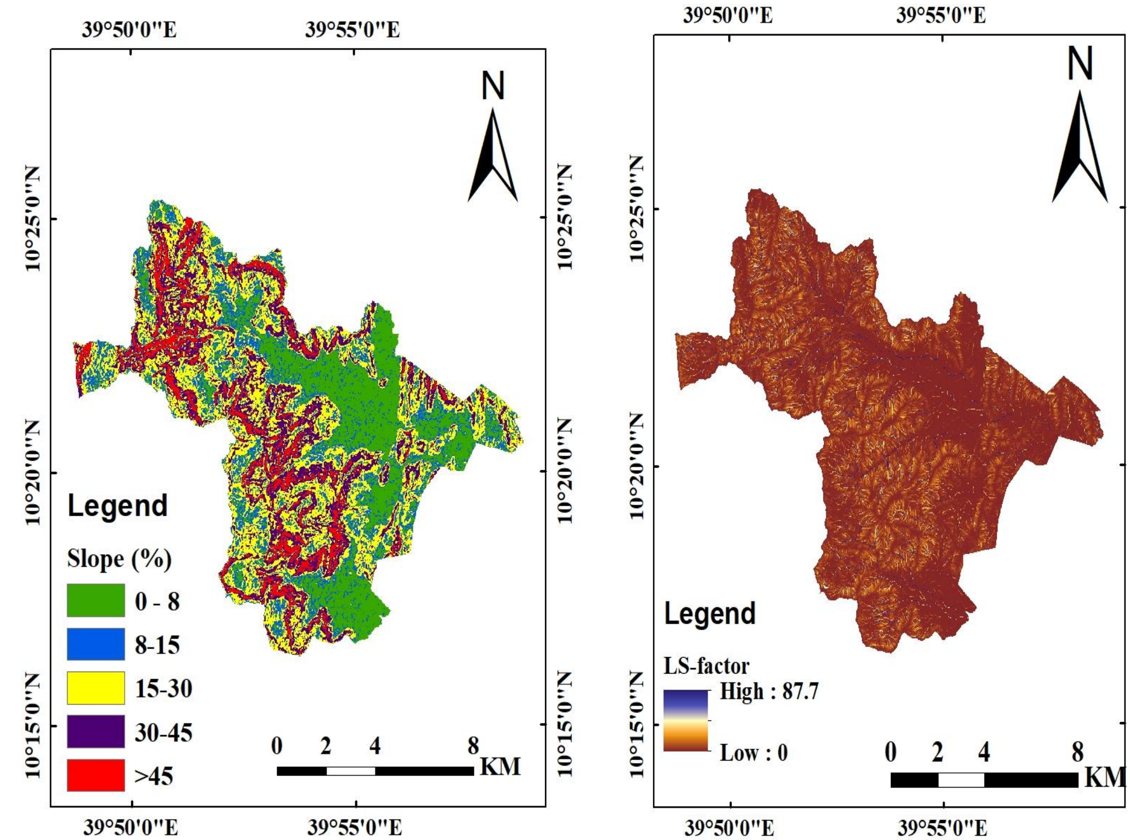

Figure 8. Slope class (a) and LS factor map (b) of the study watershed

4.1.4. LULC Classification (C_ factor)

Landsat TM of 2019, downloaded from united States geological survey with row number 168 and path number 53 May 15, 2019, is used for land use land class analyzations. The LULC of the study area was classified using supervised image classification methods (Habtamu and Amare, 2016). A total of five LULC classes were identified; the highest land use land cover is farm or agricultural area around 54% of the total LULC. the watershed dominantly five land-use classes these are forest land, shrubland, settlement, bare land, and cropland. Table 10 shows the LULC types of the study watersheds.

Table 10. LULC of the study watershed and C-factor

No	LULC	Area (ha)	Percentage (%)	C_factor
1	Corpland	6,862	54	0.17
2	Shrub land	3,390	26.6	0.01
3	Forestland	938	7.51	0.02
4	Bare land	835	6.58	0.014
5	Settlement	675	5.31	0.1

The thematic layers of the classified LULC images of the study area were validated using ground truth data and Google earth points. Out of the total sampled ground truth data collected from the field 72 points were used as a reference for image classification and validation of the classified image. The accuracy was calculated in terms of producers' accuracy, users' accuracy, overall accuracy, and Kappa Statistics. The acceptable level of overall accuracy value for reliable land cover classification is 85 % (Geremew, 2013, Gebrehana et al., 2020). The results revealed that the overall classification precision obtained per LULC map was 86.3% and the overall Kappa Statistics (Kˆ) calculated for each LULC image is 0.8227%. Based on these statistically acceptable classifications, C-Factor values and P- Factor values were calculated. Table 11 shows the overall accuracy assessment of the classified image of the study watershed.

Table 11. Accuracy assessment result of supervised image classification

LULC class	Producers Accuracy (%)	Users Accuracy (%)	Kappa (Kˆ)
Corpland	100.00	68.75	0.6016
Shrubland	77.78	100.00	1.0000
Forest	88.89	88.89	0.8651
Bare land	83.33	100.00	1.0000
Settlement	85.71	85.71	0.8344
Overall Accuracy (%)	**86.27**		
Overall Kappa Statistics	**0.8227**		

Figures (9a and b) show the land use land cover map of the study area and the C_ factor map of the study area. The result of the land use land cover classification revealed that the dominant LULUC types were the cropland, bare land, and settlement, which in turn contributed to very high soil loss.

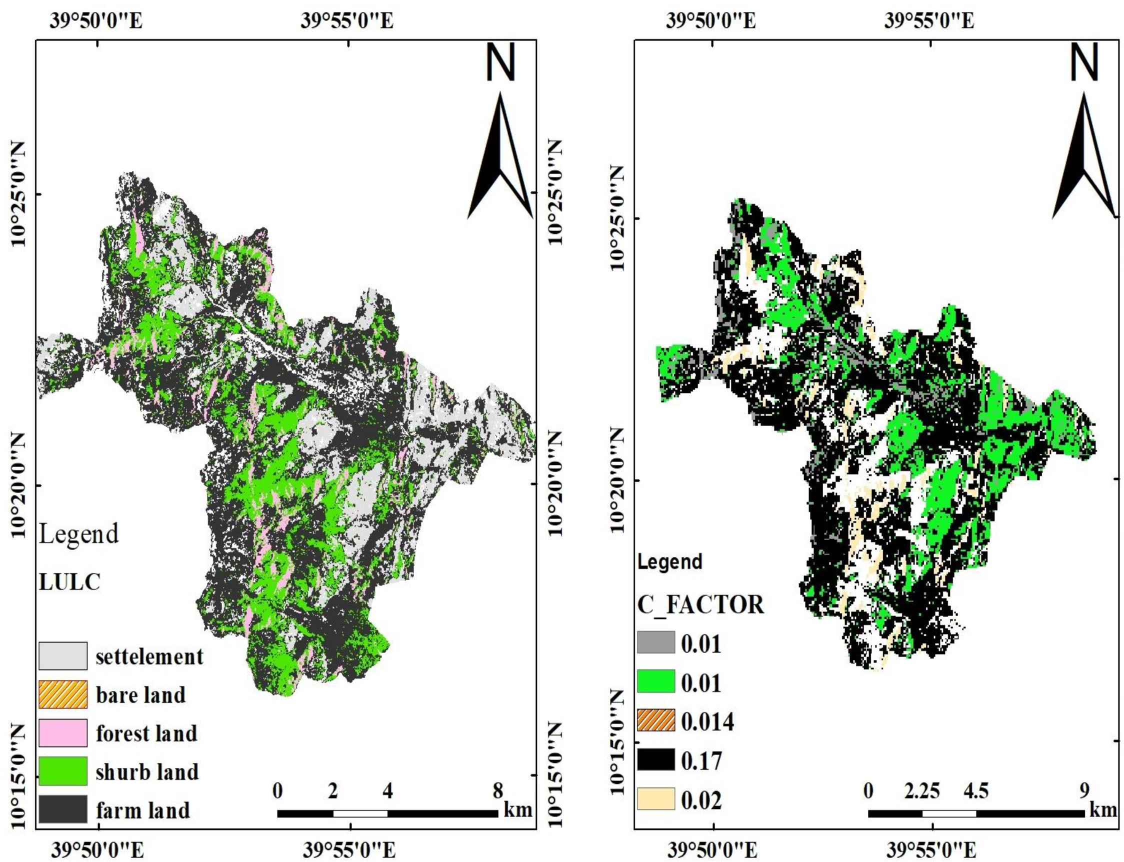

Figure 9. Land use land cover (a) and C_Facter (b) of the study watershed.

4.1.5. Management practices factor (P)

According to Wischmeier and Smith (1978), the management factor for agricultural land varies from 0.014 to 0.02. Based on the difference in the slope classes the value of p for agricultural land was categorized into six classes (Table 8). On the other hand, the p-value for non-agricultural land was assigned a value of 1. Accordingly, the P values were determined based on the value adapted by Wischmeier and Smith (1978). Most of the slope of the farming land ranges from 0-30% and all the other none agricultural area p-factor was multiplied by 1 for each pixel size as shown below (Figures 10). This indicates steep slope agricultural and none agricultural areas have a high contribution to erosion and soil loss and needs urgent soil and water conservation work to sustain the productive capacity of the lands.

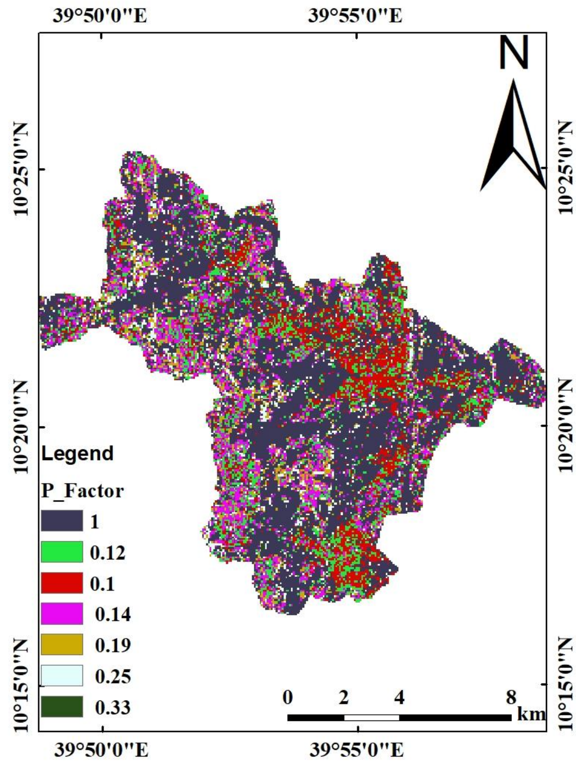

Figure 10. Management (P-factor) map of the study watershed

4.2. Final annual soil loss

The estimated mean annual soil erosion rate in the study sub-watersheds varies from 0 to 33.5 t ha^{-1} y^{-1}, but the total watershed means soil erosion rate is 17 t ha^{-1} y^{-1}. with a standard deviation of 62 t ha^{-1} $year^{-1}$. In this study, the amount of soil loss did show relatively similar to Comparing with other studies, for example, the mean annual soil loss in Ajema Watershed was 22.8 t ha^{-1} y^{-1} (Ayele et al., 2018) It was also nearest to soil loss of Andit Tid watershed, where the mean annual soil erosion rate is 8.7 t ha^{-1} y^{-1}. Almost 69% of the watershed showed soil more than 12 t ha^{-1} y^{-1}. The tolerable soil loss value as suggested by Rose (1994) is less than 10 t $ha^{-1}y^{-1}$ for the tropical region. Similarly, Hurni (1986) suggested a soil loss value of 2–18 t $ha^{-1}y^{-1}$ for the various agro-ecological belts of Ethiopia and 10 t $ha^{-1}y^{-1}$ to the northern highlands of Ethiopia (Yared et al., 2020). This means the estimated annual soil loss in the study watershed is more than the range of tolerable values. However, some of the sub-watersheds showed soil loss more severe than others so based on the rank of soil loss severity should implement SWC practice (Habtamu and Amare 2016). Previous research study results indicate that much amount of soil loss was observed in areas where conservation management was not sufficiently implemented (Gezahegn et al., 2018; Gashaw et al. 2017). The magnitude of change in the soil erosion potential and their spatial distribution was accounted for by the slope steepens, land use land cover change, rainfall distribution, and soil erodiblity level (Ebrahim Esa et al., 2018). Hence, based on the estimated rates of erosion the sub-watersheds were classified, prioritized, and ranked into ten sub-watersheds. A similar approach was utilized in different studies (Riad et al., 2020; Mengie et al., 2019, Gezahegn et al., 2018, Gashaw et al. 2017). To give the priority rank, the soil loss above 12 t ha^{-1} y^{-1} was converted into the percentage of soil loss area, and mean soil loss. Figure 12 indicates the category of soil loss.

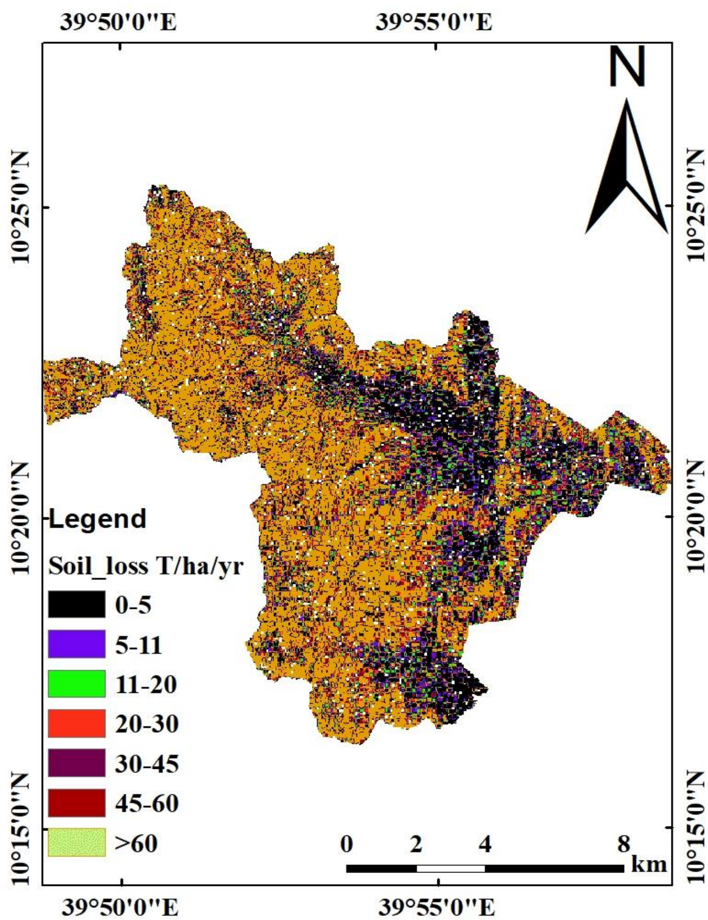

Figure 11. Annual soil loss map (t/h/yr) in the study watershed.

4.3. Prioritization of sub-watersheds based on soil loss

Based on the spatial distribution of the soil loss rate, the sub-watersheds ranking was made. As described in Table 12, the sub-watersheds showing higher soil loss rates relative to others were SW4, SW8, SW10, and SW9. Almost all of the first rank sub-watershed soil classifications lay under BE (Eutric Cambisoles) because VP (Pellic Vertisols) are relatively resistant to detachment than cambsoil class. The next factor, similarly recognized by (Trust and Oagile 2013), is a slope that is relatively higher than other sub-watersheds. But all sub-watersheds have annual soil loss relatively more severe. However, the higher soil loss rate prevailing areas are at risk which requires an urgent response of soil and water conservation planning and implementation.

Table 12. Prioritization of sub-watersheds based on soil loss values.

Sub-watershed code	Area (ha)	Soil loss (ton/ha/y)						Rank
		0-5		6-11		>12		
		Ha	%	H	%	Ha	%	
SW4	1536.0	261.4	17.0	30.0	2.0	1244.6	81.0	1
SW8	685.6	117.6	17.1	13.7	2.0	554.3	80.9	2
SW10	682.9	123.2	18.0	14.1	2.1	545.6	79.9	3
SW9	962.3	219.6	22.8	35.6	3.7	707.1	73.5	4
SW5	848.3	194.2	22.9	36.5	4.3	617.6	72.8	5
SW6	1885.6	453.5	24.1	82.5	4.4	1349.6	71.6	6
SW7	1717.9	412.7	24.0	99.6	5.8	1205.7	70.2	7
SW3	1851.1	549.7	29.7	174.3	9.4	1127.1	60.9	8
SW2	893.8	296.8	33.2	102.8	11.5	494.2	53.3	9
SW1	1170.1	498.5	42.6	104.8	9.0	566.9	48.4	10

4.4. Prioritization of sub-watersheds based on drainage density

The drainage density analysis of the sub-watersheds and the corresponding rank orders are presented in Table 13. The ranks were assigned based on the fact that the higher the drainage density the more is the degradation problem. This was also confirmed by Veera et al. (2020) that higher drainage density values result in higher surface flow velocity through the river network ending on high flood peaks, and low suitability for agricultural practices.

In general, the drainage density of the sub-watershed indicates the number of drainages (stream) with a specific watershed. Besides, the drainage pattern of a watershed helps to understand the topographic and structural/lithologic controls on the water flow. most of the time drainage density have a linear relationship with soil loss but some time nonlinear relation with soil loss the variations id depend on the physical/structural characteristics of a watershed as shown in the table most of the ranked drainage density also have soil loss these means it has a high correlation with soil loss and erosive force of rainfall in addition to physiographic futures of sub-watersheds.

Table 13. Sub-watershed rank based on drainage density

Watersheds code	Area in (km^2)	Sum of stream length (km)	Drainage Density	Rank
SW9	9.9	60.9	6.15	1
SW7	17.7	107.6	6.08	2
SW1	12.2	74.2	6.06	3
SW5	8.8	53.3	6.03	4
SW8	7.1	42.0	5.92	5
SW6	19.7	113.3	5.76	6
SW3	19.1	109.7	5.73	7
SW4	16.0	90.7	5.66	8
SW10	7.2	40.0	5.55	9
SW2	9.3	44.9	4.82	10

Based on the above result in Table 13, SW9, SW7, SW1, SW5 have shown higher drainage density, than other sub-watersheds. Relatively, SW8, SW6, and SW3 have medium drainage density. Whereas, SW4, SW10, and SW2 have less drainage density. SW9, W7, and SW1 have shown relatively higher elevation and received much runoff from the above watershed. Sitotaw and Hailu (2018). So the above three watersheds are relatively higher in elevation than others. They potentially create dense drainage networks which generate abundant sediment-laden runoff. For this reason, understanding drainage density is critical for watershed priorities due to its direct linkage with soil loss of specific watersheds.

4.5. Prioritization of sub-watersheds based on bifurcation ratio

Since the bifurcation ratio was computed from stream order analysis, the stream order of all the sub-watersheds was done to reflect their hydrological behaviors. The analysis result is shown in Table 14. Stream order of the area was directly linked to soil erosion where the considerable number of the first-order stream indicates much soil erosion in the area (Choudhari et al., 2018). Here most stream orders showed slight differences among the sub-watersheds. High stream order means high water flow and soil movements. Several sub-watersheds morphological characteristics-based priority was conducted in different parts of the world such as in Gilgel Abay Watershed (Agumassie et al., 2015), in India (Riad et al., 2020), and Bangladesh (Umair and Syed, 2014).

Table 14. Stream order of sub-watersheds

Watershed code	Area (ha)	No. of streams in their stream order category				
		I	II	III	IV	V
SW1	1170.1	23	10	0	12	2
SW2	893.8	15	4	0	0	8
SW3	1851.1	36	18	15	0	0
SW4	1536.0	30	8	17	6	3
SW5	848.3	15	8	2	8	0
SW6	1885.6	34	19	10	2	0
SW7	1717.9	36	7	20	0	4
SW8	685.6	13	10	2	0	0
SW9	962.3	18	8	8	1	0
SW10	682.9	13	5	7	0	0

Figure12 shows a stream order map computed from DEM using ArcGIS based on Sub-watershed stream order indicates that the change in stream order and stream number are flowing from high altitudes and with fewer lithological variations. Based on the result SW3, SW6 and SW7 have high first-order streams, which means they have high runoff or surface water movement and low infiltration rate.

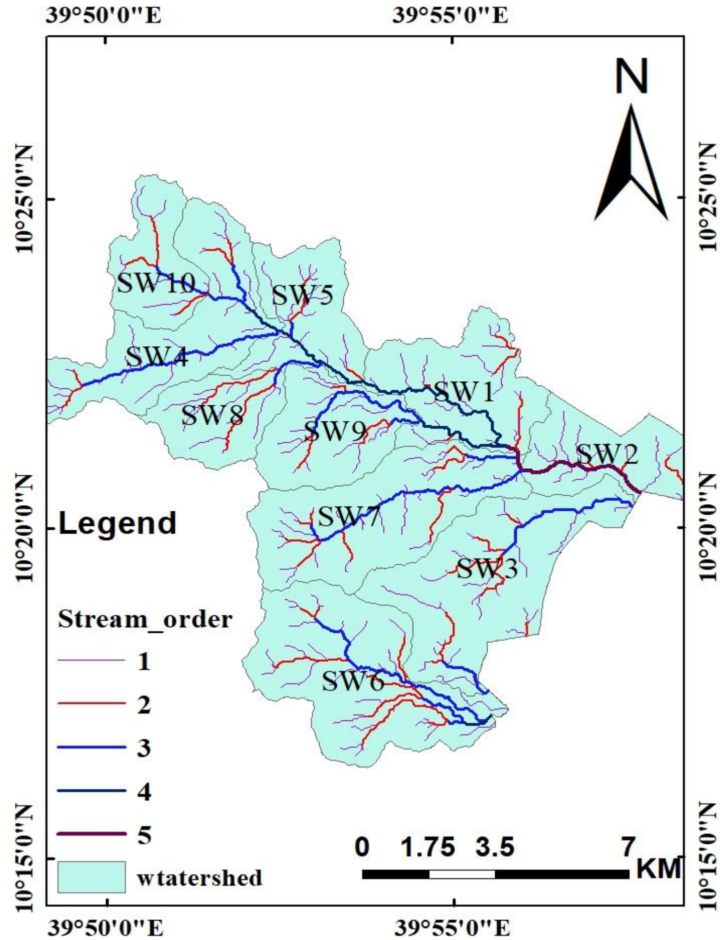

Figure 12. Stream order map of the study watershed

Based on the result of the bifurcation ratio, SW9, SW4, SW6, and SW8 have relatively higher ratios (Table 15). As mentioned before in topic 4.5 the bifurcation ratio is directly linked with the elevation and physical characteristics of watersheds. For instance, SW9 and SW4 have higher elevations and hilly areas. This means it has a high number of segments, a low infiltration rate, and high runoff generations. Whereas SW5, SW7, and SW2 have medium ratios, and the rest SW3, SW10, and SW1 exhibit lower bifurcation ratios indicating relatively low runoff and high infiltration rates. Bifurcation ratios can be considered as the best parameter to give priorities of a watershed for soil and water conservation planning and implementation.

Table 15. Bifurcation ratio of Nazero sub-watersheds

Watershed Code	Area	Stream order					Mean Rb	Rank
		I	II	III	IV	V		
SW9	962.3	18	8	8	1	0	11.3	1
SW4	1536.0	30	8	17	6	3	9.0	2
SW6	1885	34	19	10	2	0	8.7	3
SW8	685.6	13	10	2	0	0	6.3	4
SW5	848.3	15	8	2	8	0	6.1	5
SW7	1717.9	36	7	20	0	4	5.5	6
SW2	893.8	15	4	0	0	8	3.8	7
SW10	682.9	13	5	7	0	0	3.3	8
SW3	1851.1	36	18	15	0	0	3.2	9
SW1	1170.1	23	10	0	12	2	2.3	10

4.6. Sub-watershed prioritization based on average drainage density, and bifurcation ratio

Both drainage density and bifurcation ratio indicate the structural/lithologic and physical characteristics of watersheds to resist or facilitate erosive force of runoff. Based on the rank values from watershed bifurcation ratio, and drainage density, the ten sub-watershed ranks were calculated for prioritization (Table16). As suggested by Surendra and Mitthan (2014) the rank of the two prioritization methods was averaged. The averaged indices were ranked into high priority (1–3), medium priority (4–5), and low priority (6–7). By chance, here the valves of average rank indicating similar one to other sub-watersheds, for example, SW5, SW6, and SW8 possess equal rank and similarly SW2 and SW10 Out of the total 10 Sub - watersheds.

The combined rank of the sub-watersheds has full information about the nature and probability of runoff force to loss soil. It helps to give priority and prepare for soil and water conservation planning. For example, SW9 ranked 1st in both bifurcation and drainage densities. Intern of drainage density and bifurcation ratio is higher than the other, this means high over land follow, low infiltration rate.

Table 16. Watershed priority based on combined parameter results

Watershed code	Area (ha)	Dd Rank	Rb Rank	Average Rank	Priority level
SW9	962.3	1	1	1.0	1
SW7	1717.9	2	6	4.0	2
SW5	848.3	4	5	4.5	3
SW6	1885.6	6	3	4.5	3
SW8	685.6	5	4	4.5	3
SW4	1536.0	8	2	5.0	4
SW1	1170.1	3	10	6.5	5
SW3	1851.1	7	9	8.0	6
SW10	682.9	9	8	8.5	7
SW2	893.8	10	7	8.5	7

Based on the average rank of two factors of drainage density, and bifurcation ratio, almost all the valves are nearest to each other in indicating similar physiographic characteristics of watersheds. All the 10 sub-watersheds were reranked, and as we have seen from the result SW9, SW7, SW5, and SW6 got higher priority and need urgent soil and water conservation work planning and implementation. While SW8, SW4, and SW1 are showed medium severity, and finally SW3 and SW10 and SW2 showed lower severity (less priority). Hence, the result of bifurcation ratio and drainage density is the general influence for soil erosion. Most watershed level results indicate, great relationship between, physiographic characteristics of the watershed with soil loss.

previously several studies have been done and describe the result is similar to the study watershed, for example, ranking watershed high, medium and low based on physiographic characteristics parameters (Surendra and Mitthan 2014), in other study using the similar criteria priority district were selected for soil and water conservation work(Ashish et al.,2011). Similarly Agumassie et al.,2014). in Gilgel Abay Watershed express mostly the soil loss and drainage density are directly related all above mention study confirms that watershed physiographic characteristics have a high contribution for soil loss the same to the study watershed.

Generally, the variation among sub-watersheds in two physiographic characteristics of sub-watersheds and soil loss parameter is used to quantify the characteristics/ properties/ of the watershed at the watershed level. It is very significant to use more parameters for the priority of a watershed than using a single parameter to increase the precisions of watered priority. but the generally prioritized sub-watersheds for soil and water conservation is based on soil loss because it has a different parameter to done soil loss and universally considered different erosion factor. Figure 14 shows the relationship between individual parameters and the combined ranks.

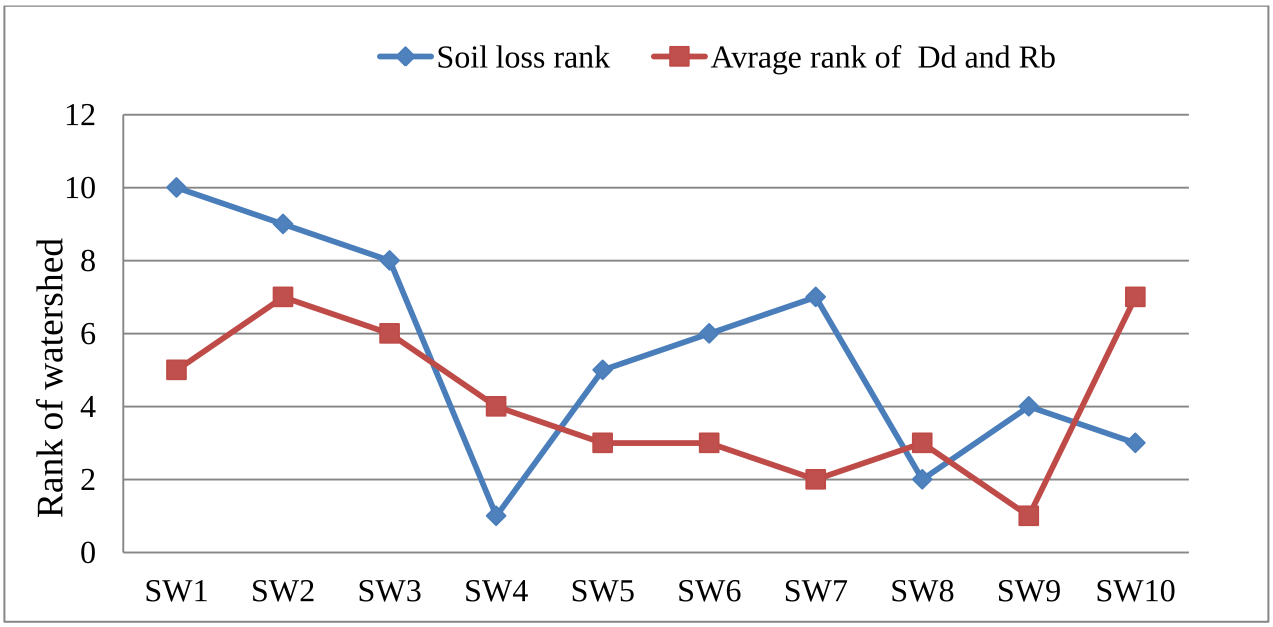

Figure 13. The rank of two variables and soil loss rank of sub-watershed

Figure 14 above indicates the two physiographic characteristics and soil loss parameter variations used to visualize the physical and erosion response of a sub-watershed and the rank of a sub-watershed. Among the ten sub-watersheds, based on soil loss SW4, SW8, SW10, and SW9 are ranked (1-4). and SW5, SW6, and SW7 are medium rank(5-7), and other SW3, SW2. and SW1 showed lower ranks for soil and water conservation. based on two photographic characteristics of sub-watersheds indicating almost similar variation among sub-watersheds for examples SW7 and SW9 are ranked 1st and 2nd, SW5, SW6 andSW8 are the same 3rd ranks this indicating the variation sub-watershed similar physiographic characteristics like erodiblity of soil and rock particles topographic future of the land and land use land cover (Riad et al., 2020).

In general, the study focuses on soil loss of sub-watersheds and emphasizes sub-watersheds based on soil loss for soil and water conservations(SWC). However, looking at physiographic characteristics also important to understand the natures and structures of sub-watersheds. the different parameters of sub-watersheds are very significant for selecting and prioritizing sub-watersheds because they can help to easily understand the natures of sub-watersheds and used for soil and water conservation planning and implementation (Surendra and Mitthan, 2014; Agumassie et al., 2015).

5. CONCLUSION and RECOMMENDATION

5.1. Conclusion

The objective of the study was to estimate annual soil loss and prioritize sub-watersheds for soil and water conservation planning across different sub-watersheds of Nazero watershed in Efratana Gidim werda. The Watershed was divided into ten sub-watersheds for the prioritization purpose. The soil erosion status of each sub-watershed was determined using the RUSLE model and geospatial technologies. Besides, the physiographic characteristics of the sub-watersheds were determined through drainage density and bifurcation ratio through DEM and ArcGIS geospatial tools. Thus, the integrated result has provided useful information for the assessment and decision-making process about the erosion susceptibility of sub-watersheds. The findings obtained after applying RUSLE, GIS, and remote sensing includes spatially distributed soil loss rate and priorities of sub-watersheds over the study area. The main results obtained from the drainage density, and bifurcation ratio was averaged into the final rank and utilized for sub watersheds' priority. However, relatively soil loss estimation is better to sub-watershed priortiy used for soil and water conservations. From the result, it was concluded that prioritization of sub-watersheds based on some priority variables is an essential task in watershed planning and management. Geospatial techniques were also found effective tools that can help to detect watershed parameters and analyze the required variables for effective watershed prioritization.

As a result, unless some conservation measures are not taken timely it would seriously reduce the production of crops and animal feeds which finally affects the food security of the farming community in the watershed. Besides, the existing soil and water conservation structure being undertaken were not implemented depending on demand-driven and site-specific approaches (watershed-based), rather most of them were not only in the study area but also in all parts of the country is a quota system. Due to the inappropriate application of site-specific and demand-driven technology, the sustainability of soil and water conservation practice was demolished every year. Hence, GIS and remote sensing approaches in prioritizing and identifying erosion hotspot sub-watersheds based on the estimated soil loss obtained from RUSLE parameters are found to be more appropriate.

5.2. Recommendation

Based on the findings drawn from the conclusions of the study, it was recommended that the prioritized watersheds should be given attention for planning and implementation of SWC measures. From the RUSLE erosion factors, since identified as a major erosion factor, slope management through proper measures should be a technical consideration. Moreover, the method can also be applied in other parts of the North Shoa Zone and the country depending on the topography, soil types, and other factors of that specific site. To effectively curb soil erosion and nutrient depletions, it needs further study in identifying effective human practices of soil and water conservation methods.

REFERENCES

Addisu Damtew Atnafe, Husen Maru Ahmed and Demeku Mesfin Adane. 2015. Determinants of adopting techniques of soil and water conservation in Goromti Watershed, Western Ethiopia. Department of Geography and Environmental Studies, Wolaita Sodo University, Wolaita Sodo, Ethiopia. Vol. 6, 168-177.

Agumassie Genet Gela, Daniel Ayalew Mengistu and Seniet Maru. 2014. Watershed Prioritization Using Morphometric Analysis & RUSLE Model for Soil Conservation Planning, in Gilgel Abay Watershed, Ethiopia.

Aisha M., Tamene Adugna , Wakjira Takala. 2018. Morphometric analysis and prioritization of watersheds for soil erosion management in Upper Gibe catchment, Department of Water Resources and Irrigation Engineering, Madda Walabu University, Robe, Ethiopia, Volume 6,1, 1419-1426.

Ananda, M., D. L. D. Panditharathne, N. S. Abeysingha, and K. G. S. Nirmanee. 2019. Application of Revised Universal Soil Loss Equation RUSLE Model to Assess Soil Erosion in "Kalu Ganga" River Basin in Sri Lanka. Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka.

Arbind K. and Madan K. Extraction of Watershed Characteristics using GIS and Digital Elevation Model. Department of Agricultural Engineering, SASRD, Nagaland University, Medziphema India, 6: 7, 2319 – 6726.

Ashish Pandey, Behra S., Pandey R.. and Singh R.P. Application of GIS for Watershed Prioritization and Management: A Case Stud, Department of Water Resources Development and Management, IIT Roorkee, Roorkee-247 667, Uttarakhand, India

Atesmachew Bizuwerk, Girma Taddese and Yasin Getahun. 2015. Application of GIS for Modeling Soil loss rate in Awash River Basin, Ethiopia. *International Livestock Research Institute* Addis Ababa, Ethiopia.

Ayele Desalegn, Abrham Tezera, and Fikrey Tesfay. 2018. Developing GIS-based soil erosion map using RUSLE of AnditTid watershed, Central highlands of Ethiopia. Debre Berhan Agricultural Research Center and Debrebrihan University, College of Agriculture and Natural Resources. Debrebrihan, Ethiopia.

B.P. Ganassi, H. Ramesh. 2015. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin, Department of Applied Mechanics & Hydraulics, National Institute of Technology Karnataka India.

Babatunde J. Fagbohun Adeleye Y. B. Anifowose Chris Odeyemi Olabanji O. Aladejana Adegoke Aladeboyeje 2016. Based on the estimation of soil erosion rates and identification of critical areas in the Anambra sub-basin, Nigeria

Bagegnehu Bekele, Alemayehu Muluneh., and Nigatu Wondrade. 2019. Geographic Information System (GIS) based soil loss estimation using the Universal Soil Loss Equation Model (USLE) for soil conservation planning in Karesa Watershed, Dawuro Zone, and South West Ethiopia. Department of Soil and Water Conservation Engineering, South Agricultural Research Institute (SARI), Institute of Technology, Hawassa University, Ethiopia.

Bekele Tsegaye. 2019. Effect of Land Use and Land Cover Changes on Soil Erosion in Ethiopia. Areka Agricultural Research Center, Southern Agricultural Research Institute, Areka, Ethiopia

Birhan Asmame Miheretu and Assefa Abegaz Yimer, 2017. Estimating soil loss for sustainable land management planning at the Gelana sub-watershed, northern highlands of Ethiopia Department of Geography and Environmental Studies, Wollo University, Dessie, Ethiopia; Department of Geography and Environmental Studies, Addis Ababa University, Addis Ababa, Ethiopia.

Boloori S, Chatrsimab Z, Ghavimi P, Vafaeinejad A. and Hazbavi Z. 2019. Prioritizing of the Sub-Watersheds using the Soil Loss Cost Approach in Case Study; Selj-Anbar Watershed, Iran. Geographic Information Systems & Remote Sensing Department, Natural Resources & Environment Faculty, and Watershed Management Engineering Department, Natural Resources Faculty, Sari University of Agricultural Sciences & Natural Resources, Sari, Iran.

Choudhari. P., Gaurav K. N., Sudhir K.r S. and Sapana T. 2018. Morphometric-based prioritization of watershed for groundwater potential of Mula river basin, Maharashtra, Department of Soil and Water Engineering, Indira.

Debjyoti D. 2014. Identification of Erosion Prone Areas by Morphometric Analysis Using GIS, Journal of Institution of Engineers India, Ebrahim Esa, Mohammed Assen, and Asmamaw Legass. 2018. Implications of land use/cover dynamics on soil erosion potential of the agricultural watershed, north-western highlands of Ethiopia.

Elzbieta Bielecka. 2020. GIS Spatial Analysis Modelling for Land Use Change. A Bibliometric Analysis of the Intellectual Base and Trends, Faculty of Civil Engineering and Geodesy, Military University of Technology. Poland.

Eweg and van Lammeren, 1996 Use of USLE/GIS methodology for predicting soil loss in a semi-arid agricultural watershed. (2007); 131:153-61.

FAO-UNESCO, 1974. Soil Map of the World was published between 1974 and 1978 at 1:5 000 000 scales. version 3.4

Fazzini M, Bisci C, Billi P. 2015. The climate of Ethiopia. And Landscapes and Landforms of Ethiopia. World geomorphologic landscapes. Springer, Dordrecht

Fernandez, C., & Vega, J. A. (2016). Effects of mulching and post-fire salvage logging on soil erosion and vegetative regrowth in Northwest Spain. Forest Ecology and Management, 375, 46–54.

Fiona J., Simon M. Mudd, Mikaël A., David T., Milodowski , and Stuart W. 2016. The relationship between drainage density, erosion rate, and hilltop curvature: Implications for sediment transport processes, School of Geosciences, University of Edinburgh, Edinburgh, UK

Firoz A. and Laxmi G. 2017. Soil and Water Conservation Prioritization Using Geospatial Technology – a Case Study of Part of Subarnarekha Basin, Jharkhand, India

Ganassi, H. Ramesh 2015. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin, Department of Applied Mechanics & Hydraulics, National Institute of Technology Karnataka, Surathkal, Mangalore, India.

Gebrehana Girmay, Audenegest Moges and Alemayehu Muluneh. 2020. Estimation of soil loss rate using the USLE model for Agremariyam watersheds, northern Ethiopia.

Geetha.N., Prasannakumar, H. Vijith, S. Abinod, 2012. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology.

Gelagaya Habtamu. Sewenet, Amare Sewnet Minale. 2016. Soil loss estimation using GIS and Remote sensing techniques: a case of Koga watershed, North-western Ethiopia. Institute of Soil Water Conservations.

Geremew A.A., 2013. Assessing the impacts of land use and land cover change on the hydrology of watershed: a case study on Gilgel-Abbay Watershed, Lake Tana Basin, Ethiopia.

Gezahegn Weldu Woldemariam, Anteneh Derribew Iguala, Solomon Tekalign and Ramireddy U.R. 2018. Spatial Modelling of Soil Erosion Risk and Its Implication for Conservation Planning: the Case of the Gobele Watershed, East Hararghe Zone, Ethiopia.

Guangyu W., Shari M., Haisheng C., Shirong L., Zhiqiang Z., Liguo W., John L. 2016. Integrated watershed management: evolution, development and emerging trends, Faculty of Forestry, University of British Columbia.

Haillemarkos Tilahun, Girma Taddesse, Asmare Melese and Tesefaye Mebrate. 2018. Assessment of Spatial soil erosion hazardinAjema Watershed, North Shewa Zone Ethiopia. Department of Plant Science, and Department of Water Resource and Irrigation Management, Debre Berhan University, Ethiopia

Hans, H and Gete zeleke. 2018. Soil and water conservations (guideline for development agency) ministry of agriculture's (MOA). Ethiopia.

Hellden, U. 1987. An assessment of woody biomass, community forests, and land use and soil erosion in Ethiopia: a feasibility study on the use of remote sensing and GIS analysis for planning purposes in developing countries.

Horton, R.E. 1932. Drainage basin characteristics. T J. hydrophysical approach to quantitative morphology. Bull. Geol. Soc.

Hurni, H. (1986). Guidelines for development agents on soil conservation in Ethiopia. Community forest and soil conservation department Ethiopia

Hurni, H. 1988. Degradation and Conservation of the Resources in the Ethiopian Highlands. Mountain Research and Development. 8:2-3.

Juliet K. and Brigitta S. 2020. Linking Land Tenure and Integrated Watershed Management, Freie Universität Berlin, Department of Earth Sciences

Latifa, B. and Mohamed, A. 2020. Soil Loss Assessment in Western High Atlas of Morocco: Beni Mohand Watershed Study. Case Geology Department, Faculty of Science Agadir, IbnZohr University.

Lon-gfie. C, Young H. 2014. Experimental study and characteristic finite element simulation of solute transport in a cross-fracture in china, Civil Engineering Department of Chongqing Three Gorges College, Wanzhou China, Young.

Marco G., Martina A , Francesco P., Federico F., Maria C., Giovanni R., Daniele B., Davide D.C., Andrea S. and Renata V. 2019. RUSLE: a dynamic model to estimate potential soil erosion with satellite time series in the Italian Alps

Mengie Belayneh, Teshome Yirgu, and Dereje Tsegaye. 2019. Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS technique Department of Geography and Environmental Studies, Mettu University,

Mesharm S. and Sharma S. 2015. Morphometric analysis and prioritization of the sub-watersheds of Shakkar River Catchment, Narsinghpur district in Madhya Pradesh State, India, is carried out using RS and GIS techniques as discussed in Gajbhiye et al. (Appl Water Sci 4(1):51–61, 2013b).

Miheretu Birhan. A Yimer A. A,2018. Estimating soil loss for sustainable land management planning at the Gelana sub-watershed, Northern Highlands of Ethiopia.

Moeini. N, K. Zarandi1 , E. Pazira1 & Y. Badiollahi. 2015. The relationship between drainage density and soil erosion rate: a study of five watersheds in Ardebil Province, Department of Watershed Management, College of Agriculture and Natural Resources, Science and Research Branch in Iran. Vol 197, 1743-3541

Moghadoseh F. Ataollah K.and Ebrahim O.2016. Watershed prioritization to implement soil and water conservation practices, *international journal of environmental earth science*

Nigussie Haregeweyn, Ademnur Berhe, Tsunekawa A, Tsubo M and Tsegaye Meshesha. 2012. Integrated watershed management as an effective approach to curb land degradation: a case study of the Enabled watershed, northern Ethiopia.

Okubay Giday, Heluf Gibrekidan and Tareke Berhe. 2015. Soil fertility characterization in vertisols of southern Tigray, Ethiopia. Department of Soil Science, Wollo University, Ethiopia. Volume 2 Issue 1

Ostovari. y, shoji. G. Bahari. 2018. Soil loss prediction by an integrated system using RUSLE, GIS, and remote sensing in the semi-arid region of India

Pamela J. Edwards, Karl W.J. Williard, and Jon E. Schoonover 2015. Fundamentals of Watershed Hydrology

Parmita B., Surya n. and Padmini P. 2009. Watershed Delineation and flow accumulation calculation using Shuttle Radar Topographic Mission (SRTM) Data India. *journal of environmental research and development.*

Prasannakumar V, Vijith H, Abinod S, Geetha N. 2012. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE).

Rediet Girma and Eshetu Gebre. 2020. Spatial modeling of erosion hotspots using GIS-RUSLE interface in Omo-Gibe river basin, the implication for soil and water conservation planning Southern Ethiopia.

Renard, K. G. (1996). Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE): United States Government Printing.

Riad A. Mohirul I.JahangirA.2020. Watershed prioritization for soil and water conservation aspect using GIS and remote sensing: PCA-based approach at northern elevated tract Bangladesh Department of Geology and Mining, University of Rajshahi.

Rubianca B, Bethanna J, Deborah M, and Kevin N. 2018. A review of the (Revised) Universal Soil Loss Equation RUSLE to increase its global applicability and improve soil loss estimates.

Safdar B, Atif J, Irshad B, and Niaz A. B 2017. Soil and Water Conservation. *Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan.*

Semu Arayaselassie Abebe. 2018. The impact of soil and water conservation for improved agricultural production in Ethiopia. 1(1):9-12.

Shivkumar G. and Neha S. 2018. Soil Erosion Types and Their mechanisms Department of Agriculture, Jagannath University

Sissay Dechasa, Basam K. And Fisaha S. 2019. Biophysical Characteristics of Weyb Watershed, Bale Mountainous, Area of South-eastern Ethiopia. International Journal of Innovative Technology and Exploring Engineering, Volume-8 Issue-9.

Sitotaw Haile. and Hailu W. 2018. Flood risk analysis: causes and landscape-based mitigation strategies in Dire Dawa city, School of Geography and Environmental Studies, Haramaya University, Dire Dawa, Ethiopia.

Solomon Gebrehiwot, U. A. I. Gardenas, and K. Bishop. 2011. Hydrological characterization of watersheds in the Blue Nile Basin, Ethiopia. *Hydrology and earth system sciences. 15 :1, 11-20*

Strahler, A.N. 1964. Quantitative geomorphology of drainage basins and channel networks. In.V.T. Chow. Handbook of Applied Hydrology. Mc Graw Hill Book Company, New York.

Suhan P. and Kaushal K. 2009. Watershed Management Concept and Principles international research institute India.

Surendra K. and Mitthan L. 2014. Prioritization of sub-watersheds based on morphometric analysis using the geospatial technique in Piperiya watershed, India

Tamrat Sinore, Endalikachew Kissi, and Abebayehu Aticho. 2018. The effects of biological soil conservation practices and community perception toward these practices in the Lemo District of Southern Ethiopia. 6:2, 123-130

Telkar, S. G., Shivendu P. Singh S. Joy K. D. and Kamal K. 2015. Soil Erosion types and Their Mechanism Dept. of Agriculture, Jagannath University, Chaksu, India. Vol. 2, 4,178-180.

Temesgen Gashaw, Amare Bantider, and Hagos G/Silassie. 2014. Land Degradation in Ethiopia: Causes, Impacts, and Rehabilitation Techniques. Department of Natural Resource Management, Adigrat University, Ethiopia. 4:9, 2225-0948.

Temesgen Gashaw, Taffa Tulu, Mekuria Argaw. 2017. Erosion risk assessment for prioritization of conservation measures in Geleda watershed, Blue Nile basin, Ethiopia. Environment Sustainable research institutions.

Tesfa Worku, Sangharsh K. 2019. Towards integrated water resources management considering hydro-climatological scenarios: an option for sustainable development, Department of Water Resource Development and Management, India Institute of Technology, Roorkee, India.

Trust Ma. and Oagile D. 2013. Using universal soil loss equation and soil erodibility factor to assess soil erosion in Tshesebe village, northeast Botswana, Department of Environmental Science, University of Botswana, Vol. 8(30), pp. 4170-4178.

Umair A. and Syed Ahmad 2014. Analysis of Drainage Morphometry and Watershed Prioritization of Romushi Sasar Catchment, Kashmir Valley, India using Remote Sensing and GIS Technology *International Journal of Advanced Research, 2:12, 5-23*

Veera N. Balabathina, R. P. Raju, Wuletaw Mulualem, and Gedefaw Tadele. 2020. Estimation of soil loss using remote sensing and GIS-based universal soil loss equation in the northern catchment of Lake Tana Sub-basin, Upper Blue Nile Basin, Northwest, Department of Geology, College of Natural and Computational Sciences, University of Gondar Ethiopia.

Wani, S P, and Sreedevi, T K and Reddy, T S V and Venkateshvarlu, B and Prasad, C S (2008) Community watersheds for improved livelihoods through a consortium approach in drought-prone rain-fed areas. *Journal of Hydrological Research and Development, 23:1.55-77.*

Wischmeier W. H, Smith D.D. 1978. Predicting rainfall erosion Losses guides conservation planning. Washington: Science and Education Administration, U.S. Department of Agriculture.

Woldemariam G. W, Iguala A. D, Tekalign S, Reddy R.U, 2018. Spatial modeling of soil erosion risk and its implication for conservation planning: the case of the Gobele Watershed, East Hararghe Zone, Ethiopia.

Wudu Abiye Abebaw. 2019. Review on Impacts of Land Degradation on Agricultural Production in Ethiopia, Sirinka Agricultural Research Center, Woldia, Ethiopia. Vol.57, 2422-8397

Yared Mesfin , Justyna J, Lemma Tiki Yadeta, Marcin S, Radosław P, and Eyob G. G. 2020. Soil Loss Estimation for Conservation Planning in the WelmelWatershed of the GenaleDawa Basin, Ethiopia. Department of forestry, College of agriculture and environmental sciences, Arsi University, Assela, MadaWalabu University, Nicolaus Copernicus University, Addis Ababa University.

Yaser O, Shoja G.D, Hossein-A, Mehdi N, Jose A. 2017. Soil loss estimation using RUSLE model, GIS, and remote sensing techniques: A case study from the DembechaWatershed, Northwestern Ethiopia Department of Soil Science, College of Agriculture, Shahrekord University, Shahrekord, Iran.

Zenebe Adimassu, Bezaye Gorfu, Demeke Nigussie, J. Mowo and Kidist Hilemichael. 2013. Farmers' preference for soil and water conservation practices in central highlands of Ethiopia. African Crop Science Journal, Vol. 21, 3, 781 – 790.

Zerihun M, Mohammedyasin M.S, Sewnet D, Adem A. A, Lakew M. 2018. Assessment of soil erosion using RUSLE, GIS, and remote sensing in north waste Ethiopia.

Appendix

Annex 1. Soil loss, area, and percent of each watershed

watershed	Area(Ha)	Soil loss(tone/ha/yr						
SW1	1170.1	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		498.5	104.8	87.5	58.0	65.2	43.1	313.1
Percent (%)		42.6	9.0	7.5	5.0	5.6	3.7	26.8
SW2	893.8	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		296.8	102.8	95.7	70.5	67.4	43.9	216.7
Percent (%)		33.2	11.5	10.7	7.9	7.5	4.9	24.2
SW3	1851.1	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		549.7	174.3	165.0	131.5	137.3	96.1	597.2
Percent (%)		29.7	9.4	8.9	7.1	7.4	5.2	32.3
SW4	1536.0	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		261.4	30.0	65.9	70.5	99.7	88.1	920.5
Percent (%)		17.0	2.0	4.3	4.6	6.5	5.7	59.9
SW5	848.3	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		194.2	36.5	50.0	41.3	49.7	43.4	433.3
Percent (%)		22.9	4.3	5.9	4.9	5.9	5.1	51.1
SW6	1885.6	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		453.5	82.5	94.8	91.4	118.6	98.2	946.6
Percent (%)		24.1	4.4	5.0	4.8	6.3	5.2	50.2
SW7	1717.9	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		412.7	99.6	103.2	92.6	119.9	89.7	800.3
Percent (%)		24.0	5.8	6.0	5.4	7.0	5.2	46.6
SW8	685.6	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		117.6	13.7	23.3	26.6	36.0	29.4	439.0
Percent (%)		17.1	2.0	3.4	3.9	5.3	4.3	64.0
SW9	962.3	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		219.6	35.6	47.8	45.9	57.9	50.5	505.0
Percent (%)		22.8	3.7	5.0	4.8	6.0	5.2	52.5
SW10	682.9	0-5	5-11	11-20	20-30	30-45	45-60	>60
Area of soil loss(ha)		123.2	14.1	26.2	26.7	39.1	32.2	421.4
Percent (%)		18.0	2.1	3.8	3.9	5.7	4.7	61.7

Annex 2. Rainfall data of each station

Table1. Station Effeson(Ataye) X 604673 Y 1143185

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
2000	0	0	0.5	69.6	51.2	14	185.3	324.8	119.2	105.8	61.2	46.9	978.5
2001	18.5	3.2	166.7	4.7	111.1	15.7	321.2	251.6	64	7.3	0	11.8	975.8
2002	80.7	15.6	71.9	0	5.5	0.8	128.2	218.2	71.3	0	0	144.9	737.1
2003	16	48.4	41.3	158.5	2.7	56.3	176.4	242.9	101.6	0	16.7	103.8	964.6
2004	75.9	16.2	96.9	160.6	1.7	31.7	147.3	408.5	113.8	59.6	49.5	14.1	1175.8
2005	36.5	0.5	30.5	132.2	85	27	236.1	278.2	85.2	8.9	67.8	0	987.9
2006	62.5	63.9	18.9	124.2	6.4	20.8	304.9	332.4	174.8	19.1	56	1.6	1185.5
2007	28.7	19.9	89.4	74.8	8.1	40.5	328	355.4	89	0	7.9	0	1041.7
2098	29.6	0	0	52.5	56.1	45.7	273.8	160	149.5	46	113.7	0	926.9
2009	79	0	105.7	81.6	81.6	57.8	251.7	436.1	51.8	0	62.2	37.2	1244.7
2010	0	140.3	160.7	79.4	76.3	28.5	312.9	427.5	16.7	1.2	21.6	9.5	1274.6
2011	3.4	0.5	28.1	13.5	70.3	2.6	71.3	271.1	17.1	0	24.4	1.5	503.8
2012	0	0	98.6	14.5	0	42.9	243.5	473	35.5	0	9	1.5	918.5
2013	0	39.9	236.6	98.3	54.8	4.3	224.8	793.1	24.1	14.4	0	0	1490.3
2014	0	34.7	99.3	103.1	199.7	0	73.7	991.6	495.9	47.2	26.1	0	2071.3
2015	35.9	0	54.7	0	145.2	0	0	969	348.6	5.7	29.6	6.3	1595
2016	0	13.2	4.2	0	0	0	309.1	336.8	49	0	78.1	15.2	805.6
2017	0	28.1	51.5	34.8	116	2	123.5	447.5	148.5	0	0	0	951.9
2018	0	17.7	57	180.1	42.5	23.2	226.1	393.1	126.2	19.2	36.8	0	1121.9
2019	0	7.4	73.9	46.9	89.9	49.5	328.8	338.7	103.9	48.7	74.7	0	1162.4
MAP													**1105.69**

Table 2. Station Jewuha X 606280 Y 1160821

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
1985	12	25	31.7	30.4	31.3	35.2	32.1	31	30.6	30	29	28.3	346.6
1986	11.1	12.1	15.6	18.2	14.2	11.5	17.1	15	16	12.3	9.3	8.4	160.8
1987	0	92.9	31	129.3	40.5	53	101	197.4	75.5	62	0	65.8	848.4
1988	28.5	28.9	30.7	29.3	32.4	33.8	33	30.4	30.2	30.6	30.4	28.4	366.6
1989	9	16.5	15.1	17.2	16.5	17.7	16	15.4	14.4	9.4	7.8	4.2	159.2
1990	0	7	87.2	117.6	185.8	0	78	191	10.4	12.4	0	15	704.4
1991	28.6	29.7	29.7	29.5	31.9	31.1	34	31.9	31.4	32.8	31.1	29.5	371.2
1992	1.6	14	14.4	10.3	9.6	10.7	13	12.9	12.2	11.7	14	38	162.4
1993	20	14	76	160.5	66	9.5	102.4	183.4	39	25	30	0	725.8
1994	19	18	32.7	32.8	17	35.9	33.1	30.1	30.6	30.8	29.8	29.5	339.3
1995	19	16.6	15	16.4	19	18.9	19.2	18.2	17.2	14.9	8.8	8.1	191.3
1996	0	71	55.5	145.2	10	13	33	43	44	17.7	34	20	486.4
1997	27.7	29.1	30.3	28.7	33.1	35.5	32.7	32	31.1	30.7	30.4	27.6	368.9
1998	12.3	14.1	15.6	17.2	15.8	17	18.4	17.9	17	13.9	11.2	15.2	185.6
1999	24	134.2	137	9	3.3	77	141.8	160.5	164.7	0	0	0	851.5
2000	29.1	29.4	30.6	34.8	36.2	33	33	32.3	32	31.1	30.7	29.3	381.5
2001	13.5	10.7	10.8	12.4	16.2	15	14.4	8.4	8.7	12.5	13.1	13.5	149.2
2002	0	239.4	241.7	23.3	30	16	196.8	211	113.5	26.7	1.2	148.3	1247.9
2003	30	29.3	29.9	31.5	30	13	32.1	30.8	32	31.3	30.1	28.6	348.6
2004	12.1	9.4	8.8	9.1	44	17	11.6	10.3	10.6	7.3	7.7	12.6	160.5
2005	146.1	132.2	12.4	31	33.8	21.5	139.8	267.1	138.4	44	17.3	41.7	1025.3
2006	26.8	26.4	31	32.1	33.5	35.5	32.7	28.3	28.7	29.1	29.1	28.6	361.8
2007	15	16.8	16.8	17.5	17.1	17.4	19.2	17.8	16.5	14.4	13.2	15.2	196.9
2008	84.2	86.3	0	360.1	121.4	1.7	156.6	121.5	15	43.9	0	1.6	992.3
2009	26.7	26	31.4	29.5	30.7	34.6	32.3	31.2	31.4	30.6	30.5	30	364.9
2010	14.5	14.9	13.9	17.4	17.6	16.7	18.3	18.1	17.5	15.6	12.6	9.8	186.9
2011	0	1	70.5	17	37.6	22.6	34	287.8	182	4.5	55.2	1.8	714
2012	30.6	31.5	32.2	33.6	34.7	36.1	32.5	29.8	30	31.8	30	28.8	381.6
2013	10.4	12.7	17.6	18.5	18.5	19.3	18.8	17.8	16.1	12.6	13	10.3	185.6
2014	0	92.5	147.6	167.5	37.6	22.6	34	287.8	182	4.5	55.2	1.8	1033.1

2015	29.7	29.6	28.6	29.8	34.7	36.1	32.5	29.8	30	31.8	30	28.8	371.4
2016	10.4	15.6	17.2	18.1	18.5	19.3	18.8	17.8	16.1	12.6	13	10.3	187.7
MAP													**454.925**

Table 3. Stations Senbeta X 608069 Y 1139644

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	sum
2000	0	0	0	31.7	76	0.9	222.2	287.7	139.5	58.1	82.9	29.9	928.9
2001	28.2	6.3	114.3	2.2	54	6.5	251.9	256.9	72.3	7.2	0	8.2	808
2002	47.3	0	71.3	68.9	20.2	11	170.5	208.9	98.3	8.9	0	127.9	833.2
2003	12.5	39	54.6	91.9	0	81.5	146.7	266.2	123.6	0	46.1	32.1	894.2
2004	49.5	0	139.1	137.3	0	33	146.4	379.5	106	27.8	58.5	17.6	1094.7
2005	48.9	3.7	38	166.1	88.5	37.4	253.7	240.9	121.8	3.6	9.5	0	1012.1
2006	62.2	21.5	24.4	123.4	18	18.3	282.3	398	65.5	12.2	0	42.1	1067.9
2007	25.1	55.3	26.1	42	12.8	10.7	263.6	352.2	146.1	0	4.4	0	938.3
2098	9.4	0	0	30.7	13	16.9	154.2	210.1	28.4	24	94.1	0	580.8
2009	75.8	0	0	74.6	0	13.5	119.4	98.6	13.3	9.8	8.5	16	429.5
2010	21.4	0	14.9	70	0	23	190.4	257	90	21	20.3	17	725
2011	0	0	0	55.2	55.2	6.1	106.6	254.5	101.6	2.6	9.9	0	591.7
2012	0	0	14.9	94.8	24.4	23.5	189.9	272.5	5.4	8.6	0	0	634
2013	0	0	70.7	89.5	35.9	4.7	212.9	252.3	67.8	33.5	12.5	0	779.8
2014	0	25.9	72.6	13	56.5	10	194.5	262.9	139.6	100.4	0	0	875.4
2015	0	0	6.8	6.8	42.6	10.2	190.4	257	81.9	20.9	0	0	616.6
2016	0	13.8	35	7	91.7	10.3	190.5	257.4	82	21	0	0	708.7
2017	0	83.8	45.4	8	140.8	10.3	208.6	262.4	92	6.4	0	0	857.7
2018	5.2	26.2	110.5	215.4	21.4	60.4	173.8	263.7	14.6	51.6	20.4	0	963.2
2019	0	0	42.6	69	41.2	61.6	138.8	108.6	56.4	0	38.8	25.2	582.2
MAP													**796.095**

Table4. Stations Majete X 593013 Y 1160821

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	sum
1993	126.5	48.6	102.0	186.7	191.7	176.0	205.3	166.1	99.7	66.5	0.0	0.0	1369.1
1994	0.0	4.6	42.0	164.0	12.3	23.6	240.7	354.5	160.7	7.1	0.0	2.2	1011.7
1995	0.0	87.3	46.8	150.7	113.0	104.0	354.6	355.6	130.8	26.1	0.0	74.9	1443.8
1996	41.2	0.0	163.3	120.8	120.4	57.0	299.3	379.0	101.9	8.9	53.1	48.0	1392.9
1997	41.0	0.0	129.7	69.4	7.9	53.6	222.4	261.0	56.9	270.3	143.9	0.0	1256.1
1998	108.0	91.8	59.7	121.6	74.3	9.0	464.8	373.8	127.2	62.7	2.3	0.0	1495.2
1999	94.9	0.3	35.6	91.3	22.9	10.0	438.6	504.9	148.5	202.3	5.6	0.3	1555.2
2000	0.0	0.0	102.0	85.1	77.5	12.2	318.0	412.7	133.5	51.3	103.3	53.5	1349.1
2001	13.9	1.5	164.2	14.4	96.6	11.0	450.8	241.3	105.9	11.2	8.0	1.8	1120.6
2002	106.4	6.8	60.4	104.9	31.4	26.8	257.5	311.2	99.4	7.4	2.6	163.1	1177.9
2003	62.9	31.7	82.7	99.7	23.0	33.0	254.1	250.6	181.1	3.0	3.9	61.1	1086.8
2004	28.5	69.9	103.7	97.6	5.9	47.5	199.9	259.4	118.9	40.4	59.1	29.2	1060.0
2005	53.3	0.0	144.4	98.0	113.9	39.9	228.6	229.3	170.3	9.5	61.6	0.0	1148.8
2006	56.3	10.7	55.4	147.3	9.0	36.4	340.0	508.3	107.3	34.9	0.0	38.0	1343.6
2007	20.9	20.1	72.9	86.1	79.4	31.4	302.9	438.1	156.9	22.6	12.0	0.0	1243.3
2008	50.1	0.0	0.0	59.6	28.3	27.9	225.8	254.5	96.7	59.7	113.4	0.0	916.0
2009	26.7	4.0	67.0	27.1	50.5	39.6	359.9	291.0	74.1	48.2	11.4	53.7	1053.2
2010	12.4	55.3	116.2	152.1	133.3	30.6	279.0	133.3	117.2	12.7	22.1	1.3	1065.5
2011	13.0	0.0	100.0	167.0	88.5	13.7	150.9	323.2	90.0	20.5	56.0	0.2	1023.0
2012	0.0	0.0	51.0	162.3	83.6	38.8	316.0	340.2	64.3	12.0	0.0	3.3	1071.5
2013	0.0	6.3	45.1	65.1	95.8	27.5	300.7	363.8	56.0	158.2	16.0	0.0	1134.5
2014	0.0	53.6	63.8	128.7	113.0	16.0	270.9	428.6	97.9	127.5	6.7	0.1	1306.8
MAP													**1200.0**

Table 5. Station ymelewo   X 598684   Y 11382112

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**sum**
2008	16	0	73.3	92.4	8.3	36	294.6	197.6	94.6	95.5	0.9	0	909.2
2009	54.4	0	48.5	7.5	77.8	39.6	338.9	443.6	45.9	32.1	31.2	183.8	1303.3
2010	0	181.2	249.5	101	0	41.8	379.3	403.3	54.8	0	48.5	0	1459.4
2011	12.2	0	113.7	23.7	78.9	0	216.6	364.6	259.3	0	115.4	0	1184.4
2012	0	0	0	265.4	29	108	651.8	488.8	94.4	0	0	0	1637.4
2013	25.1	5.6	87.8	0	0	0	314.6	244.5	117.2	12.1	11.7	15.8	834.4
2014	15	60.6	0	0	6.5	9.8	216.5	291.1	182.8	89.2	7.5	0	879
2015	36.1	0	55.3	0	117.1	32	244	333.5	141	26.5	28	0	1013.5
2016	15.2	30.2	73.3	302.8	123.6	34.6	365.3	233	171.8	9.7	40.3	0	1399.8
2017	0	40.7	82.9	29.3	99.9	10.4	207.5	298.9	84.6	0	0	0	854.2
2018	15.5	43.7	65	138.6	47.4	30	344.4	333.4	141	26.5	28.4	22.2	1236.1
2019	0	0	30.6	148	102.1	38.8	459.5	369.3	304.4	0	28.4	20.2	1501.3
MAP													**1184.333**

Annex 3. ground truth point

No	X	Y	Z	LULC
1.	600532	1136969	1445	farm land
2.	600448	1137241	1447	farm land
3.	600257	1137042	1451	farm land
4.	600618	1137519	1446	farm land
5.	599904	1137519	1446	farm land
6.	599904	1137648	1469	farm land
7.	599513	1137558	1482	farm land
8.	599204	1137891	1502	farm land
9.	600118	1444435	1523	farm land
10.	599698	1145785	1546	farm land
11.	600275	1146162	1535	farm land
12.	601590	1147139	1503	farm land
13.	592907	1151556	2801	farm land
14.	596173	1148663	1762	farm land
15.	592576	1151988	2821	farm land
16.	592273	1151681	2784	farm land
17.	592109	1148329	2695	farm land

18.	597217	1139001	1767	bare land
19.	597327	1139125	1768	bare land
20.	597357	1139116	1756	bare land
21.	597300	1139197	1796	bare land
22.	596352	1139177	1903	bare land
23.	596208	1139713	2011	bare land
24.	596314	1139938	1995	bare land
25.	599732	1143417	1552	bare land
26.	599417	1143465	1565	bare land
27.	597791	1146536	1617	bare land
28.	596249	1146863	1724	bare land
29.	595612	1146433	1893	bare land
30.	595486	1147838	1763	bare land
31.	604750	1143504	1459	Settlement
32.	604325	1143450	1465	Settlement
33.	603981	1143281	1475	Settlement
34.	604548	1142865	1464	Settlement
35.	603779	1444495	1476	Settlement
36.	602511	1144228	1525	Settlement
37.	598609	1138051	1539	Settlement
38.	599817	1144199	1541	Settlement
39.	596055	1140796	2098	Settlement
40.	595888	1148054	1743	Settlement
41.	597842	1136606	1741	shrub land
42.	597819	1137357	1800	shrub land
43.	597678	1137981	1818	shrub land
44.	596943	1138147	2003	shrub land
45.	596749	1139159	1922	shrub land
46.	597308	1139758	1976	shrub land
47.	597648	1140134	2196	shrub land
48.	596923	1142397	1907	shrub land
49.	597498	1143057	1943	shrub land
50.	598260	1143801	1903	shrub land
51.	597657	1144386	1848	shrub land
52.	597404	1144896	1840	shrub land
53.	597029	1145451	1755	shrub land
54.	593466	1148915	2128	shrub land
55.	593100	1149077	2298	shrub land
56.	592613	1149446	2282	shrub land
57.	592497	1150189	2447	shrub land
58.	592609	1147076	2318	shrub land

59.	597859	1147334	1788	shrub land
60.	597323	1148363	2053	shrub land
61.	597403	1149251	2098	shrub land
62.	596955	1149672	2028	shrub land
63.	593195	1146992	2153	forest land
64.	593325	1145096	2484	forest land
65.	595307	1145394	2103	forest land
66.	596799	1145214	1772	forest land
67.	597253	1144064	2059	forest land
68.	597169	1143684	2196	forest land
69.	596855	1143595	2229	forest land
70.	597318	1137936	1912	forest land
71.	599995	1142482	1715	forest land
72.	601222	1143083	1536	forest land