LAND SUITABILITY ASSESSMENT FOR AGRICULTURAL LAND USE BY USING GEOSPATIAL TECHNOLOGY: A CASE OF ARSI NEGELE WEREDA

ELILTEWOIN W/KIROS

A Thesis Submitted to the Department of Geomatics Engineering, School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in

Geo-informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

August, 2021

Adama, Ethiopia

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Co-Advisor: Mekonnen Ayana (PhD)

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APPROVAL SHEET

We, the advisors of the thesis entitled "Land Suitability Assessment for Agricultural Land Use by Using Geospatial Technology: A Case of Arsi Negele Woreda" and developed by Eliltewoin W/kiros, hereby certify that the recommendation and suggestions made by the board of examiners are appropriate incorporated into the final version of the thesis.

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We, the undersigned , members of the Board of Examiners of the thesis by Eliltewoin W/Kiros have read and evaluated the thesis entitled " Land Suitability Assessment for Agricultural Land Use by Using Geospatial Technology: A Case of Arsi Negele Wereda" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-informatics Engineering.

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DECLARATION

I hereby declare that this Master Thesis entitled "Land Suitability Assessment for Agricultural Land Use by Using Geospatial Technology: A Case of Arsi Negele Wereda" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

Eliltewoin W/kiros_______ ______________________ ______________________

Name of Candidate Signature Date

RECOMMENDATION

we, the advisor(s) of this thesis, hereby certify that we have read and revised version of thesis entitled “Land Suitability Assessment for Agricultural Land Use by Using Geospatial Technology: A Case of Arsi Negele Wereda” prepared under our guidance by Eliltewoin W/Kiros submitted in partial fulfillment of the requirements for the degree of Masters of Science in Geo-informatics Engineering. Therefore, we recommend the submission of revised version of the thesis to department following the applicable procedures.

Getachew B/Meskel (PhD)___	______________________	____________________
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Mekonnen Ayana (PhD)_______	_____________________	_______________________
Co-Advisor	Signature	Date

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LIST OF ACRONOMY AND ABBRIVATIONS

AHP……………………………… Analytical Hierarch Process

ALOS PLASAR………………… Advanced Land Observation Satellite

Phased Array Type L-band Synthesis Aperture Radar

ATA………………………………. Agricultural Transformation Agency

CEC………………………………. Cation Exchange Capacity

CI…………………………………...Consistence Index

CR……………………………….. ...Consistency Ratio

DEM …………………………… …Digital Elevation Model

EC ……………………….............Electrical Conductivity

GIS…………………………………..Geographic Information System

GPS…………………………………Globally Positioning System

IDW………………………………….Inverse Distance Weighted

LSA…………………………………. Land Suitability Analysis

LULC…………………………….. …Land Use Land Cover

MAP……………………………… …Mean Annual Precipitation

MCDM……………………………….Multi Criteria Decision Making

MOA…………………………………Ministry Of Agriculture

RS…………………………………. ...Remote Sensing

RUSLE……………………………. ...Revised Universal Soil Loss Equation

SNNPR……………………………….Southern Nations Nationalities People Region

SOC……………………………….......Soil Organic Carbon

USGS…………………………………United States Geological Survey

USLE…………………………………Universal Soil Loss Equation

ABSTRACT

Improper land use planning is the key factor of soil erosion which declines agricultural productivity and food security. Hence, in order to improve agricultural productivity the adoption of land suitability evaluation for agricultural use is essential for sustainable land resource management and soil erosion control in the study area. Therefore, the main objective of this study is to assess agricultural land use suitability in the study area by using geospatial technology. Sentinel 2A satellite image, ALOS DEM, Metrological and soil data were used as input data sets to generate factors for land suitability Assessment and RUSLE factor value for soil erosion. Land suitability for rain fed agriculture was generated from 12 factors such as; Slope, soil depth, soil texture, soil drainage, LULC, PH, soil erosion, temperature, rainfall, EC, CEC and SOC were used as major criteria. Likewise, land suitability for surface irrigation was generated by the same procedure with land suitability for rain fed agriculture regardless of rainfall factor. Soil erosion risk was generated by using 5 factors namely; Rainfall erosivity (R) factor, soil erodibility (K) factor, slope length and slope steepness (LS) factor, cover management (C) factor and conservation practice (P) factor. Raster calculator in Arc GIS10.8 software was used to interactively calculate annual soil loss and generate soil erosion risk map in the study area. The result showed that the study area land suitability for rain fed agriculture comprises an area of 9.9% (15993.17 ha) highly suitable (S1), 25% (40405.67ha) moderately suitable (S2) and 35.8 (57324.4ha), 29.3 (46618.17ha) marginally suitable and permanently not suitable (N2), respectively. Land suitability for surface irrigation comprise an area of 4.2% (6724.2 ha) highly suitable (S1), 70.4% (112793 ha) moderately suitable (S2) and 25.4(112793 ha) not suitable (N) for surface irrigation. The spatial distribution of annual soil loss varied from 0 to 71.95 t/ha/year. Based on the level of soil erosion rates, the study area classified into five priority categories such as 5.62% (136450.787 ha) severe, 2.23% (7698.99 ha) very high, 2.28% (3659.94 ha) high and 4.8 % (3542.72 ha), 85% (3988.99 ha) moderate and low erosion risk class, respectively. Based on soil erosion categories from moderate to severe soil erosion conservation practice of soil erosion highly recommended before further soil erosion or the erosion turning to no return.

Key words: Land suitability, RUSLE, Geospatial technology, Land use planning, Soil erosion

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Land evaluation is a foundation for sustainable land resource planning and management since it help us to know whether the resources are degraded or enhanced in quality (Dumanski et al., 2002; Mohana, Mariappan and Monaharan, 2009). The principal purpose of agriculture land suitability evaluation is to predict the potential and limitation of the land for crop production (Pan and pan, 2012). Agricultural land suitability assessment is defined as the process of assessment of land performance when used for alternative kinds of agriculture (Prakash, 2003). Proper land suitability evaluation of land resources in irrigation command area is also prerequisite for better utilization of land resources which help to optimize and sustain the productivity of these land resources. Availability of irrigation leads to land use change as well as intensive cropping system (Sulieman et al., 2015).

According to Rabia and Terrible (2013) land suitability is a multi-criteria problem which involve with the number of parameters namely: rainfall, temperature, slope percentage, soil physical and chemical property and management practice. The availability of GIS and multi-criteria decision analysis (MCDM) methods allow combining knowledge derived from different sources to support land-use planning and management (Malcyewski, 2000).

Continuous utilization of agriculture land in the past decades, regardless of land suitability has caused much more destruction than provide the resources (FAO, 2007). Land use and land cover changes and degradation are increasing at alarming rate generally throughout the country. Improper use of irrigation water has resulted in degradation of natural resources that leads to decline in the productivity of land resources and deterioration of land quality for its future use (Sulieman et al., 2015). The change in land use types played a significant role in increasing the rate of soil erosion in Ethiopia (Bekele, 2019). The problem of soil erosion is one of the major environmental constraints to agricultural sustainability and food security particularly in the highlands (Ajanaw, 2021). It can be described as the removal of organic as well as inorganic soil surface materials by wind and water (Gabriels, 1991).

Soil erosion is the most serious form of land degradation, in which its on-site and off-site effects threaten the food security and the natural economy of the country (Hurni, 1993). Erosion models can be used as predictive tools for assessing soil loss and soil erosion risk for soil conservation planning (Popp et al., 2000). Modeling soil erosion provides useful information for selection of appropriate soil conservation practices. Among the available soil erosion models Universal Soil Loss Equation (USLE) is the most widely known and used empirical soil loss model all over the world (Wischmeier and Smith, 1978). In the 1980, the United States Department of Agricultural Research Service (USDA-ARS) modified the model to the Revised Universal Soil Loss Equation (RUSLE), which was and improved version of USLE incorporating new approaches and corrections of the USLE limitation (Trojacek and Kadlubiec, 2004). It provides an estimate of the severity of erosion and also numerical results that can validate the benefits of planned erosion control measures in risky areas(Silleos,1990). The focus of this research is aimed to evaluating and mapping land suitability for agricultural land use and spatial distribution of soil erosion in the study are to utilize limited resources efficiently and for compressive soil conservation management.

1.2 Statement of the Problem

Ethiopia has great agricultural potential because of its vast area of fertile land, diverse climate, generally adequate rainfall and large labor pool (MoFED, 2009). Despite this potential Ethiopian agriculture has remained under developed as a result of land degradation due to mismanagement of land and intensive cultivation. Insufficient crop land management and rapid depletion of vegetation cover leads to erosion and significant losses of arable land. The rate of soil erosion has been accelerating in the country due to land use land cover change and inappropriate land use and management practices. The problem of soil erosion is one of the major environmental constraints to agricultural sustainability and food security in Ethiopia particularly in highlands. The overall soil loss of the country is estimated about 1.5 billion tons per year with a mean erosion rate of 42 t/ha/yr (Ajanaw, 2021).

According to Bobe (2004) Ethiopia has a total surface area of 111.8 million hectares; of which 60 million hectares are estimated to be agriculturally productive. Out of these lands, about 27 million hectares are significantly eroded, 14 million hectares are seriously eroded and 2 million hectares have reached the point of no return. Alarmingly, it takes up to 300 years for one inch of agricultural soil to form (Citizens of earth,2017). Several researches have been done so far in estimating soil erosion in Ethiopian high lands (e.g. Gelagay and Minale 2016; Gashaw et al.,2017; Haregeweyn et al., 2017; Miheretu and Yemer 2018; Wodlemariam et al., 2018 ; Zerihun et al., 2018). However, the problem of soil erosion has been prevalent and even increasing (Environment for Development (EFD), 2010). Therefore, Great attention should be paid for Land suitability evaluation process of predicting land performance over time according to specific type of use (Zonneveld, 1989). It help us to know whether the resources are degraded or enhanced in quality (Dumanski et al., 2002, Mohana, Mariappan and Monaharan, 2009).

Based on satellite image analysis from 1986-2016 there was a dynamics of LULC change in Arsi Negele in both of the three agro-ecologies namely; lowland, midland and highland (Zenebe, 2018). Arsi Negele district has undergone series of land use land cover change over the last 33 years from 1973 to 2006 (Zelalem, 2007). This practice led to sever soil erosion and decline of agricultural production and productivity. Therefore, proper land suitability assessment for agricultural land use is paramount to enhance sustainable agricultural productivity and prevention of further occurrence of soil erosion caused due to improper practices of LULC change.

1.3 Objective of the Study

1.3.1 General objective

The main objective of the study was to assess suitable land for sustainable agricultural land use planning and management by using geospatial technology.

1.3.2 Specific objective

- To estimate amount of soil loss occurs in the study area.
- To produce soil erosion risk map of the study area.
- To prepare thematic map for different land suitability factors.
- To evaluate land suitability for rain fed agricultural and surface irrigation.

1.4 Research Questions

The conducted research tried to answer the following question.

1. Which area of the study area exposed to soil erosion?
2. What is the extent of soil erosion from the study area?
3. What are the factors used for land suitability classification?
4. What is the areal extent suitable for rain fed agriculture and surface irrigation of the study area?

1.5 Significance of the Study

Land suitability evaluation is an important step to detect the environmental limit in sustainable land use planning. Many environmental problems including soil erosion may occur when the land is not used in accordance with its performance. Evaluation of land suitability and soil erosion by using geospatial techniques provide strong decision support for sustainable agricultural development and future planning. The result of the study is expected to have the following significance for administrative manager, planner, policy and decision makers in the study area.

- ➢ Land suitability evaluation identify the main constraints in agricultural production and help land use planners and managers formulate strategies to increase crop productivity and prevent further land degradation caused by improper practices, particularly in sensitive areas (pan and pan, 2012).
- ➢ Proper land suitability evaluation of land resources in irrigation command area is a prerequisite for better utilization and sustain the productivity of these land resources (Kassaye and Gezahegn, 2019) .
- ➢ Land suitability evaluation is important to guide decision makers relative to the future expansion of agricultural land use planning.
- ➢ Land suitability maps provide the necessary information for agricultural planners to reduce soil erosion by formulating sustainable land use.
- ➢ Soil erosion risk map the study area assist the authority in decision making find to a solution of preventing further erosion before turning to no return.

1.6 Scope of the Study

The scope study is geographically bounded in between West Arsi Zone of Oromia Regional state and the Southern Nations Nationalities and People Region (SNNPR) in Ziway/Abijiata basin, Ethiopia. It covers an area of 1603 sq.km (160341 ha). The scope of this study mainly focused on evaluation of land suitability and soil erosion in the district to enhance agricultural productivity. The geospatial technology applied starting from data collection to thematic mapping of agricultural land suitability and soil erosion risk.

1.7 Organization of the Thesis

This study is organized into five chapters. The first chapter contains the background of the study, statement of the problem, general and specific objectives, significance, limitation and scope of the study are represented. The next section of the research paper is chapter two which describes literature review for this study regarding to specific objective of the study. The third chapter focuses on the general methodology followed, the data sets used in the study, and a detailed explanation of the study area. The fourth chapter deals with the result and discussion which presents the quantified results of the research. The last chapter presents conclusion and recommendations this chapter elaborates the key findings and critical points that need further treatment has been forwarded as recommendation for future work and beneficiary.

CHAPTER 2: LITRATURE REVIEW

2. General Overview

Ethiopia historically passed significant dynamics in land use land cover since long time ago. Land use land cover changes and degradation are increasing at alarming rate generally throughout the country. Different studies indicated that land use land cover change triggered by aforementioned factors in the country have led to severe soil erosion, loss of bio diversity, decline of agricultural production and productivity. Improper land use land cover pattern change having significant role in this increased rate of soil erosion in the country. Soil erosion is one of the major factors causing severe land degradation problem in Ethiopia, which in turn is threatening the agricultural productivity and very survival of over whelming majority of the rural population. The rate of soil loss, depletion of soil organic matter and nutrients as a result is so high and much faster than they can be replaced (Israel, 2011). Continuous utilization of agriculture land is the past decades regardless of land suitability caused much more destruction than provide the resources (FAO, 2007). Hence proper evaluation based on agricultural land use planning is essential to solve this problem (Safa and Majed, 2019).

Land evaluation is an interpretation of land properties in terms of suitability of the land for different land use types or crop types (Safa and Majed , 2007).Which is a process of predicting land performance over a time according to the specific types of use (Zonneveld, 1989). The principle purpose of agriculture land suitability evaluation is to predict the potential and limitations of the land for crop production. Land suitability evaluation can contribute towards better land management; mitigation of land degradation; and designing land use pattern that prevents environmental problems through segregation of competing land uses. The output of suitability analyses provided not only the type of land use for which the land was suitable, but also information about the type of limitation facing the utilization of land (Safa and Majed, 2019).

The optimal use of natural resources is very important for environmental sciences. Misuse and inappropriate management of land are the major reasons for soil erosion. Land degradation and soil erosion is a major threat to natural resources. Land suitability analysis proposes the optimal land use opportunities. Reduction and degradation of land necessitates sustainable agricultural practices. One of the best ways to prevent soil degradation is land suitability analysis. Many environmental problems can occur when the land is not used in accordance with its capabilities and properties (Everest and Sungur, 2020). Environmental deterioration has become one of the most serious problems confronting mankind. Soil erosion is one of the major non-point pollution sources (Wang et al., 2002). Therefore, evaluating land suitability for agricultural land use and the extent of soil erosion risk and forwarding possible solution measures which help the future soil conservation and land management efforts in the future (Habtamu, 2018).

2.1 Soil Erosion Risk in Ethiopia

The problem of soil erosion is one of the major environmental constraints to agricultural sustainability and food security in Ethiopia particularly in the highlands. Soil erosion affects 50% of the agricultural area and 88% of the total population of the country (Desalegn et al.,2008). The rain fed agricultural areas of Ethiopian highlands are estimated to lose 940,893,165 t of net soil annually (Hurni et al., 2015b). Due to this, 50 % of the highlands are significantly eroded and causes a land productivity loss by a rate of 2.2 % per year (Greenland and Nabhan,2001). Soil erosion also led to a considerable economic costs and painful environmental impacts through soil nutrient losses (Shiferaw et al., 2009). The overall soil loss of the country is estimated at about 1.5 billion tons per year with a mean erosion rate of 42 t/ha/year. The rate of soil erosion has been accelerating in the country due to land use and land cover (LULC) change and inappropriate land use and management practices (Ajanaw, 2021). According to Bobe (2004) Ethiopia has a total surface area of 111.8 million hectares ; o which 60 million hectares are estimated to be agriculturally productive. Out of these lands, about 27 million hectares are significantly eroded, 14 million hectares are seriously eroded and 2 million hectares have reached the point of no return. By considering the severity of soil erosion and its impacts in the country, it is necessary that appropriate management measures should be taken. Sound knowledge of spatial variation in soil erosion is mandatory when planning conservation efforts (Lulseged et al., 2006).

2.2 Soil Erosion Types

Soil erosion is the removal of soil from the earth surface by erosive agents such as water and wind. Water involves the detachment, transport and deposition of soil particles by erosive forces (Renard et al., 1997). The type of erosion is triggered by anthropogenic causes such as deforestation, slash and burn agriculture, intensive plowing, intensive and uncontrolled grazing, and biomass burning. The potential for soil erosion varies from watershed to watershed depending on the configuration of the watershed (topography, shape), soil characteristics , local climatic conditions, land-use and management practices implemented on watershed (Surase,2000; Arora, 2003).

Soil erosion by running water has been recognized as the most severe hazard threatening the protection of soil as it reduces soil productivity by removing the most fertile topsoil. It is accounted that loss of topsoil and terrain deformation due to soil erosion are the consequences of deforestation, removal of natural vegetation and overgrazing in the mountainous region (Shrestha, 1997). Soil erosion by water occurs in various forms such as splash, sheet, rill, gullies. Depending on the stage of progress in erosion cycle and the position in the landscape some of the types of erosion are discussed in below:

2.2.1 Rain splash erosion

The erosion due to the impact of falling raindrops on soil surface leading to the destruction the crumb structure is known as the raindrop or splash erosion. Rain splash erosion is the result of water falling directly on the ground during rainstorms or when it is intercepted by the canopy and finds its way to the ground (Morgan ,1995). Some of the water infiltrates in the soil, while some water stays on the surface saturating and weakening natural soil aggregates so that the impact of subsequent raindrops breaks them down. Splash erosion is caused by the bombardment of soil surface by impacting raindrops (Tesfaye ,2015).

2.2.2 Sheet erosion

Sheet erosion occurs as a shallow ‘sheet’ of water flowing over the ground surface, resulting in the removal of uniform layer of soil from the soil surface. Although often difficult to recognize, sheet erosion is responsible for extensive soil loss in both cultivated and non-cultivated environments. Raindrops detach the soil particles, and the detached sediment can reduce the infiltration rate by sealing the soil pores. The eroding and transporting ability of overland flow depends on the rainfall intensity, infiltration rate, slope steepness, soil properties, and vegetative cover (Fangmeier et al., 2006).

2.2.3 Rill erosion

Rill erosion is the detachment and transport of soil by concentrated flow of water. Rills are eroded channels that are small enough to be removed by normal tillage operations. Rill erosion is the predominant form of surface erosion. Rill initiated at a critical distance down slope where surface runoff concentrates and becomes channeled. These channels are called rills when they are small enough to not interfere with field machinery operations. The water in a rill has sufficient depth for turbulence to develop in it and therefore entrain large particles (Morgan, 1995).

2.2.4 Gully erosion

Gully erosion produces channels larger than rills. There ephemeral channels carry water during and immediately after rains. Gullies are distinguished from rills in that gullies cannot be obliterated by tillage. The amount of sediment form gully erosion is usually less than from upland areas, but the nuisance from having fields or developed areas divided by large gullies is often a greater problem (Fangmeier et al., 2006). The rate of gully erosion depends primarily on the runoff-producing characteristics of the watershed, the drainage area, soil characteristics, the slope in the channel, and the alignment, size and shape of the gully (Bradford et al., 1973).

2.3 Factor Affecting Soil Erosion

The process of soil erosion and nutrient losses in agriculture are extremely dynamic and complicated, which are affected by many factors such as vegetation cover , agricultural practices, rainfall characters, topography, land use land cover and management are considered to be the most important factors influencing soil erosion.

2.3.1 Climatic factor

Rainfall is the most important climatic factor in determining areas at risk of land degradation and potential desertification. Which plays a vital role in the development and distribution of plant life, but the variability and extremes of rainfall can led to soil erosion and land degradation. The frequency, intensity and duration of rainfall are fundamental factors that determining the amount of runoff produced in given area. As both the volume and velocity of runoff increase, the capability of runoff to detach and transport soil particles also increases. Where storms are frequent, intense or of long duration, erosion risk as high. Seasonal changes in temperature, as well as rainfall influence the erosion risk.

2.3.2 Soil factor

Soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Soils high in clay have low K values, because they are resistant to detachment. Coarse textures soils, such as sandy soils also have low k values, because of low transportability even though these soils are easily detachable. Medium textured soils, such as silt loam soils, have a moderate k values, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having high silt content are the most erodible of all soils as they cause a decrease in infiltration (Saavedra, 2005).

2.3.3 Topography

The size, shape and slope characteristics influence the amount and rate of runoff. As both slope length and gradient increases, the capability of runoff to detach and transport soil particles also increases. Where storms are frequent, intense, or of long duration, erosion risks are high. Erosion would normally be expected to increase with increase in slope steepness and slope length as a result of respective increases in velocity and volume of surface runoff (Doere, 2005). Steeper terrain slopes cause higher runoff velocities, more splashes downhill and faster flow and therefore contributes greater soil erosion. Erosion only doubled for a steepness change from 2-20% and the erosion rate tends to level off (Remortel et al., 2001).

2.3.4 Ground cover factor

Land use and management influence the magnitude of soil loss. Among the different soil erosion risk factors, the cover-management factor is the one that policy makers and farmers can most readily influence in order to help reduce soil loss rates (Panos, 2015). Groundcover vegetation management has proven to be an effective means to limit soil erosion (Mansheng, 2020). It indicates how the cover of the land ,crops land uses and crop management systems determines soil loss instead of losses from bare fallow areas (Haregeweyn et al., 2017). It is the effect of vegetation canopy and ground cover in reduction of soil erosion (Renard et al., 1997).

2.3.5 Conservation practice factor

Conservation practice factor determine the effects of land conservation practices in minimizing the quantity and rate of rainfall runoff and soil erosion (Wischmeier and Smith, 1978). The conservation practices such as contouring, strip cropping and terracing reduce soil losses. For instance, in areas where there is terracing, runoff speed could be reduced with increased infiltration, ultimately resulting in lower soil loss and sediment delivery. The effectiveness of such practices is often analyzed with a support practice factor which is defined as the ratio of soil loss with practice applied and up and down slope cultivation (Wischmeier and Smith, 1978; Renard et al., 1997). The conservation practice factor has been assigned to land-use classes using ranges from 0 to 1 (Kalterieder, 2007).

2.4 Soil Erosion Models

Soil erosion is a significant problem worldwide for most of the agro-ecosystems because it is one of the primary causes of soil degradation as a result of detachment and loss of topsoil layer and soil organic matter, which are essential for plant development. Quantification of soil loss related to soil and crop management, climate, and soil conditions has, therefore, become a serious concern for water and soil conservation practitioners, as well as decision makers concerned with food security and agricultural policies. Soil erosion is the process of detachment and transportation of soil particles involving various erosive agents from the earth’s surface. Categorized into wind and water erosion, water erosion is a much more complex process and leads to substantial loss of soil and sedimentation. Water erosion is mainly affected by rainfall/runoff intensity, vegetation cover, soil edibility, topography, and land use management practices (Ahsan and Hella, 2021).

Modeling soil erosion is the process of mathematically describing soil particle detachment, transport and transport and deposition on land surfaces. There are at least three reasons for modeling erosion: (a) erosion models can be used as predictive tools for assessing soil loss for conservation planning, project planning, soil erosion inventories and for regulation; (b) physically-based mathematical models can predict where and when erosion is occurring, thus helping the conservation planner target efforts to reduce erosion; (c) models can be used as tools for understanding erosion processes and their interactions and for setting research priorities (Nearing et al., 1990). Over the years various soil erosion models have been developed. The application of these models is dependent on the soil type and climate of the given area because models differ in complexity and input requirements (Igue and Chinedu, 2017). Soil erosion models fall into three main categories, depending on the physical process simulated by model, the model algorithms describing these processes and the data dependence of the model: Empirical or Statistical; Conceptual; and Physics based models(Merrit,Letcher, and Jakeman, 2003).

2.4.1 Empirical model

Empirical soil loss models are relatively simple and have been applied in many parts of the world. These empirical models are modeling techniques or frameworks, rather than mechanistic descriptions of the system and should , therefore, make no claim of universality(Smith, 2013). These models relate input to output through some transformation function. Among the commonly used empirical erosion models include the Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE) and the soil Loss Estimation Model for South Africa (SLEMSA), RUSLE is the empirical model that has been most widely used and generally accepted by the natural resources community because it is relatively easy to use(Saavedra, 2005).

2.4.2 Conceptual models

Conceptual models play an intermediary role between empirical and physical based models. Whilst they tend to be aggregated, they still reflect the hypotheses about the process governing system behavior. This is the main feature that distinguishes conceptual model from empirical models (Beck, 1987). According to Renschler (1996), conceptual models tend to include a general description of catchment processes, without including the specific details of process interactions, which would require detailed catchment information. This allows these models to provide an indication of the qualitative and quantitative effects of land use changes, without requiring large amount of spatially and temporally distributed input data(Merritt et al., 2003).

2.4.3 Physically based model

Physically based models are generally the most scientifically robust and flexible in both input and output and are based on an understanding of the physical processes that cause erosion and are therefore applicable to wide range of soils, climatic and land use condition (Lily, Grieve, Jordan, Baggaley, Birnie, Futter, Higgins, Hough, Jones, Noland, Stutter and Towers, 2009). They further asserted that this however, means that they are often difficult to parametise. Similarly, Gnasri and Ramesh (2016) agreed that physically based models are data intensive and amount of data needed is not readily available.

2.5 Revised Universal Soil Loss Equation

Potential soil loss estimation was carried out using widely used and evaluated soil erosion mode, which was first developed as USLE (Wischmeier and Smith 1978) and modified into RUSLE (Renard et al., 1997). It was also adapted and most of the variables calibrated by Hurni (1985) in the Ethiopian highland condition. In data scarce area for validation of models, it is suggested to be cost effective soil erosion estimation method for effective conservation planning(Haile and Fetene 2012; Prasannakumar et la., 2012). Erosion models can be used as predictive tools for assessing soil loss, conservation planning, soil erosion inventories and project planning. Moreover, they can be used as tools for understanding erosion process and their impacts (Nearing et al., 1994)

The Revised Universal Soil Loss Equation (RUSLE) is and empirical erosion model recognized as a standard method to calculate the average risk of erosion on arable land. Several soil erosion models exist with varying degrees of complexity. RUSLE model is an important model for Agricultural decision support system in soil conservation and land use planning. It uses a set of mathematical equation to describe ecological processes related to conservation practices and erosion in a given landscape (Rafael, 2019). The RUSEL computes soil erosion by taking into consideration several determining factors, such as the soil erodibility factor, rainfall intensity factor, slope length and steepness factor, cover and management factor and support practice factor (Israel , 2011). The RUSLE soil loss estimation model equation is given below(Equation 1)

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

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

2.6 Role of Geospatial Technology for Soil Erosion Model

Geospatial technology is an emerging field of study that includes GIS, RS and GPS enables us to acquire data that is referenced to the earth and use it for analysis, modeling, simulations and visualization. Geospatial technology allows us to make informed decisions based on the importance and priority of resources most of which are limited in nature. Geospatial technology may be used to create intelligent maps such as soil erosion risk maps. Geospatial technologies are important tools in assessing the extent and the severity of land degradation and soil erosion and their temporal changes, and geospatial distribution in a timely and cost effective manner (Dwivedi, 2019).

2.6.1 Remote Sensing

The technology of Remote Sensing widely used since the 1990s in the study of erosion processes. Due to the variety of sensors on spacecraft, which are orbiting the earth, remote sensing makes an important contribution to erosion estimation at different spatial levels (Dhakal et al., 2002; Lu et al., 2007 ; Prince et al., 2009; Serveny and prat, 2003). Several methodologies, which are used to monitor erosion, include spectral data (Lu et al., 2007).

Remote sensing data is an important source of information for mapping, monitoring and predicting soil erosion. With the help of remote sensing of the Earth, you can quickly get information about the development of erosion processes, to observe them both at a specific moment and dynamics over time. The main advantages of remote sensing are speed, accuracy and price. The remote sensing based methods provide a cost-effective way to investigate soil erosion where there are no accessible territories or direct field methods are expensive. Remote sensing images give information about the set of erosion factors of topography, soils , vegetation, land use. Terrain characteristics can be obtained from digital elevation models created by satellite image processing, such as ALOS, SRTM, ASTER and GDEM. On this basis, the slope and shape of the slope profile, aspect of slope, slope length of the earth's surface can be calculated. To assess the condition of vegetation cover and its impact on the development of erosion, it is necessary to classify a satellite image to determine the types of land use (Lukyanchuk and Pidkova, 2020).

2.6.2 Geographic Information System

GIS often focus on the capture, storage, manipulation analysis and display data. Which imply that designed to support spatial decision making for many spatial problems. GIS became a very important factor in soil erosion studies and consequently in the development of appropriate soil conservation strategies. Each of the RUSLE factors with associated attribute data is digitally encoded in a GIS database to eventually produce five thematic layers. There are then spatially overlaid to produce a resultant polygonal layer. Application of the RUSLE model to the resultant layer yields a soil erosion map.

2.7 Land Suitability Evaluation

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process and procedure used to establish the suitability of land. It involves evaluation of the criteria ranging from soil, terrain to socio-economic and infrastructure. Land suitability evaluation is a GIS-based process applied to determine the suitability of a specific area for considered use, i.e. it reveals the suitability of an area regarding its intrinsic characteristics (suitable or unsuitable). Also this analysis involved with considering wide ranges of criteria including environment, social and economic factors. Appropriate handling of such broad and heterogeneous maps requires applying a flexible tool. The spatial Analytical Hierarchy Process (AHP) was introduced by Saaty in the in the mid1970s and developed in 1980s is among the best methods of Spatial Multi Criteria Analysis (SMCA) with GIS is a new trend in land suitability analysis. As environmental resource planning and management point of view the AHP is among the fastest growing decision-analytic techniques (Sudabe and Narges, 2010).

The process of land suitability classification is appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976). FAO (1976) Suitability classes shown in table 2.1.

Table 2.1 FAO Suitability class

Suitability classes	Description
Highly Suitable (S1)	Land having no significant limitation to sustained application for a given land use or only minor limitations that will not significantly reduce productivity or benefits and will not raise input above an acceptable level.
Moderately Suitable(S2)	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits are increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive ,will be appreciably inferior to that expected on class S1 land.
Marginally Suitable (S3)	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
Class N1 Currently Not suitable:	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of land in the given manner.
Class N2 permanently Not Suitable:	Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

2.8 Role of Geospatial Technology for Land Suitability Evaluation

The geospatial technology of satellite remote sensing (RS) coupled with geographical information system (GIS) and Global Positioning System (GPS) provides a powerful tool, not only to monitor natural resources in terms of relevant, reliable and timely information and environmental changes but also permits to study and analyze the information of other environment variables. A number of studies, carried out worldwide, demonstrate the capability of remote sensing and GIS in development planning. The RS and GIS give quicker and cost effective analysis for various applications with accuracy for planning and give a better perspective for understanding the problems and therefore helps planner to evolve a better solution for sustainable development (Erika and Silva, 2020).

CHAPTER 3: MATERIALS AND METHODS

This section explains the whole plan of the study to achieve the objective of the research .Which include the tools, techniques and data organization method employed in the research. Study area also described under this chapter.

3.1 Description of Study Area

3.1.1 Location

The study was conducted in Arsi Negele district found in Ziway/Abijata Watershed. The administrative boundary situated in West Arsi Zone of Oromia Regional state and the Southern Nations Nationalities and Peoples Region (SNNPR), Ethiopian rift valley system. The capital center of the district Negele town is located 225 km away from the capital city of Addis Abeba, Ethiopia. The geographical coordinates of the district ranges from $7^{0}08^{'}00^{''}$ N to $7^{0}49^{'}00^{''}$ latitude and $38^{0}24^{'}04^{''}$ E to $38^{0}48$’09’’ E longitude with the total area of 1603 sq.km.

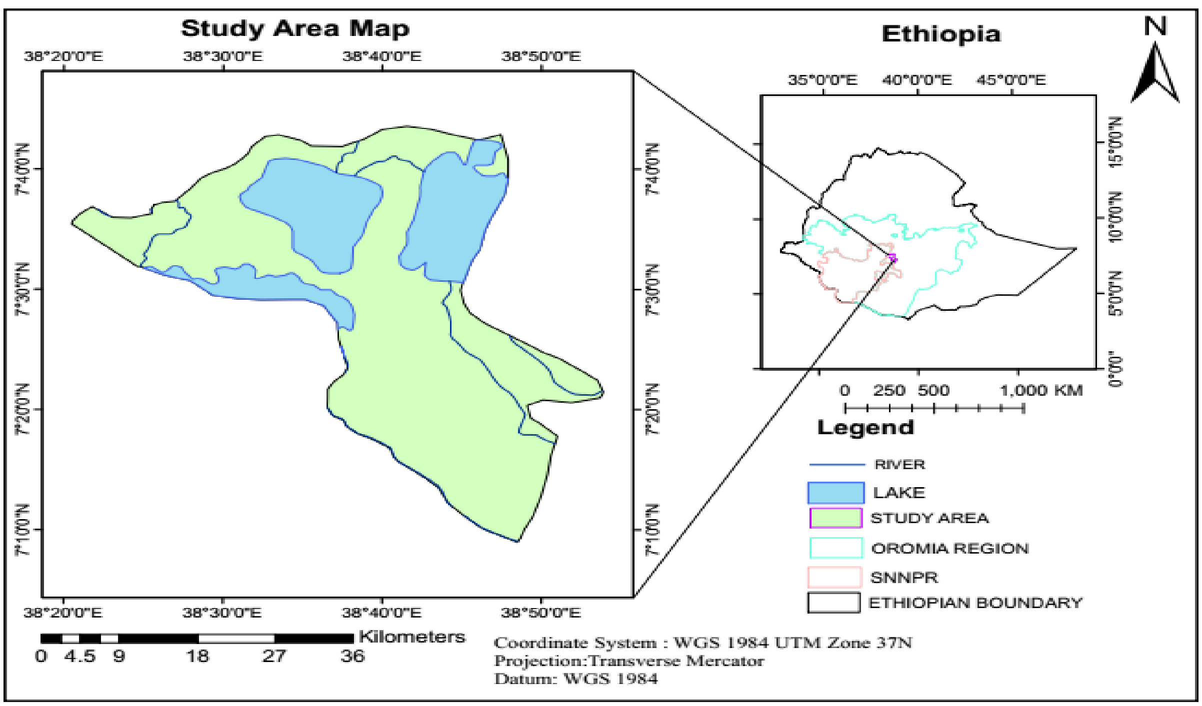

Figure 3.1: Location map of study area

3.1.2 Climate and Topography

Temperature and rainfall are the most important climatic factor for agricultural production of Ethiopia. Altitude is one of the major factor that determine the distribution of climatic factors and land suitability; This influences the crops to be grown, rate of crop growth, nature of vegetation types and their species diversity. The annual temperature of the study area varies from 10^0c – 25^0c with annual rainfall between 500 – 1000 mm. The altitude ranges from 1500 to 3000 masl. (low land < 1600 m with semi-arid climate, midland 1600 – 2200 m with mild climate and highland > 2200 m with cold climate).

The topography of the study area slightly undulating in the highland area. The altitude of the district ranges between 1500 – 3095 m above sea level. Gera Duro is the highest peak in the district with an altitude of 3095 m above sea level.

3.1.3 Land use

The total area of Arsi Negele district is about 160341 ha (1603 sq.km). Based on LULC classification of 2020 for this study larger portion of the district covered by Agricultural land and Water body. Which covers 23.9% (382 km^2) and 23.7 % (381km^2) respectively. Arsi Negele has the highest number of rivers and lakes in the zone.

Table 3.1: LULC class and their area coverage

LULC Class	**Area (km^2)**	**Area (%)**
Settlement	91	5.7
Forest	165	10.3
Shrub Land	183	11.4
Wet Land	208	12.9
Bare Land	126	7.9
Salt Pan	67	4.2
Water Body	381	23.7
Agriculture	382	23.9

3.1.4 Population

According to national census report in 2007 the total population of the district is 264,314 out of total population 52,329 people lived in urban area and 211,985 peoples lived in rural areas. About 130,998 male and 133,316 female lived in the woreda. In 2017 national census population project the total population of the district increased from 264,314 to 337,918, out of Which 63,180 (18.3%) of the population lived in rural area.

3.1.5 Agriculture

The administrative woreda is dependent on both the Belg and Meher seasons. According to the available data from the department of agriculture, The major crops cultivated during the short rain (Belg) season in order of importance are Maize, Teff, Sorghum and cash crops such as Potatoes, Onion and Cabbages . While during the main rain (Meher) season the most important cultivated crops are Sorghum, Teff, Maize , Wheat, Barley and Beans. The woreda has also benefited from irrigated crop production (Debella, 2014).

3.1.6 Soil type

Soil is defined by (Davidson, 1980) as natural body consisting of layers of horizons of mineral and organic constituents of variable thickness. Which differ from the parent material in their morphological, physical, chemical and their biophysical characteristics. The soil prevailing in the study area classified into 10 based on MOA of Ethiopia.

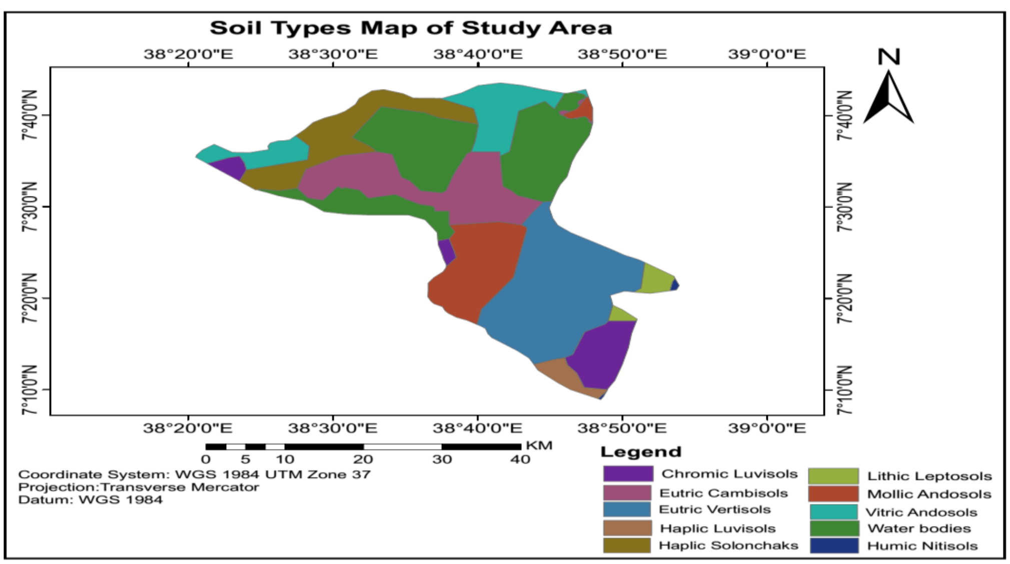

Figure 3.2 Soil Types in the study area

Table 3.2: Soil Types with area coverage

No.	MOA Soil Type Name	Description	Area (km^2)	Area (%)
1	Eutric Vertisols	Moderately poor drainage of the soils require drainage improvement to remove excess water during the rainy season (Tebebu, 2014).	360	22.5
2	Eutric Cambisols	Cambisols are important agricultural soil and well suited almost for all perennial and cereal crops(Tibebu,2014).	229	14.3
3	Mollic Andosol	This type of soils are fertile and well-drained soil (Jaetyold and Schmidt,1993)	169	10.6
4	Haplic Solonacks	Commonly had high salt content in some part or all of the control station (FAO, 2001).	158	9.63
5	Vitric Andosols	Vitric Andosols soil type is probable in location on volcanic ejected material having an abundance of volcanic glass.	146	9.1
6	Chromic Luvisols	This type of deposits of lime stones weathering, the lower slopes are commonly sown to wheat and upper slopes are in use for extensive grazing or planted tree crops (FAO,2001)	99	6.32
7	Haplic Luvisols	Haplic Luvisols is dominated by organic mineral under composed and partially decomposed.	28	1.65
8	Lithic Leptosols	This type of soils are limited in depth by continuous hard rock with in 10cm of the surface (FAO and UNESCO, 1988).	25	1.7
9	Humic Nitisols	This type of soil have relatively high contents of weathering mineral and surface soils may contain several percent of organic matter in particular under forest or tree crops (FAO ,2001)	5	0.25
10	Water body	Lake and rivers	384	23.95

3.2 Data Source and Material Used

This study incorporates the assembly of both spatial and non-spatial data from actual fieldwork and secondary data from different sources. Table 3.3 shows general description of the data source.

Table 3.3: Data Source

S.NO	Data	Source	Data type	Cell Size	Purpose
1	Sentinel 2A,(2020)	USGS http://earthexplorer.usgs.gov/	Tiff	10 m	For land use land cover classification
2	DEM (2020)	ALSOPALSAR http://search.asf.alaska.edu/	Raster	12.5 m	Slope Elevation Slope length and slope steepness (LS factor) Flow Accumulation Water Shed delineation
3	Soil Data	Agricultural Transformation Agency (ATA) Ministry of Agriculture (MOA) Harmonized world soil data base (https://iiasa.ac.at/)	Shape file ,Excel and Raster		Soil Physical and Chemical Property For Soil Erodibility (K) factor
4	Hydrology data, Study Area Boundary and LULC classification ,2018	Geospatial information institute	Shape file		For river distance from Agricultural land and Accepted study area boundary For the base of current LULC classification
6	Meteorological data	National metrology Agency (NMA) Power Access Climate Data https://Power.larc.nasa.gov/	Excel data		For rainfall erossivity factor (R) For Mean Annual rainfall map For mean annual temperature map

Materials used to conduct this research as shown in table 3.4

Table 3.4: Materials Used

S.NO	Description	Purpose
1	ENVI 5.1	For radiometric calibration and atmospheric correction
2	ERDAS IMAGINE 2015	For image mosaicking, layer stacking and layer extraction.
3	ARC GIS 10.8	For data analysis, processing, calculating and classifying the necessary information of each thematic layers .
4	Arc Hydro Toolbox	For Flow direction, Flow Accumulation and Watershed delineation
5	Ext AHP 20 (Analytical hierarchy process for ARC GIS) tool	To perform criteria weight determination of the well known AHP.
6	Google earth	Used for visual interpretation tool for Accuracy assessment for LULC classification
7	Microsoft Word and Excel	Integrating attribute data and compositing final thesis

3.3 Data Collection Methods

To achieve the objective of this research, Secondary data such as satellite image, boundary of the study area and soil data were collected from different governmental organization used to assess land suitability for agricultural use. In addition, previous reports and documents, various journal papers, thesis, textbooks and Internet were also used as secondary data.

3.4 Data set preparation

Table 3.5 Data Set

Input data	Software	Process	Output
Sentinel 2A 2020	ENVI 5.1	Radiometric calibration and atmospheric correction	Calibrated and corrected image
Calibrated and corrected Sentinel 2A 2020	ERDAS IMAGINE 2015	Supervised Classification	LULC map
DEM	ARC GIS 10.8	Slope extraction	Slope
		Flow Accumulation	LS factor Watershed delineation
LULC Map	ARC GIS 10.8	Standardizing	C factor P factor
Soil data	Arc GIS 10.8	Interpolation and clipping	Soil map K factor map
Meteorological Data	ARC GIS 10.8	Interpolation and clip	Precipitation map Temperature map R factor map

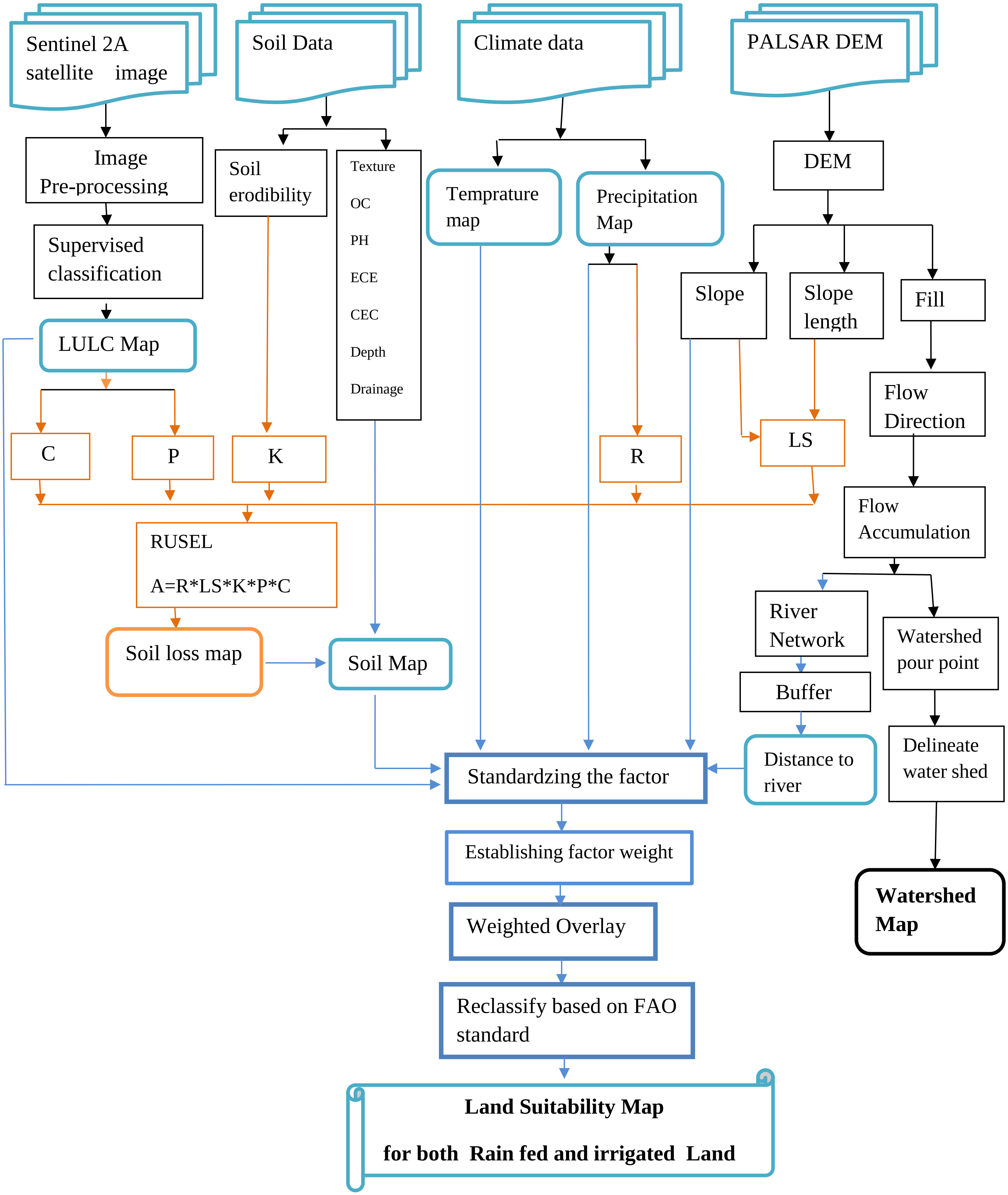

Figure 3.3: Methodological flow chart of the study

3.5 Data Analysis Methods

The process of standardizing, classifying and calculating the necessary information of each thematic layer for land suitability evaluation and soil loss risk is based on the procedure of FAO 1976 and RUSEL model. This study comprises the following five steps .The information acquired in one step of process was used as an input for the next step.

1. Identification of major factor that affect agricultural land quality and soil erosion.
2. Accessing data from which the major factor can be derived.
3. Standardizing and calculating each factor based on the model requirement
4. Rating each factor based on their influence for land quality for agricultural use
5. Combining each factor by weight overlay and map algebra raster calculator for land suitability evaluation and soil loss risk respectively.

Standardization of each factor and rating of the most influential factor is based on literature review, personal discussion with experts and nature of study area and FAO 1976 and FAO 2007b guideline. The method used in the study are summarized in the flow diagram as shown in figure 3.6

3.5.1 Image pre-processing

Radiometric calibration and atmospheric corrections are essential before any processing to reduce data uncertainty due to measuring instruments and atmospheric perturbations. Without these operations, the changes caused by artifacts relative to the sensor can be mistakenly attributed to changes in the land use and ground biophysical components. Consequently, errors can propagate in all subsequent steps taken during image processing and classification (Myneni and Asrar 1994;Bannari et al. 1999;Pahlevan et al . 2014;Vanhellemont and Ruddick 2014).The satellite image of Sentinel 2A having 10 m resolution acquired in December 14 , 2020 image were radiometrically calibrated to correct radiometric anomalies specific to the sensor atmospheric effect and geometric distortion to correct and enhance the image spectral quality by using ENVI 5.1 software .The image mosaicking and creating subset is took place in ERDAS IMAGEN 2015 software .

3.5.2 Land use land cover classification

According to FAO(1976) , for land evaluation and delineation the current land use boundary is the first step. land type is a kind of land use described in terms of its products and management practices (FAO,1996) .The current land use land cover was determined from the preprocessed Sentinel 2A image and classified by using supervised classification method with the support of less cloud cover Google earth image in ERDAS IMAGINE 2015 software. The study analysis classified the image into eight land cover type. The current land use land cover classification of the study area is based on Ethiopian geospatial institute LULC classification in 2018 and reconnaissance field observation. It supports to decide the LULC class during collecting signature from each class in supervised image classification. The major LULC type in the study area with their description shown in table 3.6

Table 3.6: Land use land cover class description

S.NO.	**Land cover type**	**Description**
1	Agricultural land	Area covered with perennial and annual crops
2	Water body	All water bodies including lakes ,river and stream
3	Wet land	Having hydrological condition and vegetation community
4	Forest	Dense forest
5	Bare land	Open space with no vegetation ,bare rocks, limestone, sand stone and gravel
6	Settlement	The land covered by residential, commercial and industrial areas and buildings.
7	Salt pan	Covered with salt and other minerals usually shining white under the sun
8	Shrub land	Areas covered with small tress, wood land and bushes

3.5.3 Accuracy assessment

Accuracy assessment is an important part of LULC classification. It compares the classified image to another data source that is considered to be accurate or ground truth data. When ground truth data is time consuming or expensive the data can be derived from interpreting high-resolution imagery. The most common way to assess the accuracy of a classified map is to create a set of random points from the ground truth data and compare that to the classified data in a confusion matrix. The classified land use land cover map typically evaluated by accuracy assessment by using ground truth data.

3.6 Soil Erosion Risk Analysis

This study uses RUSLE model in GIS environment to estimate annual soil loss of the study area. The control factors of soil erosion ,namely: climate, soils, vegetation cover, topography and management are combined in the empirical Revised Universal Soil Loss Equation(Renard et al., 1997).Each factor was calculated by means of ARC GIS 10.8 software.

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

Where A is the mean annual soil loss per unit area(ton/ha/year), R is the rainfall and runoff erosivity factor in mm, K is the soil erodibility factor, LS is the slope length and slope steepness factor without dimensions, C is the land cover management factor without dimensions; and P is the support practice factor without dimensions.

Erosion is correlated with many factors such as topographic parameter, LULC, climate condition and soil .The soil reduction due to erosion adversely affects the efficiency of the soil(Montgomery, 2007).Erosion causes soil loss ,degradation of soil structure , decreases in organic matter , plant nutrients and soil depth(Pimentel et al. 1995). Soil depth rapidly decreases when the intensity of erosion increases. Erosion can be very intense in some areas and soil completely reduces and the bedrock appears (Altinbas, 2006).

3.7 Determining RUSLE Factors

Five major factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location .that can vary considerably due to varying weather conditions. The erosion values reflected by these factors can vary considerably due to varying weather conditions. The RUSLE model was originally not intended to be used for a large area (Mati et al., 2000).

3.7.1 Rainfall erosivity (R factor)

The rainfall erosivity factor describe the rain effect as well as the amount and rate of rainfall for soil erosion risk. The input rainfall data should be for a period of 20 years (Renard et al.,1997).According to Equation (1) suggested by Hurni.H,1985 applicable for Ethiopian case of annual precipitation (mm/year) can be calculated from:

$$R = 0.55 * MAP - 24.7 \qquad (2)$$

Where: R is rainfall erosivity factor is calculated in mm, MAP is mean annual precipitation was estimated from metrological data. In this study eleven rainfall meteorological stations rainfall data were used to estimate the mean annual precipitation data two of the station found inside the district and other nine stations were outside the study area. Inverse Distance Weighted (IDW) interpolation technique was done based on distance between the point to be estimated and the measured point in ARC GIS 10.8 software. The mean annual precipitation was calculated from the period of 1997-2017 .Table 3.7 shows the mean annual rainfall from period 1997-2017 and their station.

Table 3.7: Mean Annual Precipitation in mm

Station	Latitude	Longitude	Elevation	MAP(mm) 1997 – 2017
1	7.25271	38.78981	2217.09	1274.75
2	7.51621	38.64561	1952.3	1055.507
3	7.32461	38.46661	1914.25	1305.693
4	7.33011	39.11751	2628.82	1162.272
5	7.55891	39.09011	2396.45	948.3762
6	6.63341	39.06731	2425.88	1348.58
7	7.83771	38.44931	2159.53	1268.537
8	8.12331	38.16361	2306.68	1059.11
9	8.05531	38.57561	1961.06	873.8238
10	7.36811	37.92191	1807.46	1499.914
11	7.41171	38.09221	1914.25	1305.693

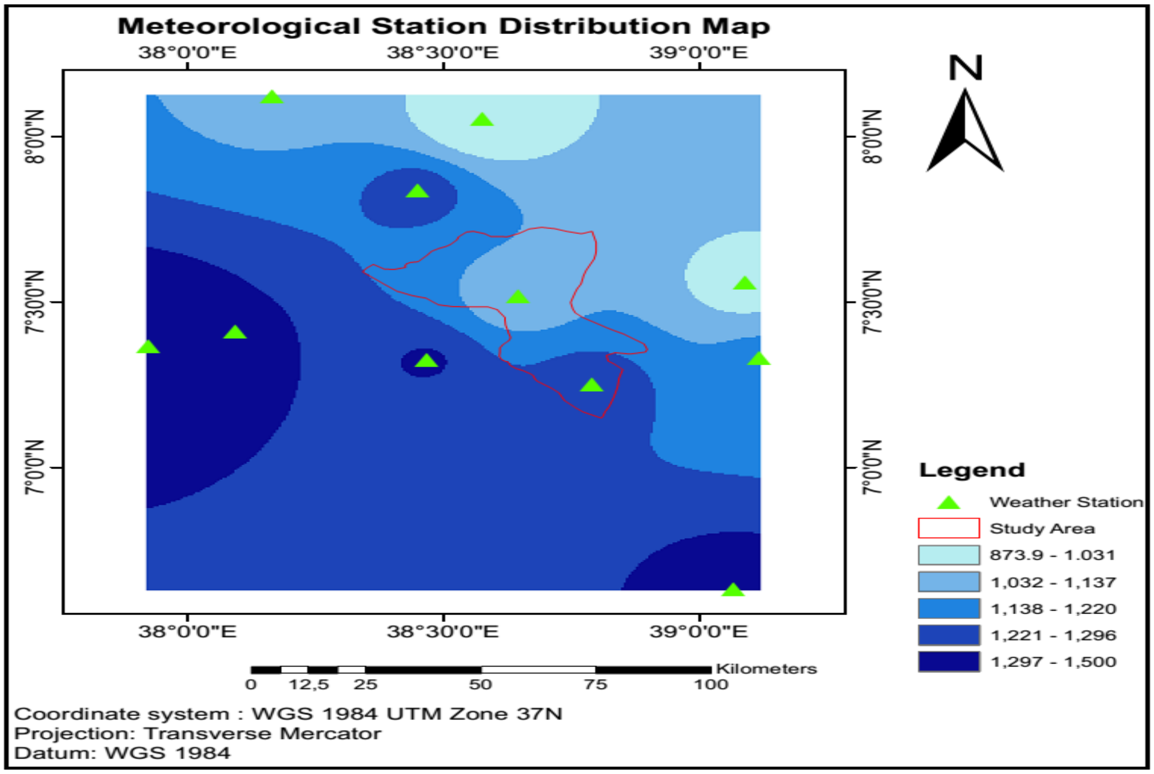

Figure 3.4: Spatial distribution of meteorological station and Interpolation map

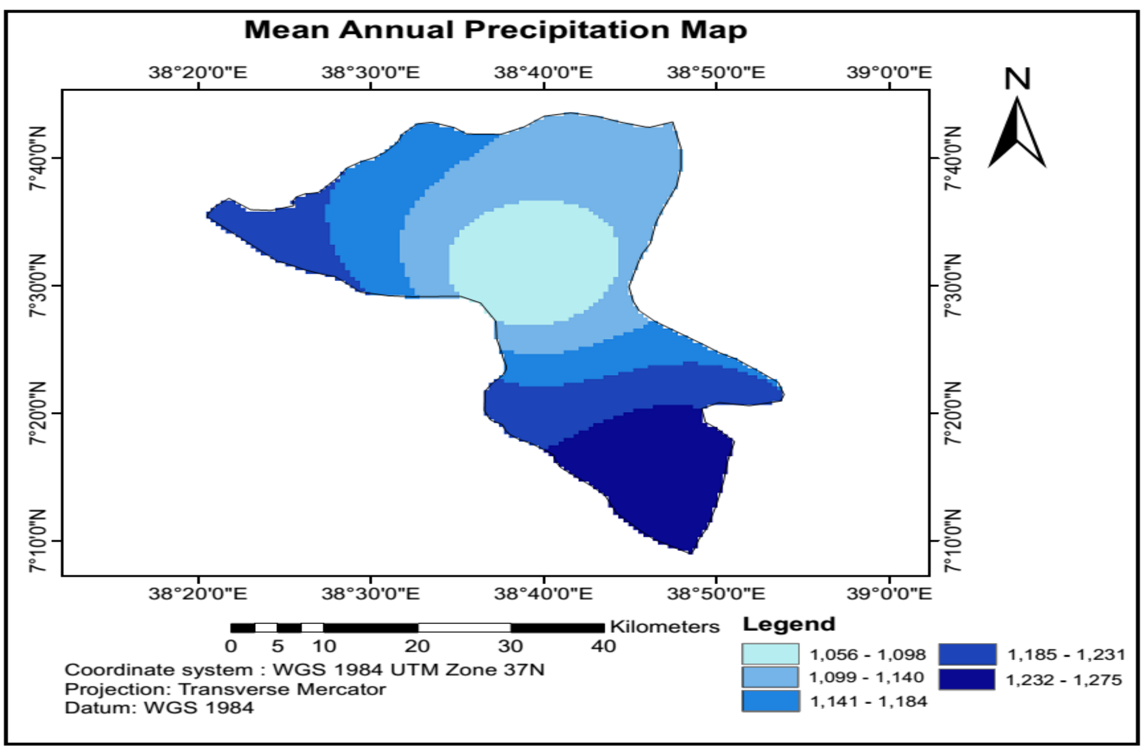

Figure 3.5: Mean annual precipitation (MAP) map of the study area

3.7.2 Soil erodibility factor

Soil erodibility factor (K) is the sensitiveness of soil to erosion (Konstantinos, 2019). Soil erodibility is related to the integrated effect of rainfall, runoff, and infiltration on soil loss and is commonly called the soil erodibility factor (K) is RUSEL accounts for the influence of soil properties on soil loss during storm events on upland areas(USDA-ARS,2001).

The most accurate way to estimate the K factor is by field measurements and for more than one year .However, direct measurements on the field for the K factor are not efficient since it is an expensive, time-consuming process and spatially variable(Wischmeier et al ., 1978). There are many equations for the calculation of the K factor (Wischmeier et al.,1978;Renard et al., 1978;David 1998;El-Swaify et al., 1976). This study employed by using williams (1995) and FAO soil to estimate k factor.

$$K = f_{csand} * f_{cl\text{-}si} * f_{org}C * f_{hisand} \quad (3)$$

Where,

f_{csand} is a factor that gives low soil erodibility factors for soils with high coarse-sand contents and high values for soils with little sand,

$$f_{csand} = (0.2 + 0.3*\exp[-0.256.m_s * (1-m_{silt}/100)]) \quad (4)$$

$f_{cl\text{-}si}$ is a factor that gives low soil erodibility factors for soils with high clay to silt ratios,

$$f_{cl\text{-}si} = (m_{silt} / m_c + m_{silt})^{0.3} \quad (5)$$

$f_{org}C$ is a factor that reduces soil erodibility for soils with high organic carbon content

$$f_{org}C = \left(\mathbf{1} - \frac{\mathbf{0.0256} * \boldsymbol{orgC}}{\boldsymbol{orgC} + \mathbf{exp}[\mathbf{3.72} - \mathbf{2.95} * \boldsymbol{orgC}]}\right) \quad (6)$$

f_{hisand} is a factor that reduces soil erodibility for soils with extremely high sand contents.

$$f_{hisand} = (1-0.7*SN/ SN + \exp (-5.51+22.9\ SN)) \quad (7)$$

Where, $SN = (1 – m_s /100)$ (8)

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 on the top soil.

The calculated K factor should be converted to raster format in ARC GIS 10.8 in order to use it as an input of RUSEL equation. Based on Equations the K factor from FAO soil of the study area calculated by using the parameters of f_{csand}, $f_{cl\text{-}si}$, f_{orgc} , f_{hisand} and K factor shown in the table 3.8

Table 3.8: K factor value of the study area

Soil unit symbol (FAO soil)	San%	Silt%	Clay %	OC %	f_{csand}	f_{cl_si}	f_{orgC}	f_{hisand}	K_Factor
NE	68.4	10.5	21.2	0.6	0.2	0.717859	0.997987	0.962738	0.137944
XH	54.8	20.6	24.9	0.53	0.200004	0.788418	0.998521	0.997509	0.157062
AF	61.7	14.4	23.9	0.91	0.2	0.745674	0.993749	0.989864	0.146701

3.7.3 Slope Length and Slope Steepness (LS) factor

The topographic factor reflect the effect of topography on erosion. The slope length factor (L) represents the effect of slope length on erosion and the slop steepness factor (S) reflects the influence of slope gradient on erosion (Lu et al., 2004).The specific effects of topography on soil erosion are estimated by the dimensionless LS factor as the product of the slope length (L) and slope steepness(S) constituents coverage into a point of interest (Geyahegn and Anteneh,2018).In USLE and RUSLE, the method of slope length calculation was with the notion that the longer the slope, the higher the soil loss without considering the three dimensional complex nature of terrain(Robert & Hillborn, 2000). However, other researchers' claimed that soil loss does not depend on slope length for three dimensional complex terrain where there is flow convergence and divergence, instead it is influenced by upslope contributing area. Thus, it should by upslope contributing area (Desmet & Govers, 1996a;

Moore & Burch, 1986a, 1986b; Mitas & Mitasova, 1996; Simms, woodroffe, & Jones, 2003). Thus, it is helpful to consider the three dimensional complex terrain geometry as well the upslope contributing area to better comprehend and spatial distribution of soil erosion and deposition process. This study therefore employed the following advanced LS factor computation method based on up slope contributing area suggested by (Desmet & Govers, 1996a; Moore and Burch, 1985, 1986, 1992; Mitasova & Mitas, 1999; Simms et al., 2003). This study employed the equation of Mitasova and mitas (1999) and Simms et al.,(2003) in equation (8).

$$LS = (As/22.13)^{0.6} (\sin\beta /0.0896)^{1.3} \qquad (8)$$

Where LS is slope steepness-length factor, the upslope contributing area per unit width of contour drains to a specific point (flow accumulation *cell size), and β is the slope angel. The 12 m spatial resolution resolution PALSAR DEM was employed to map the flow accumulation and slope gradient of the study area. Arc GIS 10.8 raster calculator using the map algebra expression in equation (9) suggested by Mitasova and Mitas (1999) and Simms et al., (2003).

POW ([flow accumulation] * cell size / 22.13, 0.6)*POW (sin([slope]*0.01745)/0.0896,1.3)….. (9)

3.7.4 Cover management (C) factor

The cover management factor C shows the impact of soil operations, plants, crop coherence, yielding and soil cover and below surface biomass on soil erosion (Emeribeole et al.,2015) .Generally, it shows the cropping and management operation in provincial administration (Kouli et al.,2009). The vegetation cover of the study area protects the soil from erosion caused by rainfall intensity and thus soil erosion can be reduced with the appropriate land cover management of the vegetation (Demirci et al.,2012; Alexakis et al.,2013;Kouli et al.,2009).The C factor is related to the LULC (Jianping et al.,2015;Van der Knijff et al.,2000).Crop management factor for different land use land cover types is shown in table 3.9.

Table 3.9: C- factor value based on LULC types

LULC	C-Value	Source
Water body	0	Erdogan et al.(2006)
Agricultural land	0.15	Yared, Justina and Eyob(2020)
Bare land	0.6	Yared, Justina and Eyob(2020)
Forest	0.01	Hurni(1985)
Wet land	0.01	Bewket and Teferi (2009)
Salt pan	0.6	
Settlement	0.99	Yared, Justina and Eyob(2020)
Shrub land	0.01	Asmamaw et al.(2012)

3.7.5 Supporting conservation practice (P) factor

The support factor (P) refers to the ratio of soil loss as a response to upslope and down slope cultivation that can have positive effects to soil loss by decreasing and minimizing the quantity and proportion of water runoff to reduce the erosion (Emeribeole et al.,2015). The value of the factor are between 0 and 1.The value close to 0 shows good support practice. In addition to values close to 1 show that no impact on the results (Ganasri et al.,2015). This study conduct the P factor based on LULC type for P value.

Table 3.10: P-Factor value (Source: Yang et al., 2003; Zhou et al., 2014)

S.No.	Land Use ´Land Cover Type	P-Value
1	Water Body	1
2	Agricultural land	0.5
3	Bare land	1
4	Forest	1
5	Wet land	0.8
6	Salt pan	1
7	Settlement	1
8	Shrub land	1

3.8 Land Suitability Evaluation for Agricultural Land Use

3.8.1 Factors of Land Suitability Evaluation

This study conducted by using number of parameters namely: metrological data (rainfall and temperature), DEM (slope percentage and watershed delineation), soil physical property (texture, soil drainage, soil depth and soil erosion) and chemical property (OC, PH, EC and CEC), LULC and distance to water. The selection of this criteria factor based on different literature reviews in area of agricultural land suitability and personal discussion with experts.

3.8.1.1 Meteorological data

Temperature and rainfall are the most important climatic factors for agricultural production in Ethiopia. Elevation is one of factor that determines the distribution of climatic factors and land suitability; this influences the crops to grown, rate of crop growth, natural vegetation types and their species diversity. There is strong inter-annual variability of rainfall all over the country. Despite variable rainfall which makes agricultural planning difficult, a substantial proportion of the country gets enough rain for rain fed crop production (FAO, 1984).

Agricultural activity and land use patterns are closely related to the temporal and spatial patterns of climatic elements and success of land use strongly depends on climatic situation of an area. Rainfall and temperature are the major climatic factors that influence agricultural processes. It influences the spatial and temporal variation of agricultural activities and land use pattern. Therefore, in the land suitability evaluation climatic variables should be considered as a diagnostic land qualities or land characteristics (Dula, 2010).

3.8.1.2 Soil physical and chemical property

a) Texture

Soil texture is an important soil characteristic that influences storm water infiltration rates. The textural class of soil is determined by the percentage of sand, silt and clay. Soil can be classified as one of four major textural classes such as sands, silts, loams and clays. Soil texture determine numerous soil properties including; drainage , water holding capacity, aeration, susceptibility to erosion, organic matter content, CEC and PH buffering capacity. The soil texture data for this study obtained from ministry of agriculture. The soil texture data obtained from MOA. The study are covered by clay ,loam and sandy loam texture class. Clay soil type covered most part of the study area.

b) Depth

soil depth is one of the most important factors for plant to reach water and nutrients. It affects the healthy growth and propagation of the roots. The plants with healthy root development can easily access nutrients and water soil depth is a significant parameter which changes the potential root volume. Root volume affects hydrological events and water exchange amounts in plants (Meyer et al.,2007). Soil depth is directly related to topographic conditions (Gabet and Mudd, 2009). In steep and sloping areas, the susceptibility to erosion increases, while soil depth decreases(Everest and Sungur, 2020).When the soil is deeper more water and nutrients to plants available than shallow soils. Soil depth determines the soil moisture content and nutrient storage that have a direct reflection of plant growth. Soil depth of this study obtained from MOA in raster format. Which ranges between 0 to 175.

c) Soil drainage

Soil drainage may determine which types of plants grow best in an area. Many agricultural soils need good drainage to improve or sustain production or to manage water supplies(Haroun,2004). Water is essential for crop growth and development. However, too much water has negative impact on plant survival and growth. Excessive water retained in soils impedes air movement causing the decline and death of crops because of inadequate supply of oxygen for root respiration and retention of carbon dioxide produced from respiration. Therefore, the soil drainage condition is an important factor in evaluating agricultural land suitability (Guiying and brad , 2017).Soil drainage for this study obtained from ISRIC world soil database .the study area soil drainage varies from very poor to somewhat excessive level.

d) Soil erosion

Erosion is correlated with many factors such as topographic parameter, LULC, climate condition and soil .The soil reduction due to erosion adversely affects the efficiency of the soil(Montgomery, 2007).Erosion causes soil loss ,degradation of soil structure , decreases in organic matter , plant nutrients and soil depth(Pimentel et al. 1995). Soil depth rapidly decreases when the intensity of erosion increases. Erosion can be very intense in some areas and soil completely reduces and the bedrock appears (Altinbas, 2006). For this study soil erosion map obtained by using empirical erosion model such as RUSLE.

e) Electric Conductivity (EC)

EC is a measure of the amount of salts in soil (salinity of soil).It is an excellent indicator of nutrient availability and loss, soil texture and available water capacity. It affects crop yields, the suitability of the soil for certain crops, the amount of water and nutrients available for plant use and the activity of soil micro-organisms. Excessive salts hinder plant growth by affecting the soil and water balance. Salt levels can increase as a result of cropping, irrigation and land management. Although EC does not provide a direct measurement of specific ions or salt compounds. It has been correlated to concentration of nitrates, potassium, sodium, chloride, sulfate and ammonia. For certain non-saline soils determining EC can be an easy. Soil EC can also be an effective way to determine the texture of the surface layer because smaller clay particles conduct more electrical current than larger silt and sand particles (USDA, 2014).The study area EC soil data obtained from Ethiopian Ministry of Agriculture (MOA).

f) Soil Organic Carbon (SOC)

Soil Organic Carbon is fundamental to soil fertility and strong indicator of soil biological health as well as its chemical, biological and physical processes (Chan et al., 2010).It have a vital role to enhance agricultural land productivity and for mitigation of climate change. SOC supports multiple soil functions (Reeves, 1997; Pan et la.,2009) . It is a source of nutrients and crucial to raise crop yields in high-input commercial agriculture but especially in low-input degraded land. SOC contributing to the productive capacity of soils for food and energy production (Lal, 2004). The adoption of SOC conserving agricultural practices can increase food production by 17.6 Mt/year (De Moraes Sa et al., 2017).The optimal SOC content can absorb and store water under extensive rain and make it available for vegetation under drought conditions. Healthy soils can provide proper aeration and consistent supply of oxygen (FAO and ITPS, 2015).

g) PH

Soil PH is a master variable in soils because it controls many chemical and biochemical process operating within the soil. It is a measure of the acidity or alkalinity of a soil. PH is very important in agriculture due to the fact that soil PH regulates plant nutrient availability by controlling the chemical forms of the different nutrients and also influences their chemical reactions. As a result, soil and crop productivities are linked to soil PH value. Though soil PH generally ranges from 1 to 14 (Suarau, 2018).   The soil PH of the study area obtained from ATA (Agricultural Transformation Agency) of Ethiopia.

h) Cation Exchange Capacity (CEC)

CEC is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil PH and the soil's reaction to fertilizers and other ameliorants (Hayleton and Murphy ,2007).Soil CEC is use full indicator of soil fertility because it shows the soil ability to supply three important plant nutrients such as calcium, magnesium and potassium. It also evaluates nutrient retention capacity and the capacity to protect ground water from cation contamination (Akbarzadeh et al., 2009). For this study the CEC soil data obtained from ISRIC world soil database.

3.8.1.3 Digital Elevation Model (DEM)

DEMs are point elevation data stored in digital computer files. These data consist of x, y grid locations and point elevation or z variables. They are generated in a variety of ways for different map resolutions or scales. The point elevation data are helpful as an input to the Arc-GIS and the data can further be processed to give important derivative products such as slope, flow accumulation, flow direction and delineate watersheds (Negash, 2004). The DEM of this study obtained from ALOS PLASAR satellite having a resolution of 12.5m used as an input data in Arc GIS 10.8 for delineation and to drive a slope map of the study area according to the objective to the study.

I. Delineation of the watershed

The watershed delineation of the study area was performed through spatial analysis Arc GIS 10.8 tools. The following steps were followed in watershed delineation using the hydrology tool in Arc GIS (source: MadGIC, 2014)

a. Fill

The fill tool in the hydrology toolbox is used to remove any imperfections (sinks) in the digital elevation model. A sink is a cell that does not have an associated drainage value. Drainage values indicate the direction that water will flow out of the cell, and are assigned during the process of and are assigned during the process of creating a flow direction grid for the landscape. The resulting drainage network depends on finding the 'flow path' of every cell in the grid, so It is important that the fill step is performed prior to creating a flow direction grid.

b. Flow Direction

A flow direction grid assigns a value to each cell to indicate the direction of flow. The direction that water will flow from that particular cell based on the underlying topography of the landscape. This is a crucial step in hydrological modeling, as the direction of flow will determine the ultimate destination of the water flowing across the surface of the land.

c. Flow Accumulation

The flow accumulation used to calculate the flow into each cell by identifying the upstream cells that flow into each downslope cell. In other words, each cell's flow accumulation value is determined by the number of upstream cells flowing into it based on landscape topography. The flow accumulation layer is now symbolized so that you are better able to visually pinpoint areas of high flow accumulation.

d. Create outlet (pour) points

The pour point placement is an important step in the process of watershed delineation. A pour point should exist within an area of high flow accumulation because it is used to calculate the total contributing water flow to that given point.

e. Delineating Watershed

To delineate the watershed, pour points are snapped to the stream and then use this grid to delineate the watershed. Finally, convert watershed raster to polygon shape file is used to calculate the area and to clip other data sets to watershed boundary (Merwade, 2012).

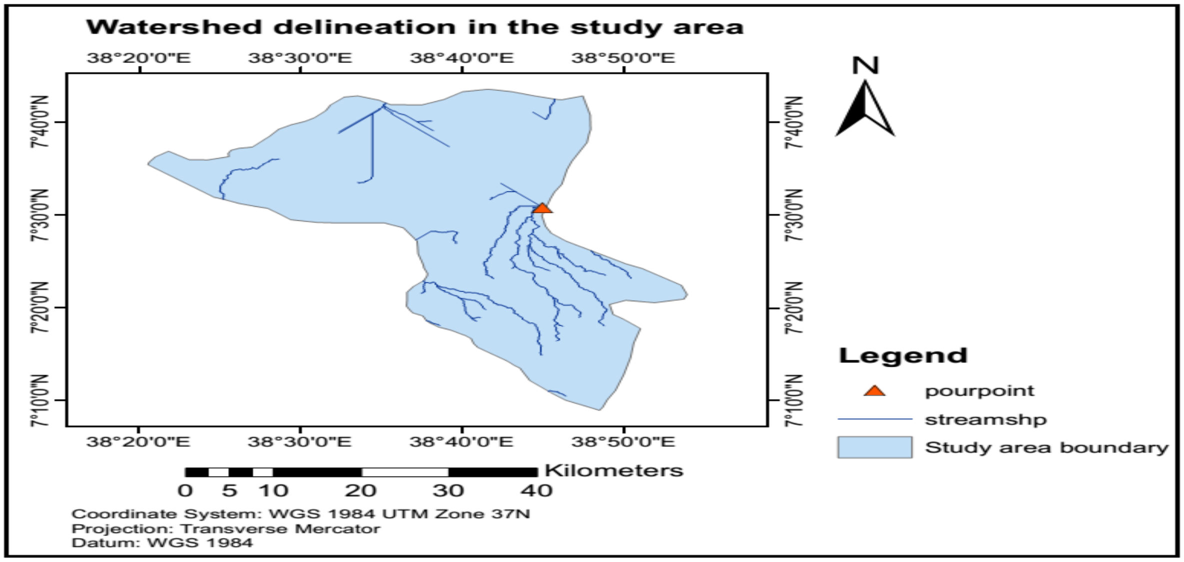

Figure 3.6: Watershed delineation map of the study area

II. Slope

Slope is an important factor for agriculture. Slope degree has a direct effect on soil depth, susceptibility to erosion, soil tillage, use of agricultural machines and irrigation plant adaptation. The steepness, length and sharpness of the slope directly affect the soil and water loss in an area. The effects of slope on soil erosion were reported by many researchers (Selby,1976; Kinnell ,2000;Parlak,2012). The effect of slope on soil formation is very effective. If the slope is different and the climatic conditions do not change, different soils can form on the same parent material (WRB,2014).

III. Distance to water

The agricultural sector is the major user of water in both irrigated and non-irrigated crop production. Water requirements naturally vary tremendously from one area to another depending on different factors such as total land under agriculture production, types of soils , climate factor , availability of irrigated water and efficiency of water use and management practice. For this study distance from water obtained from ALOS PLASAR 12.5 resolution DEM. figure 3.6 shows all of the step followed to drive distance from water map.

3.8.1.4 Land Use Land Cover

Land use map help to identify the productivity of an area for rain fed and surface irrigation agriculture. To generate land use land cover map of land suitability for rain fed and surface irrigation. Sentinel 2A image was downloaded from USGS website: the land sat imagery was classified into eight major land use classes (Water body, Settlement, Shrub land, Bare land, Salt pan, Forest, Wet land, Agricultural land).

3.8.2 Criteria standardization and rating

The most important requirement for land suitability analysis for agricultural use criteria are mainly related to soil, topography (slope), metrological data (rainfall and temperature), and land use land cover. Soil data were assessed in terms of Soil Physical property (texture, soil drainage, soil depth and soil erosion) and chemical property (OC, PH, EC and CEC). A compilation of criteria for land requirements that were considered in the evaluation were made and factor rating for land performance. Factor ratings are set of values which indicate how well each factor/ criterion is satisfied by particular conditions of corresponding land quality. Which illustrate the detail agronomical significances of each factors obtained from different data sources. This study criteria rating established based on FAO guideline, literature reviews in area of agricultural land suitability and personal discussion with experts. Table 3.12 and 3.13 shows the criteria rating for land suitability for rain fed agricultural land use and surface irrigation respectively.

Table 3.11: Criteria and their suitability range for rain fed agriculture

No	Criteria	Parameter	Suitability Class	Source
		0 – 5	Highly Suitable	
		5 – 8	Moderately Suitable	
		8 – 15	Marginally Suitable	
1	Slope	15 – 30	Currently not Suitable	Mazahreh et al., 2018
		>30	Permanently not Suitable	
		Agricultural	Highly Suitable	
2	LULC	Wet Land	Moderately Suitable	
		Shrub Land	Marginally Suitable	
		other LULC type	Permanently not Suitable	
3		0 – 10	Highly Suitable	(Hamere and Teshome ,2018)
		10 – 20	Moderately Suitable	
	Soil Erosion	20 – 30	Marginally Suitable	
		30 – 50	Currently Not Suitable	
		>50	Permanently not Suitable	
5	Rainfall (mm)	300 - 1100	Highly Suitable	
		1100 – 1300	Moderately Suitable	
		1300 – 1500	Marginally Suitable	
		< 300, >1500	Permanently Not Suitable	
		15 – 16	Highly Suitable	
6	Temperature (^{0}C)	16 – 17	Moderately Suitable	**(AL-Taani & Yusra , Land suitability evaluation for agricultural use using GIS and remote, 2021)**
		17 – 18	Marginally Suitable	
		18 – 19	Currently Not Suitable	
		>19	Permanently Not Suitable	
		Loam	Highly Suitable	
7		Sandy Loam	Moderately Suitable	Guiying ,2017
	Texture	Clay	Marginally Suitable	
		>150	Highly Suitable	
		150 – 100	Moderately Suitable	
8	Soil Depth	100 – 50	Marginally Suitable	
		50 – 30	Currently Not Suitable	Guiying, 2017
		<30	Permanently Not Suitable	

Continue…

No	Criteria	Parameter	Suitability class	Source
9	Drainage	Well	Highly Suitable	Nachtergaele et al., 2009
		Moderate	Moderately Suitable	
		Imperfect	Marginally Suitable	
		Poor Somewhat Excessive	Currently Not Suitable	
		Very Poor	Permanently Not Suitable	
10	SOC (%)	>2	Highly Suitable	Nachtergaele et al., 2009
		2 – 2.5	Moderately Suitable	
		1.5 – 0.8	Marginally Suitable	
		0.8 – 0.4	Currently Not Suitable	
		<0.4	Permanently Not Suitable	
11	PH	5.8 – 6.8	Highly Suitable	Guiying, 2017
		5.5 – 5.8 6.8 – 7.1	Moderately Suitable	
		5.0 – 5.5 7.1 – 7.6	Marginally Suitable	
		4.5 – 5.0	Currently Not Suitable	
		>7.6	Permanently Not Suitable	
12	CEC (col kg^{-1})	>20	Highly Suitable	Nachtergaele et al., 2009
		16 – 14	Moderately Suitable	
		14 – 10	Marginally Suitable	
		10 – 4	Currently Not Suitable	
		<4	Permanently Not Suitable	
13	EC	< 0.1	Highly Suitable	Nechtergaele et al., 2009
		0.1 – 1.1	Moderately Suitable	
		>1.11	Permanently Not suitable	

3.12: Criteria and their suitability for irrigated agriculture

No	Criteria	Parameter	Suitability Class	Source
1	Slope	0 – 2	Highly Suitable	Mandal et al., 2017
		2 – 5	Moderately Suitable	
		5 – 8	Marginally Suitable	
		>8	Not Suitable	
2	LULC	Agricultural	Highly Suitable	
		Wet Land	Moderately Suitable	
		Shrub Land	Marginally Suitable	
		Other LULC type	Not Suitable	
3	Soil Erosion	0 – 10	Highly Suitable	Yohannes and soromesa, 2018
		10 – 20	Moderately Suitable	
		20 – 50	Marginally Suitable	
		>50	Currently Not Suitable	
4	Distance to water source (km)	0 – 5	Highly Suitable	Mandal et al., 2017
		5 – 10	Moderately Suitable	
		10 – 20	Marginally Suitable	
		>20	Not Suitable	
5	Temperature (^{0}C)	15 – 16	Highly Suitable	Ayemen and Ibrahim, 2020
		16 – 17	Moderately Suitable	
		17 – 18	Marginally Suitable	
		18 – 19	Not Suitable	
6	Texture	Loam	Highly Suitable	
		Sandy Loam, Clay	Moderately Suitable	
7	Soil Depth	>120	Highly Suitable	
		120 – 100	Moderately Suitable	
		100 – 50	Marginally Suitable	
		<50	Not Suitable	
8	Drainage	Well	Highly Suitable	Nachtergaele et al., 2009
		Moderately Well	Moderately Suitable	
		Imperfect	Marginally Suitable	
		Poor Very Poor	Not Suitable	
9	OC (%)	>2.18	Highly Suitable	
		2.18 – 1.15	Moderately Suitable	
		1.15 – 0.74	Marginally Suitable	
		<0.74	Not Suitable	

Continue…

No.	Criteria	Parameter	Suitability Class	
10	PH	5.8 – 6.8	Highly Suitable	Guiying, 2017
		5.5 – 5.8 6.8 – 7.1	Moderately Suitable	
		4.5 – 5.5 7.1 – 7.6	Marginally Suitable	
		>7.6	Not Suitable	
11	CEC	>13	Highly Suitable	Nechtergaele et al., 2009
		12 – 13	Moderately Suitable	
		9 – 12	Marginally Suitable	
		<9	Not Suitable	
12	EC	<0.1	Highly suitable	Nachtergaele et al., 2009
		0.1 – 1.1	Moderately	
		>1.1	Suitable Not Suitable	

3.8.3 Criteria Standardization

Data are measured on different units as well as on different scales of measurements. Thus, it is necessary to standardize the factors before combination and assure they transformed, if necessary, so that all factors maps are positively correlated with suitability (Voodg, 1983).Linear scale transformation is the most frequently used GIS-based approach for criteria standardization(Malczewski, 2004). Reclassify special analysis tool in Arc GIS 10.8 were used in this study to make sure that each criterion had an equivalent measurement basis. Reclassification is the method to assign value of preference, sensitivity, priority or some similar criteria to raster (ESRI, 2011). The factor ratings are sets of values that indicate how well each factor is satisfied by particular conditions of the corresponding land quality As it was illustrated in table 3.11 and 3.12 the factors were reclassified as per the spatial existence of the factors in the study area. The reclassification is based on according to FAO framework (FAO, 1976, 1985; mandal et al., 2017 and table 3.13).

3.8.4 Assigning criterion weights

Weight assignment from pairwise comparison for the criteria was based on literature reviews ,personal discussion with experts and nature of study area and FAO,1976 and FAO, 2007b guideline of land suitability evaluation and processed in ARC GIS 10.8 AHP extension tool was shown in Appendix 1 and 2. The pairwise comparison technique developed (saaty,1987) in the context of decision making process is a ratio (reciprocal matrix) .Where each factor is compared with the other criteria in terms of their importance related to the stated objective scaled from 1 to 9 (Saaty, 1987). There are three steps for this technique:

Table 3.13: The fundamental scale of AHP (source: Saaty, 1987)

Intensity of importance on and absolute scale	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over other	Experience and judgment strongly favor one activity over another
5	Essential or Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice.
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgment	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	
Rationales	Ratios arising from the scale	If consistency were forced by obtaining n numerical values to span the matrix.

3.8.5 Aggregating the criterion weights and the standardized criterion maps

GIS can be used only for automatically producing maps, but it is unique in its capacity for integration and spatial analysis of multisource datasets (Malczewski,2003). Once the criteria maps (Factors and constraints) are developed , and evaluation (or aggregation) stage is undertaken to combine the information from the various factors and constraints. In the context of GIS, three decision rules are known i.e. Boolean overlay, weighted overlay and ordered weighted averaging are common for MCE(Jiang and Eastman,2000; Malcyewski, 2000; Malcyewski, 2003). For this study weighted overlay method was used to aggregate standardize rated criteria in ARC GIS 10.8 spatial analyst weight overlay tools and produced thematic ma p for both rain fed agricultural land use and surface irrigation. These maps were reclassified based on the FAO land suitability classification in table 3.11 which converts suitability values into classes to produce the final land suitability map.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Land Use Land Cover Classification

The current LULC classified from Sentinel 2A, 2020 satellite image by using supervised classification method was the first step for land evaluation and management. The produced LULC map generated from 8 major LULC types such as; bare land, settlement, shrub land, wet land, agricultural land, forest, salt pan and water body. The study area was mostly dominated by agricultural land (23.78%) and water body (23.78%) of the total land.

4.2 Accuracy Assessment

After the classification process, accuracy assessment was performed to evaluate the supervised classification .The classified image was verified by using Google Earth imagery by generating a total of 552 random points. During accuracy assessment user accuracy, producer accuracy, overall accuracy and Kappa coefficient were computed from error matrix as suggested by (Congalton ,2001). The result of calculated error matrix shown in table 4.1

Table 4.1: Confusion matrix for the land cover map

Classified Data	Water Body	settlement	Wet Land	Forest	Shrub Land	Salt Pan	Bare Land	Agricultural Land	Row Total	Users Accuracy
Water Body	96	5	0	0	0	0	0	0	101	95%
Settlement	6	70	0	1	2	0	3	2	84	83.3%
Wet Land	0	0	27	0	0	0	0	3	30	90%
Forest	0	0	1	98	0	1	0	0	100	98%
Shrub Land	1	0	2	0	94	0	0	1	98	95.91%
Salt Pan	4	0	0	0	0	34	0	0	38	89.47
Bare Land	0	0	1	0	0	0	31	0	32	96.87%
Agricultural Land	0	0	0	0	0	0	0	69	69	100%
Column Total	107	75	31	99	96	35	34	75	552	
Producers (%)	89.71	93.3	87	98.98	97.9	97.1	91.1	92	92.9	

Overall Accuracy = 94%

Overall Kappa coefficient =92.98 %

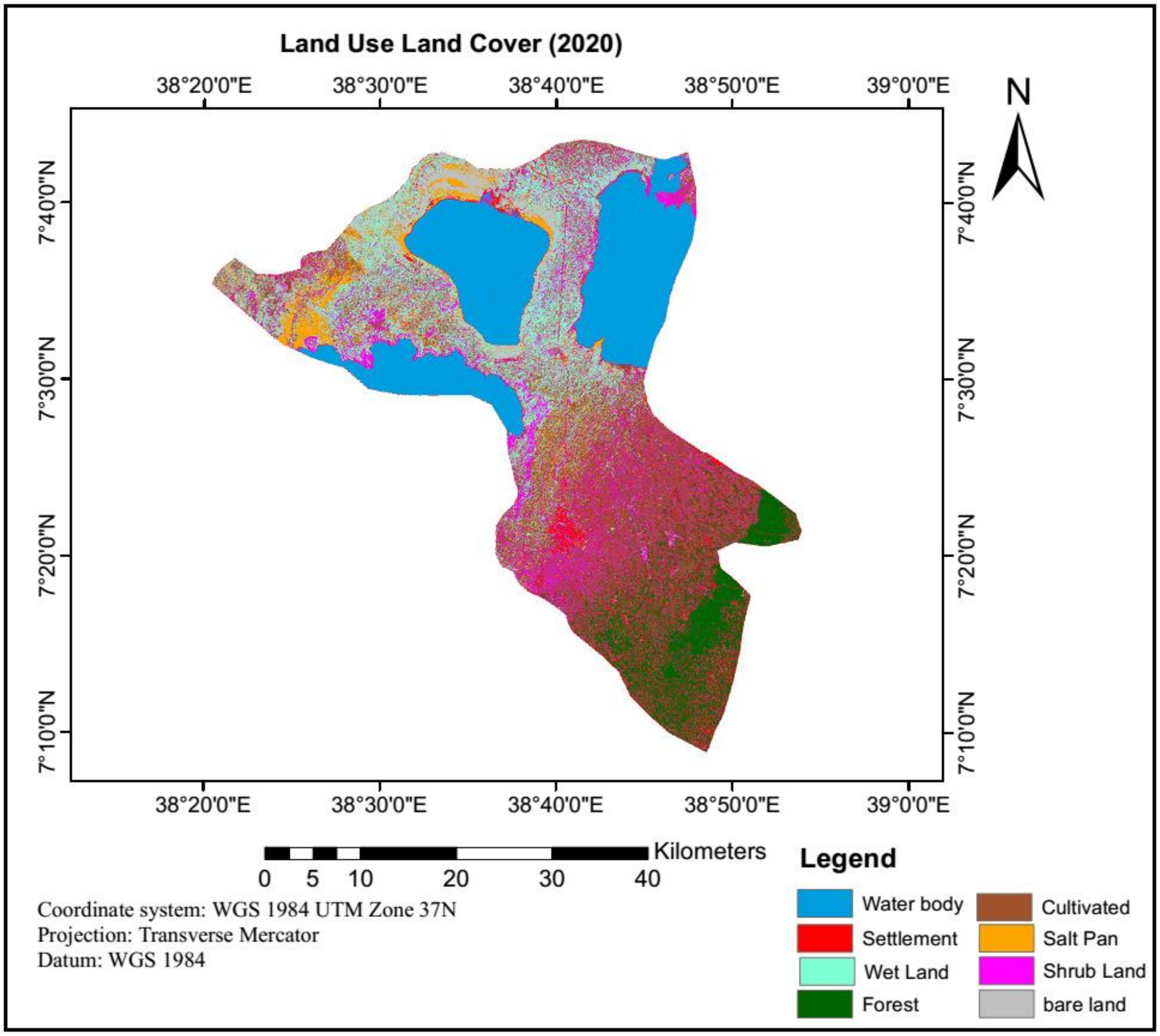

Figure 4.1: LULC map of the study area

4.3 Preparation Factor Map for Soil Erosion

4.3.1 Rainfall Erosivity (R) Factor

Rainfall is one of the major factor of soil erosion. The R factor map was calculated based on Equation (1) in previous chapter. As shown in the map below the minimum maximum and mean R-factor value of the study area is 555.859, 676.382 and 612.63 mm respectively.

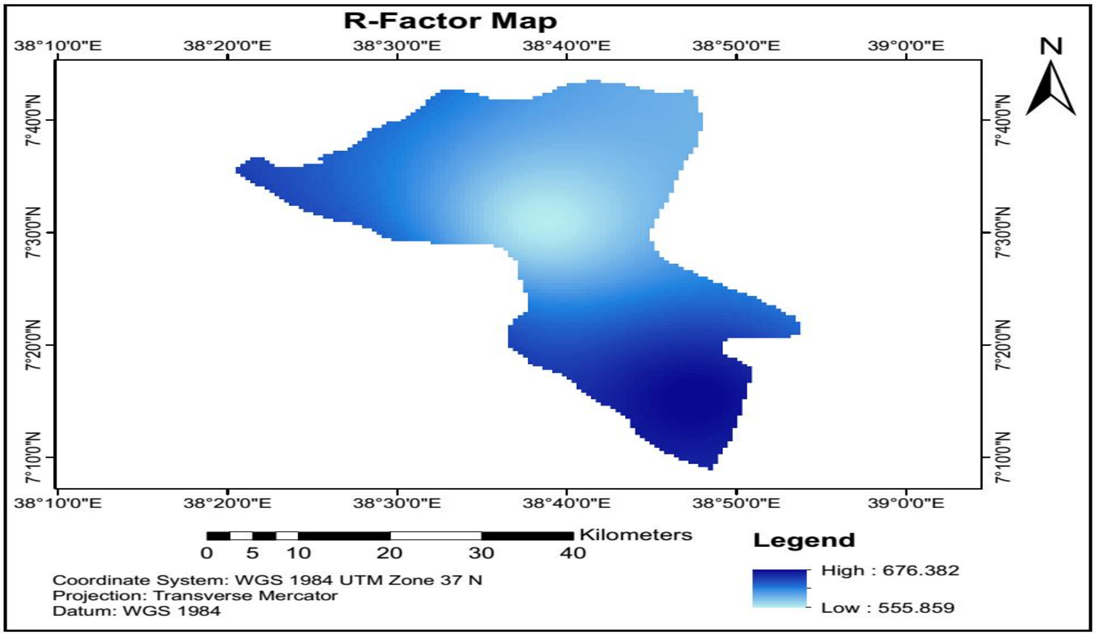

Figure 4.2: R-Factor map of study area

4.3.2 Soil Erodibility (K) Factor

The K factor was calculated based on the equation (2) in previous chapter from FAO soil. The calculated K factor values ranges between 0 to 0.157 as shown in figure 4.3.

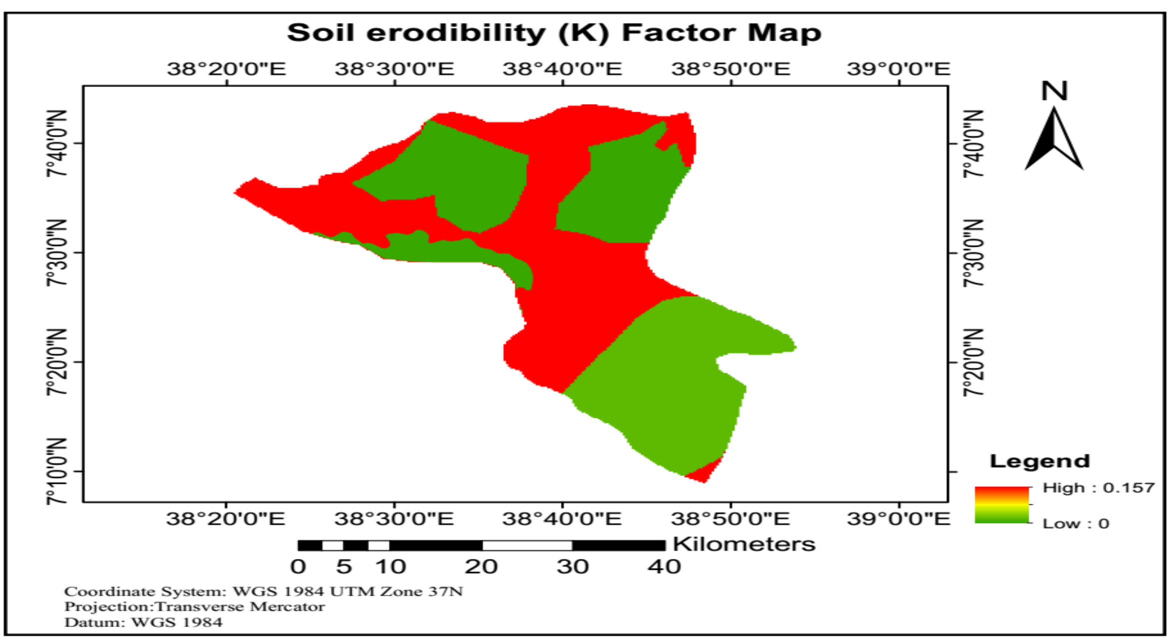

Figure 4.3: K-Factor map of the study area

4.3.3 Slope length and Slope Steepness (LS) factor

The calculated LS factor value ranges from 0 to 44 based on equation (8) in previous chapter.

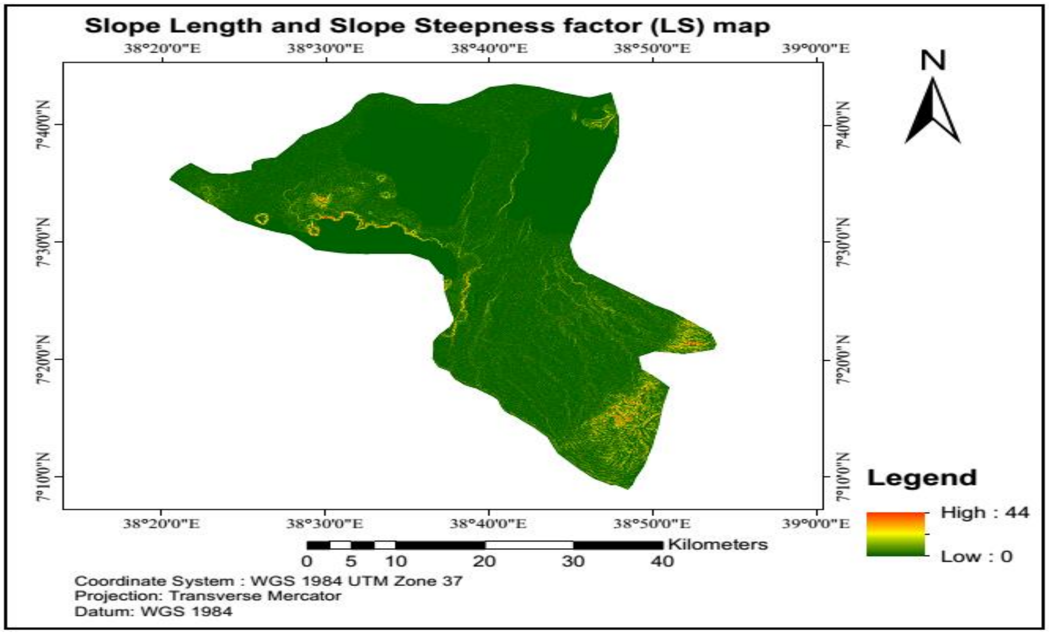

Figure 4.4: LS-Factor map of the study area

4.3.4 Cover management (C) factor

The C factor were estimated based on LULC classification 2020 of study area in table 3.9 .

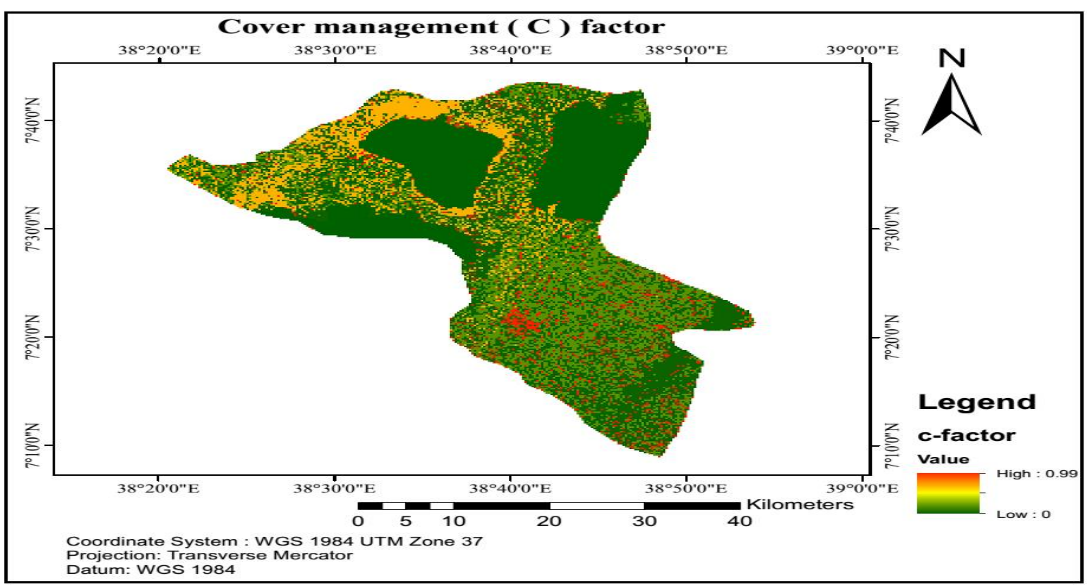

Figure 4.5: Cover management factor map of the study area

4.3.5 Support Conservation Practice (P) factor

The P factor value of the study area based on land use land cover classification as shown in table 3.10 in previous chapter

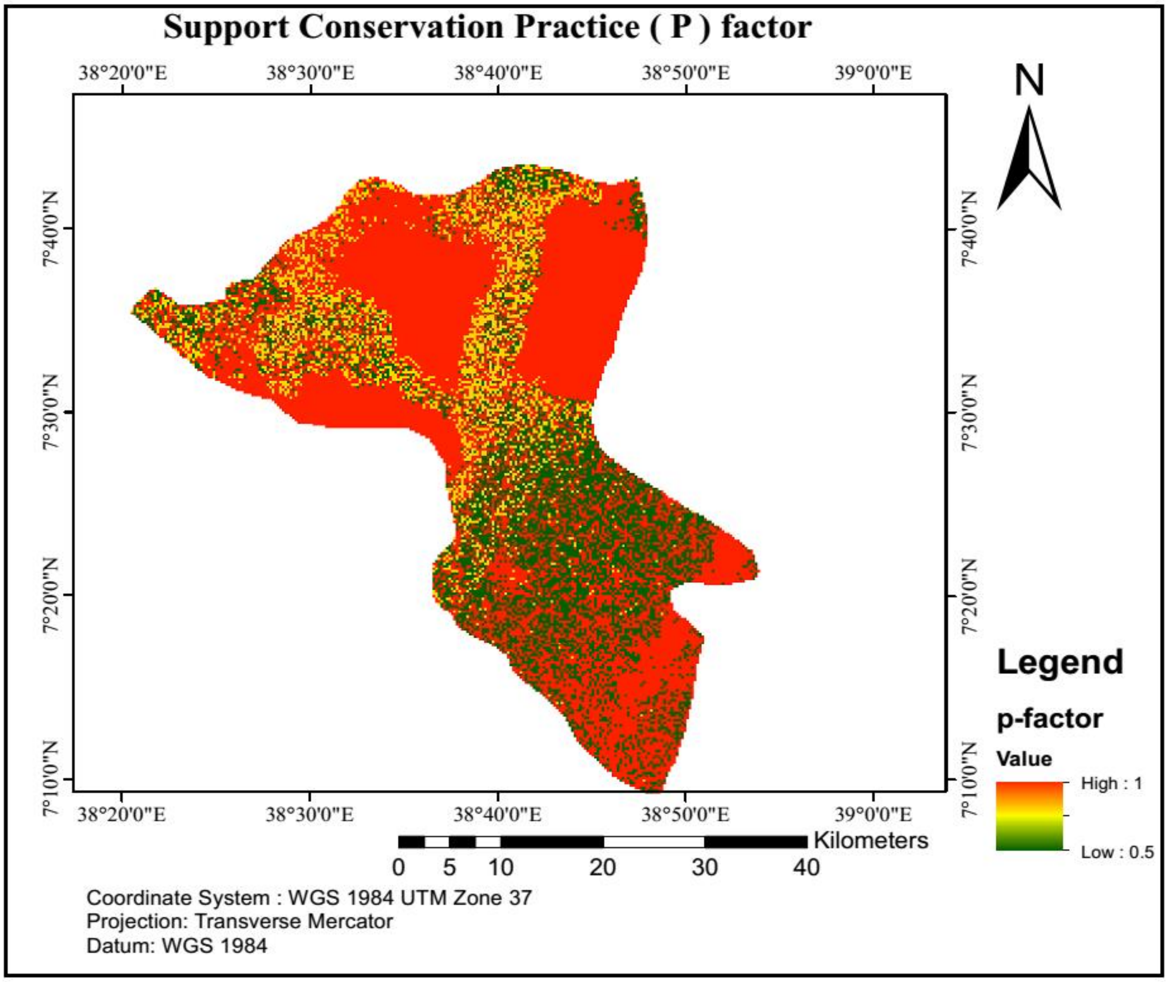

Figure 4.6: Support Conservation Practice (P) factor map of the study area

4.4 Soil erosion risk map

By using raster calculator in Arc GIS 10.8 .The calculated result from the five factors. The spatial distribution of the soil loss amount of the study area ranges from 0 ton/ha/yr to 71.9 ton/ha/ yr with mean annual soil of 0.19 t/ha/yr .which is much greater than the tolerable level 10 t/ha/year (Hurni, 1983).

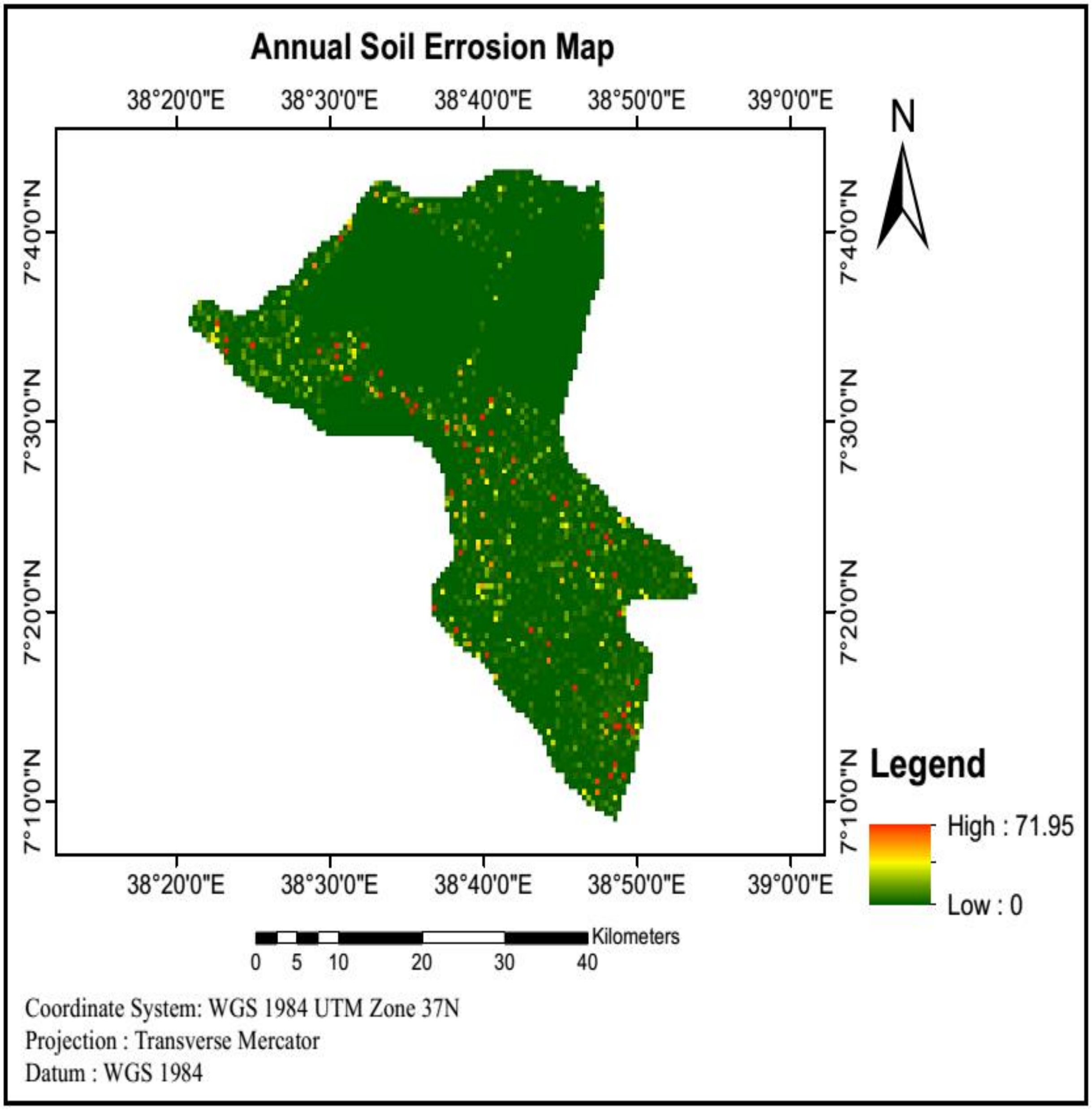

Figure 4.7: Soil Erosion risk map of the study area

4.5 Identification and Prioritization Based on Risk of Soil Loss

Based on the level of soil erosion rates, the study area divided into five priority categories in Arc GIS 10.8.This categories very important for soil conservation practice.

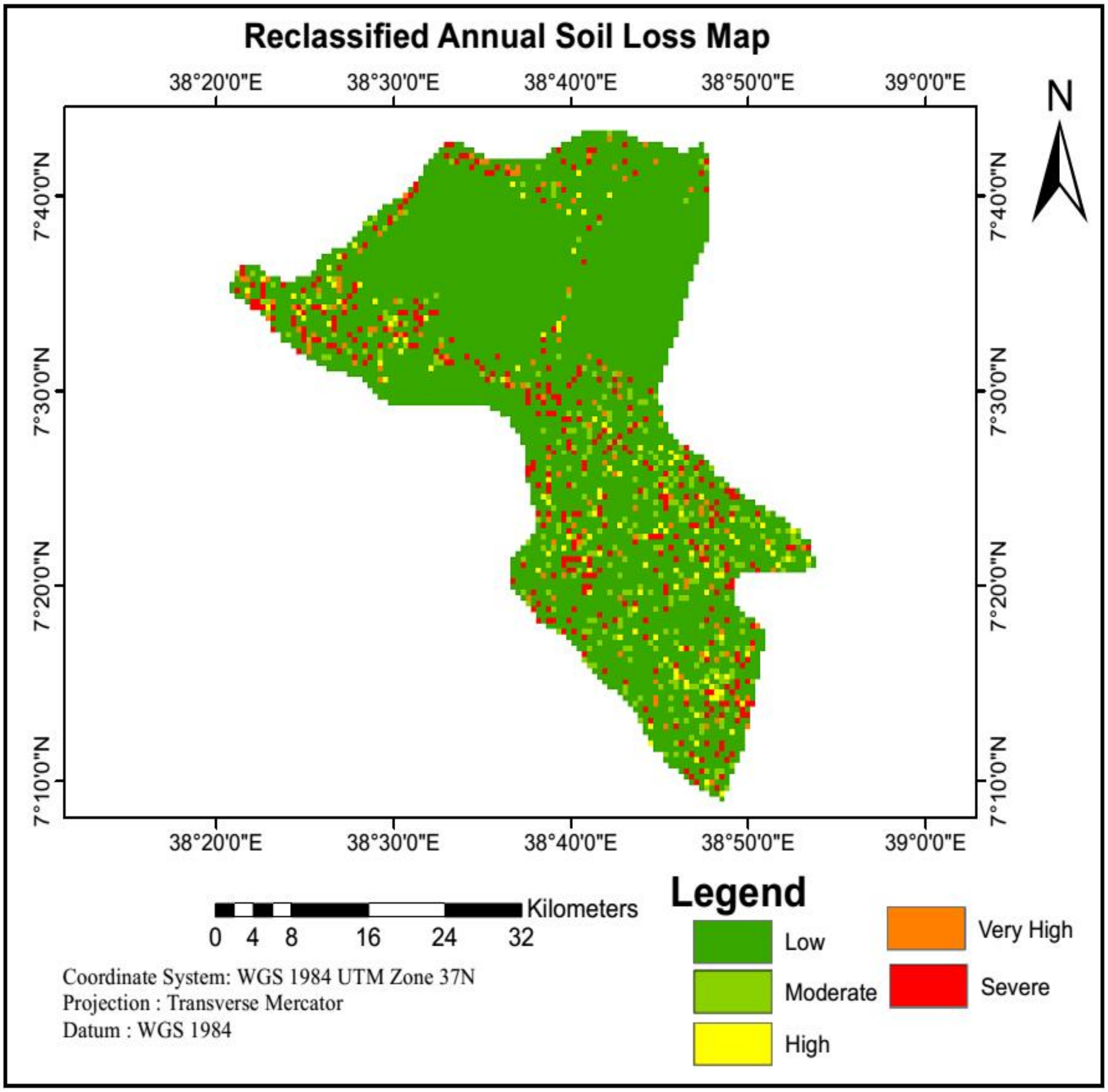

Figure 4.8: Soil Loss Risk Map of The Study Area

4.6 Land Suitability Assessment Criteria Maps

4.6.1 Reclassified slope

Slope is major topographic element related to erosion hazard, land management practice, Workability of the area and climatic factor. Slope of the study area was derived from the digital elevation model (DEM) which in turn clipped from Advanced Land Observing Satellite

(ALOS) and Phased Array type L-band Synthetic Aperture Radar (PALSAR) having resolution of 12.5 by using a masking layer of the study area boundary in ARC GIS 10.8.

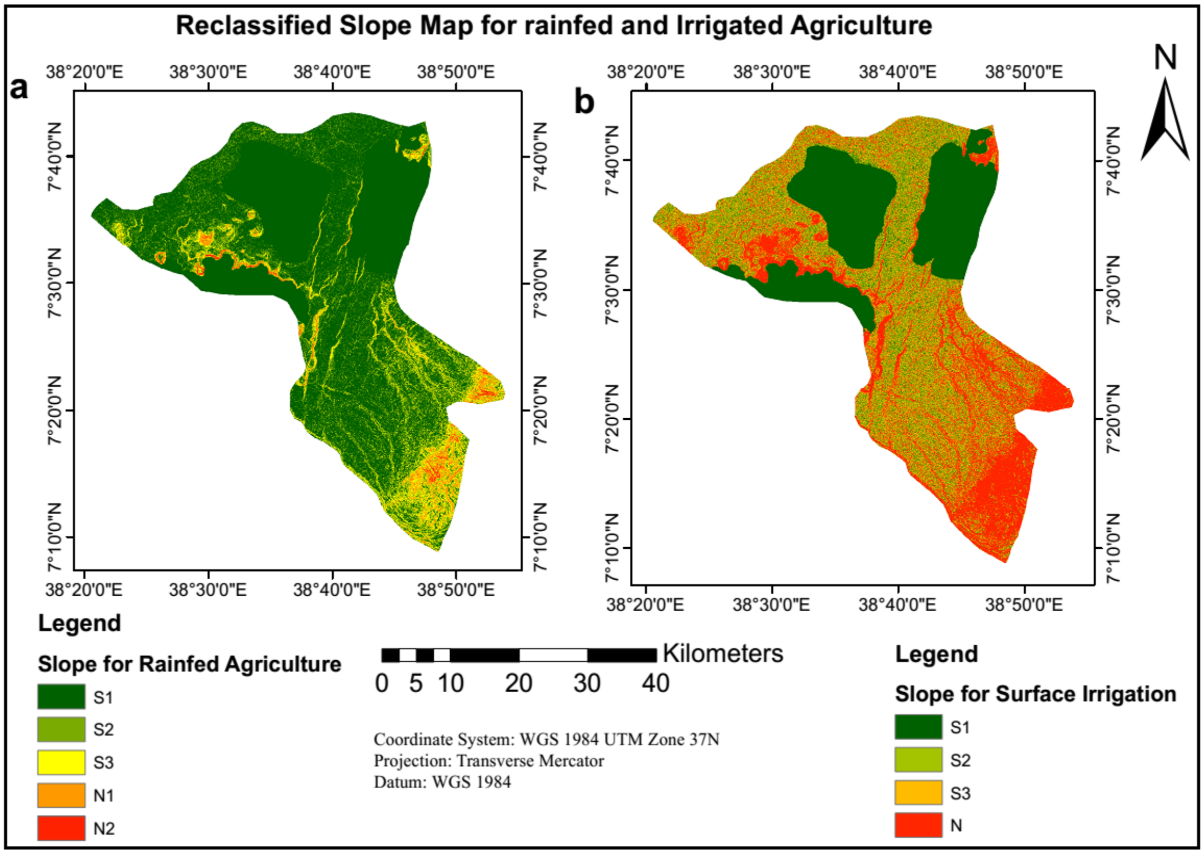

Figure 4.9: Slope Suitability Map for Rain fed **a)** and **b)** for surface irrigation

Table 4.3: Slope Suitability Class and Their Area Coverage for Rain fed Agriculture

No.	Suitability class for Rainfed agriculture	Area (ha)	Area (%)
1	S1	117038.4	72.99
2	S2	22146.3	13.84
3	S3	14449	9
4	N1	5988.7	3.73
5	N2	719	0.44
	Total	160341.4	100

Table 4.4: Slope Suitability Class and Their Area Coverage for Surface Irrigation

No.	Suitability class for Surface Irrigation	Area (ha)	Area (%)
1	S1	53978	33.68
2	S2	28646.2	17.86
3	S3	31322	19.51
4	N	46395.2	28.95
	Total	160341.4	100

4.6.2 Reclassified LULC and Distance to Water Source

Land use land cover classified from Sentinel 2A, 2020 satellite image by using supervised classification method reclassified based on the table 3.11. Distance water generated from ALOS PLASAR DEM by follow the step of fill, flow direction, flow accumulation, River Network, Buffer by using Arc GIS 10.8 software .

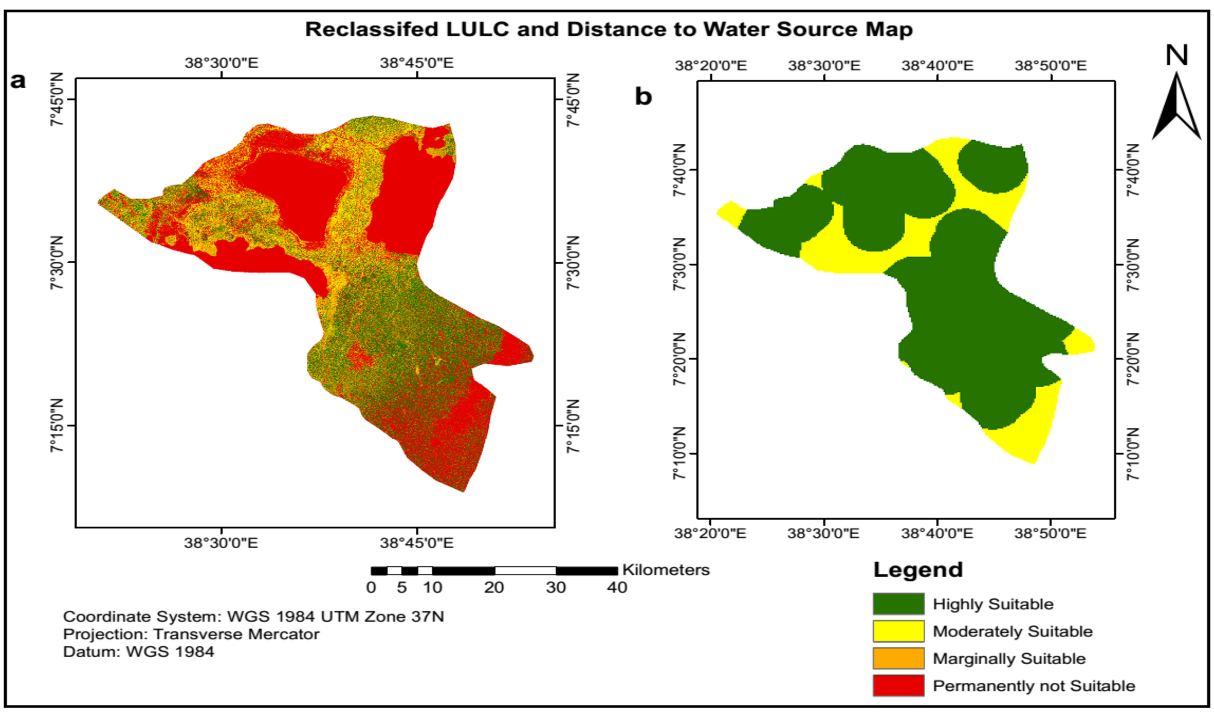

Figure 4.10: Reclassified LULC and Distance to Water Map for both Rain fed and Surface irrigation a) LULC map b) Distance to Water Map

4.6.3 Reclassified Temperature and Rainfall map

Climate is the most important dominating factor influencing the suitability of a crop to particular region. The yield potential of crop mainly depends on climate. More than 50% of variation of crops is determined by climate. The most important climatic factors that influence growth, development and yield of crops are solar radiation, temperature and rainfall (TNAU, 2016). The study area rainfall and temperature data obtained from NMA and Power Access Climate Data online source.

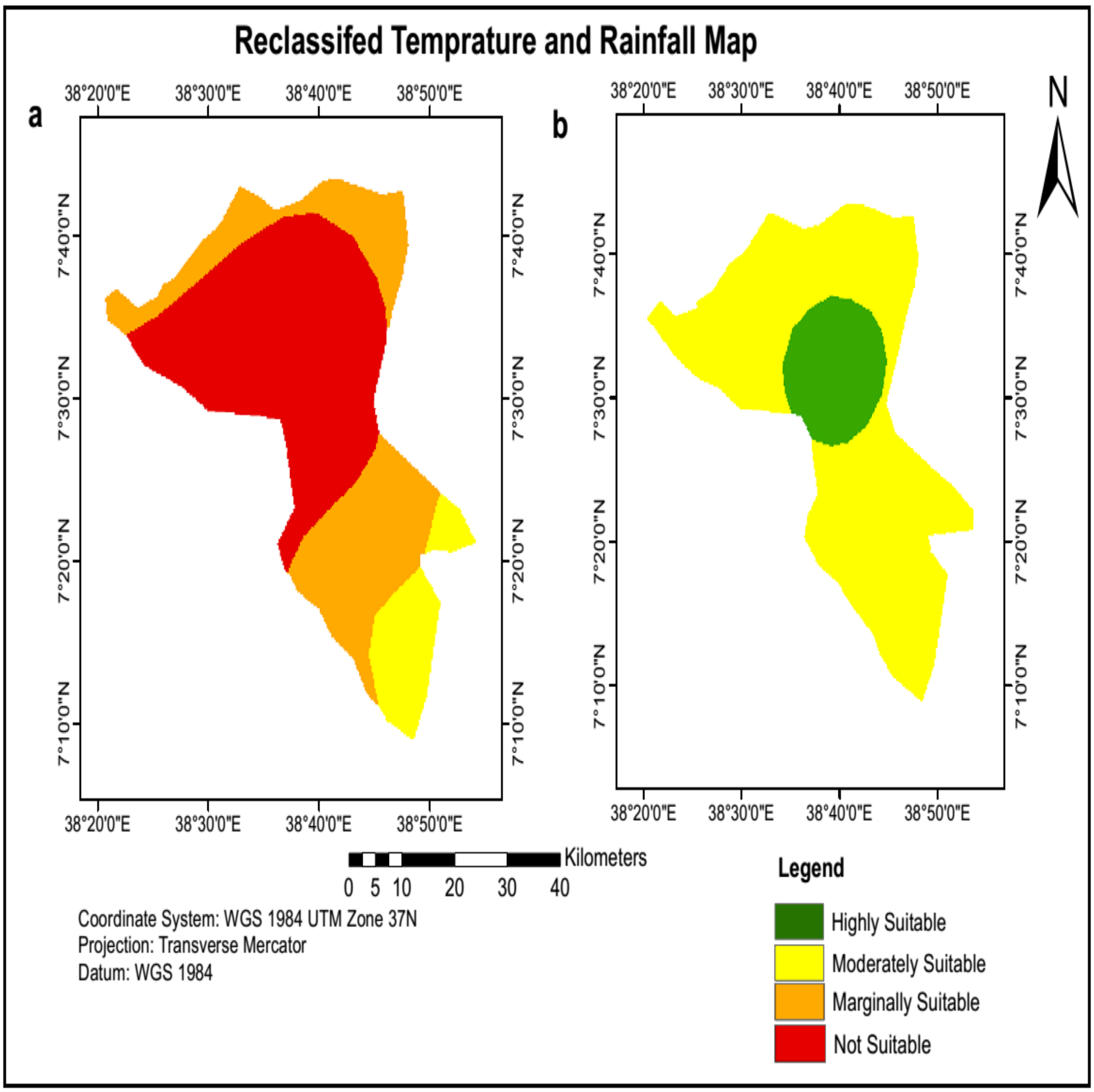

Figure 4.11: Reclassified Temperature and Rainfall map **a**) Temperature **b**) Rainfall

4.6.4 Reclassified Soil Chemical Property for rain fed agricultural use

Soil chemical property for this study obtained from MOA, ATA and world soil information (ISRIC). The classification is based on the table in 3.11 in previous chapter. The chemistry of the soil also very important property as this will determine what will grow and how well it will grow.

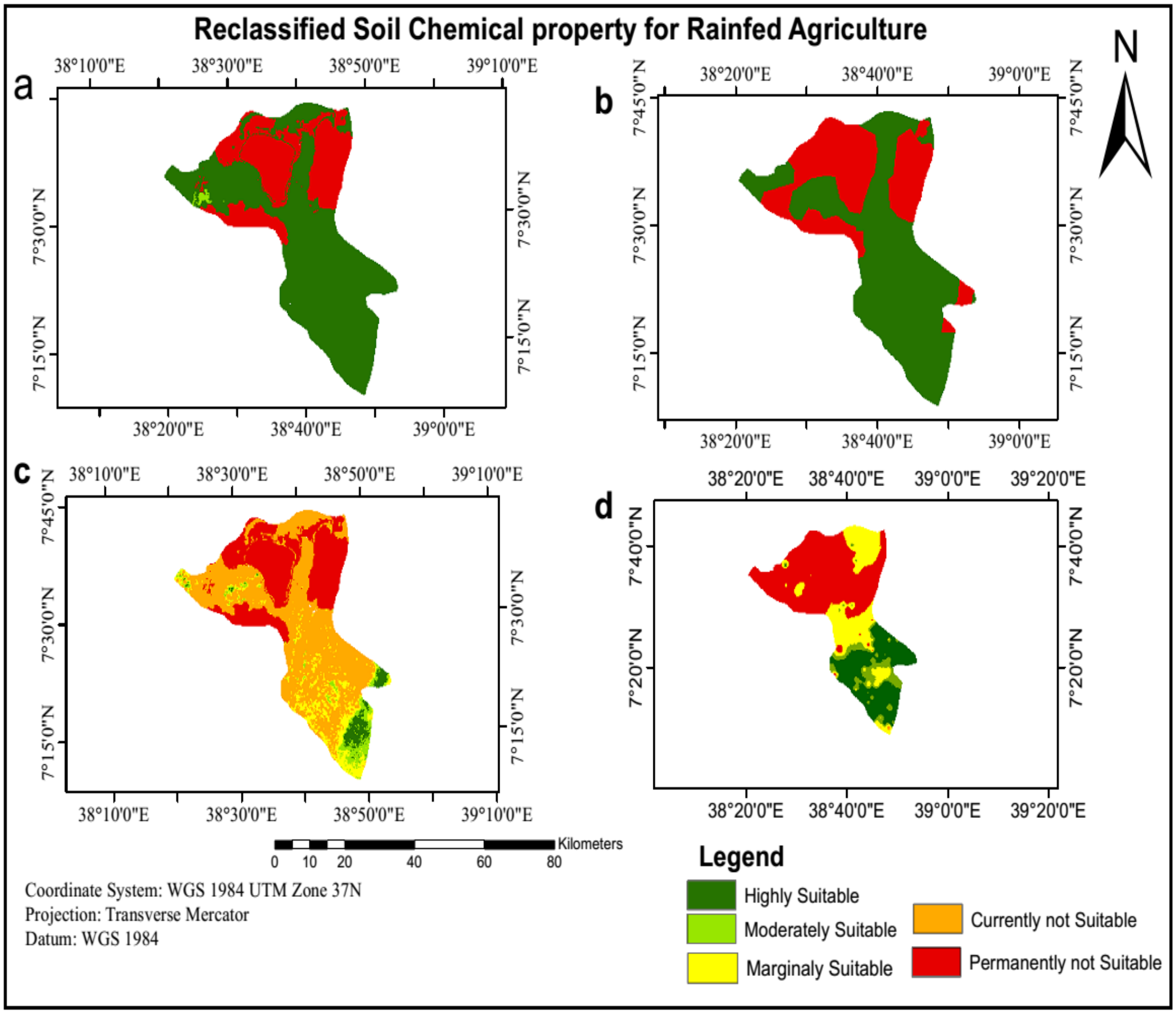

Figure 4.12: Reclassified Soil Chemical Property for Rain fed agriculture **a**) CEC **b**) EC **c**) OC and **d**) Soil PH

4.6.5 Reclassified Soil Chemical Property for Surface Irrigation

The chemical properties of soil can greatly influence how irrigable soils are by affecting the hydraulic characteristics and the suitability of soil for crop production. The soil must also have and adequate supply of available plant nutrients. Many chemical elements are essential for plant growth and are necessary to obtain large and satisfactory crop yields. Soil chemical property for this study obtained from MOA, ATA and world soil information (ISRIC). The classification is based on the table in 3.12 in previous chapter.

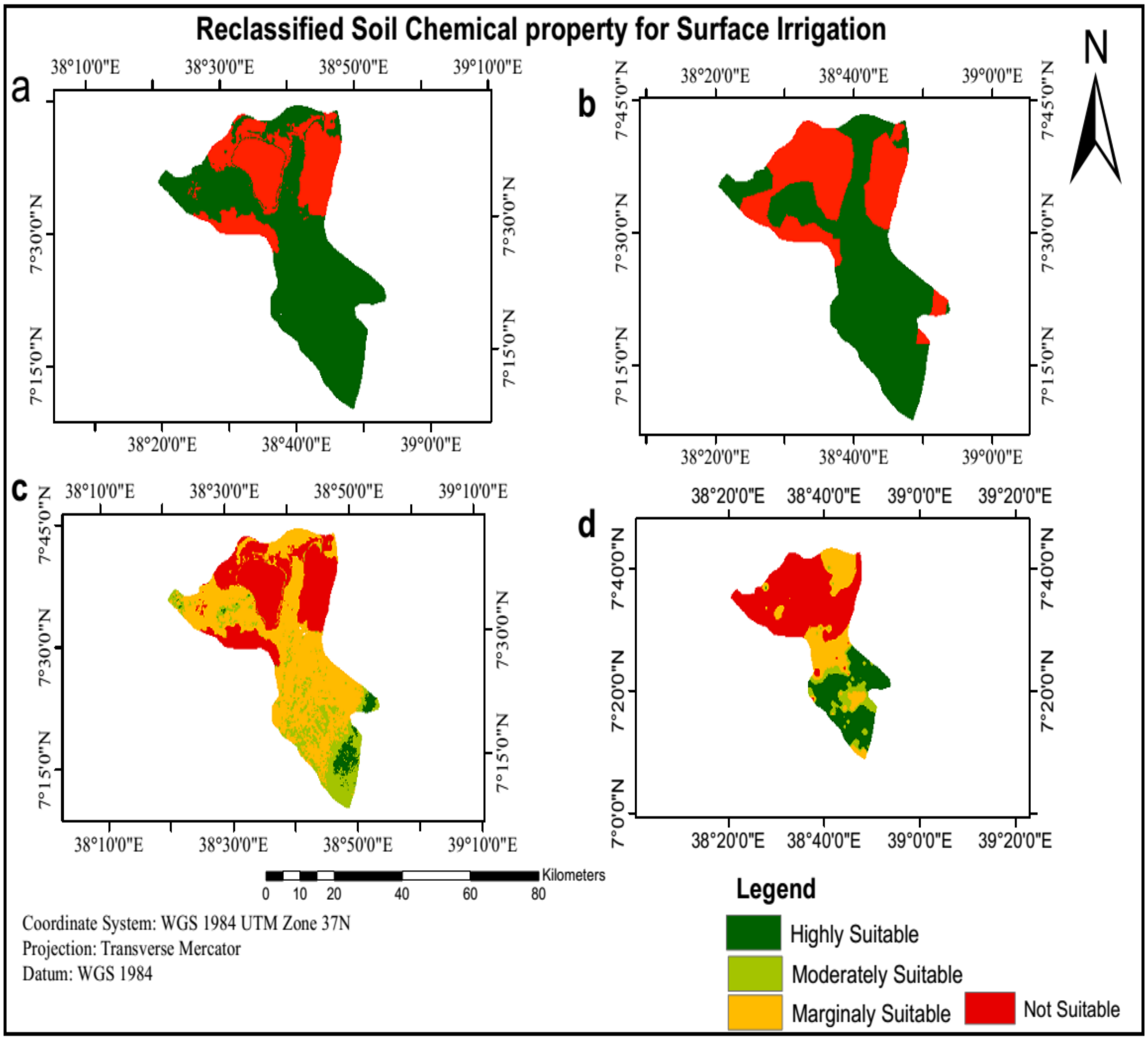

Figure 4.13: Reclassified Soil Chemical Property for Surface Irrigation a) CEC, b) EC , c) OC d) PH

4.6.6 Reclassified Soil Physical Property for Rain Fed Agricultural Land Use

The physical property of soil for this study obtained from MOA, ISRIC world information system and previous Soil loss erosion map by using RUSLE model. The physical properties of the soil are very important for agricultural production and sustainable soil use. Soil physical property classified based on table 3.11.

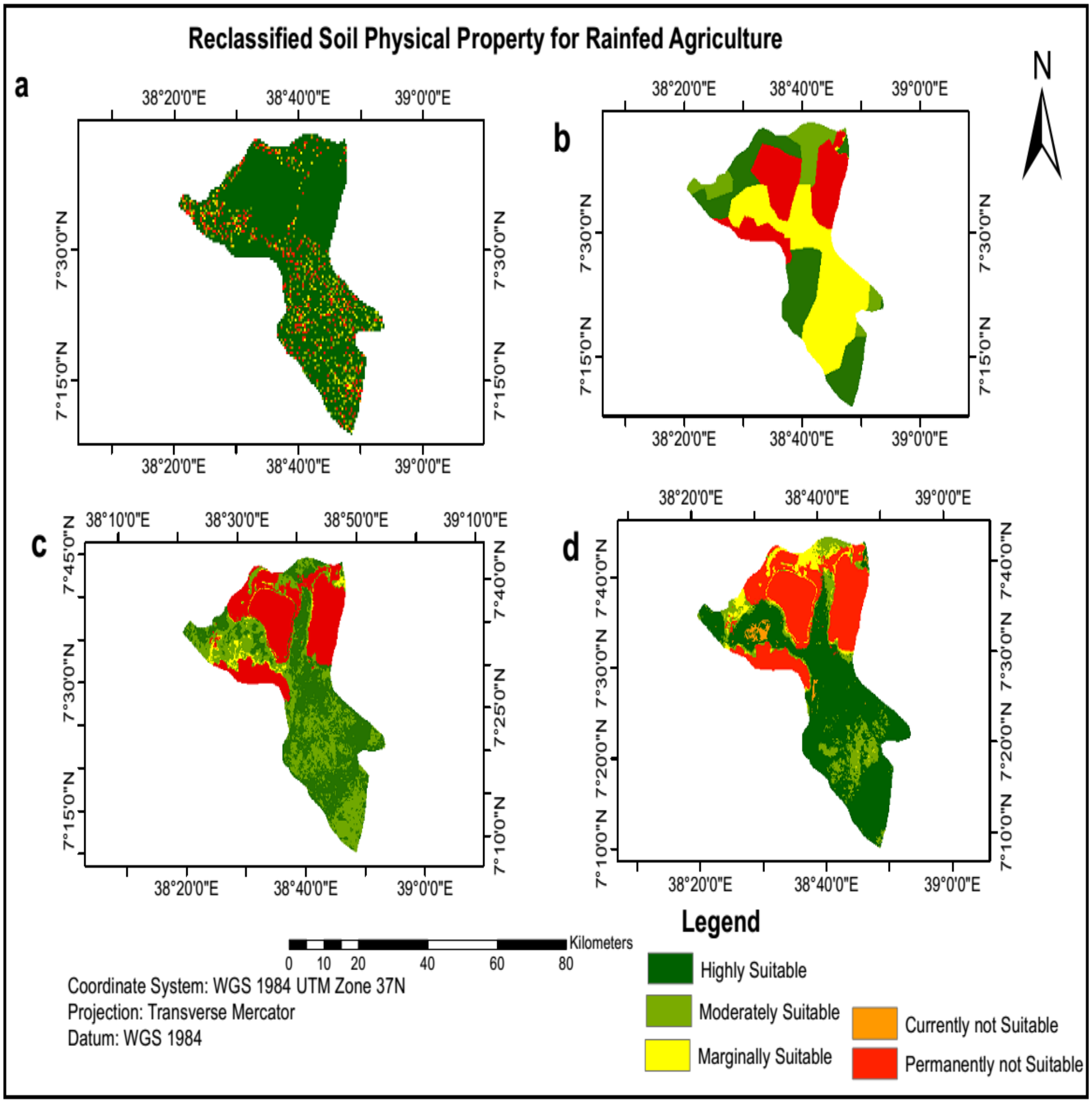

Figure 4.14: Reclassified Soil Physical Property for rain fed Agriculture a) Soil erosion b)Soil Texture c) Soil Depth d) Soil Drainage

4.6.7 Reclassified soil physical property

Reclassified Soil Physical Property for surface irrigation soil texture primary soil structure greatly influences the porosity and distribution of pore sizes, and there by the permeability of soil to air, water and roots, which is as important to crop growth as adequate supply of nutrients.

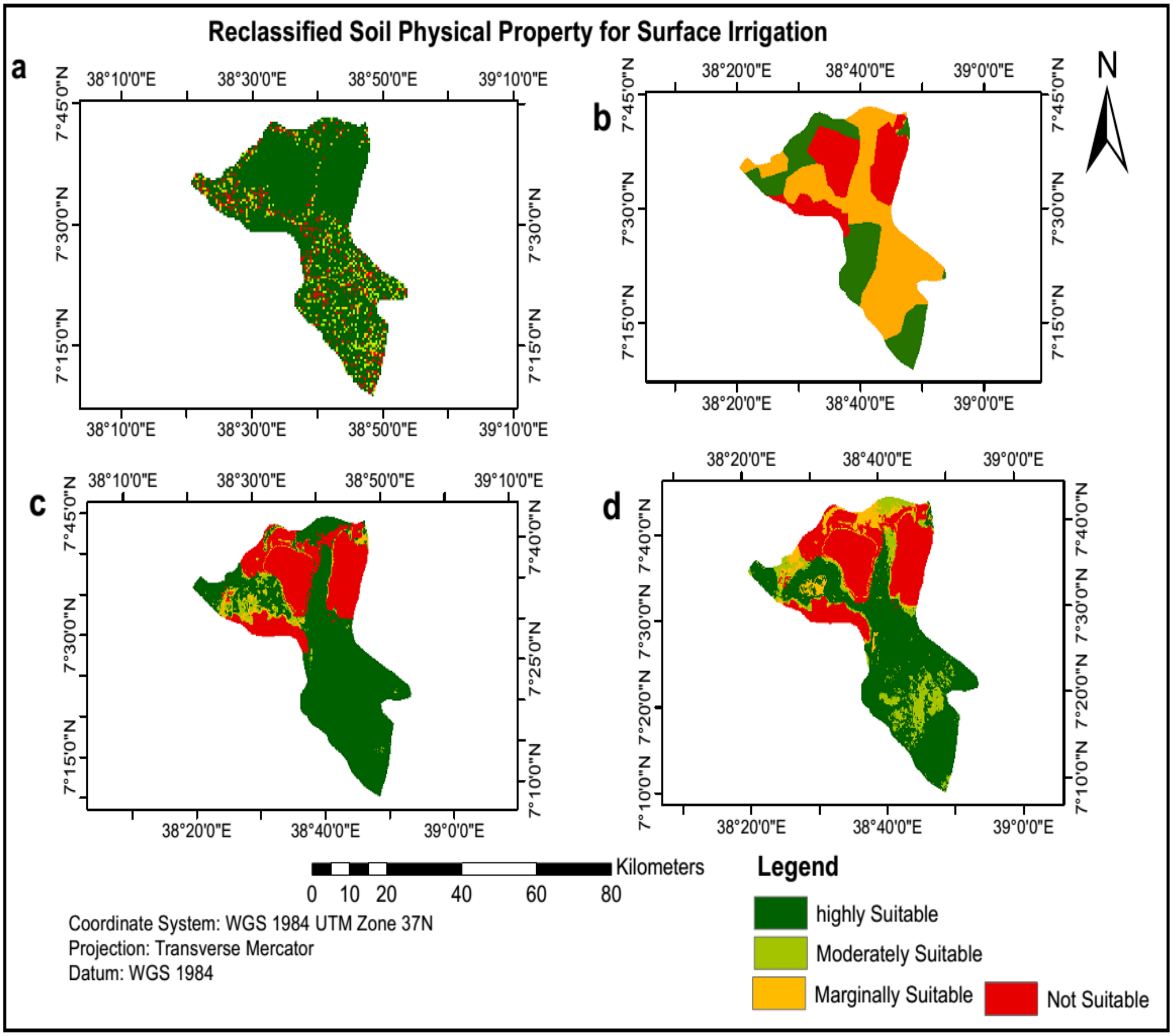

Figure 4.15: Reclassified Soil Chemical Property for Surface Irrigation a) Soil Erosion, b) soil texture c) soil depth d) soil drainage

4.7 Agricultural Land Use Suitability Map

As explained in the methodology part preparation of criteria maps involves the identification of the factors (criteria) required for land suitability for agricultural land use. The land suitability factors must be considered when evaluating the suability from highly suitable to permanently not suitable land for agriculture land use. The availability of GIS and multi-criteria decision analysis (MCDM) methods allow combining knowledge derived from different sources to support land use planning and management(Malcyewski ; 2000). In this study AHP is used to drive the weight factor. The pair-wise comparison was done for factor used to determine the agricultural land use suitability.

The preparation of land suitability map involves a weighting of relating factor that affect agricultural capability of the land. The factor is identified by personal discussion with different experts, nature of the study area, literature review of related study. A total of 13 parameters used in this study such as soil physical property (soil erosion, soil texture, soil depth and soil drainage) and soil chemical property (soil CEC,EC, OC and PH) as shown in figure 4.12 and 4.14 respectively, LULC , , meteorological data (rainfall and temperature) as shown in figure 4.11 .Likewise, land suitability for surface irrigation consider a total of 12 parameters such as soil physical property (Soil CEC, EC,OC and PH) and soil chemical property (soil erosion, soil texture, soil depth, soil drainage) as shown in figure 4.13 and 4.15 respectively, LULC ,Distance to water source as shown in figure 4.10 , Metrological data such as temperature as shown in figure 4.11. Before merging the reclassified image , weight must be assigned using the Analytical Hierarch process based on (satty, 1987) Analytical Hierarch process (AHP) , which involves creating a pair wise comparison matrix for each map using a nine-point priority scale as shown in table 3.12 in previous chapter . Each factor is compared with the other criteria in terms of their importance related to the stated objective. Table 4.5 and 4.6 shows weights derived for rain fed agriculture and surface irrigation respectively. In this study AHP is used to drive the weight for the factor by using AHP extension tool in Arc GIS 10.8.

Table 4.5: weight derived from pairwise comparison matrix for Rainfed agriculture

No.	Factors	Weight
1	Soil Depth	12.704
2	Organic Carbon	6.333
3	PH	3.945
4	LULC	22.508
5	Slope	5.504
6	Soil Erosion	2.13
7	Soil Texture	6.593
8	Soil Electric Conductivity	5.578
9	Temperature	3.815
10	Soil Drainage	4.425
11	Cation Exchange Capacity	8.81
12	Rain fall	18.134
	Total	100
	CR	0

Table 4.6: weight derived from pairwise comparison matrix for surface irrigated land

No	Factor	Weight
1	Texture	10.274
2	Depth	9.197
3	Soil Erosion	2.145
4	Soil Drainage	6.632
5	Temperature	3.042
6	Organic Carbon	4.559
7	LULC	4.345
8	Distance to water source	26.522
9	Electric Conductivity	4.576
10	Cation Exchange Capacity	11.167
11	PH	2.256
12	Slope	15.284
	Total	100
	CR	0.064

4.8 Land Suitable for Rain fed Agricultural Use

The land suitability Evaluation for rain fed agricultural land use using the weighted overlay analysis results showed four classes of suitability. These are highly suitable, moderately suitable, marginally suitable and permanently not suitable. However, there is no land that is classified as currently not suitable for rain fed agricultural use. Table 4.7 shows demonstrate the suitability class of rain fed agricultural land use and their area coverage.

Table 4.7: Land Suitability Class and Area Coverage for rain fed agriculture

No	Suitability Class	Area(ha)	Area (%)
1	Highly Suitable	15993.17	9.9
2	Moderately Suitable	40405.67	25
3	Marginally Suitable	57324.4	35.8
4	Permanently Not Suitable	46618.17	29.3
	Total	160341.4	100

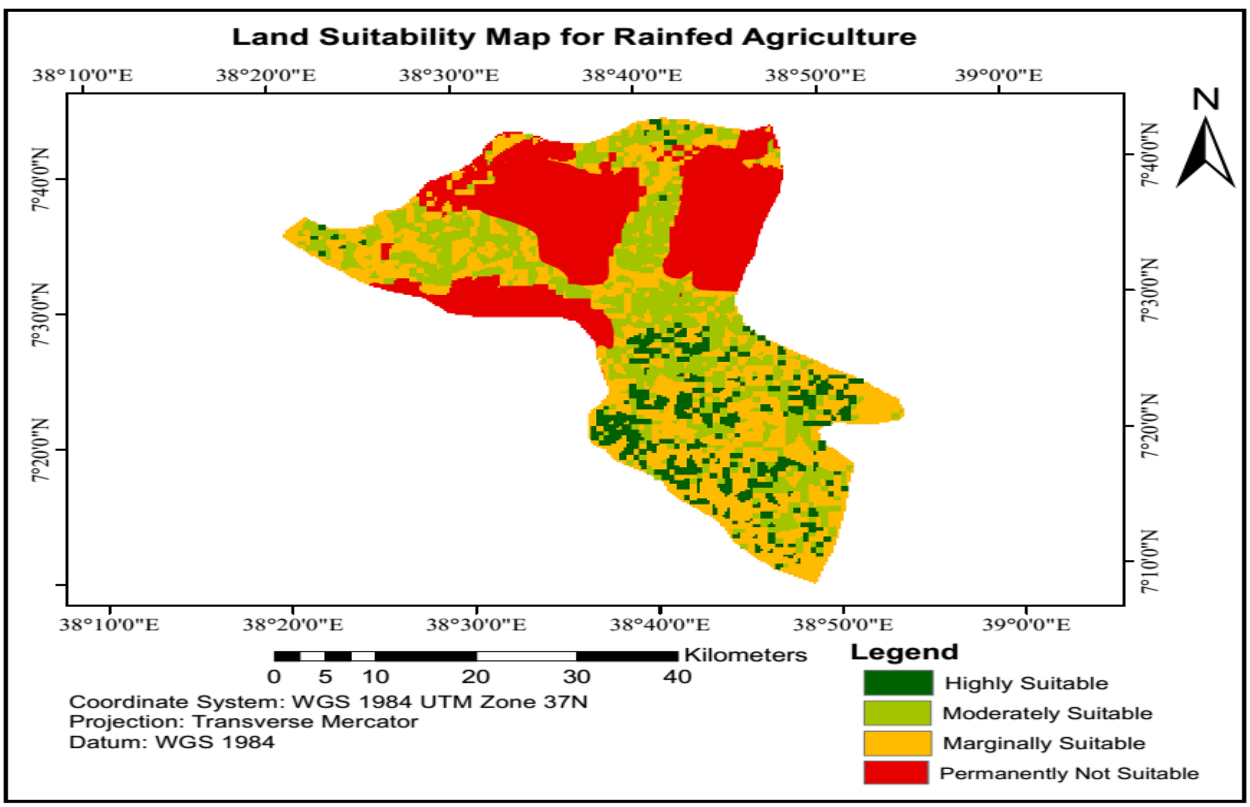

Figure 4.16: Land Suitability Map of Rain fed Agriculture

4.9 Land Suitable for Surface Irrigation

The land suitability analysis for surface irrigation using weighted overlay analysis results showed three classes of suitability. These are highly suitable, moderately suitable and Not suitable. However, there is no land that is classified as marginally suitable for surface irrigation land. Table 4.8 showed the suitability class for surface irrigation and their area coverage of the study area.

Table 4.8: Land Suitability Class and Area Coverage for Surface Irrigation

No	Suitability Class	Area (ha)	Area (%)
1	Highly Suitable	6724.2	4.2
2	Moderately Suitable	112793	70.4
3	Not Suitable	40824.25	25.4
	Total	160341	100

The land suitability evaluation maps for surface irrigation were presented in figure 4.15

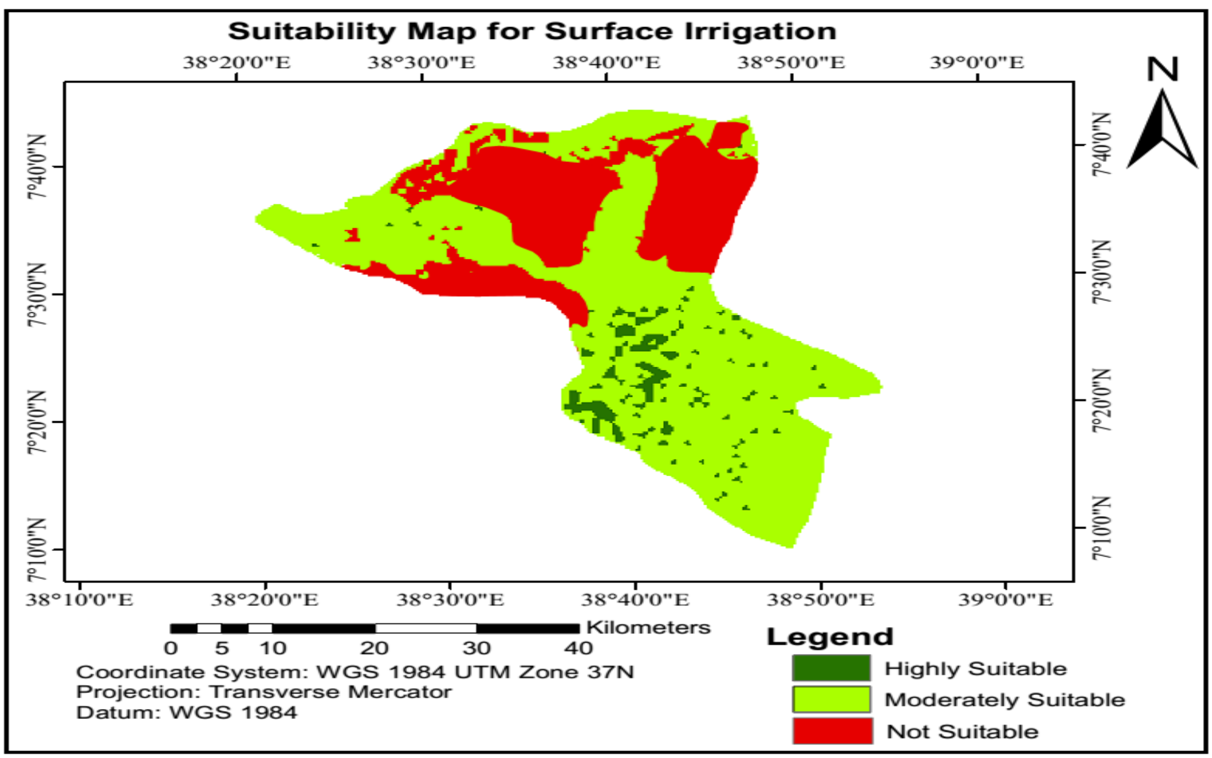

Figure 4.17: Land Suitability Map for Surface Irrigation

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

To enhance agricultural production and productivity, the need of land suitability evaluation for agricultural land and soil erosion is unquestionable specially, in Ethiopian highland when soil erosion is a serious problem. This study aimed to evaluate and mapping agricultural land suitability and spatial distribution of soil erosion in the study area which is necessary for sustainable land use to utilize limited resources efficiently and for compressive soil conservation management. To conduct this research soil data, DEM, Satellite image and climate data were used as input data set to generate land suitability and soil erosion map.

Evaluation of agricultural land suitability for both rain fed and surface irrigation land was identified based on the specified criteria. Land suitability analysis involved weighting of values of all the factors by using AHP multi-criteria decision making method. The weighted criterions showed in table (4.5) and (4.6) for land suitability rain fed and surface irrigation land respectively. The criteria were aggregated in weighted overlay analysis to produce a final land suitability map for both rain fed and surface irrigation land according to the defined regulation in ArcGIS 10.8.

This study also demonstrate that an empirically based erosion assessment model, the RUSLE, integrated with satellite remote sensing and geographical information systems can provide use full information for prevention and rehabilitation of soil erosion. The RUSLE model is a relatively simple soil erosion model with good data accessibility. By integrating RUSLE and GIS the annual soil loss and its spatial distribution evaluated in the study area as shown in figure 4.8.

The findings of this study shown that geospatial technology are useful tools for studies of land suitability evaluation for agricultural land use and soil erosion for sustainable agricultural land use. The result of the study enabled to make the following recommendation for farmers, policymakers, development actors and researchers who have responsibility to sustain agricultural land productivity by prevention and rehabilitation of soil erosion.

Based on the findings of this study Arsi Negele wereda agricultural land suitability comprises area which are 9.9% (15993.17 ha) land highly suitable (S1), 25% (40405.67ha) moderately suitable (S2), 35.8% (57324.4 ha) were marginally suitable and 29.3 (46618.17 ha) land were permanently not suitable (N2) for rain fed agricultural land suitability and 4.2 % (6724.2 ha) land were highly suitable (S1), 70.4 %(112793 ha) land moderately suitable (S2) and 25.4 % (40824.25 ha) land not suitable (N) for surface irrigation land .

The spatial distribution map of annual soil loss varied from 0 to 71.95 t/ha^{-1}/year^{-1}. The average annual loss in the evaluated wereda is 0.19 ton/ha^{-1}/year^{-1}. Based on the level of soil erosion rates, the wereda divided into five priority categories for soil conservation. The spatial risk categorization rate was 5.62% severe (>50 t/ha^{-1}/year^{-1}), 2.23 % very high (30 – 50 t/ha^{-1}/year^{-1}) , 2.28 % high (20 – 30 t/ha^{-1}/year^{-1}), 4.8 % moderate (10 – 20 t/ha^{-1}/year^{-1}) and 85 % low (0 – 10 t/ha^{-1}/year^{-1}).

5.2 Recommendation

- For sustainable agricultural land use and to prevent further soil erosion, before changing any land use land cover pattern land suitability evaluation must be performed.
- In this study, evaluation of land suitability limited to agricultural land use, but further researches should be continued the suitable crop selection and crop rotation for both irrigated and rain fed agriculture to improve agricultural land productivity.
- This study only evaluate agricultural land suitability further studies should be continued in the evaluation of other land use land cover pattern such forest, urban etc.
- Further research highly recommended from moderately to severe soil erosion risk class to find a solution of rehabilitate before further erosion or turning to no return.
- Future studies are required for the validation of calculated soil loss by using RUSLE model for the administrative boundary scale with the help of another soil erosion model in the same area.

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Adama, Ethiopia

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APPENDICES

Appendices I: Pairwise comparison matrix of criteria for rianfed agriculture

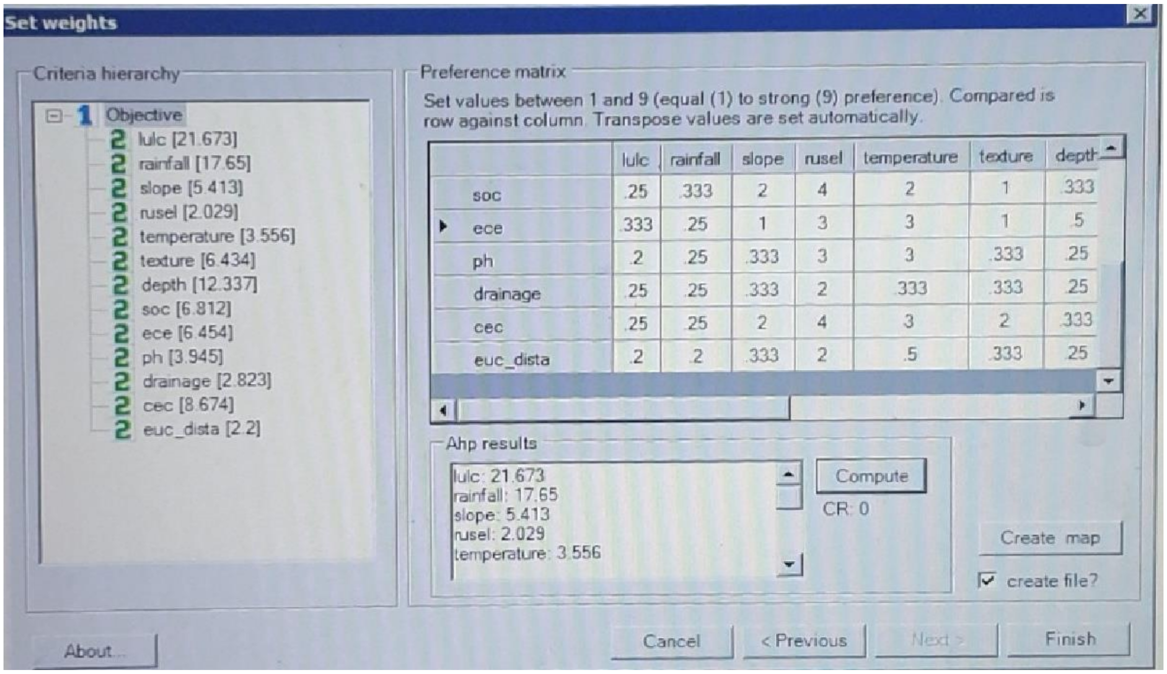
Pairwise Comparison Matrix of Criteria

	LULC	Rainfall	Slope	Erosion	Temperature	Texture	Detph	OC	EC	PH	Drainage	CEC	Distance to Water
LULC	1												
Rainfall	0.5	1											
Slope	0.25	0.25	1										
Erosion	0.2	0.25	0.3333	1									
Temperature	0.25	0.3333	0.5	2	1								
Texture	0.2	0.25	2	3	3	1							
Depth	0.25	0.3333	3	5	3	3	1						
OC	0.25	0.3333	2	4	2	1	0.3333	1					
EC	0.3333	0.25	1	3	3	1	0.5	1	1				
PH	0.2	0.25	0.3333	3	3	0.3333	0.25	0.3333	0.3333	1			
Drainage	0.25	0.25	0.3333	2	0.3333	0.3333	0.25	0.3333	0.3333	0.5	1		
CEC	0.25	0.25	2	4	3	2	0.3333	1	3	3	4	1	

Appendix II: Pairwise matrix of criteria for Surface irrigation suitability

Pairwise matrix of criteria												
	Slope	Texture	Temperature	PH	OC	LULC	Distance to Water	Erosion	EC	Depth	Drainage	CEC
Slope	1											
Texture	0.3333	1										
Temperature	0.25	0.333	1									
PH	0.25	0.25	0.5	1								
OC	0.3333	0.3333	3	2	1							
LULC	0.3333	0.3333	2	2	0.5	1						
Distance to water	3	4	5	6	5	5	1					
Erosion	0.25	0.2	0.5	1	0.3333	0.3333	0.1667	1				
EC	0.25	0.3333	3	3	2	0.5	0.2	3	1			
Depth	0.3333	0.5	3	4	4	3	0.2	4	3	1		
Drainage	0.3333	0.5	2	4	3	2	0.2	3	3	0.3333	1	
CEC	0.5	1	3	4	2	3	0.25	4	3	3	3	1

Appendix III: Weight derived for Rainfed agriculture



Appendix IV: Weight derived for Surface irrigation