ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Agricultural Land Suitability Analysis Using GIS and Remote Sensing Techniques: The Case of Mecha Woreda, Amhara, Ethiopia

A thesis submitted to the Graduate Studies of the School of Civil and Environmental Engineering at Addis Ababa Institute of Technology, in order to partially fulfill the requirements for the Master's degree in Geodesy and Geomatics, with a specialization in Geomatics.

By: ABEBE NEGUSSIE

Advisor: Dr. Hamere Yohannes

January, 2024

Addis Ababa

ADDIS ABABA UNIVERSITY

Department of Civil and Environmental Engineering

at the School of Graduate Studies

Agricultural Land Suitability Analysis Using GIS and Remote Sensing Techniques: The Case of Mecha Woreda, Amhara, Ethiopia

By : ABEBE NEGUSSIE

This has been given approval by the board of examiners:

Advisor: Hamere Yohannes (PHD --- Signature-----------Date-------------

Internal Examiner---------------------------Signature----------Date--------------

External Examiner --------------------------Signature ---------Date--------------

Chairman -------------------------------------Signature------------Date-------------

DECLARATION

I now declare that this thesis has been solely authored by me and was completed under the guidance of Hamere Yohannes (PHD), and that it hasn't been submitted to any other university or institution in order to be considered for a degree. I confirm once again that all the information sources used in the thesis have been appropriately acknowledged through citations.

Name: Abebe Negussie **Advisor: Hamere Yohannes (PHD)**

Signature: _________ **Signature: _________**

Date: _____________ **Date: _____________**

Acknowledgments

First and foremost, I would want to thank the "Almighty God," who has assisted and directed me in every aspect of my life and particularly in getting this work done. I'm grateful to the Lord for addressing and mitigating the challenges I encountered during this research.

Second, I want to sincerely thank Dr. Hamere Yohannes, my advisor, for her intelligent, helpful, and invaluable advice and remarks during this research project. Throughout the entire thesis process, her counsel, patience, wisdom, sharp observation, motivation, and kindness were immensely helpful. I sincerely appreciate her steadfast assistance.

Third, I would also express my gratitude towards the Ethiopian Metrology Institute Agency (EMIA), and the Food and Agricultural Organization for generously providing data and documents without any cost.

I would also like to express my sincere gratitude to Ato Shumet Mengesha, who gave me all the tools I required to support my academic endeavors, including technological help and academic advice. His guidance, counsel, and encouragement were much valued during the thesis phase.

Lastly, aspecial thank you to each and every one of my families for helping me with this paper by providing both ideas and materials.

Contents page

List of Tables

List of figures

Acronyms

ALSA	Agricultural Land Suitability
DEM	Digital Elevation Model
DN	Digital Number
GIS	Geographic Information System
LST	Land Surface Temperature
LULC	Land use Land Cover
MCDM	Multi - criteria decision making
NDMI	Normalized Difference Moisture Index
NDWI	Normalized Difference Water index
OLI	Operational Land Imagery
RS	Remote Sensing
SRTM	Shuttle Radar Topographic Mission
TIRS	Thermal Infrared Sensor

Abstract

Agricultural land suitability study plays a vital role in determining forthcoming agricultural cropping patterns, as well as in the formulation of plans and activities related to agriculture. The assessment of land suitability is a critical endeavor that involves the evaluation of a specific area to ascertain its appropriateness and suitability for a particular use within a given locale. This process encompasses a comprehensive analysis that takes into consideration a multitude of factors, including soil characteristics, climate conditions, topographical features, and the availability of water resources. This analysis on land suitability employs a multi-criteria analytical approach in order to determine the most appropriate land for rain-fed purposes. The results of this analysis demonstrate that a considerable proportion of the region being examined exhibits a high level of suitability for agricultural activities. Approximately 20.92% of the region can be designated as significantly suitable for agricultural practices, and an additional 33.03% can be described as highly suitable. These statistics reveal that around 54% of the entire area possesses a substantial capacity for prosperous farming endeavors. According to the research's discoveries, a substantial segment of the evaluated territory is either highly suitable or very high suitable for irrigation, with a combined total of 82.66%.However, there are also notable areas that are only moderately or low suitable (13.96% combined), while a smaller proportion is not suitable (3.38%) for irrigation purposes In conclusion, the results suggest that a significant proportion of the region being examined exhibits a considerable level of suitability, ranging from high to extremely high, for agricultural purposes.

Key Words: Agricultural land use suitability, GIS, Weighted Overly Analysis, surface irrigation

CHAPTER ONE

1. Introduction

1.1. Background of the Study

Agricultural land suitability analysis plays a critical role in the determination of future agricultural cropping patterns, planning, and activities. It involves evaluating a specific area to ascertain its suitability for a particular land use in a specific geographical location (Singha & Swain, 2016). Conducting a suitability analysis for cropland is crucial in order to effectively use available land resources and achieve sustainable agricultural production (Samanta et al., 2011). Suitability can be assessed by examining the crop requirements and land characteristics, thus providing an indication of the extent to which the attributes of the land unit correspond with the demands of a particular type of land utilization. (Aymen et al., 2021). An essential element in attaining sustainable agricultural production involves the examination of the appropriateness of agricultural land, as it contributes to the improvement of the utilization of current land resources and the detection of prospective new land for agricultural purposes. (Hassan et al., 2020). The evaluation of agricultural land suitability is depending upon the fulfillment of crop prerequisites and the assessment of soil or land attributes. The arrangement of land characteristics with the demands of specific crops determines the level of suitability (Singha & Swain, 2016). Land suitability analysis can assist in formulating approaches to enhance agricultural productivity (Yalew et al., 2016).

Agricultural resources are widely regarded as being among the most crucial natural resources that are renewable and constantly evolving (Perveen et al., 2007). In contemporary times, there has been a substantial escalation in the global population. Consequently, the agricultural sector is compelled to enhance its output in order to meet the heightened demand for sustenance. Given the prevailing circumstances, the availability of land poses a constraint, rendering it unfeasible to expand the cultivated area. As a result, agricultural communities must confront the task of augmenting food production within the confines of the existing land exclusively (Prakash, 2003).

Multi-Criteria Decision Making (MCDM) or Multi-Criteria Evaluation (MCE) has been developed with the purpose of augmenting the spatial decision-making process, especially in circumstances where a variety of options require assessment based on contradictory and incomparable criteria (A. Mustafa et al., 2011).

Therefore, this study used a Multicriteria analysis strategy to determine the best area for irrigation and rain-fed agriculture using geographic information system (GIS) and remote sensing techniques.

1.2. Statement of the Problem

In recent decades, the region has faced the challenge of unsuitable land utilization, which poses a significant risk to its sustained social and economic progress. This has consequently led to the emergence of numerous significant environmental concern (Teka et al., 2013). In the context of developing nations, there has been a growing inclination towards agricultural methodologies carried out with a focus on environmental sustainability. Therefore; agricultural productivity should be given attention by selecting suitable land. The agricultural productivity has been significantly influenced by the population growth from the beginning of the twenty-first century (Ozsahin & Ozdes, 2021). Agriculture is crucial for the majority of individuals living in impoverished nations, especially in Sub-Saharan Africa, as it serves as a primary means of sustenance. Consequently, it is recognized as a fundamental element for fostering economic progress, eradicating poverty, and improving the availability of food (Albore, 2018). In recent years, there have been significant transformations in land use policies in the northern region of Ethiopia. Nevertheless, the extent of research conducted on the influence of these modifications on land utilization and their effects on the advancement of agriculture is severely restricted (Teka et al., 2013). The significant erosion and decline in cultivability of the Ethiopian highlands necessitate prioritizing the improvement and preservation of natural resources. This is crucial for attaining sustainable development and guaranteeing food security (Worku, 2015). The nature of agricultural production in Ethiopia is distinguished by its focus on subsistence, resulting in low productivity and a limited application of technology. Furthermore, this sector is highly vulnerable to fluctuations in rainfall. The performance of productivity within the agricultural domain holds significant importance in enhancing the overall economic prosperity of Ethiopia. The absence of irrigation development, the prevalence of land degradation, infertile soil, excessive grazing, and the process of deforestation represent a number of the constraints that have impeded agricultural productivity in recent times (Bekabil et al., 2014). The problems mentioned above apply to the current study area, Mecha, west Gojjam.

Integrating suitable analysis for rain fed agriculture and irrigation is crucial for optimizing crop yields, reducing water waste, improving crop quality, and enhancing sustainability

(Kim et al., 2023). Through the utilization of appropriate analysis, agricultural practitioners possess the capability to reduce judicious determinations concerning the oversight of water resources, the preservation of soil condition, and the facilitation of crop development, thereby culminating in enhanced levels of output and financial gain.

Previously, numerous investigations were undertaken in relation to this research within alternative fields of study.Among these, Ozsahin & Ozdes (2021), Tekirdağ province in Turkey; Everest et al. (2021), in Northwestern Turkey and Yalew et al. (2016) conducted in the Abbay basin, assessed land suitability for agricultural productivity. Still, they didn't identify the best for rain-fed and irrigation purposes. In the study performed by Ennaji et al. (2018), an analysis was carried out relating to the appropriateness of land for the purpose of promoting sustainable agriculture within the northeastern region of Tadla plain, situated in Morocco. However, the study focused solely on the investigation of slope and soil suitability as the factors influencing agriculture. The study carried out by Aymen et al. (2021) aimed to ascertain appropriate land for rain-fed and irrigation purposes in Ma'an Governorate, Jordan. This was achieved through the utilization of five key factors, namely, rainfall, temperature, slope percentage, soil types, and the distribution of water wells. The current study aims to fill such information gaps by understanding the above detailed studies. Therefore, by using GIS and RS techniques, this study was located the optimum suitable land for rain-fed and irrigation agricultural purposes in the study area using the following eleven factors. These are land use land cover (LULC), land surface temperature (LST), normalized difference moisture index (NDMI), soil type, soil depth, rainfall, slope, elevation, aspect, proximity of rivers/water wells, and proximity of roads.

1.3. Objectives of the study

1.3.1. General Objective

The general objective of the study is to analyze Land Suitability for Agricultural Purposes Using GIS and RS techniques.

1.3.2. Specific Objectives

- To analyze the parameters for agricultural land suitability analysis
- To determine the optimum land suitable for rain-fed agriculture by using multi-criteria analysis
- To map the suitable land for irrigated agriculture purposes in the study area by using MCE method

1.4. Basic research questions

- What are the parameters for agricultural land suitability analysis?
- Where is the optimum suitable land for rain-fed agriculture located in the study area?
- Which part of the study area is suitable for irrigation purposes?

1.5. Significance of the study

This study is expected to have scientific contributions to the rural environment's agricultural productivity. It also contribute to understanding the application of GIS and remote sensing on evaluating the land suitability for irrigation and rain fed, and inform different stakeholders on their decision-making processes for agricultural productivity. Therefore, the current research helps the concerned body to prevent or minimize land surface temperature within the environment. Additionally, this study offers valuable insights to other researchers who are interested in conducting similar research.

1.6. Scope of the study

This study was conducted at Mecha woreda and carried out to identify the parameters for agricultural land suitability analysis; to locate the optimum land suitable for agricultural production by using multi-criteria analysis and to map the suitable land for irrigated agricultural purposes in the study area. In order to carry out this study, the Landsat-8 satellite imagery from the year 2022, digital elevation model (DEM) data from the Shuttle Radar Topographic Mission (SRTM), climatic data, information on road networks, and data on river systems was be employed.

1.7. Organization of the study

There are six chapters in this thesis. An overview of the study is given in the first chapter, which is divided into four sections: Background, Problem Statement, Objectives, Significance of the study, and scope of the study. The review of linked literatures is the subject of the second chapter, which focused on the following topics: the Concept of Agricultural Land Suitability Analysis, The Role of GIS and RS in Agricultural Land Suitability Analysis, and Multi-Criteria Decision Making (MCDM). The research's materials and methods are covered in the third chapter. These consist of an overview of the research area, data utilized in the study, and data analysis. The results of the analysis for the research region are covered in the fourth chapter. Chapter Five discusses discussions , whereas Chapter Six discusses the conclusion.

Chapter Two

Literature Review

2.1. Concept of Agricultural Land Suitability Analysis

Estimating a land unit's intrinsic ability to sustain a particular land use for an extended length of time without degrading is the primary goal of land evaluations, with the aim of reducing the costs associated with both the environment and society (Wakassa, 2010). Agriculture practices are crucial for ensuring food security and sustainability in our communities. With the growing population and limited resources, it is essential to utilize suitable lands efficiently for agriculture. Suitable lands, also known as prime agricultural lands, are characterized by their fertility, accessibility, and favorable climate conditions (Zolekar & Bhagat, 2015). These lands provide the ideal conditions for crop cultivation, livestock rearing, and other farming activities (Sahoo et al., 2018).

Assessing the suitability of agricultural land (ALSA) is a useful method for identifying the features of agricultural productivity. (Ozsahin & Ozdes, 2021). In order to maximize the use of available land resources for sustainable agriculture, it is important to assess the suitability of cropland. Developing countries often have land use that is not ideal, making it urgent to find the most rational and feasible ways to utilize the land (Perveen et al., 2007). The appropriateness depends on the qualities of the land and the specific demands of the crop, and it gauges how effectively the attributes of a particular plot of land align with the requirements of a given land usage (Mustafa et al., 2011). Assessing the suitability of land for agriculture is essential in determining the optimal crops to cultivate and effectively planning and executing farming operations. This assessment entails determining if a specific area is appropriate for a particular land use, such as cultivating a specific type of crop, considering its location and attributes. (Singha & Swain, 2016).

2.2. Parameters for Agricultural Land Suitability Analysis

2.2.1. Suitable Topography for Agriculture

The appropriateness of a region for the practice of water harvesting is heavily dependent upon the unique characteristics of its topography. Infiltration volume and runoff yield are greatly influenced by the topography. The gradient of a land, which is a crucial element for water harvesting, significantly impacts the choice of a micro catchment system. Gentle slopes are more suitable for micro catchment systems (Oweis et al., 2012). The presence of high elevations, steep slopes, exposed rocks, and limited access to irrigation water have resulted in the identification of areas unsuitable for agricultural activities. As a result, only small portions of land are suitable for agriculture (Hassan et al., 2020). The incline plays a pivotal function in ascertaining the appropriateness of rangeland for various applications (Jafari & Zaredar, 2010). The analysis of slopes is beneficial in identifying suitable locations for agriculture. The presence of nutrients in the soil differs depending on the slope. Steep slopes with increased erosion tend to have thin soils, while deep soils are found in gently sloping areas such as valleys and foothills. Soil nutrients and minerals levels differ based on environmental conditions and the amount of soil available. The productivity of agriculture also varies with slope due to local variations in soil nutrients and minerals. There is a positive correlation between variations in slope and productivity (Zolekar & Bhagat, 2015a).Slope plays a crucial role in agriculture as it significantly impacts various aspects such as soil depth, erosion susceptibility, soil tillage, use of agricultural machinery, irrigation, and plant adaptation. The degree of slope, along with its length and sharpness, directly influence the loss of soil and water in a given area(Everest et al., 2021). The impact of soil slope on erosion is especially significant (Ennaji et al., 2018). The slopes are responsible for the variability in the distribution of soil qualities such as soil depth, soil moisture, soil texture, and nutrient availability.(Zolekar & Bhagat, 2015a).

2.2.2. Soil for agricultural suitability

To evaluate the overall appropriateness of the soil for agriculture, markers such as soil type, soil depth, and soil water content are used.

2.2.2.1. Soil type

Characteristics of texture and color are used to identify different types of soil; texture is the primary factor in determining suitability classes. When determining a property by touch, the most crucial factor is its texture. In order to ascertain texture, one must consider the relative amounts of sand, silt, and clay as well as the existence or absence of laterites and gravels. Soils are categorized as stony, clay, sandy, and loamy using this straightforward procedure. (Adewole Osunade, 2010)

Table.2. 1: Types of soil

Classes	Soil types
Stone soils	Gravelly soil Lateritic soil Stoney soil Reddish brown Stoney soil Dark Stoney soil
Sandy soils	Coarse sandy soil Reddish brown sandy clay soil Light sandy soil Dark sandy soil
Clay soils	Clay soil Reddish brown clay soil Dark clay loamy soil Light clay, light clay sandy soil Stoney clay soil Loamy clay soil
Loamy soils	Loamy soil Reddish brown loamy soil Dark loamy soil

Source: (Adewole Osunade, 1988)

2.2.2.2. Soil Depth

The thickness of the soil above a layer that prevents root growth is known as the effective soil depth (Samanta et al., 2011). One of the key elements in a plant's ability to get nutrients and water is the depth of the soil. It has an impact on the roots' ability to grow and spread healthily. Plants with well-developed roots have easy access to water and nutrients. (Everest et al., 2021). One important factor that modifies the potential root volume is the depth of the soil.(Meyer et al., 2007). Plant water exchange rates and hydrological events are influenced by root volume. Topographic conditions are directly related to soil depth (Gabet & Mudd, 2009). Soil depth reduces and erosion vulnerability rises in steep and sloping locations. Soil depth rises and falls as slope rate increases as slope declines (Ennaji et al., 2018).

2.2.2.3. Soil Moisture

The temporary storing of rainwater in a thin layer of the earth is referred to as soil moisture (Yalew et al., 2016). A variety of biological processes and agricultural operations depend on the moisture content of the soil. Sufficient soil moisture is necessary for the germination of seeds, the growth of roots, and the general expansion of plants. Plants under drought stress due to low soil moisture levels might have an impact on crop quality and output (Zolekar & Bhagat, 2015a). The determining factor for the agricultural suitability zone is soil moisture (Sahoo et al., 2018). Soil moisture is a crucial factor in agriculture as it affects the availability and use of surface water resources. It plays a vital role in the growth of plants, agricultural productivity, and the overall balance of local ecosystems. The local administration has found it challenging to manage water resources and make decisions because of a lack of understanding regarding changes in soil moisture. Thus, using remote sensing to monitor soil moisture turned into a practical method for planning crop irrigation schedules and assessing irrigation effectiveness. Therefore, accurate and up-to-date monitoring of soil moisture levels across large areas using high-resolution remote sensing data is crucial for practical purposes such as assessing ecological stability in the basin and promoting efficient usage of resources (Nie et al., 2020). There is a favorable correlation between crop output and soil moisture, which serves as a useful indicator of soil characteristics. A soil's depth and texture both affect how much moisture it contains. A sensitive measure of the amount of water in vegetation, the NDMI is a reliable indicator of soil moisture (Zolekar & Bhagat, 2015a). According to Pramanik (2016), By measuring the moisture map using the Near-Infrared (NIR) and Shortwave-Infrared (SWIN) bands of Landsat 8 satellite pictures, the Normalized Difference Moiter Index (NDMI) can be computed.

$$\text{NDMI} = \frac{NIR - SWIR}{NIR + SWIR} \quad (1)$$

2.3. The Role of GIS and RS for Agricultural Land Suitability Analysis

Using GIS techniques in agricultural planning can be a valuable tool for determining the most suitable land use in a specific area. A number of tools that enable the input, storing, retrieval, manipulation, analysis, and output of spatial data comprise the technology component of GIS (Singha & Swain, 2016). An adaptable tool for the challenging process of land use evaluation is offered by GIS and remote sensing technologies. With the ability to gather information on drainage, terrain, land use/cover, and drainage, remote sensing provides an all-encompassing and objective source of landscape data. GIS is a useful tool for assessing natural resources and analyzing the surroundings (Perveen et al., 2007). The use of geographical information system (GIS) allows for a more precise and flexible analysis of multiple geospatial data in land suitability analysis, particularly for agricultural development. GIS techniques are utilized to create different maps based on specific criteria, which are then incorporated into the analytical hierarchy process to establish a site suitability model (Pramanik, 2016). The use of GIS multi-criteria decision-making (MCDM) methods allowed for the incorporation of different datasets, helping to determine the best possible arrangement for soil utilization in upcoming years. (Ennaji et al., 2018).

Remote sensing is crucial for land suitability analysis at both regional and local scales, as it provides a dependable and efficient approach for mapping agricultural lands. The combination of GIS and remote sensing allows for a clear visualization of the spatial patterns of agricultural land suitability (Singha & Swain, 2016). The integration of Geographical Information System (GIS) and Multi-criterion Decision Making (MCDM) techniques has proven to be valuable in land suitability analysis as it allows for the analysis of multiple geo-spatial data with greater precision and flexibility. This integration has been utilized in various studies to provide decision support for land use planning (Zolekar & Bhagat, 2015b).

2.4. Multi-Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) techniques are used to measure the suitability of land for various purposes, such as agriculture. However, there is no widely agreed-upon approach in this field. The incorporation of GIS into MCDM is now widely adopted in research on determining the appropriateness of agricultural land (Mistri & Sengupta, 2020). Multi Criteria Decision Making (MCDM) or Multi Criteria Evaluation (MCE) has been formulated with the intention of enhancing the process of spatial decision-making in situations where a collection of alternatives necessitate assessment on the basis of contradictory and incommensurate criteria. MCE serves as a potent instrument for addressing the complexities of multiple criteria decision-making concerns(Mustafa et al., 2011). Using a GIS-based Multi Criteria Decision Making technique, a land suitability analysis was carried out. Numerous elements, including soils, climate, and water availability, were evaluated in this investigation. Based on the information supplied by various levels of stakeholders, these aspects were evaluated. To rank the suitability factors, an Analytical Hierarchical Process was applied. The suitability map layers were then created using the weights that were produced. These maps were made with the calculated weights in mind for both dry and irrigated farm agriculture. (Feizizadeh & Blaschke, 2013).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study area description

3.1.1. Location Map

This study area is carried out in Mecha woreda which is situated in the West Gojjam Zone of the Amhara Region. Extends from 11°05'00" N to 11°38'00" N latitude and 37°01'00"E to 37° 22'00"E longitude (Fig. 1). In addition, the elevation is between 1792 and 3064 meters above sealevel.

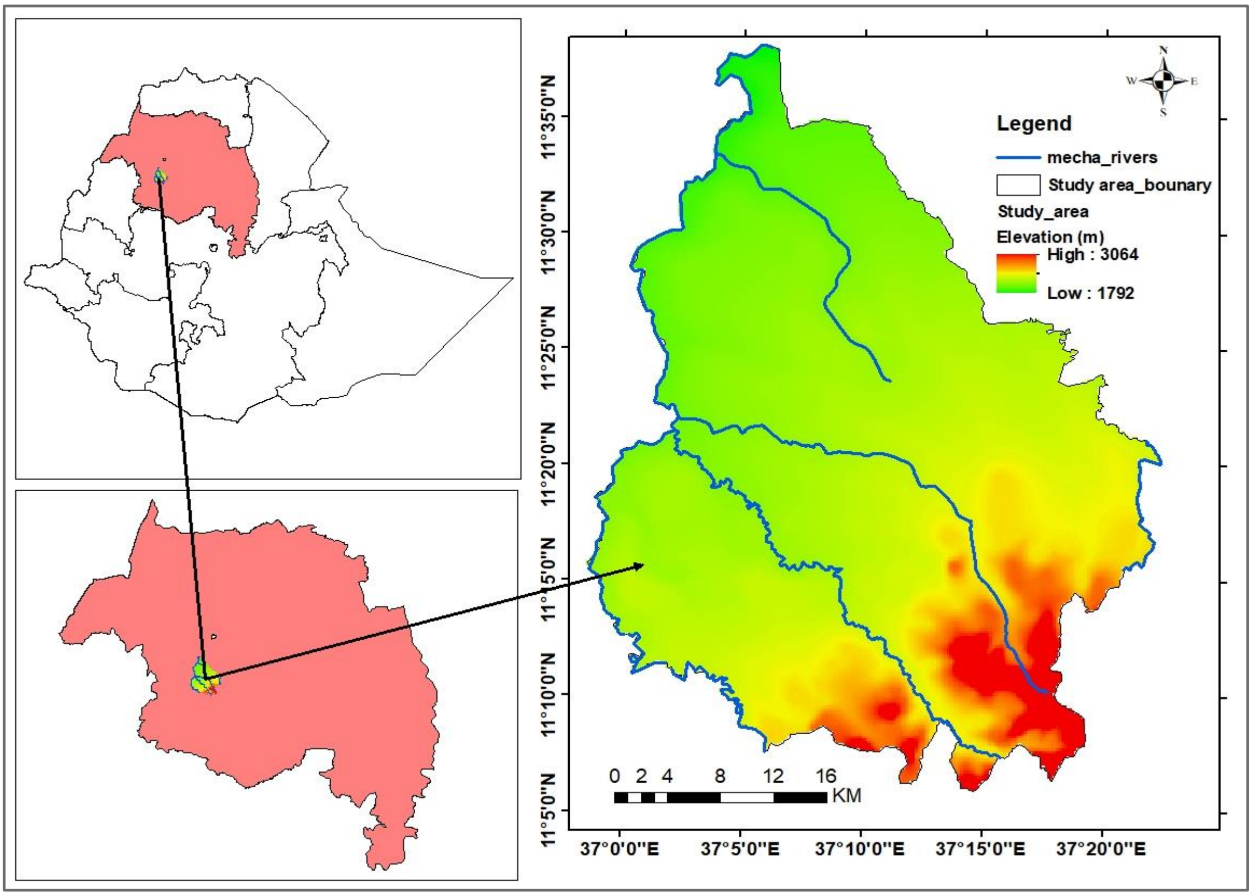


Fig3. 1: Location map of the study area

3.2. Data types and sources

This study's data obtained from a number of sources. Table 1 below summarizes and presents the extra data and satellite photos that are important to this investigation

Table3. 1: Data types and sources used in the study

No	Data	Format of the data	Purpose and description	Source
1	Landsat 8 OLI and TIRS of year (2022)	Raster	To estimate LST, LULC, NDMI	https://earthexplorer.usgs.gov/
2	Soil type	Shape file	To produce soil type map	FAO
	Soil depth	Raster	To produce map soil depth	https://data.isric.org/
3	Rainfall data	Raster	To create a map of rainfall	National meteorological agency
4	SRTM, DEM	Raster	In order to compute aspect, elevation, and slope	https://earthexplorer.usgs.gov/
5	Transport network	Shape file	To show the proximity From agricultural land	Ethio-GIS
6	Previous studies, published books ,journals		To achieve the goals and conduct a literature review.	Secondary sources, internet, library...

3.3. Softwares Used to Analyze the Data

The subsequent software applications are employed for the examination of data that is essential in attaining the research objectives in a proficient and productive manner (Table 2). Consequently, there has been a rise in the demand for novel investigations concerning agricultural production and evaluations of land suitability

Table3.2: Software and its functions

No	Software & tools	Purpose and description
1	Arc GIS	To create maps and use raster calculators for LST and NDMI calculations
2	ERDAS imagine 2015	For improving satellite images, preprocessing, classifying images to create LULC maps, and evaluating accuracy
3	IDRISI SELVA 17.0	For pairwise comparison/ weight decision analysis
4	Google earth	To understand photos those are unclear based on the accuracy rating of Landsat images.

3.4. Data Analysis

3.4.1. Factors for agricultural land suitability analysis

During the course of this study, a number of variables are identified for agricultural land suitability analysis, including slope, elevation, aspect, soil type, soil depth, land use land cover (LULC), land surface temperature (LST), normalized difference moisture index (NDMI), rainfall, water source proximity, and road proximity.

3.4.1.1. Topographic Factors

The three factors of aspect, slope, and elevation are used in the decision-making process to determine the suitable terrain for agricultural development. These criteria are considered during the evaluation of potential agricultural zones for the identification of suitable sites (Pramanik, 2016). The slope is the primary topographic element that influences the appropriateness of a region in relation to land modification for irrigation and the execution of irrigation activities (Hussien, 2019). Therefore, the investigation of slope is a fundamental aspect in the assessment of land compatibility for the application of surface irrigation (Mandal et al., 2017a). The degree of slope exerts a direct impact on the depth of the soil, its vulnerability to erosion, the practice of soil tillage, the utilization of agricultural machinery, the provision of irrigation, and the adaptation of plants, among other factors. The steepness, length, and angularity of the slope exert a direct influence on the loss of soil and water within a given region (Everest et al., 2021). The slope of the study area was determined using a 30m resolution DEM and categorized into five groups (0 – 5%, 5 – 8%, 8 – 15%, 15-25 and > 25%) through a similar approach (Aymen et al., 2021).

3.4.1.2. Distance from Water Supply (Source)

Water is essential to life and one of the most valuable resources for raising agricultural yields (Aymen et al., 2021). Euclidean distance indicates the amount of lands that are in close proximity to the water supply, making it a crucial component in the assessment of surface irrigation land suitability (Shitu & Berhanu, 2020). To locate irrigable land near water sources such as rivers, reclassified in to five classes (0 – 0.5, 0.5 - 1, 1 – 2, 2-3 and >3km) buffer zone distance from the watershed outlets (Pramanik, 2016). Therefore, this study was done accordingly.

3.4.1.3. Soil

The suitability of a land for surface irrigation development and agricultural output heavily relies on the quality and characteristics of its soil. Analysis is done using the kinds, depth, and physical characteristics of the soil-mapping units. GIS provides an advantage of mapping surface irrigation (Mandal et al., 2017b).

The depth of soil has a significant impact on allowing plants to access essential nutrients and water, impacting the growth and spread of their roots. A well-developed root system enables plants to easily obtain the necessary resources (Everest et al., 2021). The data on the depth of soil was acquired from the ISRIC World Soil Information website.

The soil type plays a significant role in determining the porosity of the soil, which affects how easily water can flow through it. If there is no ongoing leaching process, salt can accumulate in the soil and potentially harm the surrounding landscape and plant(Mandal et al., 2017b), (Hussien, 2019). These properties of soils separately to identify which unit is the best or worst for the selected.

3.4.1.4. Rainfall

Both crop productivity and water shortage are caused by the high degree of rainfall variation and unreliability (Hussien, 2019). The majority of the nation's agricultural output is rain-fed, which makes it extremely vulnerable to fluctuations in rainfall and unpredictability. Rainfall varies in space (highlands receive more rain) and time (maximum rain falls between July and mid-September and lowest rain falls between October and January) (Worku, 2015). The more severe climate conditions limiting agriculture are rainfall and water availability (Mandal et al., 2017b). To create a map showing the distribution of rainfall in the research area, annual rainfall data was utilized.

3.4.1.5. Temperature

Temperature is a measurement of how hot a land surface is at a particular moment and can be defined as the skin temperature of the surface (Ibrahim & Rasul, 2017), (Choe & Yom, 2020). To locate suitable land for agricultural suitability assessment, temperature was considered as a factor. High temperature, scarce rainfall amounts.

Because of the absence of temperature information, the land surface temperature (LST) can be derived from the Digital Number (DN) values of the thermal bands 10 and 11 of Landsat 8 TIRS. In the initial stage, the spectral radiance (Lλ) of the Landsat 8 TIRS bands can be determined using Equation (1), and subsequently, the land surface temperature (LST) in Kelvin can be calculated using Equation (2) as mentioned in the study by Nurwanda and Honjo (2020).

$$L\lambda \text{ (Landsat 8 TIRS)} = ML \times DN + AL \quad (1)$$

$$LST = \frac{K2}{\ln[\left(\frac{k1}{L\lambda}\right) + 1]} \quad (2)$$

The band-specific multiplicative rescaling factor (ML) of 0.0003342 and the band-specific additive rescaling factor (AL) of 0.1 are used to adjust the values in the dataset. The band specific thermal conversion constants, K1 and K2, are also applied. To obtain temperature in Celsius (LST), the value calculated using equation 2 is reduced by 273.15. To convert Celsius temperature to Kelvin, you can use the formula K = °C + 273.15.

3.4.1.6. Soil Moisture

The characteristics of the land, such as the soil, rocks, water body, vegetation cover, built-up area, etc, affect the spectrum reflectance. Because of its high absorption, water has a lower spectral reflectance than other surfaces (Hui et al., 2008). Several research, including Bhagat (2009), Bhagat and Sonawane (2011), Zolekar and Bhagat (2015), and others, have effectively used the computed Normalized Difference Water Index (NDWI) to detect water bodies and soil moisture. Soil moisture has a favorable correlation with crop yield and is a useful indication of soil quality (Wang et al., 2012). Soil texture and depth have an impact on the amount of moisture in the soil (Zolekar and Bhagat, 2015). Therefore, by employing

ArcGIS, NDMI is calculated using Near-Infrared (NIR) and Shortwave-infrared (SWIN) bands of Landsat-8 imagery to produce a soil moisture map of the study area (Eq.3).

$$\boldsymbol{NDMI} = \frac{\boldsymbol{NIR - SWIN}}{\boldsymbol{NIR + SWIN}} \quad (3)$$

3.4.1.7. Road Distance from Agricultural Area

Roads are essential for the suitable transportation of agricultural raw materials. To select site suitability for agriculture, different studies used distance from roads as a parameter on agricultural land suitability (Pramanik, 2016); (Yalew et al., 2016) and (Yohannes & Soromessa, 2018). Therefore, the current study was conducted using proximity analysis of road by using ArcGIS 10.7 and the proximity class was performed according to the above studies mentioned (Pramanik, 2016).

3.4.1.8. Land Use Land Cover

The categorization of land use capability is a crucial principle employed to assess the suitability of land for agricultural purpose. In order to create and evaluate a map indicating the suitability of land for surface irrigation, the researchers utilized a satellite image captured by Landsat-8. Image preprocessing is required before using the raw digital satellite image for the desired purpose. The presence of various atmospheric gases, aerosol particles, and clouds between the Earth's surface and satellite sensors leads to the scattering and absorption of light, which alters the original reflectance of objects on the ground(Ullah et al., 2020).

The Landsat imagery was classified according to the reality of the land coverage of the study area. In this particular study, supervised classification serves as a crucial method for extracting quantitative data from the remotely collected image data. Various techniques have been developed to categorize 2022 satellite images, which are the most recent records. Supervised classification approaches are deemed more precise for quantitative classification of remotely sensed data. In a supervised classification method, instead of relying on the computer to generate spectral signatures, the user creates them to assign pixels to distinct land categories in a classified image (Ullah et al., 2020). Therefore, according to (Choudhury et al., 2019) a supervised image classification method that uses the maximum likelihood approach can be used to display how land cover and use have changed over time. The processing time for large scenes is significantly reduced by the maximum likelihood classifier. Maximum likelihood classification is a reliable method with minimal risk of misclassification. (Sisodia et al., 2014). Image classification was done using ERDAS IMAGINE 2015 image processing software.

To verify the outcome, the accuracy of the classified land cover maps was assessed using the confusion matrix method (Imran et al., 2021). (Chughtai et al. 92021) conducted accuracy assessment by employing 100 ground control points (GCPs) for evaluating all the classes related to land use and land cover. Evaluating the performance of land classification is most commonly done through accuracy assessment (Ara et al., 2021). The current study collects 300 points by using handheld GPS and Google Earth images for all classified images, which is matched with Google Earth images for verification and accuracy calculation. For each land use land cover class the point is given according to the area coverage. For high land use coverage, high number of points. The accuracy assessment of land use classification such as overall accuracy, the Kappa coefficient, was applicable.

3.4.2.Suitability Analysis for rain fed Agriculture Using Multi-Criteria Evaluation Method

In this study, eleven factors are selected to analyze and identify suitable land for agricultural purposes. These are land surface temperature (LST), land use land cover (LULC), normalized difference moisture index (NDMI), soil type, soil depth, rainfall, slope, elevation, aspect, road proximity and water well or drainage proximity to the agricultural area. Each factor was reclassified by using the standards. The vector maps should be converted to raster form. The raster dataset values 1, 2, 3, 4 and 5 are represented by suitability level, very high suitable, highly suitable, moderately suitable, low suitable, and not suitable respectively (Aymen et al., 2021).

The use of weighted overlay techniques, employing analytic hierarchy and multi-criterion decision-making processes, has determined the appropriateness of land for agricultural development (Pramanik, 2016). The weights of each raster layer were given by employing IDRISI SELVA 17.0 software and producing a pairwise comparison matrix (Table 3.3). The reclassified raster layers are combined by comparing their cell values on a consistent scale. Each criterion is assigned a weight value, and these weight values are then integrated with the corresponding cell values.

Table3.3: Pairwise comparison matrix and eigenvector values

Layers	A	B	C	D	E	F	G	H	I	J	K	Weight
Slope (A)	1											0.2494
LULC (B)	1/2	1										0.1890
NDMI (C)	1/2	1/2	1									0.1598
Soil-Depth(D)	1/2	1/2	1/3	1								0.1126
Dist.-Water (E)	1/4	1/2	1/2	1/2	1							0.0843
Soil Type (F)	1/5	1/2	1/3	1/2	1/2	1						0.0589
Elevation (G)	1/6	1/5	1/4	1/3	1/2	1/2	1					0.0446
Aspect(H)	1/7	1/6	1/5	1/2	1/3	1/2	1/2	1				0.0344
Dist. Road (I)	1/7	1/6	1/5	1/4	1/3	1/2	1/2	1/2	1			0.0290
Temperature(J)	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1/2	1/2	1		0.0225
Rainfall (K)	1/9	1/8	1/8	1/7	1/6	1/5	1/4	1/4	1/2	1/2	1	0.0156

Consistency ratio = 0.02, Consistency is acceptable.

3.4.3. Suitability Analysis for Irrigational Agriculture

Irrigated agriculture plays a vital role in addressing the challenges posed by unpredictable rainfall patterns and food insecurity. By supplementing and extending the irrigation season, it helps mitigate the impacts of rainfall variability. Therefore, investing in irrigation development can offer a solution to food insecurity by reducing harvest fluctuations and increasing crop production through multiple cropping (Mandal et al., 2017b). The key factors to determine possible areas suitable for irrigation are soil depth, soil texture, slope, and distance from water supply (Shitu & Berhanu, 2020) and (Mandal et al., 2017a). Therefore, the current study is applicable by taking in to account irrigation suitability factors such as soil type, soil depth, slope, and distance from water supply. Potential irrigable land is obtained by creating an irrigation suitability model analysis, which involves weighting of the values of all data sets by using pairwise comparison matrix, and then overlaying these datasets by employing ArcGIS 10.7 spatial analysis (Table 3.4). The raster dataset values 1, 2, 3, 4 and 5 are represented by suitability level, very highly suitable, high suitable , moderately suitable, low suitable, and not suitable, respectively.

Table3. 4: Pairwise comparison matrix and eigenvector values

Layers	Dist.-water	Slope	Soil-Depth	Soil- Type	Weight
Dist.-water source	1				0.4642
Slope	1/2	1			0.2544
Soil-Depth	1/3	1/2	1		0.1839
Soil- Type	¼	1/2	1/3	1	0.0975

Consistency ratio =0.05, consistency is acceptable.

The four parameters: distance from water source, slope, soil depth, and soil type were selected to produce irrigational agriculture suitability map for the following reasons: Distance from Water is essential as it determines the accessibility of water for irrigation. Areas situated in close proximity to water sources such as rivers, or reservoirs exhibit greater suitability for irrigation purposes owing to the convenient availability of water supply (Aymen et al., 2021). Slope of the land plays a significant role in irrigation suitability. Steep slopes can lead to water runoff and erosion, making irrigation challenging and less effective. In contrast, flat or gently sloping areas are more suitable for irrigation as they allow for better water retention and distribution across the land (Hussien, 2019). Soil depth is also a critical factor in determining irrigation suitability as it directly affects the root development of crops. Deeper soils provide more space for root growth and better water retention, making them more suitable for irrigation purposes. Shallow soils may have limitations in capacity for storing water and can hinder proper plant growth (Everest et al., 2021). Different soil types have varying properties that affect their suitability for irrigation. Soils with good drainage and water retention properties are highly suitable for irrigation (Mandal et al., 2017b).

3.5. Methodological Flow Chart of the Study

In order to accomplish the intended objectives, different data were collected from a multitude of sources and synthesized from satellite images with multi-spectral capabilities. In order to carry out this investigation, the subsequent flowchart will be applicable (Fig3.2).

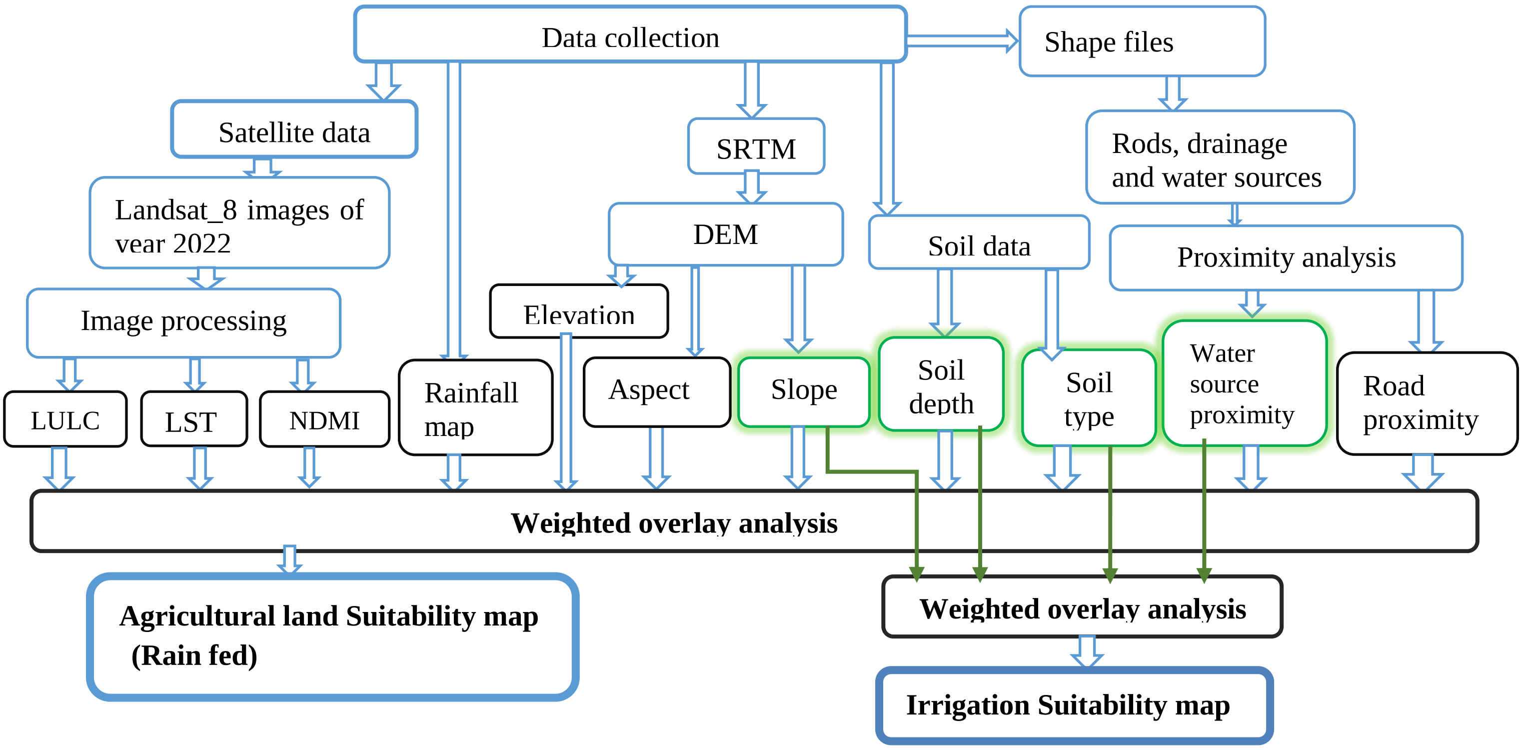


Fig3. 2: The overall Methodological flow-chart of the study

CHAPTER FOUR

RESULT

4.1. Factors for Agricultural Land Suitability Analysis

4.1.1. Topographic Factors

The topography of the land affects water drainage, erosion potential, and accessibility. The slope suitability class categorizes the area based on its suitability for various activities, while the aspect suitability class focuses on the suitability of different aspects (directions) within the area. According to the results, the highly suitable slope class covers 77.754% of the total area. The moderately suitable slope class covers 7.592% of the area. The marginally suitable slope class covers 9.435% of the area. Not suitable slope class covers 4.361% of the area, suggesting that this portion is not suitable for most activities due to unfavorable slope conditions. Steep slopes, unstable terrain, or other factors that make it unsuitable for agriculture may characterize it. Lastly, the permanently unsuitable slope class covers only 0.860% of the area.

Moving on to aspect suitability, the highly suitable aspect class covers 36.110% of the total area. The moderately suitable aspect class covers 15.784% of the total area. This suggests that there are certain aspects within the study area that are more favorable than others for agricultural activity. The marginally suitable aspect class covers 18.027% of the area, indicating that there exist certain restrictions or challenges associated with these aspects. Low suitable aspect class covers 13.725% of the area, suggesting that these aspects are more restrictions than that of the marginally suitable part. Lastly, the not suitable aspect class covers 16.354% of the area generally unfavorable for agricultural activities (Fig 4.1 and Table 4.1).

Table 4. 1: Slope and aspect suitability for agriculture

Parameter	Classification	Suitability Class	Area (Ha)	Area (%)
Slope (%)	0 – 5	Highly suitable	115610.488	77.754
	5 – 8	Moderately suitable	11288.452	7.592
	8 – 15	Marginally suitable	14028.711	9.435
	15 – 25	Not suitable	6485.182	4.361
	>25	Permanently not suitable	1279.366	0.860
Aspect	South, southwest, west	Highly suitable	53692.48	36.110
	Southeast; east	Moderately suitable	23470.31	15.784
	Northwest	Marginally suitable	26804.77	18.027
	Northeast	Low suitable	20407.36	13.725
	North	not suitable	24317.28	16.354
elevation	1806-2000	Highly suitable	50664.642	34.074
	2000-2100	Moderately suitable	53792.460	36.177
	2100-2200	Marginally suitable	19314.713	12.990
	2200-2500	Not suitable	18167.636	12.218
	2500-3205	Permanently not suitable	6752.743	4.541

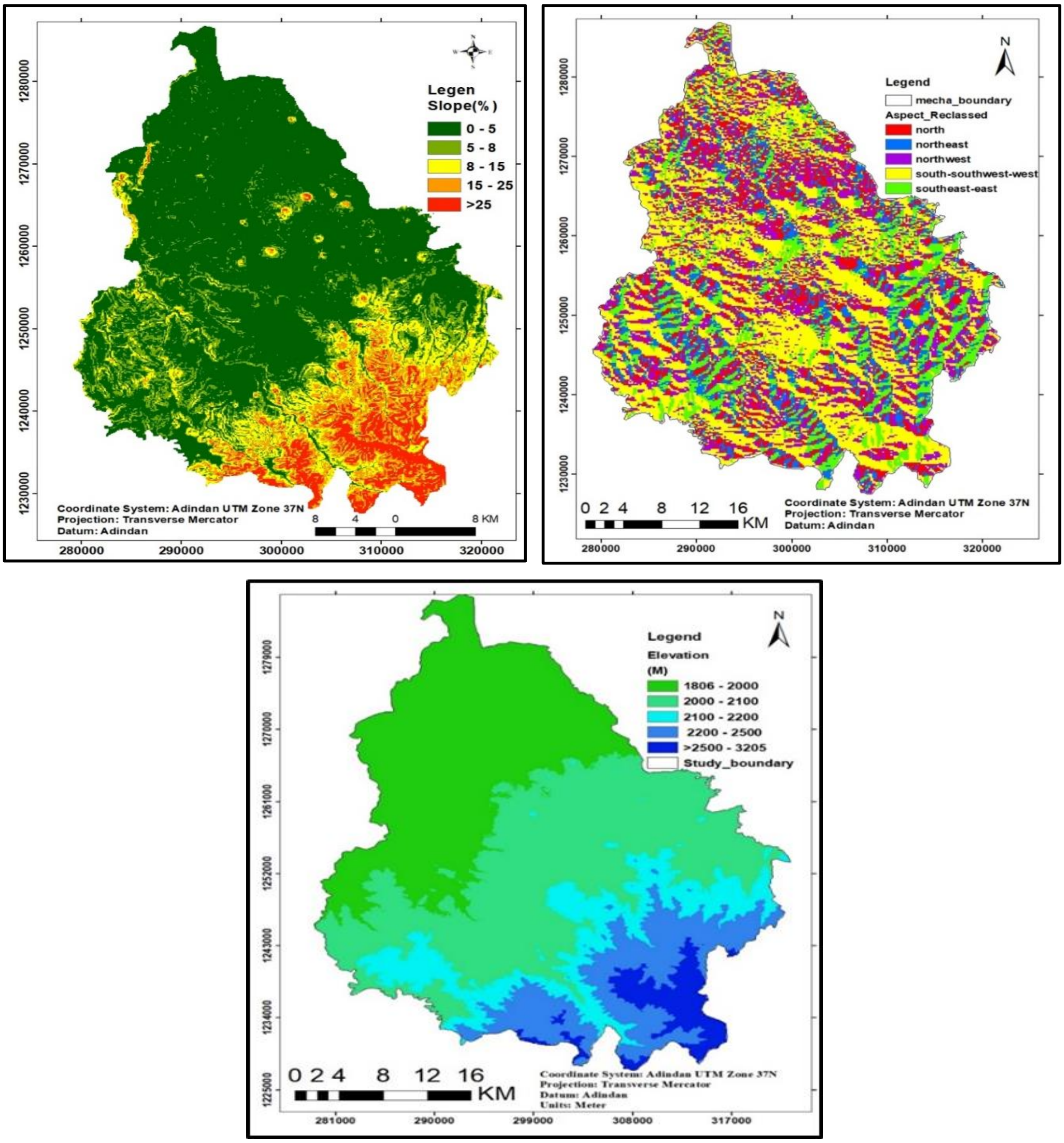


Fig 4. 1: Topographic factor maps for agricultural suitability

4.1.2. Soil Type

As shown in the following table the area of study is divided into various soil types, including chromic camisoles, eutric nitisols, pellic vertisols, lithic leptosols, dystric gleysols, chromic vertisols, chromic luvisols, and dystric nitisols. The suitability of each soil type is categorized as very high suitable, high suitable, or not suitable. Based on the findings/outcomes presented in table 4.2, chromic camisoles cover 1.622% of the area, Eutric nitisols cover 5.599% of the area, chromic luvisols cover 8.037% of the area and dystric nitisols cover only 0.049% of the area are considered to be extremely well suited. On the other hand, chromic vertisols, covering 27.186% and Pellic vertisols, which cover 17.008% of the area, also fall under the high suitable category. Lithic leptosols, covering 0.646% of the area, are not suitable for agricultural productivity purpose and Dystric gleysols, cover a significant portion of the area with 38.598%, are also unsuitable.

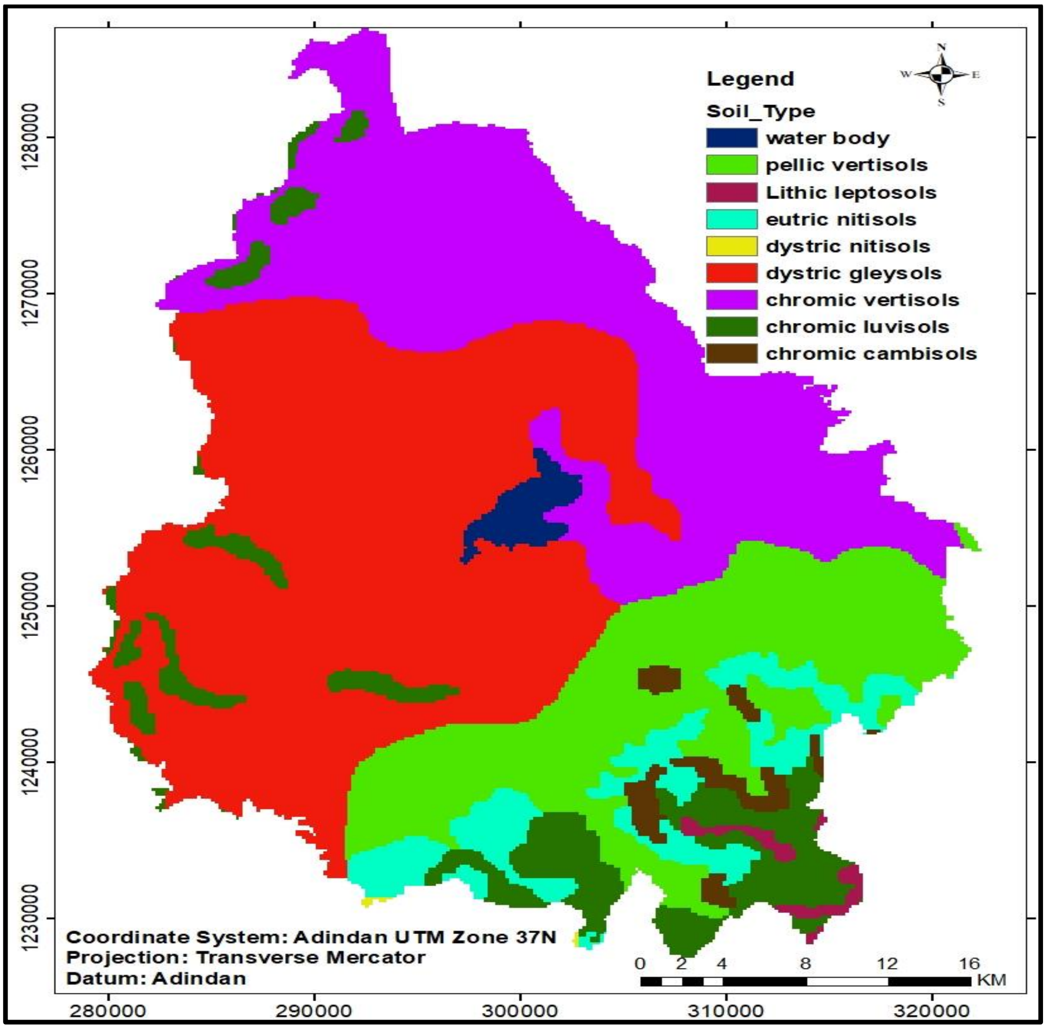


Fig 4. 2: Soil type map of the study area

Table4. 2: **Soil type and Agricultural Suitability Level of the study area**

Id	Soil type	Area (Ha)	Area (%)	Suitability
1	water body	1866.71	1.255	
2	chromic camisoles	2411.4	1.622	Very high suitable
3	eutric nitisols	8324.66	5.599	Very high suitable
4	pellic vertisols	25290.2	17.008	high suitable
5	Lithic leptosols	960.746	0.646	Not suitable
6	dystric gleysols	57392.25	38.598	Not suitable
7	chromic vertisols	40422.95	27.186	high suitable
8	chromic luvisols	11950	8.037	Very high suitable
9	dystric nitisols	73.2594	0.049	Very high suitable
	Sum	148692.1754	100.000	

4.1.3. Soil Depth

The investigation classifies the different categories of soil depth into four distinct categories: very highly suitable, highly suitable, moderately suitable, and low suitable. Additionally, it includes a category for water bodies, which are not suitable for agricultural purposes. As indicated in table 4.3, the area of soil classified as very highly suitable falls within the depth class range of 158.6-175 cm and covers an area of 105802.89 Ha, 71.156% of the total area. This suggests that soil with a depth class that is very suited for agricultural use makes up a sizable portion of the research region. The next category is highly suitable soil depth, which falls within the depth class range of 142.2-158.6 cm. It covers an area of 23530.612 Ha, representing 15.825% of the total area. Although this category represents a smaller proportion of the study area compared to the very highly suitable category, it still indicates a substantial amount of land with soil that is considered highly suitable. The third category is moderately suitable soil, which falls within the depth class range of 125-142.2 cm. It covers an area of 9443.49 Ha, accounting for 6.351% of the total area. This category represents a smaller proportion compared to both the very highly suitable and highly suitable categories but still denotes a significant amount of land with moderately suitable soil. Lastly, there is a category for low suitable soil depth, which falls within the depth class range of 93-125 cm. It covers an area of 7687.31 Ha, which is 5.17% of the total area. This category represents a relatively smaller proportion compared to the other three categories and indicates that there is less land with soil depth that is considered suitable for agriculture. The table also includes a category for water bodies, which covers an area of 227.89 Ha, 1.498% of the total area. Water bodies are not suitable for agriculture (Fig 4.3).

Table 4. 3: Soil depth and suitability for agriculture

Rank	**Soil depth class**	**Area(Ha)**	**Area (%)**	**Suitability level**
1	158.6-175 cm.	105802.889	71.15564	very highly suitable
2	142.2-158.6 cm.	23530.61	15.82505	highly suitable
3	125-142.2 cm.	9443.49	6.351034	moderately suitable
4	93 -125.8 cm.	7687.31	5.17	low suitable
Water	Water body	2227.89	1.498323	Not suitable
Sum		148692.195	100	

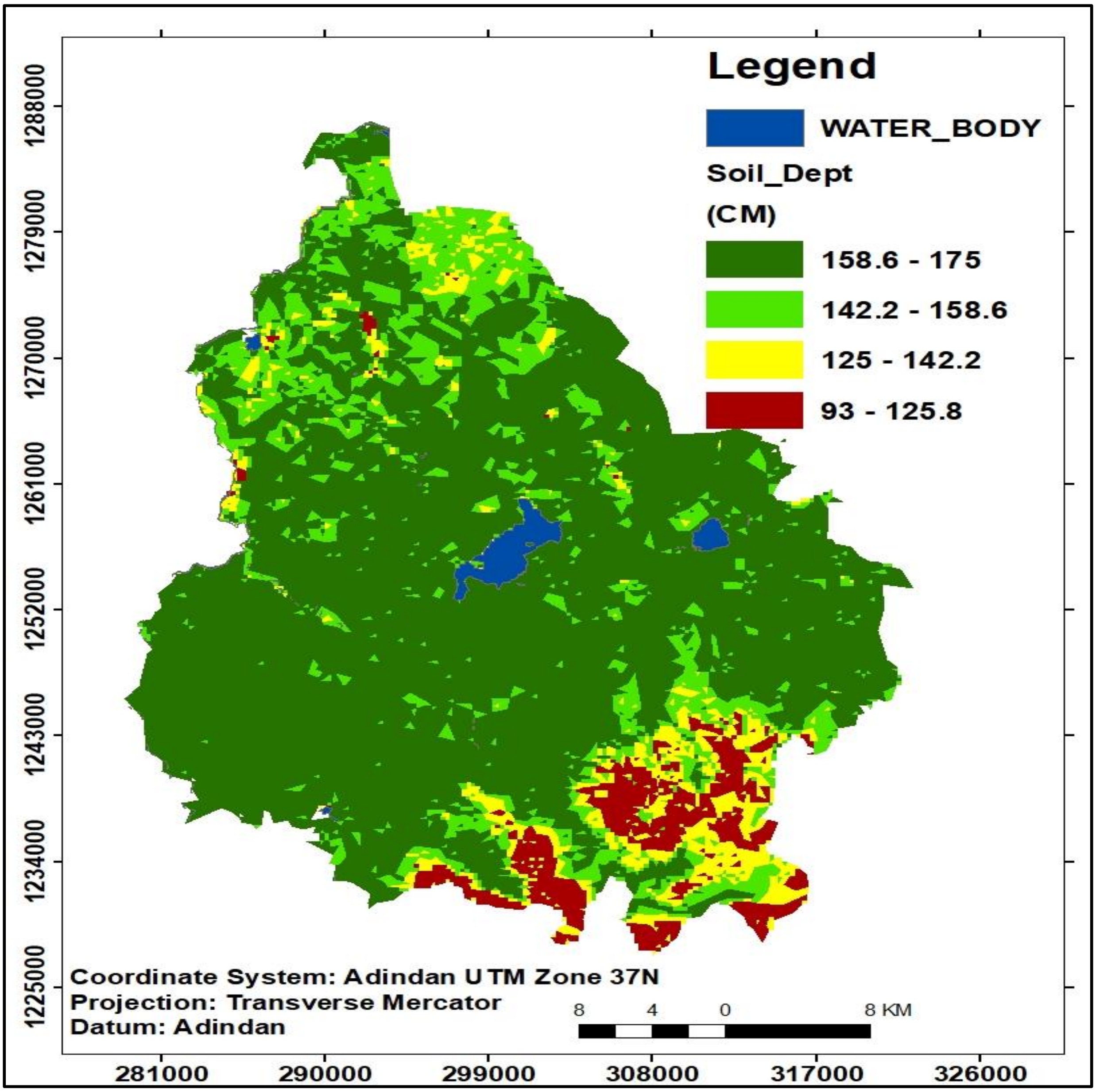


Fig 4. 3: Soil depth classification map of the study area

4.1.4. Land Use Land Cover (LULC)

The study area's primary land use/cover types in 2022 was farmland, built-up areas, forests, water bodies, and bare land. Cropland accounts for 79.37% of the total area and is the type with the largest proportion of land use/land cover, as shown in Fig. 4.4. 9.296%, 7.146%, 2.689%, 1.498%, and other areas are covered by the remains, built-up area, forest, barren ground, and water body, respectively (Table 4.4).

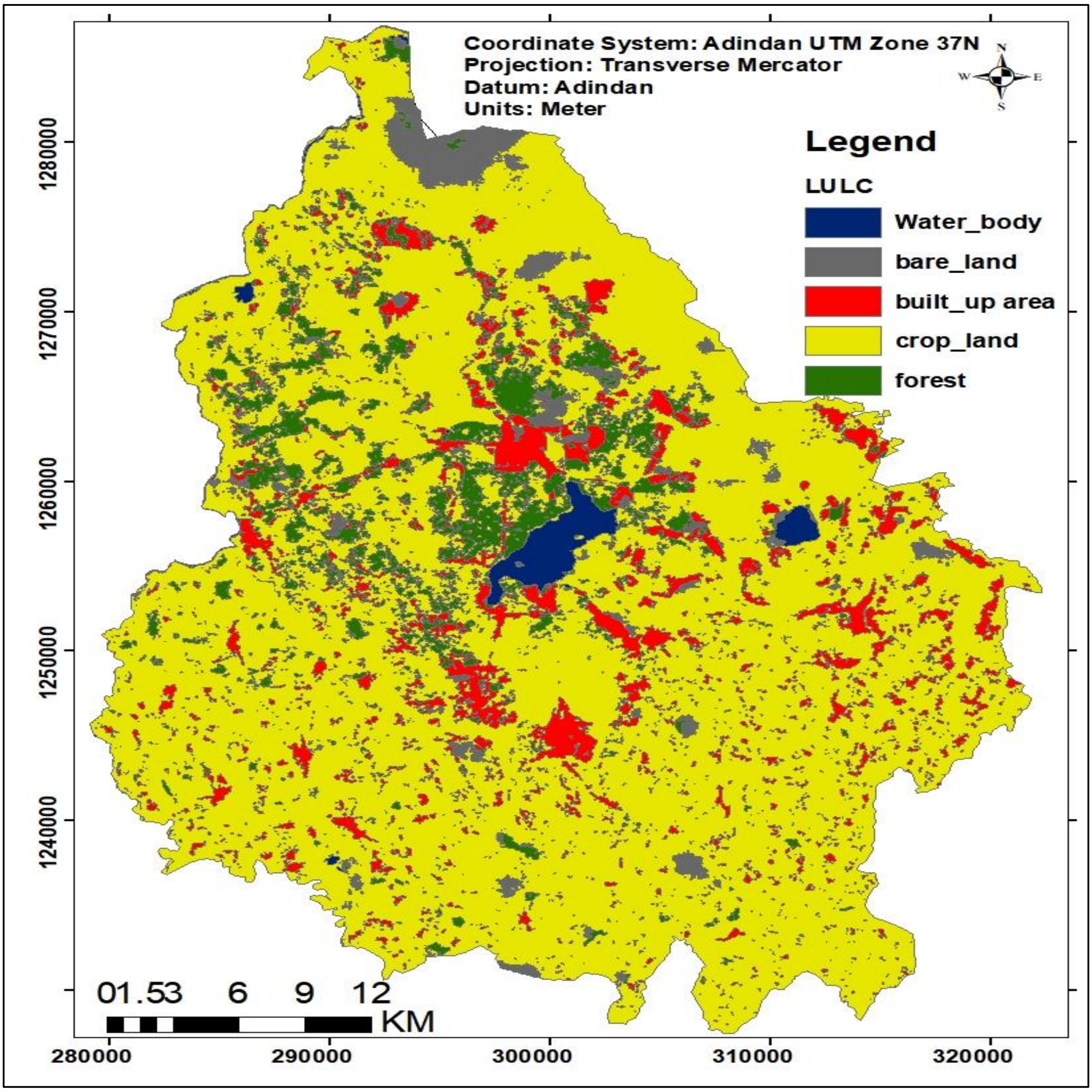


Fig 4. 4: Land use/land cover map of study area in 2022

Table4. 4: LULC suitability for agriculture

LULC	Suitability class	Area(Ha)	Area (%)
Waterbody	Permanently not suitable	2227.409	1.498
Forest	Moderately suitable	10625.545	7.146
Cropland	Highly suitable	118018.485	79.371
built-up area	Permanently not suitable	13822.427	9.296
bare land	Not suitable	3998.333	2.689
Sum		148692.199	100

4.1.5. Land Surface Temperature (LST)

The temperature of the study area ranges from 1^{o}C to 38.89^{o}C, which is calculated in the date of 2022-11-06. In the study area, temperature suitability for agriculture is classed in to five, very high suitable, high suitable, moderately suitable, low suitable and not suitable. From the total of the study area, 59.228%) is very high and high suitable for agriculture. The remains 23.311%, 3.104% and 14.357% are moderately suitable, low suitable and not suitable respectively for agriculture (Table 4.5 and Fig 4.5).

Table 4. 4: suitability classes of land surface temperature for agriculture

Code	Class interval (Degree-Celsius)	Area (Ha)	Area (%)	Suitability (Temperature)
5	(19-25)	37203.042	25.020	very highly suitable
4	(18-19)	50864.577	34.208	highly suitable
3	(10-18)	34661.653	23.311	moderately suitable
2	(4-10)	4615.984	3.104	low suitable
1	(<4 & >25)	21347.135	14.357	not suitable
Sum		148692.392	100.000	

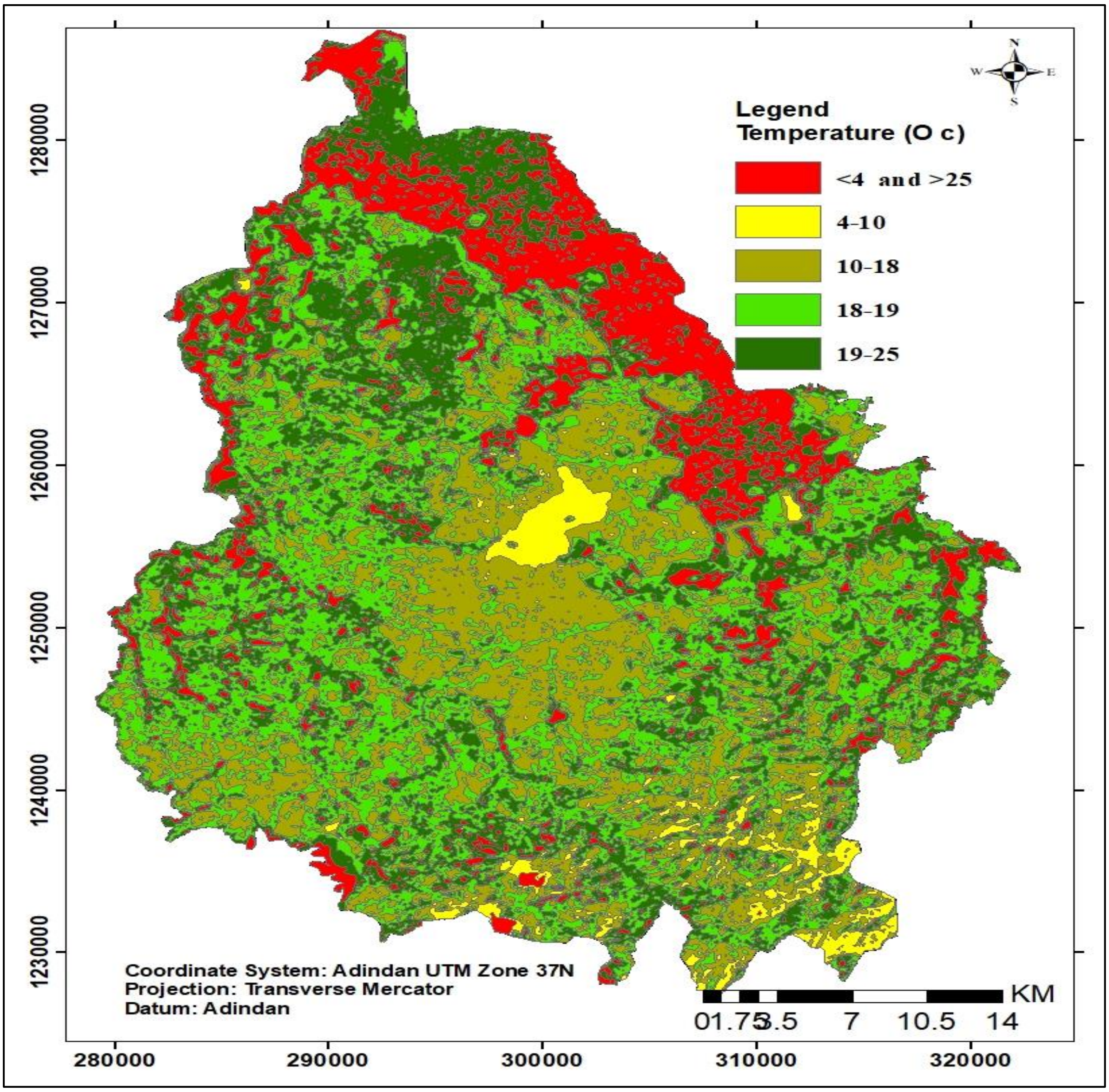


Fig 4. 5: land surface temperature map of the study area

4.1.6. Normalized Difference Moisture Index (NDMI)

The study area has 81.296% very high suitable land for agricultural production, 9.897 % high suitable land, 3.91% moderately suitable land, 1.639% low suitable land for agricultural production, and 3.257 % unsuitable for agriculture productivity, according to the moisture index land suitability map (table 4.6 and Fig 4.6).

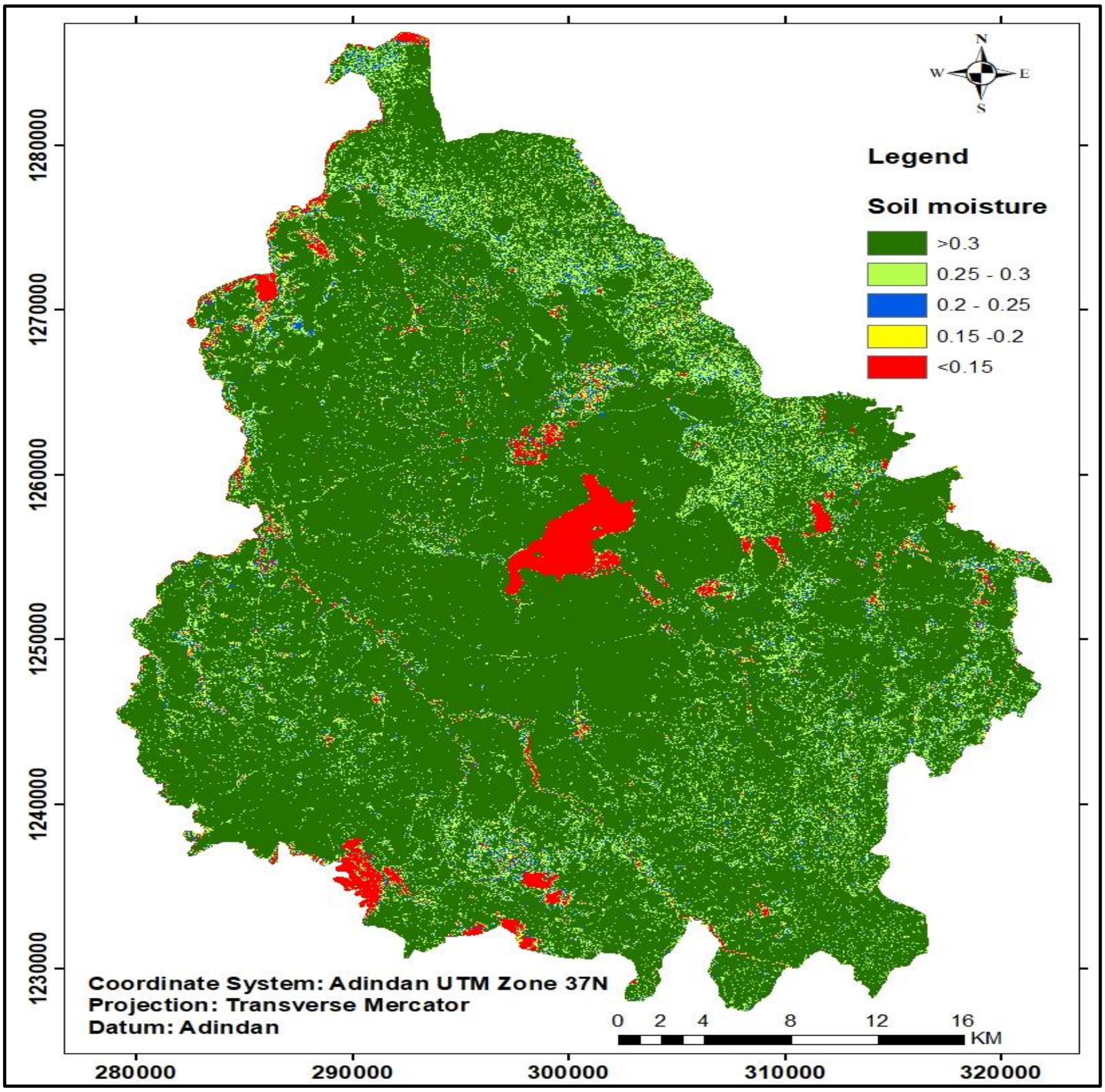


Fig 4. 6: Normalized difference moisture index agricultural suitability map

Table4. 5: Normalized difference moisture index suitability for agriculture

Code	NDMI_interval	Area(Ha)	Area (%)	Suitability
1	>0.3	120881.5	81.296	very highly suitable
2	0.25-0.3	14716.7	9.897	highly suitable
3	0.2-0.25	5814.608	3.91	moderately suitable
4	0.15-0.2	2437.223	1.639	low suitable
5	<0.15	4842.748	3.257	not suitable
Sum		148692.8	100	

4.1.7. Rainfall

As the study indicates, the rainfall classes are categorized based on the amount of rainfall received in millimeters (mm), and the suitability levels are classified as very high, high, moderate, low, and very low. The table includes the corresponding area coverage in hectares (Ha) and the percentage of total area. According to the (Fig 4.7), the rainfall class of 220-237 mm is considered to have a very high suitability level for agriculture. This rainfall class covers an area of 613,635.75 Ha, which accounts for 4.13% of the total area. The next rainfall class is 200-220 mm, which is classified as high suitability for agriculture. This class covers a larger area of 4,951,891.87 Ha, indicating about 33.30% of the total area. The rainfall class of 185-200 mm belongs to the group of moderate suitable for agricultural land. It covers a significant area of 7,239,959.742 Ha, which is 48.69% of the entire surface. The suitability levels, the rainfall class of 170-185 mm is classified as low suitability for agriculture. This class covers an area of 2,005,376.538 Ha, representing 13.49% of the total area. Lastly, the rainfall class of 148-170 mm has a very low suitability level for agriculture. This class covers a smaller area which is 58,356.104 Ha, representing 0.39% of the total area (Table 4.7). Generally, the study indicates that areas with higher amounts of rainfall tend to have higher suitability levels for agriculture.

Table4.6: Rainfall suitability for agricultural productivity

Rainfall class (mm)	**suitability level for agriculture**	**Area(Ha)**	**Area (%)**
220-237	very high	613635.75	4.13
200-220	high	4951891.87	33.30
185-200	moderate	7239959.742	48.69
170-185	low	2005376.538	13.49
148-170	very low	58356.104	0.39
SUM		**148692.2**	**100**

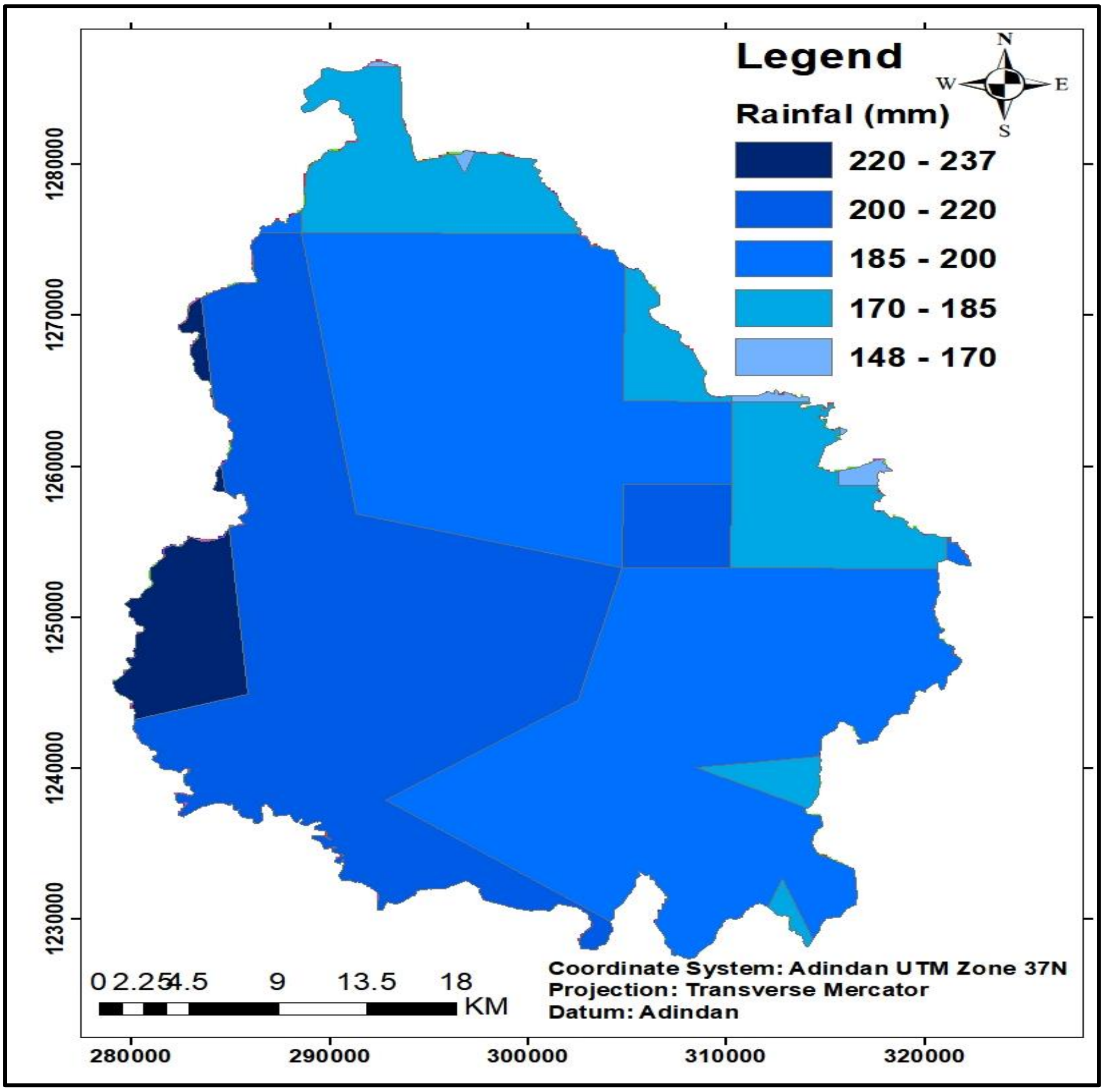


Fig 4. 7: Suitability map for rainfall agricultural of the study area

4.1.8. Water Source Proximity

The current study identified irrigable land close to the water supply (rivers) by performing the proximity analysis and re-classed in to five classes. The study categorized different areas based on their distance from rivers and assessed their suitability for irrigation. The proximity to rivers is measured in kilometers (Km), and the suitability classes range from "very highly suitable" to "not suitable." As indicated in (Table 4.7), the area classified as "very highly suitable" (0 - 0.5 Km) covers 34,904 hectares, which covers 23.474% of the total area studied. This indicates that a significant portion of the land within a 0 - 0.5 Km distance from rivers is considered very highly suitable for irrigation. The next category, "highly suitable" (0.5 - 1 Km), encompasses an area of 31,932.22 hectares, representing 21.475% of the total area. While this category has a smaller area of coverage in contrast with the previous one, it still indicates a substantial amount of land that can be considered suitable for irrigation within a slightly greater distance from rivers. Moving further away from the rivers, the "moderately suitable" category (1 - 2 Km) covers an area of 49,210.19 hectares, accounting for 33.095% of the total area. This shows that there is still a significant portion of land that can be utilized for irrigation purposes within this range. The "low suitable" category (2 - 3 Km) includes an area of 24,290.56 hectares, representing 16.336% of the total area studied. Although this category has a smaller coverage compared to the previous ones, it still indicates some potential for irrigation at a greater distance from rivers. Lastly, the "not suitable" category (>3 Km) encompasses an area of 8,355.21 hectares, which accounts for only 5.62% of the total area studied. This category represents the land that is considered unsuitable for irrigation due to its significant distance from rivers (Fig 4.8). The results of the study indicate that a substantial portion of the land within a 0 - 2 Km distance from rivers is suitable for irrigation purposes. The suitability decreases as the distance from rivers increases, with only a small percentage of land being estimated unsuitable for irrigation at distances greater than 3 Km.

Table 4.7: water source proximity and suitability land for irrigation productivity

Class Code	**Proximity to rivers (Km)**	**Suitability Class**	**Area (Ha)**	**Area (%)**
1	0 - 0.5	very highly suitable	34904.009	23.474
2	0.5 – 1	highly suitable	31932.222	21.475
3	1 – 2	moderately suitable	49210.197	33.095
4	2 – 3	low suitable	24290.560	16.336
5	>3	not suitable	8355.211	5.619
Sum			148692.198	100.000

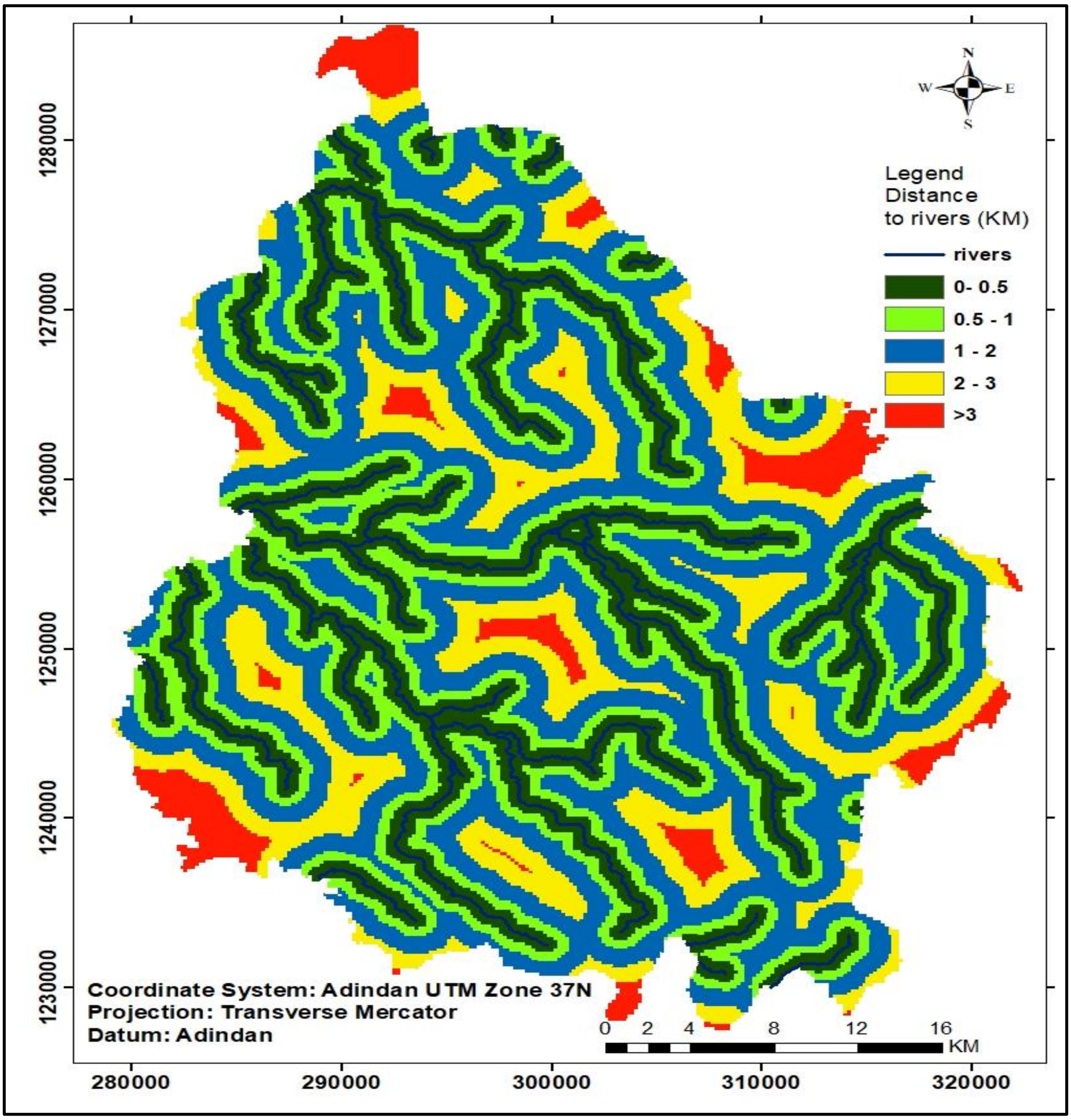


Fig 4. 8: Water source proximity map for irrigation agriculture suitability

4.1.9. Road Proximity

The results of the study on road buffer suitability classes based on their range in kilometers (KM) and corresponding area in hectares (Ha) as well as percentages. The study aimed to assess the suitability of different road buffer ranges for agricultural purposes or activities. As indicated in the table (Table 4.9), there are five suitability classes identified: very highly suitable, highly suitable, moderately suitable, low suitable, and not suitable. Each class represents a range of road buffer distances and is associated with a specific area in hectares and percentage. The first suitability class is "0-1 KM," which is categorized as "very highly suitable." This class covers an area of 283.32 Ha, accounting for 3.85% of the total area. It indicates that road buffers within this range are highly suitable for the intended purpose or activity. The second suitability class is "1-2 KM," classified as "highly suitable." This range encompasses an area of 260.27 Ha, representing 3.22% of the total area. It indicates that road buffers within this distance are still highly suitable but may have slightly different characteristics or limitations compared to the previous class. The third suitability class is "2-4 KM," categorized as "moderately suitable." Within this range, the study found that road buffers cover an extensive area of 402.61 Ha, accounting for 6.61% of the total area. Road buffers falling within this distance are considered moderately suitable for the intended purpose or activity. The fourth suitability class is "4-8 KM," labeled as "low suitable." This range encompasses a larger area of 417.20 Ha, representing 9.45% of the total area. Road buffers falling within this distance are considered less suitable compared to the previous classes but may still serve certain purposes or activities with limitations. Finally, the fifth suitability class is ">8 KM," which indicates that road buffers beyond 8 kilometers are "not suitable" for the intended purpose or activity. This class covers an area of 123.28 Ha, accounting for 1.68% of the total area. Overall, the study provides a comprehensive assessment of road buffer suitability based on their range in kilometers. It offers valuable information for decision-makers, and environmentalists to consider when determining appropriate road buffer distances for agricultural purposes or activities.

Table4. 8: Road proximity from agricultural area and area coverage

Road Buffer range(KM)	**Suitability Class**	**Area (Ha)**	**Area (%)**
0 – 1	very highly suitable	28323.854	19.049
1 – 2	highly suitable	26032.277	17.507
2 – 4	moderately suitable	40286.608	27.094
4 – 8	low suitable	41720.945	28.059
>8	not suitable	12328.516	8.291
Sum		148692.199	100.000

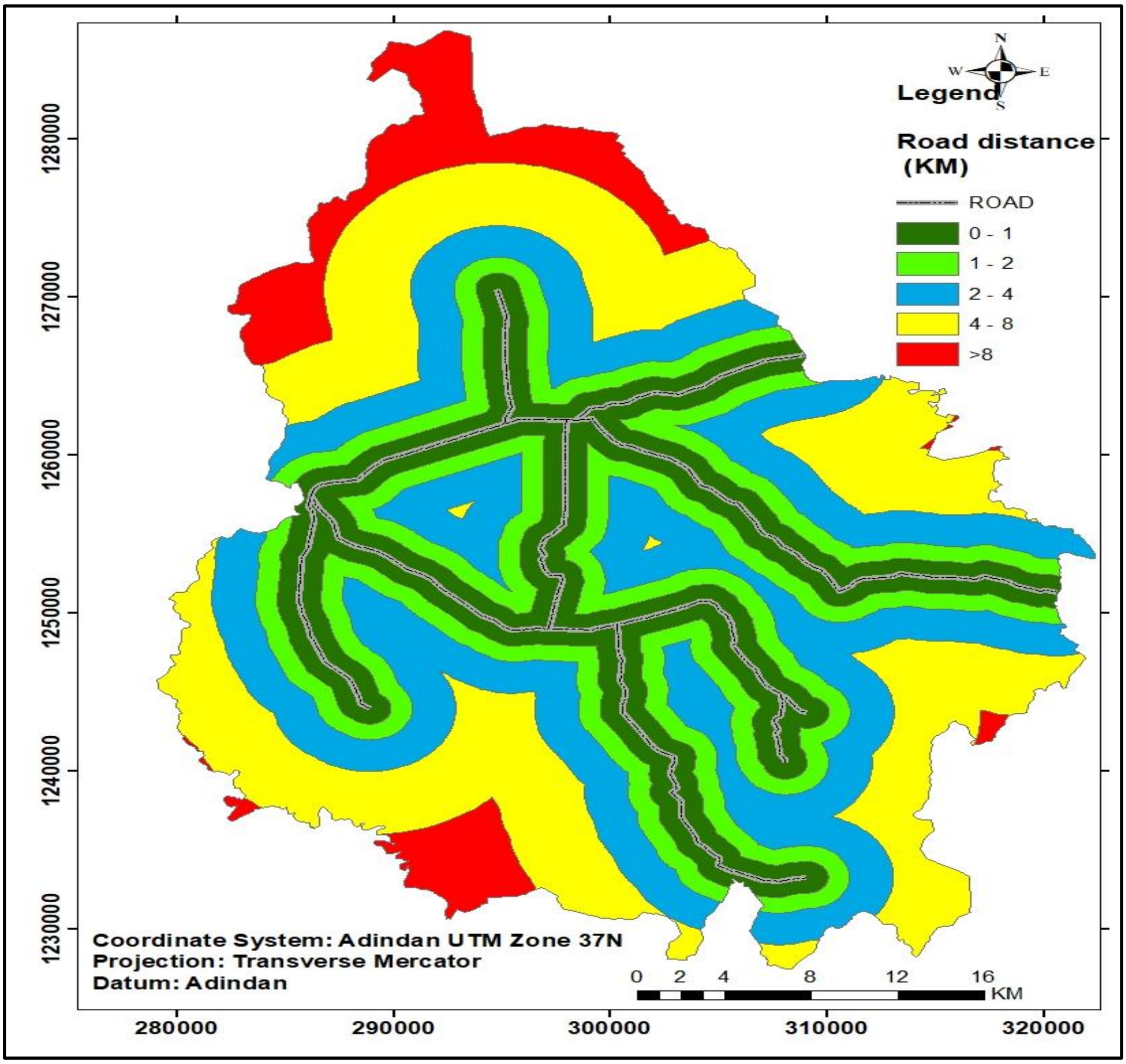


Fig 4. 9: Road proximity map from agricultural area

4.2. Suitability for Rain-Fed Agriculture by Using Multi-Criteria Analysis

The provided data represents the results of a study that assessed the suitability of different areas based on their value. The investigation classified the regions into five classes of suitability: very highly suitable, highly suitable, moderately suitable, low suitable, and not suitable. The table also includes the area in hectares and the percentage of the total area for each suitability class.

The result indicates that very high suitable for agricultural use covers 31111.69 which represents 20.92% of the study area and the most extensive suitability class is highly suitable, covering an area of 49,104.89 hectares, which accounts for 33.03% of the total area. This shows that a substantial portion of the research area is considered to be highly suitable based on the specified criteria. The second most extensive suitability class is "moderately suitable," cover an area of 34,732.68 hectares, which is equivalent to 23.36% of the total area. This indicates a considerable portion of the studied area falls into this category. The third most extensive suitability class is "low suitable," covering an area of 20,629.07 hectares, which represents 13.87% of the total area. This implies that a notable portion of the studied area is classified as having low suitability based on the specified criteria. The least extensive suitability class is "not suitable," with an area of 13,113.98 hectares, accounting for 8.82% of the total area (Table 4.10). This indicates that a relatively smaller portion of the studied area is considered unsuitable according to the defined criteria (Fig 4.10).

Table4. 9: Distribution of Agricultural land suitability level in the study area

No	Agricultural Suitability	Area(Ha)	Area (%)
1	very high suitable	31111.69	20.92
2	highly suitable	49104.89	33.03
3	moderately suitable	34732.68	23.36
4	low suitable	20629.07	13.87
5	not suitable	13113.9	8.82
	Sum	148692.2	100

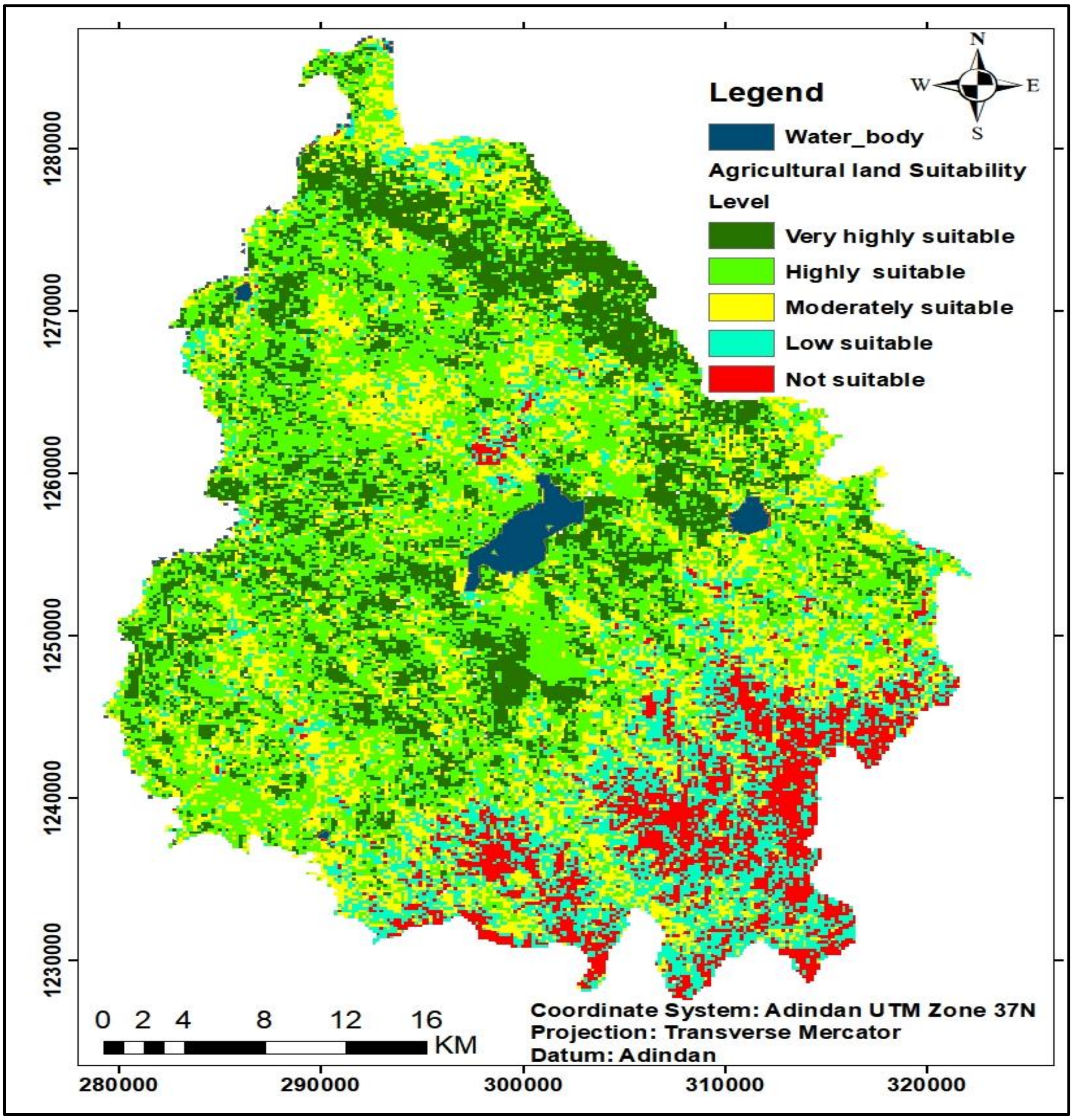


Fig 4. 10: Agricultural land suitability map of the study area

4.3. Suitable Land for Irrigational Agriculture Purposes

The study found that out of the total area of 148,692.21 hectares, 67,942.16 hectares (45.69%) were classified as very highly suitable for irrigation, while 54,978.32 hectares (36.97%) were classified as highly suitable. Moderately suitable areas accounted for 7,766.149 hectares (5.23%), low suitable areas accounted for 12,984.88 hectares (8.73%), and not suitable areas accounted for 50, 20.77 hectares (3.38%) (Table 4.11). The results of the study indicate that the study area has a significant amount of land that is highly suitable for irrigation, with over half of the total area falling into this category.

Table4. 10: Distribution of irrigation Agricultural land suitability level in the study area

Value	Irrigation Suitability	Area(Ha)	Area (%)
1	very highly suitable	67942.16	45.69
2	highly suitable	54978.32	36.97
3	moderately suitable	7766.149	5.23
4	low suitable	12984.88	8.73
5	not suitable	5020.774	3.38
	Sum	**148692.2**	**100**

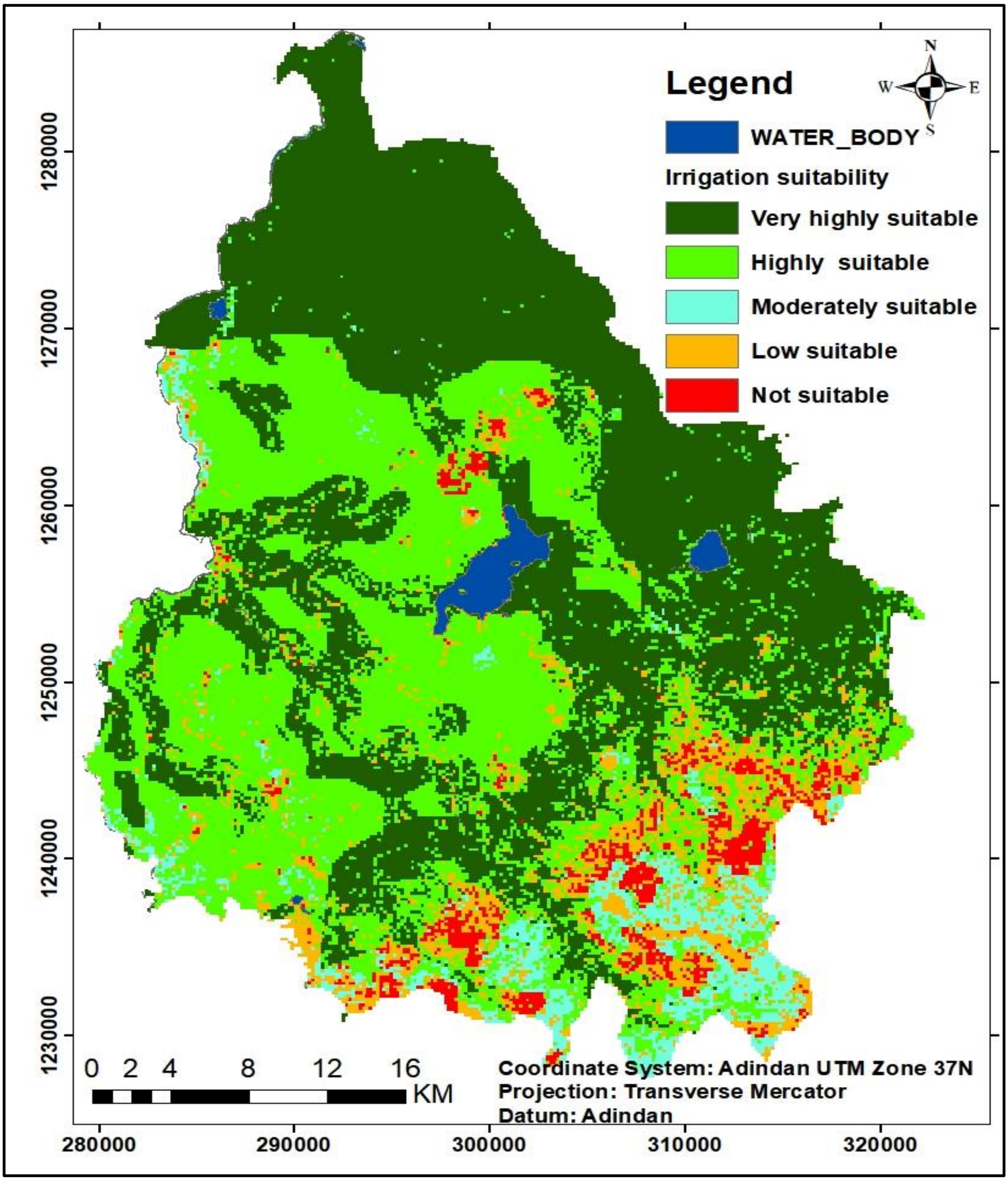


Fig 4. 11: Irrigation agricultural suitability map of the study area

CHAPTER FIVE

DISCUSSION

5.1. Factors for Agricultural Land Suitability Analysis

Agricultural land suitability analysis involves evaluating various factors such as soil characteristics, climate conditions, topography, water availability, Infrastructure and Accessibility. The suitability of land for particular agricultural operations is determined by the combined effects of these elements.

The topography of the land affects water drainage, erosion potential, and accessibility. The slope suitability class categorizes the area based on its suitability for various activities, while the aspect suitability class focuses on the suitability of different aspects (directions) within the area. Based on the findings,the highly suitable slope class covers 77.754% of the total area. This shows that a substantial portion of the area is highly suitable for various activities. The moderately suitable slope class covers 7.592% of the area. The marginally suitable slope class covers 9.435% of the area, indicating that this portion has more limitations compared to the previous classes. Activities in this category may face challenges that are more significant and may require careful planning and management to ensure their success. Not suitable slope class covers 4.361% of the area, suggesting that this portion is not suitable for most activities due to unfavorable slope conditions. Steep slopes, unstable terrain, or other factors that make it unsuitable for agriculture may characterize it. Lastly, the permanently not suitable slope class covers only 0.860% of the area. This designates a very small portion of land that is permanently unsuitable for any kind of activity due to extreme slope conditions.

Moving on to aspect suitability, the moderately suitable aspect class covers 15.784% of the total area. This suggests that certain aspects within the study area are more favorable than others for agricultural activity. The marginally suitable aspect class covers 18.027% of the area, indicating that there are some restrictions or challenges associated with these aspects. Not suitable aspect class covers 13.725% of the area, suggesting that these aspects are generally unfavorable for agricultural activities. Lastly, the permanently not suitable aspect class covers 16.354% of the area. This specifies a considerable part of land where certain aspects are permanently unsuitable.

5.2. Suitability for Rain-Fed Agriculture by Using Multi-Criteria Analysis

The optimum suitable land for rain-fed agriculture in the study area would be determined by analyzing climate conditions, soil characteristics, topography, and water availability. By considering these factors, it is possible to identify areas that are most conducive to rain-fed agriculture. The provided information presents the distribution of agricultural suitability areas in terms of percentage. The result indicates that 20.92% of the area is classified as very high suitable for agriculture, while 33.03% is highly suitable. Moderately suitable areas account for 23.36% of the total, followed by low suitable areas at 13.87%. Lastly, 8.82% of the area is not suitable for agriculture. This indicates, a significant portion of the studied area is suitable for agricultural activities. Approximately 53.95% fall under the categories of very high and highly suitable, indicating favorable conditions for cultivation and farming practices. Additionally, 23.36% is moderately suitable; implying that with proper management and adjustments, these areas can be utilized for agricultural purposes. However, it is worth noting that a considerable proportion of the area, 22.69%, is classified as either low suitable or not suitable for agriculture. This suggests that certain limitations or constraints may exist in these regions, such as unfavorable soil conditions, inadequate water availability, or other factors that hinder agricultural productivity. A study published in the journal "Agricultural Systems" titled "Assessing Agricultural Suitability at a Global Scale" by Fritz et al. (2011) also supports the findings of the provided information. The study utilized remote sensing data and modeling techniques to assess global agricultural suitability. It concluded that a significant portion of the Earth's land area is suitable for agriculture, with varying degrees of suitability, which is consistent with the results presented in the provided information. Yalew et al., (2016), conducted a comprehensive assessment of agricultural suitability in the given basin area. It reveals that a significant portion of the land is very high suitable or moderately suitable for agriculture. However, there are also areas with high suitability or unsuitability for agricultural activities. Therefore, the distribution of agricultural suitability areas as indicated in the current study is in line with existing literatures.

5.3. Suitable Land for Irrigational Agriculture Purposes

To identify the exact section of the research area suitable for irrigation, an in-depth evaluation of multiple factors such as the depth and type of soil, topography, and availability of water is crucial. By considering these factors collectively, it is possible to identify the most suitable areas within the study region for irrigation. According to the study's results, a significant proportion of the evaluated region shows a high or very high level of suitability for irrigation, totaling 82.66% collectively. However, there are also notable areas that are only moderately or low suitable (13.96% combined), while a smaller proportion is not suitable (3.38%) for irrigation purposes. This discovery is consistent with existing literature on the subject, which suggests that the suitability of land for irrigation is influenced by various factors such as topography, soil type, and water availability. The slope and elevation of the land, as well as the presence of surface water bodies, influence the suitability of land for irrigation (Kim et al., 2018).

The implications and significance of the study's findings on irrigation suitability indicate that there are opportunities for agricultural development, economic growth, and informed water resource management decisions. For areas highly suitable for irrigation, stakeholders can attribute the potential for increased agricultural productivity, improved livelihoods, and sustainable water use. The findings of the study regarding the suitability of the assessed area for irrigation align with the general understanding and previous research in this field. The identification of highly suitable, moderately suitable, and unsuitable areas provides valuable insights for decision-makers, land managers, and agricultural practitioners to plan and implement irrigation projects effectively.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. CONCLUSION

The study reveals that the majority of the area falls under the highly suitable and moderately suitable classes for agricultural productivity, while a smaller portion is classified as low suitable. The least extensive category is the not suitable class, indicating that it covers the smallest share of the total area. The results of this study have significant implications for land-use planning and agricultural development in the study area. The identification of highly suitable and moderately suitable areas can help guide decision-makers in prioritizing resources and investments for agricultural activities. Additionally, the identification of areas that are not suitable for agriculture can help avoid the misallocation of resources and minimize the risk of environmental degradation.

This study provides a valuable understanding of the suitability of different areas for a specific purpose. The results highlight that a considerable portion of the land is highly and moderately suitable, offering many opportunities for utilization. However, it also emphasizes the need to consider and manage areas categorized as low suitable or not suitable to ensure sustainable land use practices.

The study's conclusions show that, of a total area 148692.21 hectares there are varying levels of suitability for irrigation. The study classified the land into different categories based on its suitability for irrigation. Overall, the study highlights that a significant proportion of the region's land is highly suitable for irrigation, with over half falling into either the "very highly suitable" or "highly suitable" categories. The significance of the study's findings lies in its ability to provide a comprehensive assessment of land suitability for irrigation in the given region. The results highlight the substantial potential for expanding irrigated agriculture, improving food security, and promoting sustainable development. By identifying areas with varying degrees of suitability, the study offers valuable insights for policymakers, agricultural planners, and water resource managers to make informed decisions regarding land use, water allocation, and investment priorities. Land suitability for irrigation can change over time due to various factors such as climate change, land use changes, and technological advancements. The findings of this study represent the current in time and may not account for future changes in land suitability. Future research could focus on developing dynamic models that consider long-term changes and provide insights into the developing suitability of land for irrigation. The study suggest that the region has a significant amount of land that is highly suitable for irrigation, with over half of the total area falling into this category. This implies that there is great potential for agricultural activities requiring irrigation in the region.

6.2. RECOMMENDATION

The study's conclusions lead to the following recommendations being put out for improving agricultural productivity and promoting sustainable agricultural development in the study area:

- The study area has a large proportion of highly suitable and moderately suitable lands for agricultural productivity. Therefore, it is recommended to prioritize land use planning and management to ensure that these areas are used efficiently and effectively for agricultural purposes.
- The study area has limited access to infrastructure such as irrigation systems, roads, and storage facilities, which can delay agricultural productivity and market access. Therefore, it is recommended to invest in infrastructure development to support the growth of agricultural sector and improve the livelihoods of farmers and their communities.
- Based on the study, there is a large area suitable for irrigational agriculture, but the area is not properly utilized for irrigation. The study area has limited capacity in agricultural research and education, which can limit the adoption of new technologies and best practices. Therefore, it is recommended to invest in capacity building and training programs to improve the skills and knowledge of farmers and other stakeholders in the agricultural sector.
- The study recommends that, the concerned body should work by focusing on the development of irrigation infrastructure, including canals, dams, and reservoirs, to support the growth of irrigated agriculture in the region.

References

Adewole Osunade, M. A. (1988). Soil Suitability Classification by Small Farmers. *The Professional Geographer*, *40*(2), 194–201. https://doi.org/10.1111/j.0033-0124.1988.00194.x

Albore, A. (2018). Review on role and challenges of agricultural extension service on farm productivity in Ethiopia. *International Journal of Agricultural Education and Extension, 4*(1), 93–100.

Ara, S., Alif, M. A. U. J., & Islam, K. M. A. (2021). Impact of Tourism on LULC and LST in a Coastal Island of Bangladesh: A Geospatial Approach on St. Martin's Island of Bay of Bengal. *Journal of the Indian Society of Remote Sensing*, *49*(10), 2329–2345. https://doi.org/10.1007/s12524-021-01389-4

Aymen, A.-T., Al-husban, Y., & Farhan, I. (2021). Land suitability evaluation for agricultural use using GIS and remote sensing techniques: The case study of Ma'an Governorate, Jordan. *The Egyptian Journal of Remote Sensing and Space Science*, *24*(1), 109–117.

Bekabil, U. T., Box, P. O., & Sabu, H. (2014). *Review of Challenges and Prospects of Agricultural Production and Productivity in Ethiopia*. 9.

Choe, Y.-J., & Yom, J.-H. (2020). Improving accuracy of land surface temperature prediction model based on deep-learning. *Spatial Information Research*, *28*(3), 377–382. https://doi.org/10.1007/s41324-019-00299-5

Chughtai, A. H., Abbasi, H., & Karas, I. R. (2021). A review on change detection method and accuracy assessment for land use land cover. *Remote Sensing Applications: Society and Environment*, *22*, 100482. https://doi.org/10.1016/j.rsase.2021.100482

Ennaji, W., Barakat, A., El Baghdadi, M., Oumenskou, H., Aadraoui, M., Karroum, L. A., & Hilali, A. (2018). GIS-based multi-criteria land suitability analysis for sustainable agriculture in the northeast area of Tadla plain (Morocco). *Journal of Earth System Science*, *127*(6), 79. https://doi.org/10.1007/s12040-018-0980-x

Everest, T., Sungur, A., & Özcan, H. (2021). Determination of agricultural land suitability with a multiple-criteria decision-making method in Northwestern Turkey. *International Journal of Environmental Science and Technology*, *18*(5), 1073–1088. https://doi.org/10.1007/s13762-020-02869-9

Feizizadeh, B., & Blaschke, T. (2013). Land suitability analysis for Tabriz County, Iran: A multi-criteria evaluation approach using GIS. *Journal of Environmental Planning and Management*, *56*(1), 1–23.

Gabet, E. J., & Mudd, S. M. (2009). A theoretical model coupling chemical weathering rates with denudation rates. *Geology*, *37*(2), 151–154. https://doi.org/10.1130/G25270A.1

Hussien, K. (2019). *A GIS-Based Multi-Criteria Land Suitability Analysis for Surface Irrigation along the Erer Watershed, Eastern Hararghe Zone, Ethiopia*. https://www.academia.edu/69093471/A_GIS_Based_Multi_Criteria_Land_Suitability_Analysis_for_Surface_Irrigation_along_the_Erer_Watershed_Eastern_Hararghe_Zone_Ethiopia

Ibrahim, F., & Rasul, G. (2017). Urban Land Use Land Cover Changes and Their Effect on Land Surface Temperature: Case Study Using Dohuk City in the Kurdistan Region of Iraq. *Climate*, *5*(1), Article 1. https://doi.org/10.3390/cli5010013

Imran, H. M., Hossain, A., Islam, A. K. M., Rahman, A., Bhuiyan, M. A. E., Paul, S., & Alam, A. (2021). Impact of land cover changes on land surface temperature and human thermal comfort in Dhaka City of Bangladesh. *Earth Systems and Environment*, *5*(3), 667–693.

Kim, S., Kumar, M., & Kam, J. (2023). Rain-fed to irrigation-fed transition of agriculture exacerbates meteorological drought in cropped regions but moderates elsewhere. *Environmental Research Letters*, *18*(7), 074024. https://doi.org/10.1088/1748-9326/acddfb

Mandal, B., Dolui, G., & Satpathy, S. (2017a). Land suitability assessment for potential surface irrigation of river catchment for irrigation development in Kansai watershed, Purulia, West Bengal, India. *Sustainable Water Resources Management*, *4*(4), 699.

Mandal, B., Dolui, G., & Satpathy, S. (2017b). Land suitability assessment for potential surface irrigation of river catchment for irrigation development in Kansai watershed, Purulia, West Bengal, India. *Sustainable Water Resources Management*, *4*(4), 699.

Meyer, M. D., North, M. P., Gray, A. N., & Zald, H. S. (2007). Influence of soil thickness on stand characteristics in a Sierra Nevada mixed-conifer forest. *Plant and Soil*, *294*(1), 113–123.

Mistri, P., & Sengupta, S. (2020). Multi-criteria Decision-Making Approaches to Agricultural Land Suitability Classification of Malda District, Eastern India. *Natural Resources Research*, *29*(3), 2237–2256. https://doi.org/10.1007/s11053-019-09556-8

Mustafa, A. A., Singh, M., Sahoo, R. N., Ahmed, N., Khanna, M., Sarangi, A., & Mishra, A. K. (2011). Land suitability analysis for different crops: A multi criteria decision making approach using remote sensing and GIS. *Researcher*, *3*(12), 61–84.

Ozsahin, E., & Ozdes, M. (2021). Agricultural land suitability assessment for agricultural productivity based on GIS modeling and multi-criteria decision analysis: The case of

Tekirdağ province. *Environmental Monitoring and Assessment*, *194*(1), 41. https://doi.org/10.1007/s10661-021-09663-1

Perveen, M. F., Nagasawa, R., Uddin, M. I., & Delowar, H. K. (2007). Crop-land suitability analysis using a multicriteria evaluation & GIS approach. *5th International Symposium on Digital Earth (ISDE5), June*, *5*(9).

Pramanik, M. K. (2016). Site suitability analysis for agricultural land use of Darjeeling district using AHP and GIS techniques. *Modeling Earth Systems and Environment*, *2*(2), 1–22.

Sahoo, S., Sil, I., Dhar, A., Debsarkar, A., Das, P., & Kar, A. (2018). Future scenarios of land-use suitability modeling for agricultural sustainability in a river basin. *Journal of Cleaner Production*, *205*, 313–328. https://doi.org/10.1016/j.jclepro.2018.09.099

Samanta, S., Pal, B., & Pal, D. K. (2011). Land suitability analysis for rice cultivation based on multi-criteria decision approach through GIS. *International Journal of Science and Emerging Technologies*, *2*(1), 12–20.

Shitu, K., & Berhanu, S. (2020). Assessment of Potential Suitable Surface Irrigation Area in Borkena River Catchment, Awash Basin, Ethiopia. *Journal of Water Resources and Ocean Science*, *9*(5), 98.

Singha, C., & Swain, K. C. (2016). Land suitability evaluation criteria for agricultural crop selection: A review. *Agricultural Reviews*, *37*(2).

Teka, K., Van Rompaey, A., & Poesen, J. (2013). Assessing the role of policies on land use change and agricultural development since 1960s in northern Ethiopia. *Land Use Policy*, *30*(1), 944–951.

Ullah, M., Li, J., & Wadood, B. (2020). Analysis of urban expansion and its impacts on Land surface temperature and vegetation using RS and GIS, A case study in Xi'an City, China. *Earth Systems and Environment*, *4*(3), 583–597.

Wakassa, D. (2010). *Gis and Remote Sensing Based Land Suitability Analysis for Agricultural Crops in Mojo Watershed, Upper Awash Subbasin, Ethiopia* [Thesis, Addis Ababa Universty]. http://etd.aau.edu.et/handle/123456789/5857

Worku, T. (2015). Watershed management in highlands of Ethiopia: A review. *Open Access Library Journal*, *2*(06), 1.

Yalew, S. G., Van Griensven, A., Mul, M. L., & van der Zaag, P. (2016). Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. *Modeling Earth Systems and Environment*, *2*(2), 1–14.

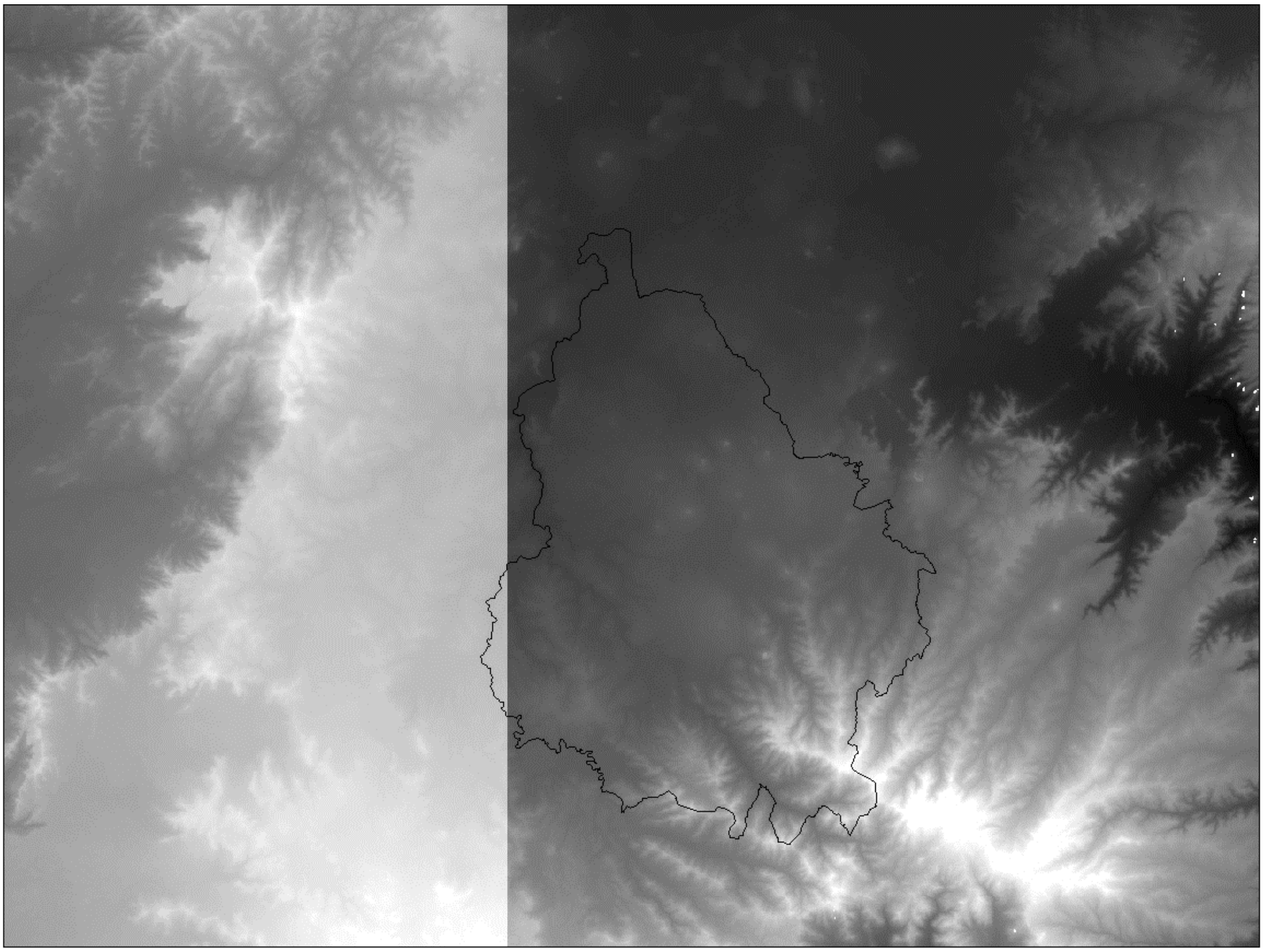
Yohannes, H., & Soromessa, T. (2018). Land suitability assessment for major crops by using GIS-based multi-criteria approach in Andit Tid watershed, Ethiopia. *Cogent Food & Agriculture*, *4*(1), 1470481. https://doi.org/10.1080/23311932.2018.1470481

Zolekar, R. B., & Bhagat, V. S. (2015a). Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. *Computers and Electronics in Agriculture, 118,* 300–321. https://doi.org/10.1016/j.compag.2015.09.016

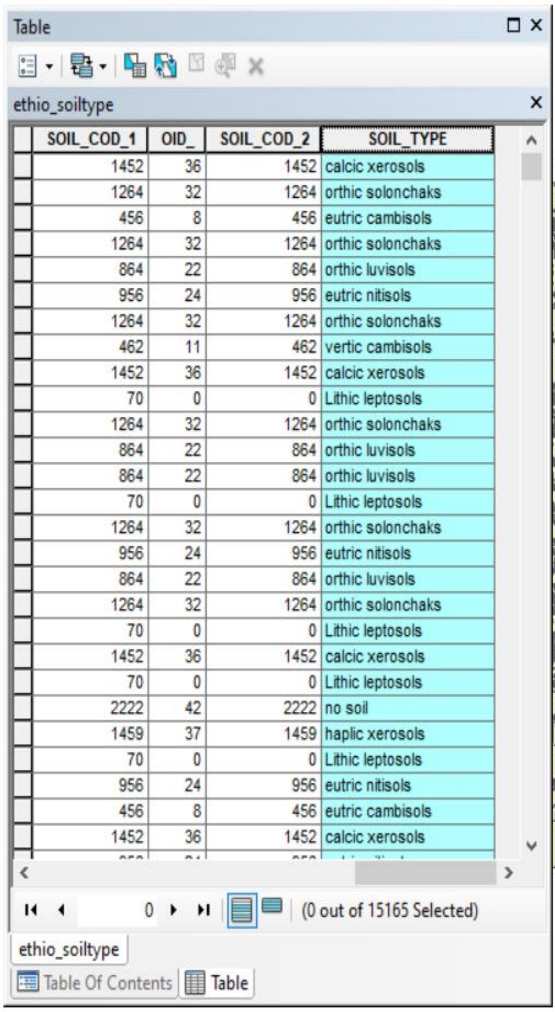
Zolekar, R. B., & Bhagat, V. S. (2015b). Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. *Computers and Electronics in Agriculture, 118*, 300–321. https://doi.org/10.1016/j.compag.2015.09.016

APPENDIXES

Appendix 1: digital elevation model (DEM) raster data of the study area

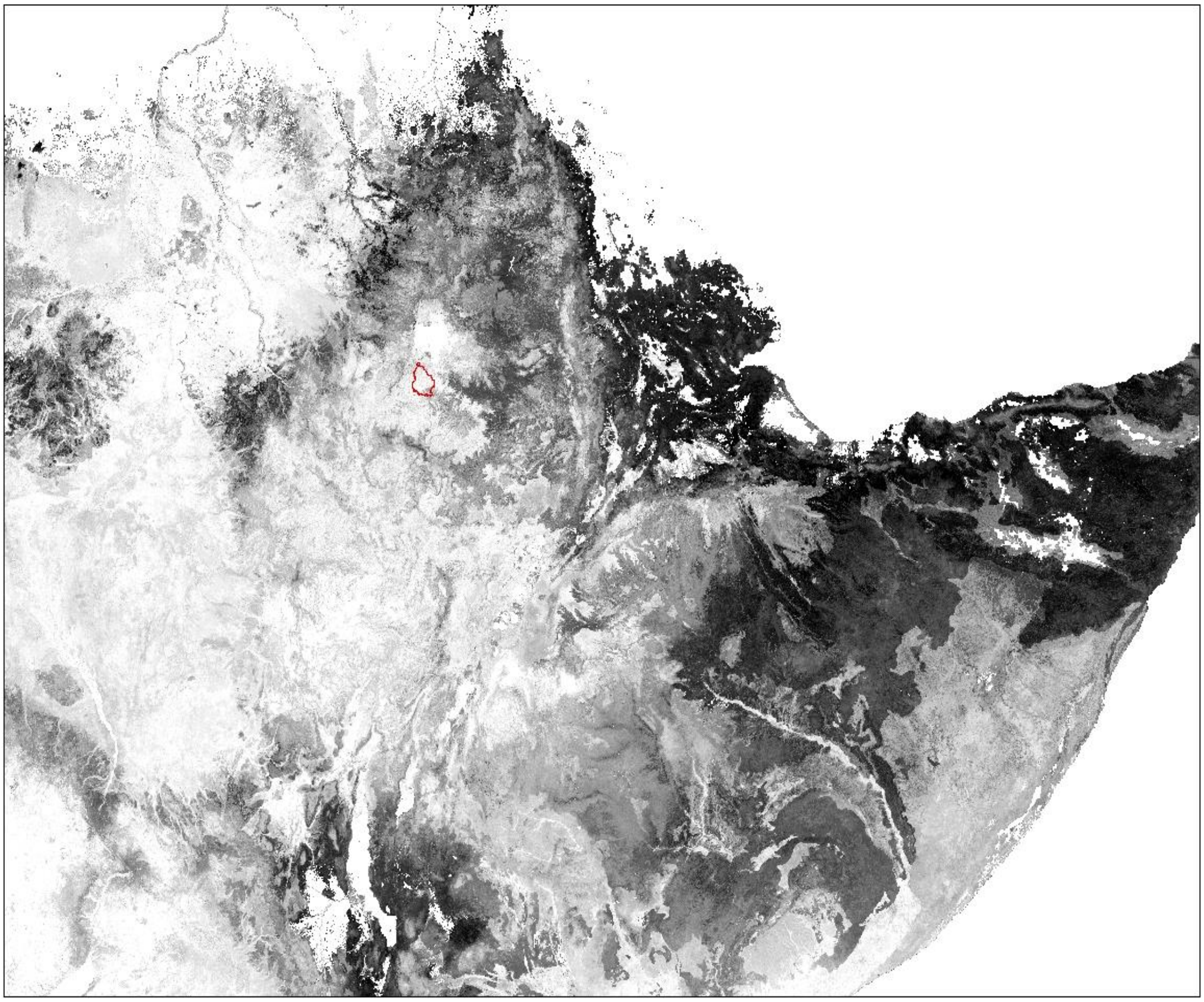


Appendix 2: Soil Type Data (spatial with attribute)



SOIL_COD_1	OID_	SOIL_COD_2	SOIL_TYPE
1452	36	1452	calcic xerosols
1264	32	1264	orthic solonchaks
456	8	456	eutric cambisols
1264	32	1264	orthic solonchaks
864	22	864	orthic luvisols
956	24	956	eutric nitisols
1264	32	1264	orthic solonchaks
462	11	462	vertic cambisols
1452	36	1452	calcic xerosols
70	0	0	Lithic leptosols
1264	32	1264	orthic solonchaks
864	22	864	orthic luvisols
864	22	864	orthic luvisols
70	0	0	Lithic leptosols
1264	32	1264	orthic solonchaks
956	24	956	eutric nitisols
864	22	864	orthic luvisols
1264	32	1264	orthic solonchaks
70	0	0	Lithic leptosols
1452	36	1452	calcic xerosols
70	0	0	Lithic leptosols
2222	42	2222	no soil
1459	37	1459	haplic xerosols
70	0	0	Lithic leptosols
956	24	956	eutric nitisols
456	8	456	eutric cambisols
1452	36	1452	calcic xerosols

Appendix 3: Soil depth raster data



Appendix 4: Landsat-8 satellite images for Land Use Land Cover Classification