JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

EVALUATION OF SURFACE IRRIGATION SUITABILITY FOR SELECTED CROP USING GIS AND REMOTE SENSINGTECHNIQUES: A CASE OF LIMMU KOSSA DISTRICT, SOUTHWEST ETHIOPIA.

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December, 2020

Jimma, Ethiopia

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A thesis submitted to department of Geography and Environmental Studies, Jimma University in partial fulfillment of the requirement for the degree of Master of Science in Geographic Information System and remote sensing.

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This thesis entitled with "Evaluation of Surface Irrigation suitability for selected crop suitability using GIS and Remote Sensing techniques: A case of Limmu kossa district, South west Ethiopia'' has been approved by the following examiners in partial fulfillment of the requirements for the degree of Masters of Science in geographic information system and remote sensing.

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Acronym/abbreviation

AHP: Analytical Hierarchy Process

ASTER: Advanced Space borne Thermal Emission and Reflectance Radiometer

AVHRR: Advanced Very High-Resolution Radiometer

CSA: Central Statistics Agency

DEM: Digital Elevation Model

ERDAS: Earth Resources Data Analysis System

FAO: Food and Agricultural Organization GIS

GIS: Geographic Information Systems

GPS: Global Positioning Systems

MCDE: Multi- criteria decision method evaluation

MCDM: Multi- criteria decision method

MCE: Multi- criteria method

MSS: Multiple Spectral Scanners

Mha: Million hectares

MOA: Ministry of Agriculture

MCE: Multi-Criteria Evaluation

PCA: Principal Component Analysis

PCM: Pair wise comparison matrices

UTM: Universal Transverse Mercator

USGS: United States Geological Survey

Abstract

Assessing available land resources for irrigation potential for crop suitability is important to planningthe development of irrigation and crop production potential. This study was initiated to assess the land resources potential of the district for irrigation potential suitability for crop production development by collecting different types of necessary data from a different source by usinga mixed method of data analysis and interpretations with different types of GIS tools such as reclassification, overlay, clip, multiple buffer and others to overcome the problem of land use management and food insecurity. Multi-criteria decision evaluation method was used to evaluate the physical land characteristics of the study area for surface irrigation. There are techniques, which were used to the weight and standardized the factors, which are used to evaluate the land in the study area throughout the pairwise comparison. To identify potential irrigable area, the factors reclassified into suitable class based on FAO guideline were physical soil property (texture, depth, and drainage), slope, distance to stream, distance to market and land use land cover were taken respectively. Accordingly irrigation suitability result were shows, 10716.2ha (8.1%) very suitable, 60821.2ha (46.2%) moderately suitable, 52236.0 ha (39.7%) marginally suitable, 7831.6ha (6.0%) not suitable.Secondly, the land in the study area was evaluated for suitability of groundnut and maize crops by using different factors for both crops. The results regarding maize were shown that, 65332.6ha (49.6%) highly suitable, 58414.3ha (44.4%) moderately suitable and only7858.1ha (6%) was not suitable. For groundnut 63963.2ha (48.6%) highly suitable, 59784.4ha (45.4%) moderately suitable and 7857.4ha (6%) was not suitable.In general, as the result of the study shows most parts of Limmu kossa district was suitable for irrigated agricultural production.

Key words: *Irrigation, suitability, GIS, Remote Sensing,*

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Agriculture is one of the world's most important activities supporting human life and which is a continuous dynamic changing from the ancient old system to the present exactness agriculture. On a global scale, agriculture has the demonstrated potential to increase food supplies faster than the growing demand, a pattern to be expected in the predictable future (Meier, 2018).

By the year 2025, 83 % of the expected global population of 8.5 billion is expected to live in developing countries. Yet the capacity of available resources and technologies to satisfy the demands of this growing population for food and other agricultural supplies remains uncertain (Shiferaw, 2007). While the total global food supply/demand figure is relatively good, there will be worsening food insecurity in sub-Saharan Africa. Until 2025, food production must grow by at least 40% to meet the needs of a 33% increase in population and to satisfy the trends for improved sustenance(Tadesse, 2012).

Africa's river systems have been the target of development planners since the 1960s, and many of the major rivers of the continent have been inhibited for irrigation, (FAO, 1995). Ethiopia has an irrigation potential of 5.3 million hectare of which 3.7 Mha can be developed using surface water resources, and 1.6Mha using ground water and rain water management(Awulachew et al., 2011).

Even though agriculture in Ethiopia is mainly dependent on rain fed systems, and this dependency has put the majority of the Ethiopian population at the mercy of meteorological variability. With increasing meteorological variability due to changing climate, it is highly probable that the rain fed agriculture of Ethiopia will be vulnerable to its effects. On the other hand agriculture in Ethiopia is small-scale, dominated by limited access to technology and institutional support services. There are about three million smallholder farmers, with an average farm size from 0.5 hectares to 2 hectares, currently producing 95 percent of the country's food crops (FAO, 2015).

Both irrigated and rain-fed agriculture is important in the Ethiopian economy. Nevertheless, almost all food crops (97 percent) in Ethiopia come from rain-fed agriculture, with the irrigation subsector accounting for only about 3 percent of the food crops (FAO, 2015). The major cereal crops are dominated by volume and value, followed by commercial crops and fruits are mostly irrigated (Mosissa, 2017).

Sustainable production increase can be achieved in two ways in irrigated agriculture, either new irrigation projects can be developed or existing schemes can be evaluated and their performance can be improved. Improving irrigation systems performance is more better than developing new irrigation areas due to the fact that investment in irrigation has failed to produce the expected result in many countries (Winnie, 2015).

Irrigation in Ethiopia is considered as a basic strategy to resist poverty and hence food security. It is useful to transform the rain-fed agricultural system which depends on rainfall into the combined rain-fed and irrigation agricultural system. This is believed to be the most prominent way of sustainable development in the country. However, the development of irrigation practices in Ethiopia has to be investigated to seriously know the history of irrigation emergence and its successive developments (Haile, 2015).

Surface irrigation development requires favorable topography and information on land and water resources for proper planning. Therefore, the planning process for surface irrigation has to integrate information about the suitability of the land, water resources availability, and water requirements of irrigable areas in time and place (FAO, 1997).Surface irrigation offers several benefits for the less skilled and poor farmers. Irrigation has contributed significantly to poverty alleviation, food security, and improving the quality of life for rural populations.

In Ethiopia, as in many developing countries, current land-use practices are not based on suitability analysis; therefore, there is an urgent need to use land most rationally and possibly. One of the most important and urgent problems in Ethiopia is to improve agricultural land management and cropping patterns to increase agricultural production with efficient use of land resources (Hailu, 2008). In this sense, GIS and remote sensing technology offer a dynamic tool for the multidimensional process of land use (Dula, 2010).

Evaluation of land suitability of potential irrigation for selected crops is very necessary to improve the capacity of food production in general and particularly in study area to overcome food security and economic development.

There are different types of irrigation (sprinkler, drip, surface, etc.). But this study focused on the evaluation of surface irrigation for crop suitability analysis with multi-criteria evaluation (MCE) integrating with GIS to delineate the suitable areas for surface irrigation for agricultural crop production of study area.

1.2. Statement of the problem

One of the major challenges of the 21st century is feeding the world's growing population, due to the population of the planet is growing dramatically (Meier et al., 2018). Ethiopia is one of the developing countries that are searching for alternatives to increase food production due to the rapid increase in population (Ayehu, 2015). The study area has significant natural resources, such as soil, water, natural vegetation, and suitable climate as well as human resources, but depends on the rain-fed agriculture with limited use of irrigation for agricultural production.

Nowadays, the high degree of rainfall variability and unreliability is the major problem, because more of the food supply in our country comes from low productivity rain-fed smallholder. On the other hand, as indicated in (Girma & kanate, 2017), the problem of selecting the correct land for the cultivation of a certain agricultural product was also mainly practiced issue.

In Limmu Kossa District, there are 5(five) major rivers named: Gibe, Dembi, Degidage, Indiris, and Awetu at the border. Even though this large number of rives, the exploitation of their water resources for irrigated agriculture has remained very low in the District. The District's production practice is depending on rain-fed and most of the population lives in poverty and low life level, because of the less experience on irrigation and lack of selecting suitable land for suitable crop, and also the lack of access to market in close proximity has greatly reduced the income.

Some researcher's deals with surface irrigation potential and crop suitability in different regions, such as Slehak (2007) on the Upper Kesem (Awash Basin) and Shiferaw (2007) on the Beles Sub Basin, BeneshangulGumez Region carried out the same study title and used parameters such as climate, topography, land use/cover and physical soil data. But they are not used socioeconomic such as distance to road and market distance suitability's as factor. So in this study access suitability was used as a parametric factor, because the distribution of access can be affecting the stability of irrigation potential for crop production. The second gap is the land resource factors were not the same everywhere and needs study. But there were no or few researches at the study area.

The main lists of problems which prioritize in these study are, First, potentially irrigable areas in the district have not been identified and mapped to encourage the small scale of local farmers, second, even though maize and groundnut were the importance crops to develop the economy of the farmer, but the farmers were not product groundnut widely as maize, andavailable physical land resources or which land is a suitable for what crop was not assessed. In general the main gap intended to fill in this study was the communities were not product the selected crop according to the potential of the district. Therefore, this study mainly focused to improve the community's awareness or experience of using irrigated crop according to potential of land in order to overcome the problem of food insecurity. To overcome those uncertainties, this study was carry out by using GIS and remote sensing as a tool for assessing irrigation potential for selected crop suitability in Limmu Kosa District.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study is to evaluate the potential physical land suitability for surface irrigation for selected crops using the multi-criteria decision Evolution (MCDE) method.

1.3.2. Specific Objectives

- To identify total available physical land resource and access suitabilityin the study area
- To evaluate physical land suitability for irrigation potential of the district.
- To produce the suitability map for potential surface irrigation and for selected crop.

1.4. Research question

- How can identifytotal availablephysical land resource and socioeconomic factors in the study area?
- How can evaluate physical land suitability for irrigation potential of the district?
- How can produce the suitability map for potential surface irrigation and for selected crop?

1.5. Significance of the study

Assessment of GIS-based surface irrigation suitability for maize and groundnut is the most precise technique and an interesting issue. These study findings used for Governmental sectors, Private sectors, decision-makers, individual householders or farmers, as well as researchers.

The study was used to evaluate the current irrigation potential, to achieve useful information on surface water availability to improve householder productivity participation on irrigation, to identify suitable lands in the study area for investment, to facilitate the investment area for private sector, to deliver facts or suggestion for decision-makers, suggesting to improve the management of the surface irrigation based on the result for governmental sectors, and to give interested information for researchers.

1.6. Scope of the Study

The study was dealing with the surface irrigation potential for selected crop suitability analysis in Oromia regional state, Jimma zone, Limmu Kosa District. This study was delimited with geographically, thematically and assessed based on physical land resource and socio economic data analysis by using qualitative and quantitative approach.

1.7. Organization of the Study

The study was organized in to five chapters; chapter One, introduction, statement of the problem, objectives, scope, and significance. Chapter two review literature and theoretical frame work for the study. Chapter three contains location, methods, design, and data analysis. Chapter four focused on results and discussions. Lastly chapter five was contained conclusion and recommendations.

1.8. Limitation

In this study the chemical properties of soil of the study area were not evaluated for surface irrigation potential for crops suitability and the study evaluated only with the secondary soil data due to shortage of time and budget. The GPSpoint was taken from some part of the study area as sample, because it was difficult to cover all parts of the study area due to lack of suitable access and transport.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definition of irrigation potential

Irrigation is defined as an artificial application of water to irrigated crop fields to supplement the natural sources of water to satisfy the crop water requirements and increase crop yields on a sustainable basis without causing damage to the land and soils (MOA, 2011).

Irrigation can be referred to as the process by which water is diverted from a river or pumped from a well and used for the purpose of agricultural production. The area, which can potentially be irrigated, depends on the physical resources, soil, and water, combined with the irrigation water requirements as determined by the cropping patterns and climate (Shiferaw, 2007).

2.2. The importance of irrigation

Irrigated agriculture plays an important role in providing general stability in the food production required to keep step with the population growth in Sub-Sahara Africa and Irrigation is a cornerstone of global food security. The relative high crop yields farmers could get with a controllable water supply can play a vital role in feeding millions being added to the existing population(Palamang, 2011).

2.3. Irrigation potential in Ethiopia

Ethiopia has 12 river basins with an annual runoff volume of 122 billion m3 of water and an estimated 2.6 - 6.5 billion m3 of groundwater potential, which makes an average of 1575 m3 of physically available water per person per year, a relatively large volume (Awulachew, 2010).

In Ethiopia, irrigation projects are classified as large projects with a command area greater than 3,000 ha medium projects with a command area between 200-3,000ha and small projects with a command area less than 200ha(Meron, 2007).The total potential irrigable land in Ethiopia is estimated to be around 3.7 million hectares (MoA, 2011).

2.4. Irrigation Technology

Local factories are coming up and actively engaged in manufacturing irrigation technologies and improved farm implements, which could be considered as a promising step in strengthening the irrigation sub-sectors (AMOSRN, 2011).

From the early days of irrigated agriculture, now day irrigation is becoming modern systems and the value from irrigation also increasing (Svendsen, 2009). But most of still our framers are not using different technology and using traditional systems yet in the study area. One of these concepts was the localized application of water directly to the root zone. Another concept was a subsurface water application to avoid evaporation from the soil surface.

Irrigation investment in new systems will expand the irrigated areas, while rehabilitation can be expected to increase the utilization of existing irrigation facilities. Modernizing existing systems may facilitate private investment in more efficient and productive water application technologies, such as sprinklers and drip irrigation. Irrigation investments may also be targeted directly at increasing the use of pressurized irrigation technology by strengthening production and marketing systems for such equipment (Svendsen, 2009)

2.5. Trends of irrigation and factors hindering the development of the sectors

Irrigation has played a very important role in increasing global agricultural production and improving global food security in the past decades. From 1961 to 2009, the global area equipped for irrigation increased by 117 percent, Currently, more than 40 percent of global agricultural products are produced on irrigated land, which is less than 20 percent of global arable land area (FAO, 2016,). In the meantime, irrigation has also been analyzed for inefficient water use, poor system performance and some negative externalities, including irrigation-induced soil salinization, water reduction, water-borne diseases, and water pollution, environmental degradation, limited access to new agricultural technologies, traditional methods of cultivation, high dependence on natural factors and unsatisfactory institutional support services (Asrat, 2019).

2.6. Land Suitability Evaluation for Surface Irrigation potential for crop production

Land suitability is the fitness of a given type of land for a defined use, or suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use. The process of land suitability classification is the assessment and grouping of specific areas of land in terms of their suitability for defining uses (Meron, 2007).

Land suitability refers to the ability of a portion of land to tolerate the production of crops in a sustainable way. Its evaluation provides information on the constraints and opportunities for the use of the land and therefore guides decisions on optimal utilization of resources, whose knowledge is an essential prerequisite for land use planning and development (Swamy, 2017). Successful irrigation requires a suitable physical medium for appropriate crop development. The land suitability for irrigation and crop includes soil characteristics and land slopes. Texture, depth, and salinity define soil characteristics. Soil texture is determined by the size of soil particles and it affects water storage, infiltration and holding capacity (Anane, 2012).

Soil depth refers to the thickness of the soil materials which provide structural support, nutrients, and water for plants and depth is an important factor that offers a medium to the roots to develop and influences the amount of water available to the crop(Neameh, 2003). Shallow soils require more frequent irrigations while deep soils require less frequent irrigations allowing the roots to penetrate deeper (Maniyunda & Gwari, 2014). As for salinity, plants are sensitive to soil salinity because it delays or prevents crop germination. It also reduces the plant growth due to the high osmotic pressures between the soil–water solution and the plants, which affect the plant's ability to absorb water (Douh, 2016).

When salinity exceeds a certain value it harms crops. According to a land slope, it influences runoff and soil drainage and determines the erosion hazard to which the field is exposed. Furthermore, farmlands management and irrigation techniques, as well as crop production, depending on the slope (Anane *et al.*, 2012).

Structure of Suitability Classification

According to FAO's Framework for Land Evaluation, the arrangement of the land suitability classification is described as recognizing quantitative, qualitative, and current or potential suitability in four classifications of decreasing overview. Each category has been taken its basic meaning within the context of the different classifications and applied it to different kinds of land use (FAO, 1976).

2.6.1. Land Suitability Orders

A Land Suitability order indicates or reflects a kind of suitability, whether the land is assessed as suitable or not suitable for the use under consideration (S or N.) respectively. According to the

FAO framework of land suitability classes, there are two orders Suitable and not suitable represented in maps, tables, etc. by the symbols S and N respectively.

Order S suitable: Land on which sustained use of the kind under consideration is expected to yield benefits that justify the inputs, without unacceptable risk of damage to land resources.

Order N not suitable: Land which has qualities that appear to preclude sustained use of the kind under consideration.

Land may be classed as Not Suitable for a given user for a number of reasons. It may be that the proposed use is technically impracticable, such as the irrigation of rocky, steep land, or that it would cause severe environmental degradation, such as the cultivation of steep slopes. Frequently, however, the reason is economic: that the value of the expected benefits does not justify the expected costs of the inputs that would be required.

2.6.2. Land Suitability Classes

A subdivision of a land suitability order serving to distinguish types of land which differ in degree of suitability. Land Suitability Classes reflect degrees of suitability. “Order Suitable’, as can often be recommended, the following names and definitions may be appropriate in a qualitative classification:

Class S1 Highly Suitable: The Land having no significant limitations to sustain the application of a given use or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2 Moderately Suitable: Land has limitations which in aggregate are moderately severe for sustained application of a given user; the limitations will reduce productivity or benefits and 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.

Class S3 Marginally Suitable: according to FAO framework of land evaluation Land has limitations which in the aggregate are severe for sustained application of a given user and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

In a quantitative classification, both benefits and inputs must be expressed in common measurable terms, normally economic. In many circumstances, different variables may express more clearly the degree of suitability.

Class N not suitable: Land having a limitation for surface irrigation development in both currencies and permanently due to topographic effect, soil type, and land cover conditions.

Table 1:Structure of land suitability order and classes(FAO, 1976)

Order	Class	Description
Suitable (S)	S1 (Highly suitable)	Land having no, or insignificant limitations to the given type of use
	S2 (Moderately suitable)	Land having minor limitations to the given type of use
	S3 (Marginally suitable)	Land having moderate limitations to the given type of use
Non-suitable(N)	N (unsuitable)	Land having severe limitations that exclude the given type of use

2.7. Land Productive Capacity

Productive capacity refers to crop adaptability and crop yields. The value of any farmland depends largely on its ability to sustain the production of crops of use to mankind. Climate; land features such as soil, topography, and drainage; water supply quantity and quality; environmental restrictions; and accepted cultural practices may influence the level of productivity. Productivity is also influenced by the management level, Because of the inability to measure accurately the actual level of management in the area over an extended period of time, a constant or typical level must be assumed in establishing specifications for an irrigation suitability land classification investigation (BORTSC, 2005).

2.8. Factors contributing Irrigation Potential for Crop Suitability

The basic physical factors in determining the suitability of surface irrigation and crop suitability are: climate, soil physical property, socio economic, and topography.

2.8.1. Climate

Climate has a distinct effect on land characteristics; its most important influence on irrigation suitability is the range and type of crops permitted by the climate in a specific area. These effects greatly influence the net income from the land under an irrigation regime and also Climate is the single most important factor in productivity. Length of the growing season or frost-free period; frequency and type of storms; humidity; prevailing winds; and precipitation have a major influence on kinds of crops grown and their yields (BORTSC, 2005). Cultural practices may also be influenced climate. Soil, topography, and drainage are influenced indirectly by past and present climatic conditions.

2.8.2. Slope gradient

The slope is the incline or gradient of a surface and is commonly expressed in percent. The slope is important for soil formation and management because of its influence on runoff, drainage, erosion, and choice of crops. The slope gradient of the land has a great influence on the length of the irrigation run, crop adaptability, erosion control practices, and irrigation method. Slope is important for soil formation and management because of its influence on runoff, drainage, erosion and choice of crops. As slope gradient increases, erosion hazard increases, water control becomes more difficult, the practical length of irrigation runs decreases, and crop selection becomes more limited(Kebede & Ademe, 2016). With surface irrigation, the following adverse effects occur as the gradient increases: erosion hazard increases, water control becomes more difficult, the practical length of irrigation runs decreases, and crop selection becomes more limited (Shiferaw, 2007).

The slope of the land affects the suitability of an area in terms of land preparation for irrigation and irrigation operation. The slope of the land will be estimated by using the Digital Elevation Model (DEM) (Worqlul *et al.,* 2017). According to FAO standard guidelines for the evaluation of slope gradient, mostly slopes which are less than 2% are very suitable for surface irrigation. But slopes, which are greater than 8%, are not widely recommended (FAO, 2016)

2.8.3. Soil assessment

It is important that soil description is done thoroughly; it serves as the basis for soil classification and site evaluation as well as interpretations of the genesis and environmental functions of the soil. (FAO, 2016)

The assessment of soils for irrigation involves using physical properties that are permanent in nature and cannot be changed or modified. Soil is an important determining factor for land suitability assessment for surface irrigation development. The physical properties of the soil mapping units, i.e., depth, texture, and drainage that are used for interpretation and analysis (Bengal, 2018).

GIS provides an advantage of mapping these properties of soils separately and make them ready for further overlay analysis to identify which unit is the best or worst for the selected surface irrigation and selected crop production

2.8.3.1. Soil depth

Although soil is a nonrenewable natural resource in a short period of time, it can be degraded in a short period of time by different processes such as erosion and inappropriate land use. The actual soil depth is the thickness of soil existing above the bedrock or resistant layers. For classifying land, suitability for a particular class, the effective depth can be deep, moderately deep, moderate shallow, shallow and very shallow which is greater than 1.2m,0.9 to 1.2m,0.5 to 0.9m,0.20 to 0.5m and less than 0.20m respectively (Tadese *et al.*, 2012).

2.8.3.2. Soil Drainage

Drainage can be defined as the removal of excess water and salt from the soil at a rate and to a depth that will permit normal plant growth. Prediction of the drainage requirement is a critical element in selecting land for irrigation (Meron, 2007). Soil drainage is one of the important soil properties affecting plant growth, water transfer, and solute transport in soils. Soil drainage is also an environmental component affecting irrigation and soil reclamation, land capability for agriculture, flood control systems, engineering, health and infectious diseases Drainage Class refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed (Gayathri *et al.*, 2018).

2.8.3.3. Soil texture

Soil texture provides a measure for permeability, and to some extent, for water retention capacity. Soils with potentially high percolation losses and soils with low water retention capacity, e.g., vitric Andsols, Aerosols, Podzols, and all soils with coarse textures have been considered not suited for gravity irrigation. For medium and fine-textured soils excessive percolation and low water retention capacities are less relevant. However, for Acrisols, Nitosols, and Ferralsols, the irrigation suitability ratings are slightly different as compared to rain-fed conditions, because of their specific clay mineralogy, which results in a relatively low water retention capacity and slightly higher percolation losses. (Velthuizen *et al.*, 2002)

2.8.4. Land Use Land Cover

Land use/land cover often used interchangeably. However, they are actually quite different. Land cover is observed physical cover on the earth’s surface or physically appearing on the surface of the ground as a natural or manmade entity including vegetation (natural or planted) and human construction such buildings, roads, and others (Asmerom, 2015). Which cover the earth's surface, Water, ice; bare rock or sand surfaces also count as land cover. Given land use may take place on one, or more than one, pieces of land and several land uses may occur on the same piece of land. However, the definition of land use establishes a direct link between land cover and the actions of people in their environment. Thus, land-use can be defined as a series of activities undertaken to produce one or more goods or services. Definitions of land cover or land use in this way provide a basis for identifying the possible land suitability for surface irrigation with precise and quantitative economic evaluation (kebede, 2010).

2.8.5. Water Availability

Water is the most important resource of the country, and of the entire society as a whole since no life is possible without water. The availability of water largely determines the spatial pattern of the Earth's terrestrial biomes (forest, grasslands, and deserts): it covers 71% of the Earth's surface providing habitat for fresh and saltwater ecosystems (Engdaw, 2016).

It plays a significant role to make sure of the deficiency of irrigation water. If there is a shortage of water during supply in some part of the irrigation season, crop production may be suffering and the returns may decline in some part of the scheme's investment may lay lazy (Yizengaw, 2017). Therefore, water supply is a key factor to evaluate the land suitability for irrigation according to the volume of water during the period of the year when it is available.

2.9. Role of geospatial information in evaluation of irrigation land suitability

GIS is computer software that offers a suitable and powerful platform to carry out a suitability assessment. GIS methods and procedures have a great role to play in analyzing decision problems. Certainly, GIS is often known as a decision support mechanism connecting the integration of spatially referenced data for problem-solving environment. We can enable the spatial analysis of the detected change through time by applying GIS and overlaying the spatial components of the same feature during two or more periods of time. Consequently, many spatial decision problems give growth to a multi-criteria decision analysis based on GIS technique (Yizengaw, 2017)

Remote sensing is a technology that has a close draw to GIS. Remote Sensing technology produces a reliable source of information for surveying, identifying, classifying, mapping, monitoring, and planning of natural resources and disaster mitigation, preparedness and management as a whole. Remote sensing can provide timely data at scales appropriate to a variety of applications. As such many researchers feel that the use of GIS and RS can lead to important advances in research and operational applications. Merging these two technologies can result in a great increase in information for many kinds of users (Ganole, 2010).

2.10. Mapping

A map is the most common view for users to work with geographic information. It's the primary application in any GIS to work with geographic information. The map represents geographic information as a collection of layers and other elements in a map view. Common map elements include the data frame containing map layers for a given extent plus a scale bar, north arrow, title, descriptive text, and a symbol legend (Ganole, 2010)

2.11. Multi-criteria decision making (MCDM)

Multi-criteria decision making (MCDM) is a process where geographical data is combined and transformed into a decision. Multi-criteria decision making includes input data, the decision maker’s preferences and manipulation of both information using specified decision rules (Prakash, 2003).

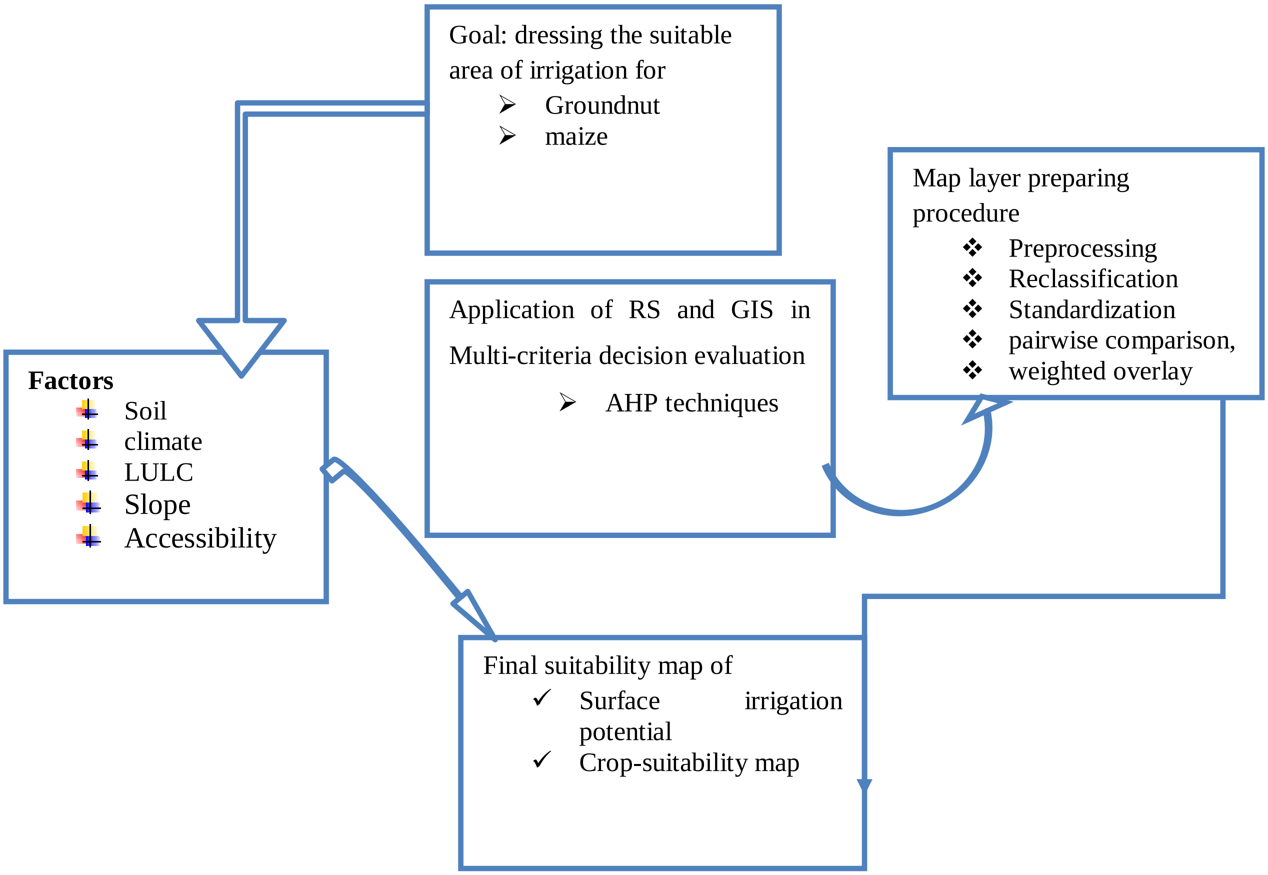
MCDM aims to achieve solutions for spatial decision problems, derived from multiple criteria. These criteria also called attribute must be identified carefully to arrive at the objectives and final goal. The performance of an objective is measured with the help of these attributes. These objectives and underlying attributes form a hierarchical structure of evaluation criteria for a particular decision problem. These evaluation criteria should be comprehensive and measurable. In a hierarchy, a set of criteria should be decomposable, non-redundant, complete, slight, and computational. Further, a map layer in the GIS represents each criterion in the hierarchy (kefelegn, et al., 2019). So in this study, multi-criteria is an important method in order to evaluate different parametric maps.

2.12. Empirical Literature of surface irrigation potential for crop suitability

Irrigation is considered as an obvious option to increase and stabilize crop production and its Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use(Meron, 2007). Irrigation has played a very important role in increasing global agricultural production and improving global food security (FAO, 2016). Land suitability analysis can help to achieve sustainable irrigation potential for crop production with proper use of natural resources (El-aziz, 2018). Access to irrigation is expected to expand farmers' production opportunities. It mitigates production risks, even in low quantities when crop-saving irrigation (Wijngaart *et al.*, 2019).

Most studies found that irrigation has a positive and significant influence on food security and income. Dula (2010) conducted a study of Land Suitability Analysis for Agricultural Crops in Mojo Watershed, Upper Awash Sub Basin, Ethiopia. Yizengaw, (2017) conduct the study on GIS-based Surface Irrigation Potential Assessment on Temicha Watershed in East Gojam Zone of Amhara Region; Ethiopia. Slehak (2007) conducted a study of Land capability, Irrigation Potential, and crop suitability analysis using GIS and Remote Sensing in Upper Kesem (Awash Basin). Shiferaw (2007) conducted a study of Irrigation Potential Evaluation and Crop Suitability Analysis Using GIs and Remote Sensing technique in Beles Sub Basin, BeneshangulGumez Region. This study also used the same parameters such as soil depth, soil drainage, soil texture, climate data rainfall and temperature with crop requirement and additionally access suitability.

2.13. Conceptual framework



CHAPTER THREE

3. Material and methods

3.1. Description of Study Area

3.1.1. Location

The study was conducted in the Limu Kosa District of Jimma Zone, Southwestern Ethiopia (Figure 1). As Limmu Kosa agricultural office (2019) report, the District is located at 420 km southwest of Addis Ababa, the capital city of Ethiopia, and located between Latitude of 7°48′28″and 8°15′17″ North and Longitude of 36°43′36″ and 37°16′55″ east. The District covers about 131,605 hectares (1316 km2) and as 29, 138 households (92.3% male-headed)

Figure 1 Map of the study area

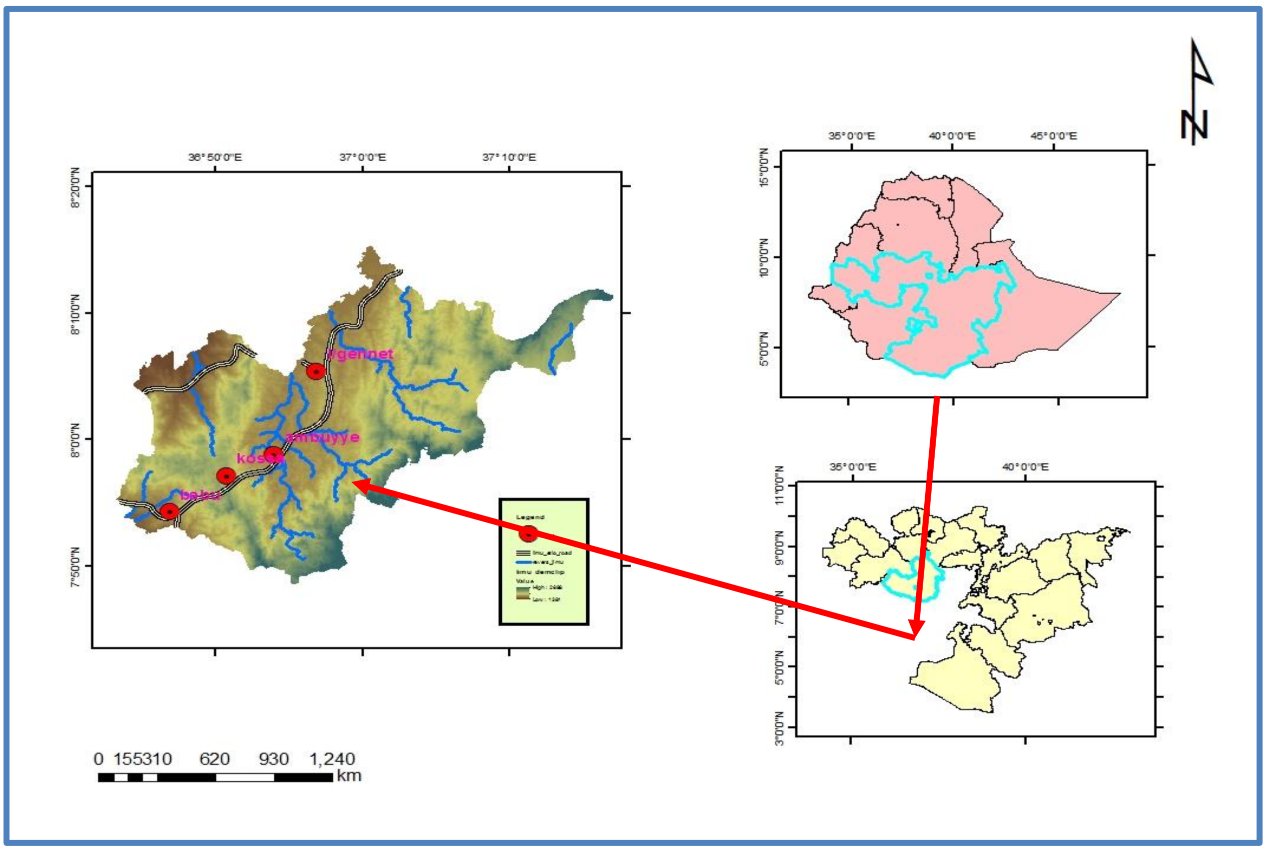


Figure 2: Location Map of study area

Source: Central statistical Agency (2013)

3.1.2. Topography

Topography is the arrangement of the natural and artificial physical features of an area. The topography of the district was characterized by different class, which frequently divides as lower, gentle, and higher which vary between altitudinal ranging from 1377 up to 2721 above mean sea level as shown on below figure:2

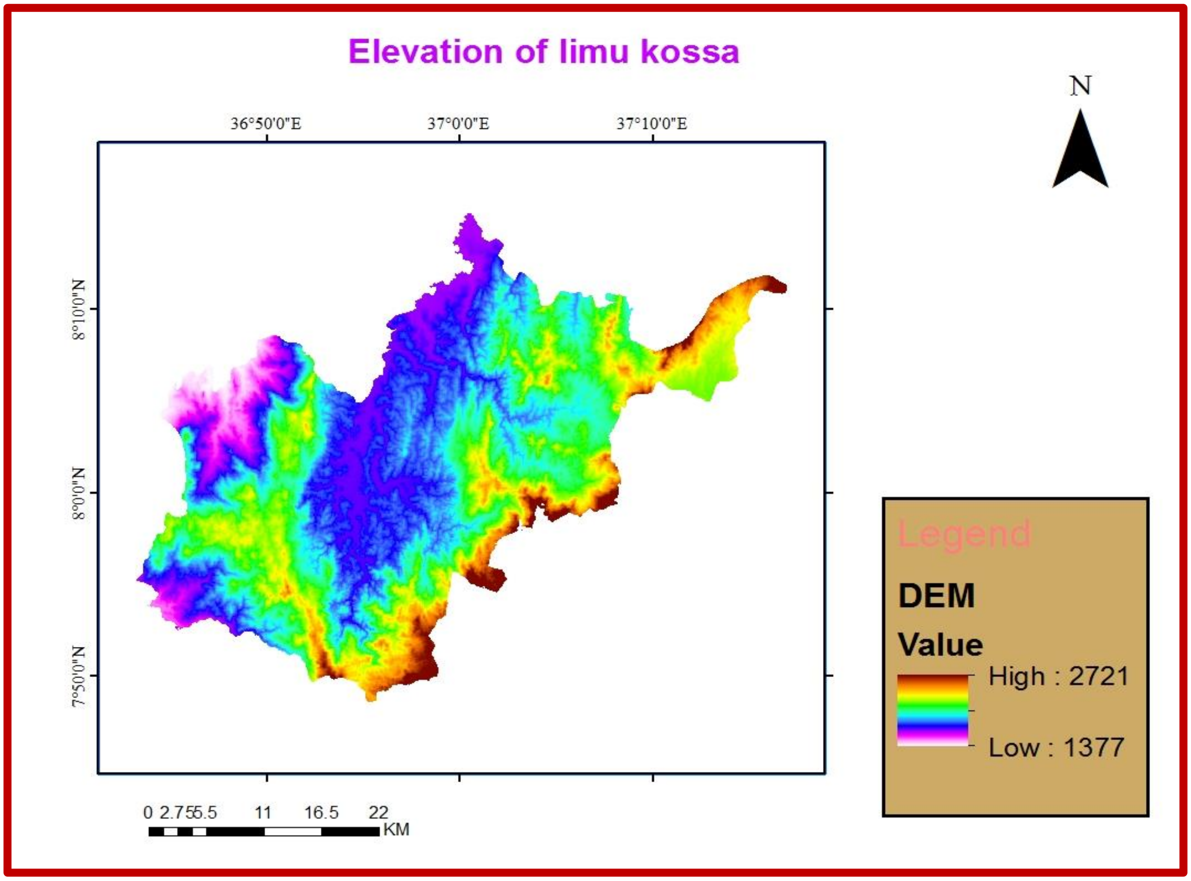


Figure 3:Elevation map of the district

3.1.3. Drainage

Limmu Kosa District has about 5 perennial rivers. Those revers are Gibe, Dembi, Indris, Dagdage and Awetu. The district is across two basin, namely Abay and Omo basin.

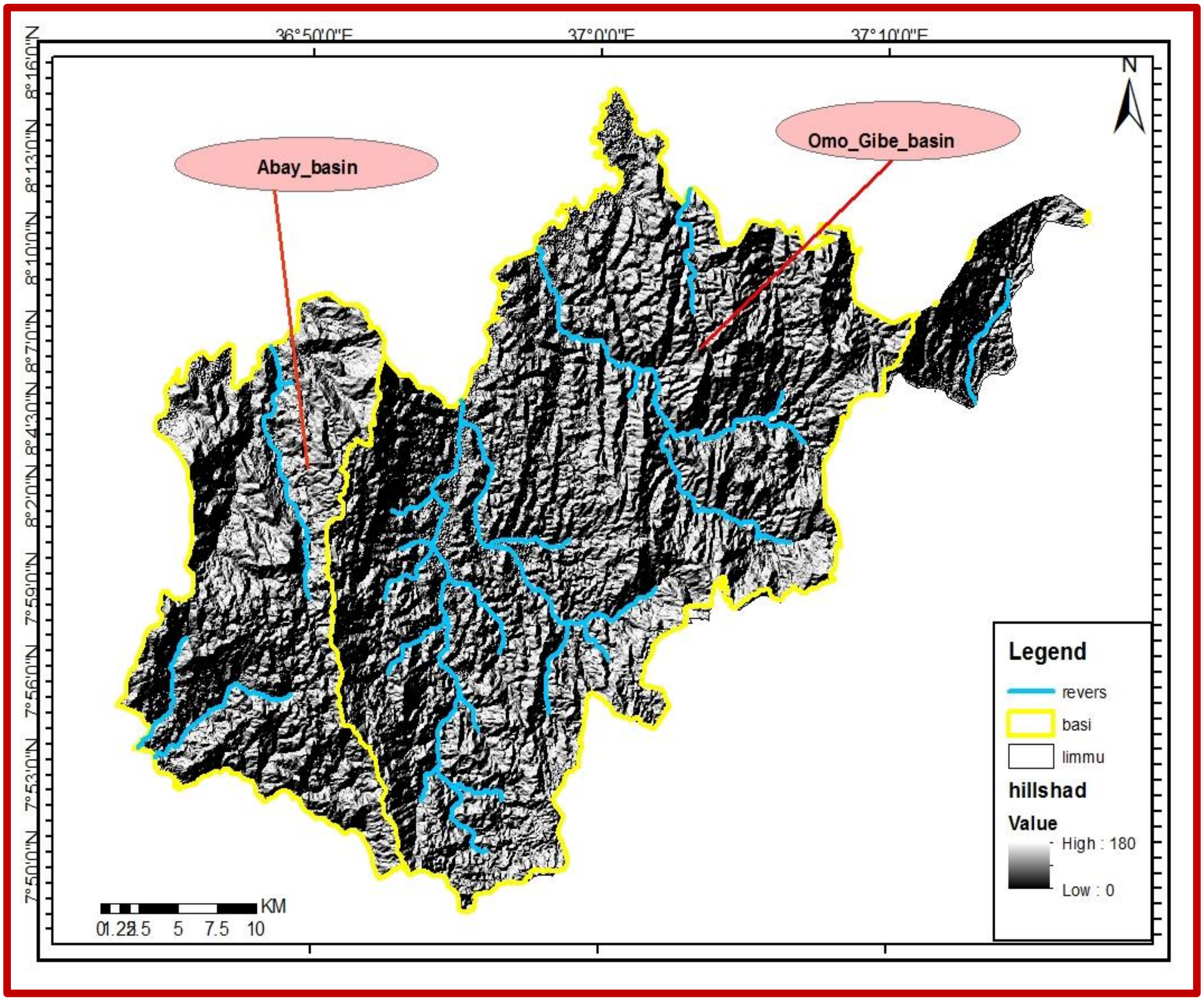


Figure 4:Drainage map of the district

3.1.4. Climate

According to AMOSRN, (2011) indicated, temperature determines the distribution of vegetation, soil, and farming system of a certain area. As twenty (20) years data taken from Jimma meteorological agency shows, the district is known with Minimum temperature of 20^{o}C and maximum of 27.7^{o}c and Minimum rainfall of 500mm and maximum rainfall of 2000 mm range.

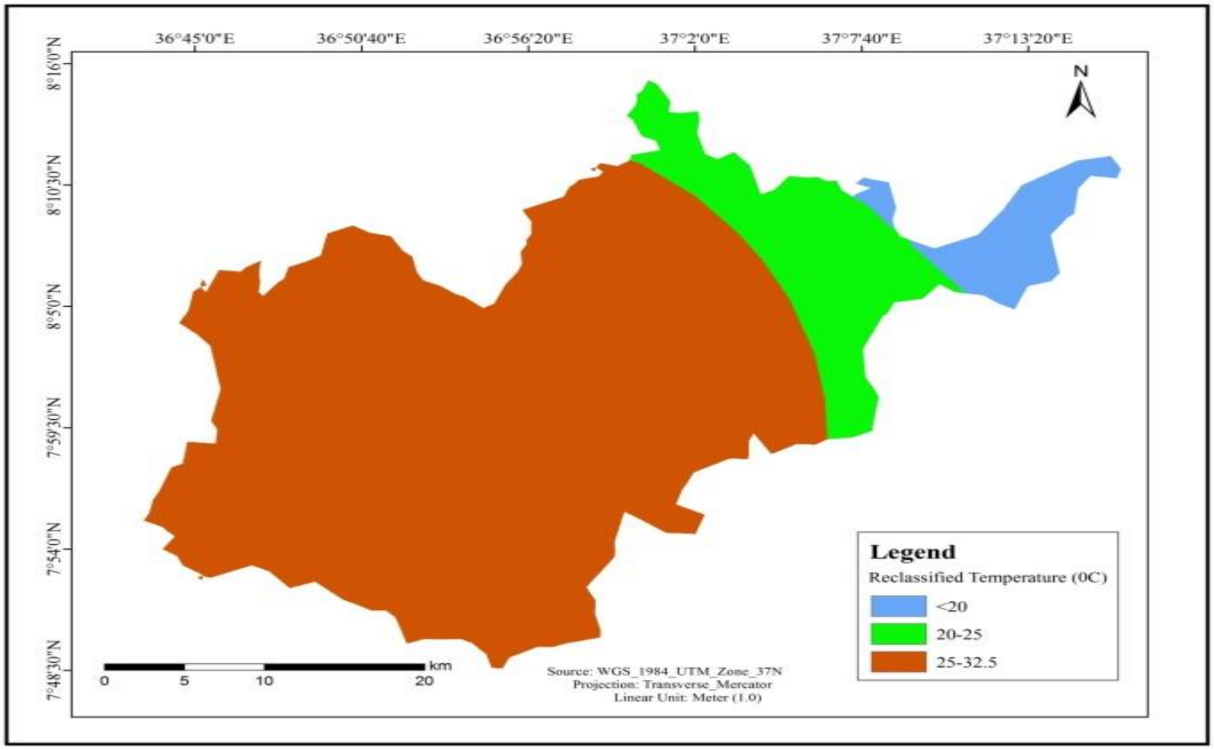


Figure 5: Temperature of the study area

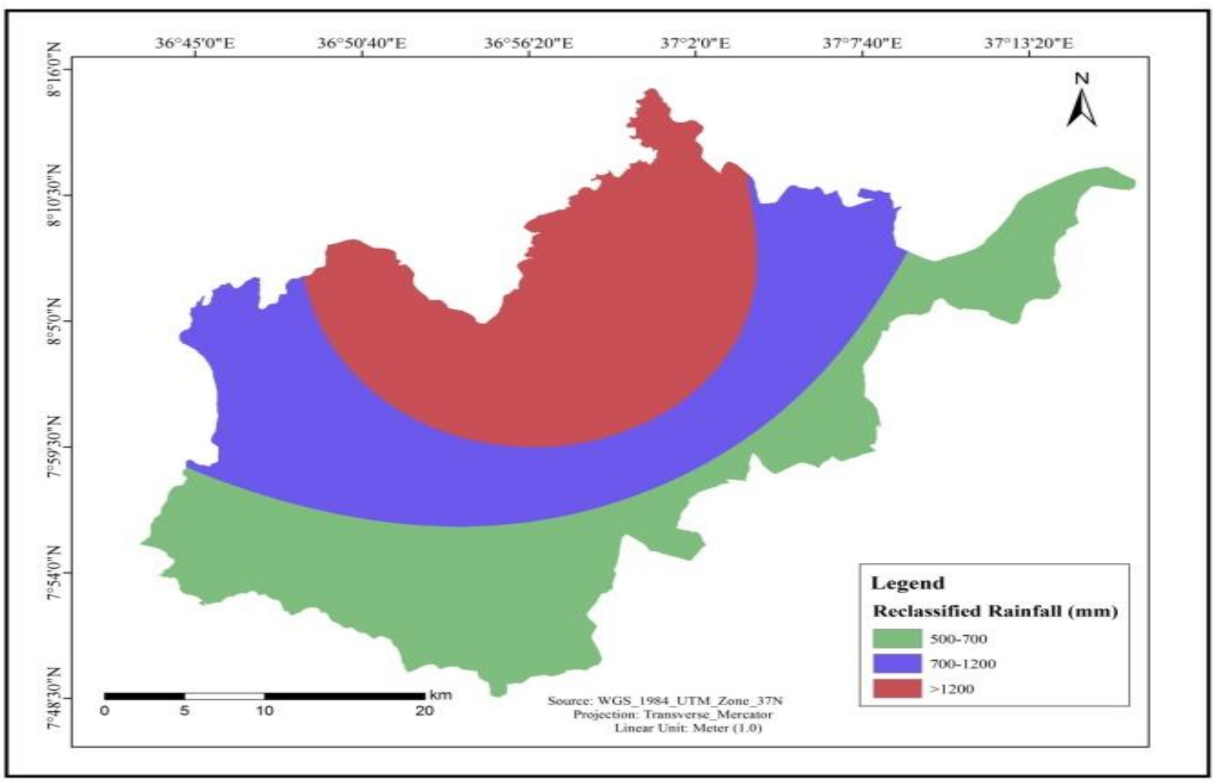


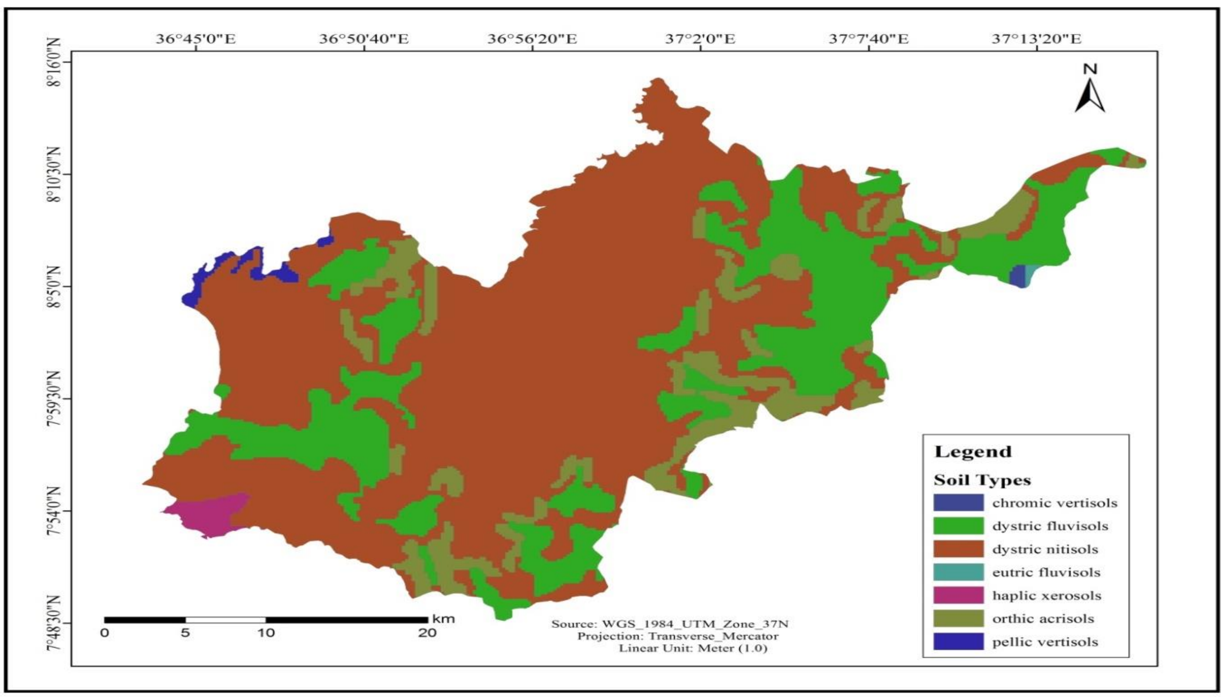
Figure 6: Rainfall map of the study area

3.1.5. Demographic

According to the national census (2007), a total population of Limmu district was 162,877, of whom 82,215 were men and 80,662 were women; 15,508 or 9.2% of its population were urban dwellers. The majority of the inhabitants are Muslims with 72.6% of the population, about 24.41% of the populations were orthodox and the left 2.72% were protestant. Most of the residents are Oromo (80.94%), the Amara (11.33%), and others cover the left percent

3.1.6. Soil types

The types of soil found in the study area were, chromic vertisols, dystric fluvisols, dystric nitisols, eutric fluvisols, haplic xerosols, orthic Acrisols, pellic vertisols



Source: ISRIC African soil

Figure 7:Soil types of the area

3.1.7. Socio-economic characteristics

The main farming activities in Limmu districts are mixed farming systems, subsistence crop production farming, and livestock. The most widely cultivated crops are maize, sorghum, *teff*, and coffee. Such groundnut, sugarcane, sesame, different fruit and ground roots in less percent cultivated and livestock such as sheep, goat, cows, donkey, and others. Coffee is the dominant crop which cover the wide part of the district‘s land. Natural forests and manmade forests are predominant in the district (Tegegn, 2017)

3.2. Research Design

The study was followed by Explanatory design qualitative and quantitative mixed approaches research techniques. As indicated in Harrison, et.al., (2011), quantitative and qualitative phases occur ones after the others. In explanatory designs, researchers first collect and analyze quantitative data, then build on those findings in a qualitative follow up, which seeks to provide a better understanding of the quantitative results.

In this study, the qualitative approach used for field observation, and quantitative research approach was employed to image analysis, measure, quantify and describe data.

3.3. Methods of the Study

This study was assessed by collecting available data from different offices, agencies and websites such as, Agriculture and natural resource office, Ethiopian national Meteorological Agencies and others. After collecting, the necessary data for the research and then filling of missed data and quality checking have been done carefully. GIS software for determining land suitability analysis for surface irrigation for selected crop considering topography, soil physical properties meteorology, socioeconomic and land use land cover were implemented.

3.4. Data Types and Sources

Different types of data were utilized to achieve the objectives of this paper.Primary and secondary data were collected respectively during data work out.The most important data for this study were soil map, satellite image (Landsat- 8), DEM to derive (stream flow, elevation and slope map), and the mean annual temperature & rainfall data. The primary sources of data were field observation and survey (GPS) point. The secondary sources of data were topographic maps from Ethiopian Mapping Agency (EMA), satellite image (Landsat-8) from USGSUnited States Geological Survey), ASTER digitally elevated model from USGS, meteorological data (rainfall and temperature) from meteorological agency, soil map from ISRIC (https://www.isric.org/projects/soil-property-maps-africa-250-m-resolution) and different published and unpublished document were collected to achieve the study objective.Details of the data characteristics are tabulated in Table 2.

Table 2: Source and types of data

Data type	Path	Row	Resolution	Data source	Application
ASTER DEM	169	55	30M	USGS	Steam flow, and slope map
Soil data	_	_	250M	ISRIC	For soil depth, texture, and soil drainage map
Access	_	_	_	CSA	To produce road distance
Climatic data	_	_	_	NMA	for Rainfall and temperature map
Landsat -08	169	55	30M	USGS	To produce land use/land cover map

3.5. Materials and tools

For this study GPS and Camera was used for ground truth assessment and capturing photos in the study area. Software like Arc GIS10.3, ERDAS Imagine 2015, MS Excel, and others were used.

Table 3: Materials and tools

No	Types of Materials	Description
1	Instrument	Garmin GPS60, Digital Camera
2	Software	ERDAS 2015, Arc GIS 10.3, MS excel, IDRSI

3.6. Method of Data Analysis

3.6.1. Land Use/ Cover Map

To prepare land use land cover map, Landsat_8 of (2020) image was downloaded with 30m spatial resolution from USGS. In the preparations of land use land cover map of the study area, first all bands of the image layer stacked together and clipped in the study area extent by using extract by mask tool.

Secondly the sample of training site for each of the class collected. Theidentification of training sites were based on 110 GPS points, which collected from the site with ground positioning system (GPS). The identified or collected ground control points were added to the image as a coordinate of the training site. Thenby using supervised classification with maximum Likelihood algorithm, five land cover classes were classified for the study area such as grass land, agricultural land, forest land, bare land and water body.

Image preprocessing_ Image preprocessing which comprises, image enhancement, layer stacking, image mosaics, false color combination, resampling, and sub settingwere applied to the images to improve image quality, interpretability andextract information from an image.

Image classification_to convert image data to thematic data, image classification is necessary. The present study applied a supervised classification technique with maximum likelihood algorithm using 99 training samples randomly collected from image to train software to categorize the image of the study area into different land use/ land cover classes from the 2020 Landsat 8 image. Thus, multispectral band 2-7 recorded in Landsat 8, Operational Land Imager (OLI) sensor layer stacked in ERDAS Imagine 2015 software

3.6.2. Accuracy assessment

Accuracy assessment is considered as an integral part of any image classification because image classification using different classification algorithms may classify pixels or group of pixels to wrong classes. Thus error of omission or error of commission will occur while classifying an image. One of the most common methods used to assess classification accuracy is the use of an error matrix and also called a confusion matrix (Kefelegn, *et al.*, 2019).

Land use/cover map of the study area accuracy assessment was tested based on the collected ground truth of 110 GPS point(forest (25), cultivate land (30), bare (18), water (15), and grass land (22) and by using Google earth application extension. Then kappa cofficiant,user accuracy and Overall accuracy were calculated

$$(\boldsymbol{OA}\%) = \frac{\mathbf{SCC}}{\mathbf{TS}} * 100 \quad \text{..Eq. (1)}$$

Where:$\boldsymbol{OA}$ is other overall accuracy?

SCC is the sum of correctly classified, and **TS** is the total sample

The Users Accuracy

These measures show the probability that pixels classified on map/image actually represent those categories on the ground. It is computed dividing the total numbers of pixels in a category by the total numbers of pixels that were classified in that category and it is measures of commission error.

Kappa Coefficient

Kappa coefficient can be used as another measure of agreement or assess classification accuracy. It expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification (Congalton, 2001). Computed using the formula provided by congalton (2001).

$$K = \frac{N\sum_{i=1}^{r} Xii - \sum_{i=1}^{r}(X_{i+} * X_{i+1})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{i+1})}$$ --------------------------------------equation (3)

where r is the number of rows in the matrix, xii is the number of observations in row ì and column ì xi+ and x +ì, are the marginal totals of row ì, and column ì, respectively, and N is the total number of observations.

3.6.3. Meteorological suitability analysis

According to (AMOSRN, 2011) specified, surface Irrigation is considered necessary when the natural supply of water is not sufficient to satisfy the crop water requirements for sustaining crop production. Climate is one of the most important factors determining the crop water requirements needed for unrestricted optimum growth and increased crop yields.

Twenty years (2000_2019) of meteorological data obtained from the National Meteorological Agency of Jimma Branch. The data were interpolated based on four neighbor districts to come up with the overall the district's map of temperature and rainfall in terms of their respective mean value. The interpolation technique was processed in ArcGIS with the use of spatial analyst tool an inverse distance weighted (IDW).

To identify suitable potential surface irrigation for selected crop the mean annual temperature and rainfall data were reclassified. Therefore reclassification of rainfall and temperature for surface irrigation were based on the available rainfall amount and temperature. This shows that surface irrigation more suitable in areas of low rainfall and high temperature. In this study the higher the mean annual rainfall and the less mean annual temperature were classified as not currently suitable for surface irrigation, and the high mean annual temperature and low mean annual rainfall were classified as highly suitable for surface irrigation based on FAO (1984) standard.

3.6.4. Analyses of Stream Flow suitability

The stream flow data was derived from the ASTER digital elevation model with spatial resolution of 30m. By using the hydrology tool the stream flow and basins was generated.

For identification of potential surface irrigation area, the stream flow data are categorized or ordered according to flow accumulation. Areas of higher values of flow accumulation werewhere water collects and drains. Areas of very high values are likely perennial streams or rivers and areas with lower values may be intermittent streams. Depending on the flow accumulation of the stream, five (5) perennial rivers were identified. The identified perennial rivers were used to identify potentially suitable irrigation area. Based on(frehiywet, 2019)and (Kolajo, etl at, 2019) document, the distances from River to a specific potential irrigation area was measured by multiple buffering zones. Finally, the river distance was reclassified and the value was assigned based on suitability result.

3.6.5. Soil Suitability Analysis

Soil is the most important factor in the analysis of surface irrigation potential for crop suitability development. To assess soil suitability for irrigation potential the ISRIC (2016) soil data of 250m resolution was used. The basic physical parameters of the soils in the district are texture, depth and drainage classes were used in the suitability analysis. The following soil suitability ratings were used based on (FAO, 1985) guidelines for land evaluation and (FAO, 1984)guidelines for land use planning.

Table 4: Factors suitability class range (FAO 1984)

Factors	Suitability class			
	S1	S2	S3	N
Depth	>150	100-150	100-50	>50
Texture	CL	SCL-CL-CL-C	L	Coarse sand
Drainage	W	MW	I	P

Source: FAO (1985 and 1984) guideline for land evaluation of the united nation

Based on this classification range all factors were reclassified with in ArcGIS reclassification tools. The new values were given based on a common evaluation scale from 1_4 suitability class of S1 represents highly suitable, S2 moderately suitable, S3 marginally suitable, and Nnot suitable classes.

3.6.6. Slope Suitability analysis

Land slope is the most important topographical factor influencing land suitability for irrigation potential suitability for selected crop. To derive slope suitability maps of the study area, digital elevation model of the area was clipped from ASTER with 30 meter resolution by masking layer of the study area. Then slope maps of the study area were derived using the “Spatial Analysis tool” in ArcGIS. The Slope derived from the DEM was reclassified to suitability classes of surface irrigation according to Global Agro Ecological Zone (GAEZ, 2012) by using the “Reclassification” tool, in ArcGIS. The four suitability ranges (S1, S2, S3 and N) were classified for surface irrigation potential suitability for selected crop.

Table 5: Slope suitability class range

No.	Slope range	Code	Suitability classes
1	0-5	S1	Highly suitable
2	5-8	S2	Suitable
3	8-16	S3	moderately suitable
4	>16	N	Not suitable
	Total		

*Source**:** Global agro- ecological zone (2012).*

The classified raster data layers were then converted to feature (vector) data layers using the conversion tools in the arc tool box and areas of each parcel of land with different slope class were calculated in the attribute table of the slope shape file.

3.6.7. Elevation

Topography influences the distribution of different natural resources. Elevation is one of topographic factors which can influence the suitability of irrigation potential and crop production. Elevation is the height of a place above or below a reference level, such as mean sea level. To drive Elevation suitability map, DEM data with 30m resolution was derived from ASTER. Then the DEM data clipped with the study area extent by using extraction tools. Then the elevation map reclassified in to suitable range of irrigation suitability for crop production based on FAO (1984) document.

3.6.8. Socio Economic Data

3.6.8.1. Market suitability

The market access is essentially the identification of the place where products can be sold. It is important to assess the accessibility of the market in the district of potential irrigation areas. By using GPS point three (3) major market centers in the District were identified. The market area was used as the input for the identification of the District's potential surface irrigation area and to evaluate how the farmers can be benefited from its production. According to (firehiywet, 2019)the market suitability was categorized according to its proximity in terms of distance (i.e. shorter the distance highly suitable) for irrigation agricultural product exchange. To measure the distance from respective market are to specific potential surface irrigation area multiple ring buffer tool was used. It was categorized with in the suitability classes range of highly suitable, suitable, moderately suitable, and not suitable in the distance interval of5, 5_8, 8-10 and >10 km respectively based on firehiywet (2019). Finally, the market accessibility map was rasterized, in order to match with the other factors layers.

3.6.8.2. Road accessibility

The road is the major access to transport the output production and to transport different input which necessary for irrigation potential and crop production development. So in order to analyses the suitability of road access in the study area the distance from road to current irrigation potential area was identified according to its proximity estimation of suitable distance by using multiple buffering tool. According to Neves (Gonçalves, et al., 2014) document, the road suitability for transportation was classified. By using multiple buffering tool the road suitability classes categorized in the range of highly suitable, suitable, moderately suitable, and not suitable in the distance interval of 2, 2_6, 6-8 and >10 km respectively. Finally, the roadsuitability map was rasterized, in order to match the other layers of this study.

Resampling

Resampling methods is used to draw samples from the observed data to draw certain conclusions about the population of interest (Efron, 1982).The three resampling methods; Nearest Neighbor, Bilinear Interpolation and Cubic Convolution, determine how the cell values of an output raster is done. The method used depends upon the input data and its use after the operation is performed. In this study bilinear is used for metrological data and Nearest Neighbor for soil data.

3.6.9. Standardization criteria map

Before performing an overlay, all the datasets generated were reclassified to a common scale. To execute weighted overlay analyses for land suitability, the criteria maps need to be converted into a similar scale through standardization techniques(Yalew et al., 2016). The generated raster datasets will have different numbering systems such as present for slope, temperature in degree Celsius and meters for elevation and they could therefore not be added or combined successfully in an overlay analysis. In order to compare their relative influence on the objective of the study all factors was reclassified using the Spatial Analyst tool in ArcMap into four comparative categories as highly suitable, moderately suitable, marginally suitable and unsuitable. Once all the criteria maps are standardized, the weights of each criteria map can be calculated using AHP according to the requirement of surface irrigation land suitability.

3.6.10. Assigning factor Weights

The pairwise comparison matrix was prepared to determine the weights of parameters according to the AHP. Ranks indicate the strength and dominance of criterion(Zolekar and Bhagat, 2015). Accordingly, a pairwise comparison matrix was done for factors used in suitability analysis of the study area for surface irrigation potential suitability for selected crop production.

The experts' opinions were used to decide the ranks of influencing criteria and the Pairwise Comparison Matrix to determine the weights. The PCM required for the AHP procedure based on forming judgments between two criteria and attempting to prioritize the entire list of parameters(Saaty, 2008). The difference in rating of factors is mostly solved by making scales to the same range and the derivation of the relative criterion importance using the pairwise comparison method. The criterion weights are automatically calculated; once the pairwise comparison matrix is entered in the IDRISI_AHP weight derivation module

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and was introduced by Saaty (1980). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub-criteria, and alternatives.

AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment. The score of differential scoring assumesthat the row criterion is of equal or greater importance than the column criterion. Thereciprocal values (1/3, 1/5, 1/7 have been used where the row criterion is less importantthan the column criterion.

Based on theproperties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR < 0.1indicates that the level of consistency in the pairwise comparison is acceptable. Saaty (1980)suggests that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable.

The preference scale for pairwise comparison in AHP

Intensity of Importance	Definition and explanation
1	Equal importance: two activities contribute equally to the objective
3	Moderate importance: Experience and judgment slightly favor one activity over another.
5	Strong importance: Experience and judgment strongly favor one activity over another.
7	Very strong/demonstrated importance: An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance: The evidence favoring one activity over another is

	of the highest possible order of affirmation.
2,4,6,8Reciprocals of above number	Intermediate values between the two adjacent judgments when compromise is needed.
1/2, 1/3, 1/4., 1/5, 1/6, 1/7, 1/8 and 1/9	Reciprocal values of the previous appreciation

3.6.11. Weighted Overlay Analysis

To identify potential surface irrigation suitability for selected crops, a multi criteria decision making approach was used. Weighting of decision factors were determined based on different document and key informant expert knowledge. Several previous studies conducted on potential irrigation suitability studies, such as (Meron, 2007, Yizengaw, 2017, Dula 2010, Slehak 2007 and Shiferaw, 2007).Additional to those documents, the expert's knowledge was the important one. That is why the expert participation is needed in this section. With regard to factor maps, weight for each factor maps was assigned based on their relevance.

A weighted overlay was used to combine all factor layers maps into new information to produce individual value for each pixel and the new map was produced (Hezan, 2010). The criteria that were used to weight were mainly the physical land resources and socio economicfactors. Because of the assumption that the physical land resources can be highly influence the potential irrigation for crop production availability in specific geographic locations.

The main physical land resources criteria that were used in this study were soil, slope, mean annual temperature and precipitation, land use /cover and socio-economic accessibility. Firstly all the vector format data were converted to a raster format of 30m*30m cell size. Each of the criteria was reclassified to a common scale or suitable class in ArcGIS environment. Finally, the reclassified raster format suitable map of each factors result were assigning with in IDRISI.

Methodological flaw chart

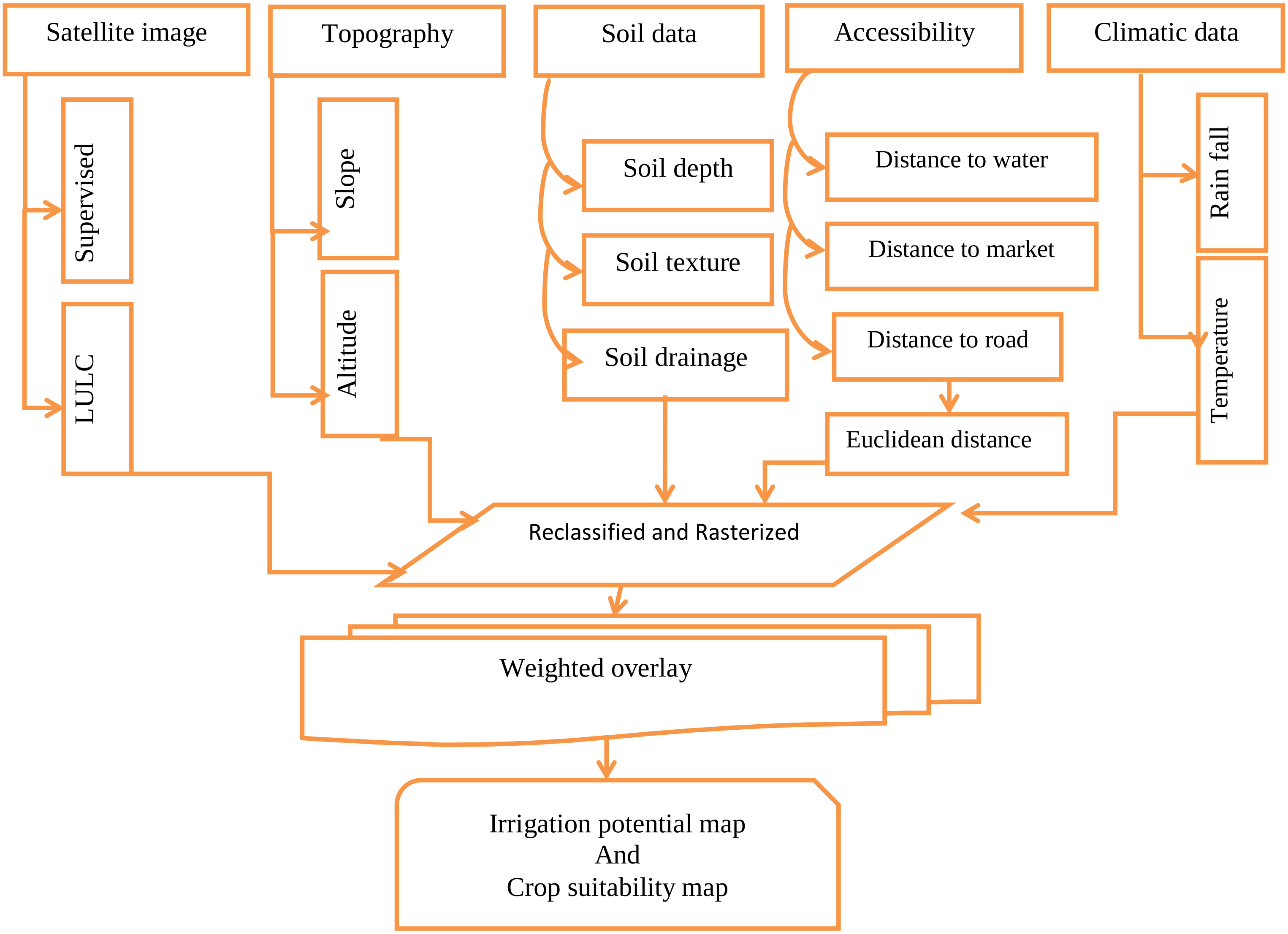


Figure 8: Methodology Flow chart

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

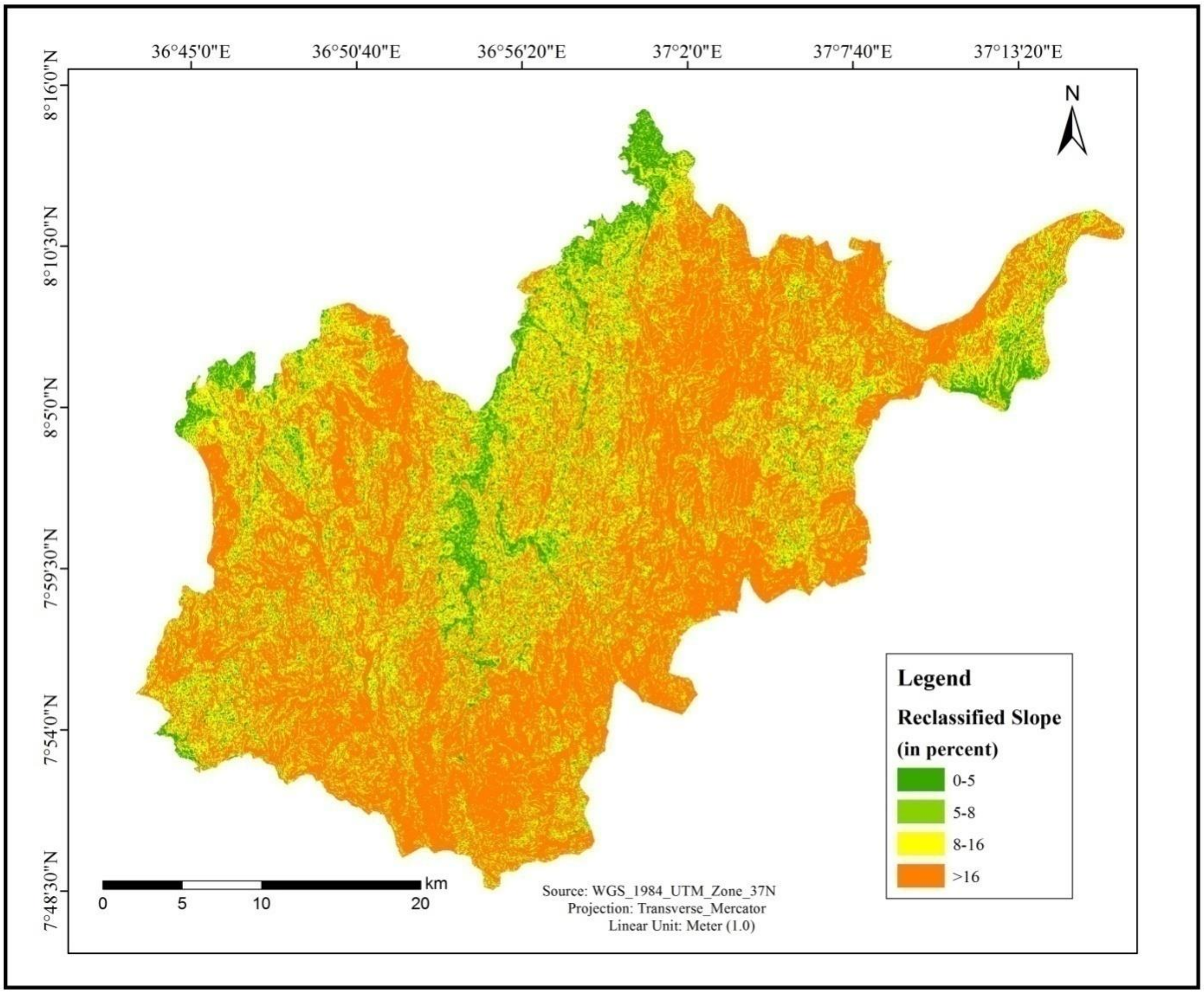
4.1. Factors Determining Surface Irrigation Potential for crop suitability

As FAO (2016) document refers, physical, chemical, socio economic and topographic factors of the land as well as climate are the major factors that determine irrigation potential of a given area. However the factors, which were evaluated to analyze suitability of the land for surface irrigation for crop suitability in the study area, are physical land factors, slope, soil depth, soil texture, soil drainage, land use land cover and socio economic factors (distance from market and distance from road), as well as climate factors included.

4.1.1. Physical land resource suitability evaluation

4.1.2. Slope suitability evaluation

Slope is the most important factor to identify suitable sites for surface irrigation and crop adaptability. Slope map was generated in percent for the entire area on Arc GIS using DEM of the area as input. The slope map generated was reclassified into four classes. The reclassified raster slope map of the area was converted to a polygon (feature) using the conversion tool and area of each polygon was calculated based on the scale considered. According to GAEZ (2012), slope map of the district was classified into four suitability classes (0-5, 5-8, 8-16 and >16) or (S1, S2, S3, and N).Slope suitability map of the district and area coverage of each suitability class was described in Table (6) and Figure (9) below.



Source: GAEZ (2012)

Figure 9: Slope suitability map of the area

Table 6: slope suitability and area coverage of the district (own process)

No.	Slope range	Area Share (he)	Total area (%)	Suitability classes
1	0-5	23500	17.8	Highly suitable
2	5-8	23200	17.62	moderately Suitable
3	8-16	57700	43.84	Marginally suitable
4	>16	27200	20.62	Not suitable
	Total	**131600**	**100**	

The result in the above table revealed that 17.8% of the total area of (235 km2) is in the range of highly suitable, 17.62% or (232 km2) moderately suitable, 43.84% or (577km2) marginally suitable and 20.62 or (272km2) of the total was not suitable for surface irrigation potential.

4.1.3. Elevation suitability evaluation

Elevation is the one of topographic factors which can influence the suitability of irrigation potential and crop production depending on the height of a place above (or below) a reference level. Elevation suitability was reclassified basedon FAO (1984).Based on this document the elevation suitability of the study area classified into three (3) suitable range of400_1400 (highly suitable), 1400_1800 (moderately suitable), and >1800 (not suitable) as shown in below table (7) and figure (10).

Table 7: Elevation suitability class and area coverage of the study are (own process).

No.	Elevationsuit. range	Area Share (he)	Total area (%)	Suitability classes
1	400-1400	50762	38.5	Suitable
2	1400-1800	39076	29.6	moderately suitable
3	>1800	41707	31.6	Not suitable
Total		**131605**	**100**	-

From the total area of the study area elevation suitability coverage was calculated with its suitability class rage. Accordingly the area which covered about 50762ha (38.5%) classified as highly suitable was found from northern part to center by following river flow and some western part, 39076ha (29.6%) was moderately suitable which cover from east to west including central part and 41707ha (31.6%) was classified in to not suitable for irrigation potential for crop suitability which found around southwest to southeast.

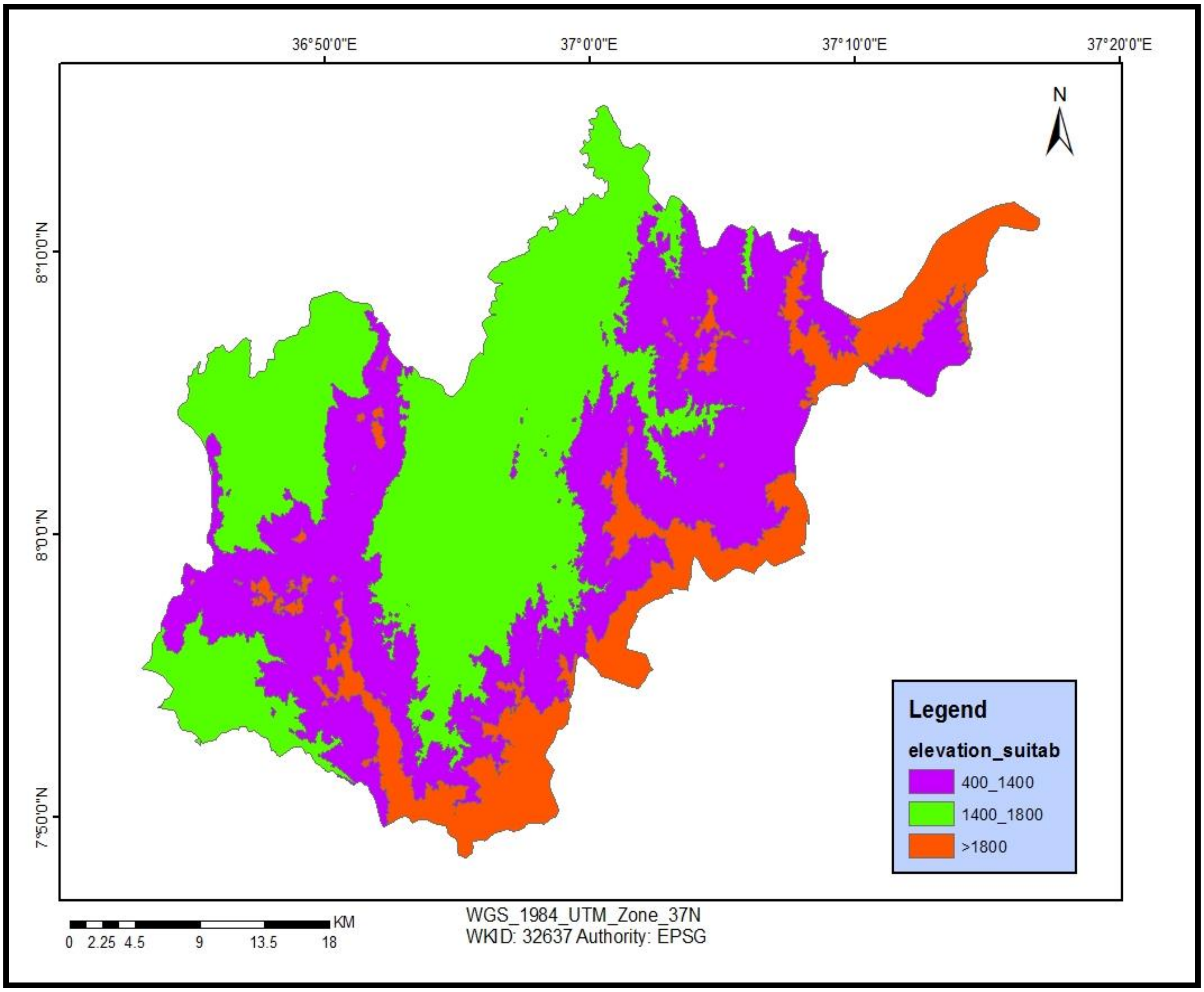


Figure 10: Elevation suitability map of the district

4.1.4. Soil suitability evaluation

4.1.4.1. Soil depth

Soil depth is one of the important physical soil parameters used to evaluate soil suitability for surface irrigation potential and crop suitability development. Soil depth of the district was interpreted from ISRIC soil map and classify according to FAO (1984). The districthave a soil depth varying from 36cm to >150cm. Accordingly, the soil depth was reclassified into four classes (>150, 100-150cm, 50-100 and <50) which means highly unsuitable, moderately suitable, marginally suitable and not suitable for surface irrigation potential respectively. The soil depth map of the area was shown in table (8) and Figure (11) below

.

Table 8: Soil depth class and area coverage

No.	Code	Depth class	Area Share (he)	Total area (%)	Suitability classes
1	1	<50	6	0.004	Not suitable
2	2	50-100	2561	1.94	Marginally suitable
3	3	100-150	103098	78.33	Moderately suitable
4	4	>150	20661	15.69	Highly Suitable
		Total	**131605**	**100**	-

Soil depth of the study area was evaluated for surface irrigation potential for crop suitability which cover about 20661hek (15.69%)as highly suitable, the wide area coverage of 103098hak (78.3%) as moderately suitable, about 2561hek (1.9%) as marginally suitable, and the few area which cover only 6hak (0.004%) was classified as not suitablerespectively.

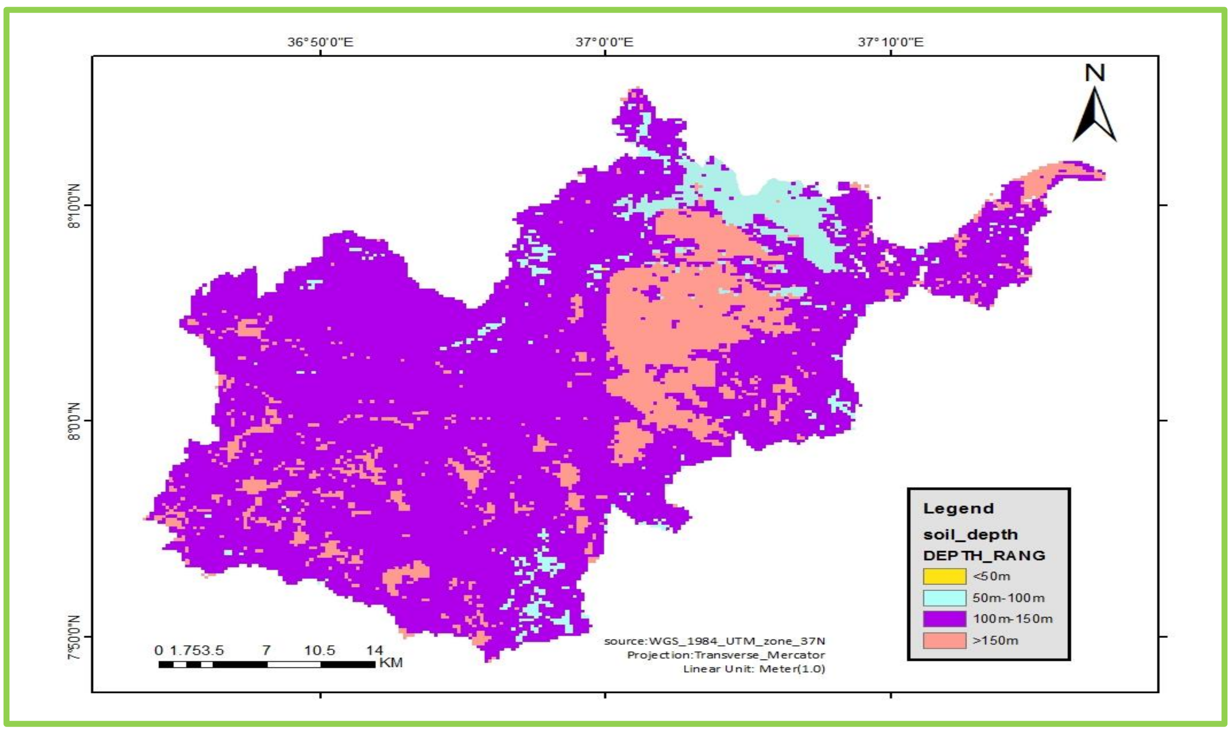


Figure 11: Soil depth suitability map of the study area

4.1.4.2. Soil drainage

Soil drainage is very important parameter of evaluation of the area for surface irrigation potential and crop suitability. The well drained soils are good for agriculture production development. Soil drainage permits normal plant growth. Suitable soil drainage is essential to ensure sustained productivity and to allow competence in farming operations. The Drainage classes were assigned according to the Guidelines for Soil Description of FAO(2006). Therefore the soil drainage properties of the study area were classified into suitability range based on FAO (1984) document. Accordingly the soil drainage of the district contains, imperfectly drained, moderately well, well, and somewhat excessive drained. (Fig12).

Table 9: Soil drainage class and area coverage (own process).

No.	Code	Drainage class	Area Share (he)	Total area (%)	Suitability classes
1	3	Imperfect	962	3.71	Not suitable
2	4	Moderately well	15420	11.71	Marginally suitable
3	5	Well	109561	83.24	Moderately suitable
4	6	Somewhat excessive	384	1.29	Highly suitable
	Total		**131605**	**100**	

The drainage suitability map of the area shows the well-drained area which covers a higher percentage area of 83.24% which indicates as suitable class and 11.71of the area covered by moderately suitable and very little percent area was covered somewhat excessive and unsuitable class which estimates about 1.29 and 3.71 of the total area.

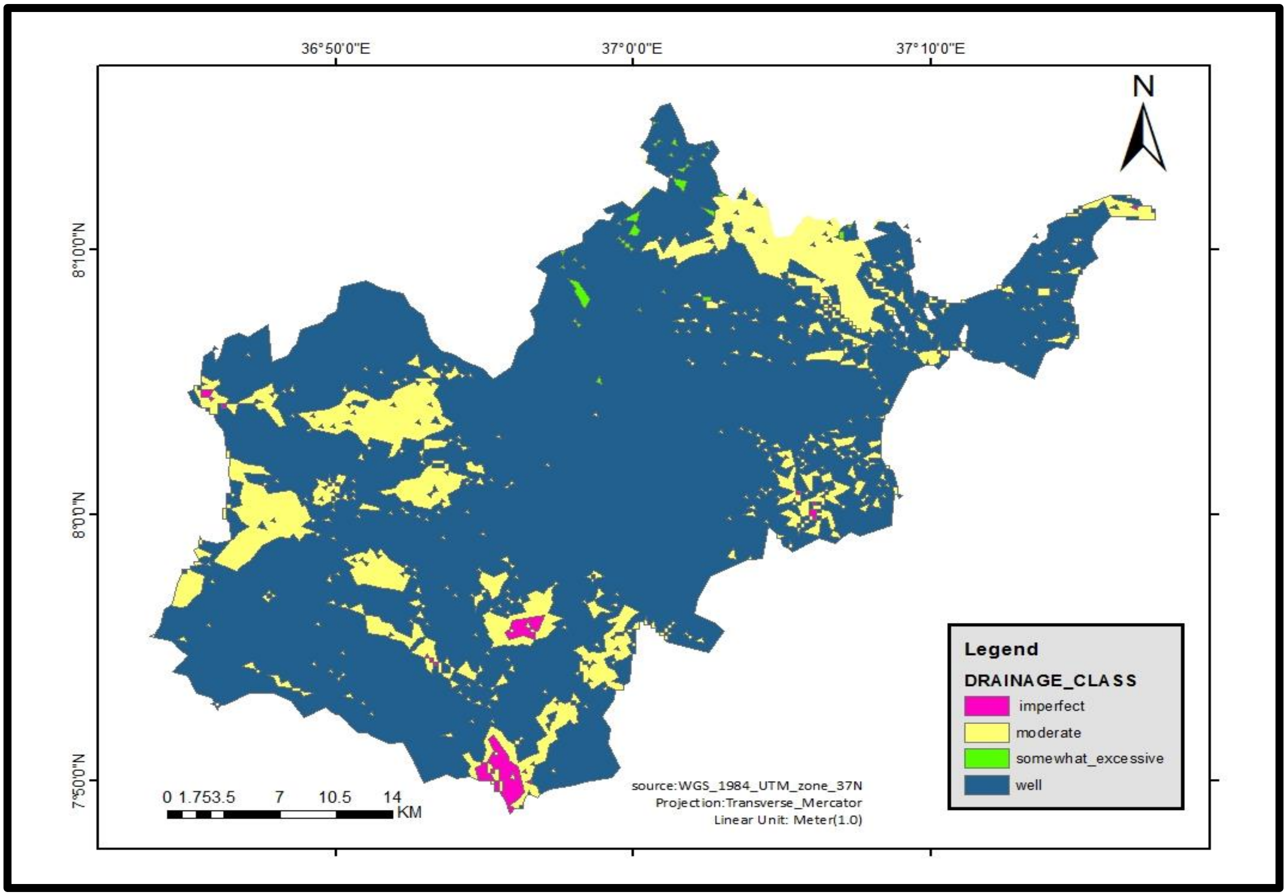


Figure 12: Soil drainage suitability map of the study area

4.1.4.3. Soil texture

Soil texture is one of the important physical characteristic of the soil. Based on its particles size, soils are divided in to three major type soil textures. These include clay, silt and sand soils. Textural class defined according to USDA system at 6 intervals (clay, silt-clay, clay-loam, sandy loam, sandy clay loam and loam) which derived from sand, silt and clay contents predicted using the Africa Soil Profiles (ASP). Accordingly clay, clay loam and silt clay loam are classified as fine-textured soils, while sandy clay loam, loam, and silt loam classified as medium textured soils and the others like sandy soils are classified as coarser-textured soils. Based on FAO (1996) guidelines, the study area soil texture was classified in to four suitability classes (S1, S2, S3 and N).According to the standard the soil texture of the district was dominated by medium textured soils. Texture of a given soil affects infiltration capacity and water retention capacity. Fine textured soils have high water holding capacity and low infiltration rate, whereas not fine textured soils have low water holding capacity and a high infiltration rate.

The below Figure (13) indicates the identified soil textural classes in the area.

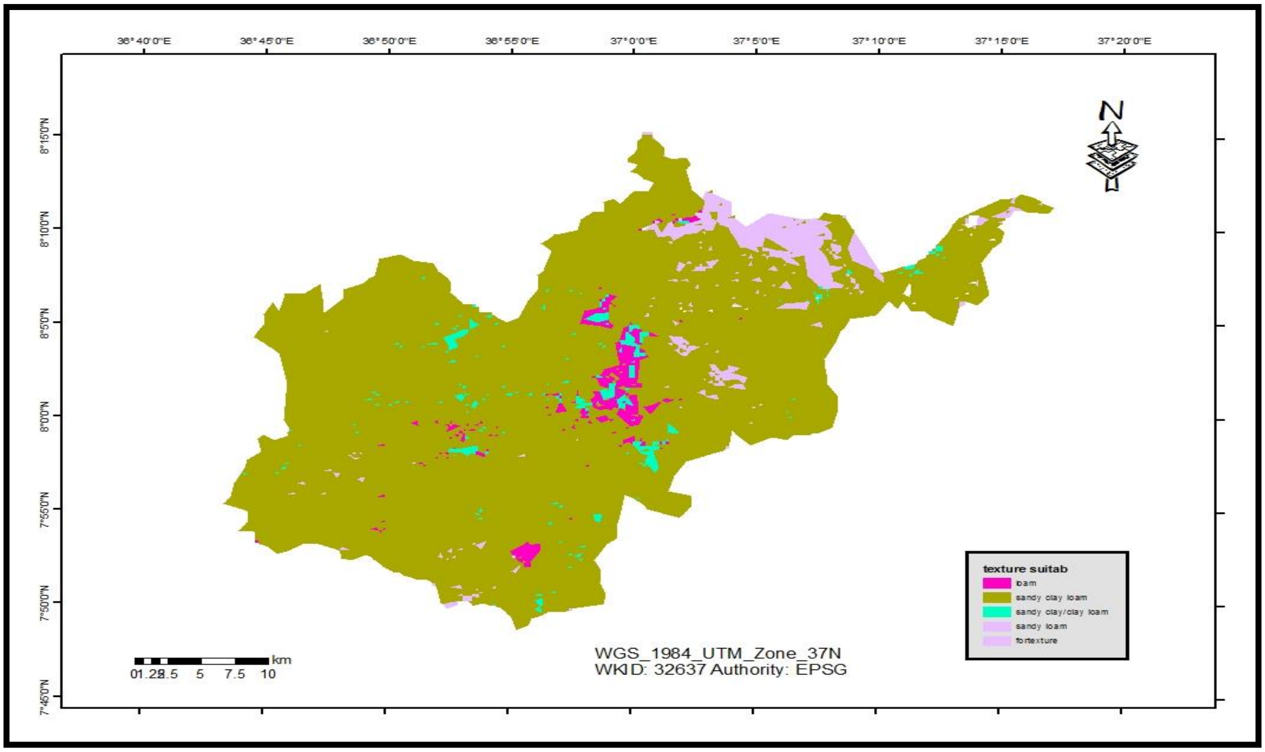


Figure 13: Soil texture map of the area

Table 10: Soil texture class and area coverage (own process)

No.	Code	Texture class	Area Share (he)	Total area (%)	Suitability classes
1	1	CL	2106	1.6	Highly suitable
2	2	SCL	119700	90.95	Moderately suitable
3	3	L	2972	2.2	Marginally suitable
4	4	SL	1633	1.24	Not suitable
		Total	**131605**	**100**	

CL= clay loam, SCL=sandy clay loam, L= loam, SL=silt loam

Soil textural class suitability analysis for surface irrigation potential for crop suitability development of the area show that the only about 1.6% of the soil categorized under highly suitable class. The highest coverage of the study area soil class about 90.95% were dominated under suitable and about 1.5% of the area's soil were categorized under unsuitable class.

4.1.5. Stream suitability analysis

Distance to water sources to be the variable most likely to influence the site location for surface irrigation. Therefore, the map was made by creating a buffer area of a specified distance to water based on frehiywet(2019) document. Very small channels or cell counts of less than 500m were removed from the layer and multiple polygon were constructed for the remaining streams through proximity analysis tool of multiple ring buffer tool. The vector format of buffered stream converted to raster format. Based on Kolajo(2019) and frehiywet(2019)the suitability class of stream flow were categorized in the distance of 500 meter, 1 kilometer, 2 kilometers and 3kilometers with suitability range of highly suitable, moderately suitable, marginally suitable and not suitable respectively as shown in below table.

Table 11: Stream suitability class and area coverage

No.	Stream suitability range(meters)	Area Share (he)	Total area (%)	Suitability classes
1	500	20299	16.42	Highly suitable
2	1000	18780	14.26	Moderately Suitable
3	2000	32065	24.36	Marginally suitable
4	>3000	60461	45.94	Not suitable
	Total	**131605**	**100**	

Out of the total area of the district highly suitable area covered about 20299 ha or (16%), moderately suitable covered about 18780 ha (14%), marginally suitable covered about 32065ha (24%) and the wide area covered under not suitable range which calculate about 45% of the total area. so the area which is the nearest to the river was classified as highly suitable and the inverse was classified as not suitable.

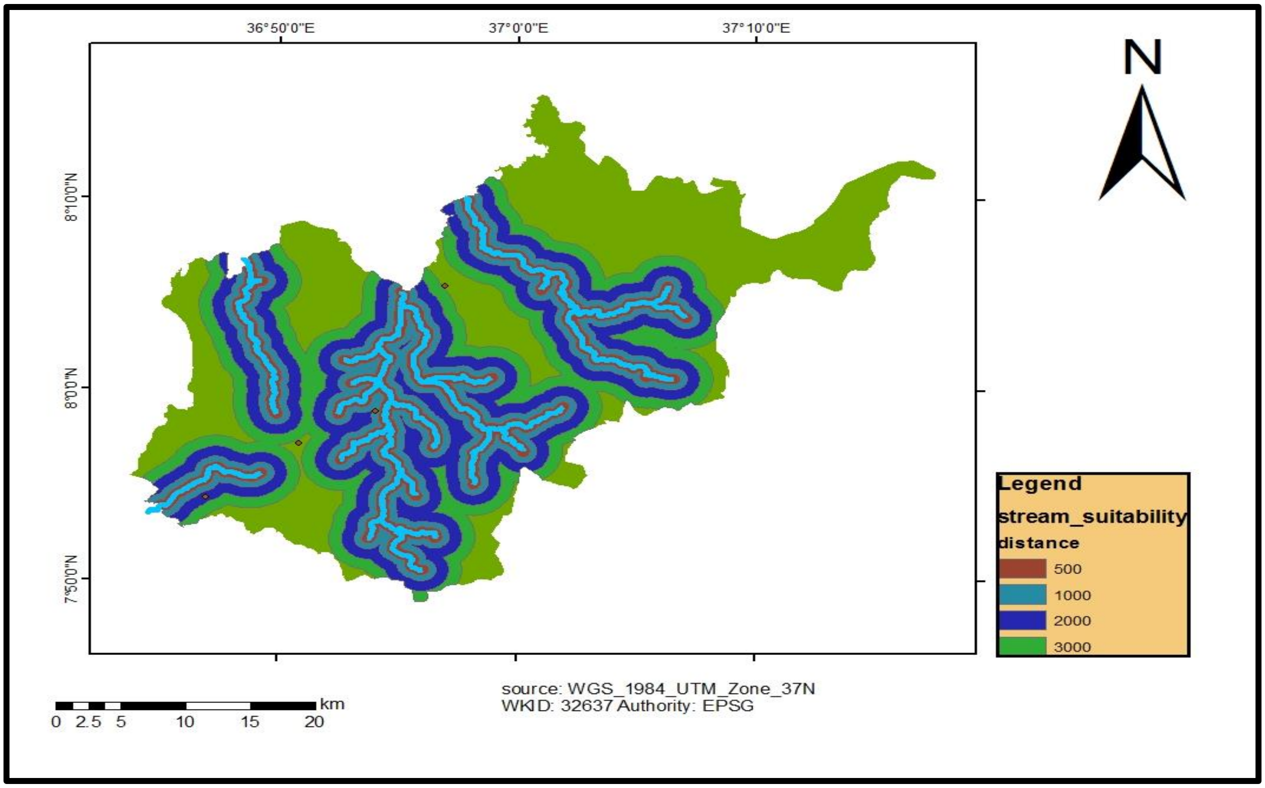


Figure 14: Stream suitability map of the study area

4.1.6. Meteorological data analysis

Climate is one of the important factors influences on the suitability of lands for irrigation potential and crop production suitability. The characteristics of the soil drainage conditions, distribution of vegetation, and crop adaptation are related to climate. Thus, the physical environmental factors (including climate) determine what will or will not grow. Twenty years rainfall and temperature data were obtained from meteorological agency of four stations such as Agaro, limu genet, Yabu, and Bacho stations and then interpolated. Rainfall and temperature map of the study area were developed using Inverse Distance Weighted (IDW) technique and reclassified into suitable class according to FAO (1984)guideline.

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Table 12:Temperature suitability class and area coverage of the district

Temperature suitability				
S/No	Temperature (0C)	Area (he)	Area (%)	Suitability classes
1	25-32.5	107455	81.6	Highly suitable
2	20-25	17378	13.2	Moderately suitable
3	>20	6772	5.1	Not suitable
	Total	131605	100.0	

From the total land of the district, about 107455 ha (81.6%) of the total area is covered by highly suitable temperature range, and the left few percent of the area covered by moderately suitable and not suitable temperature range as shown in below figure.

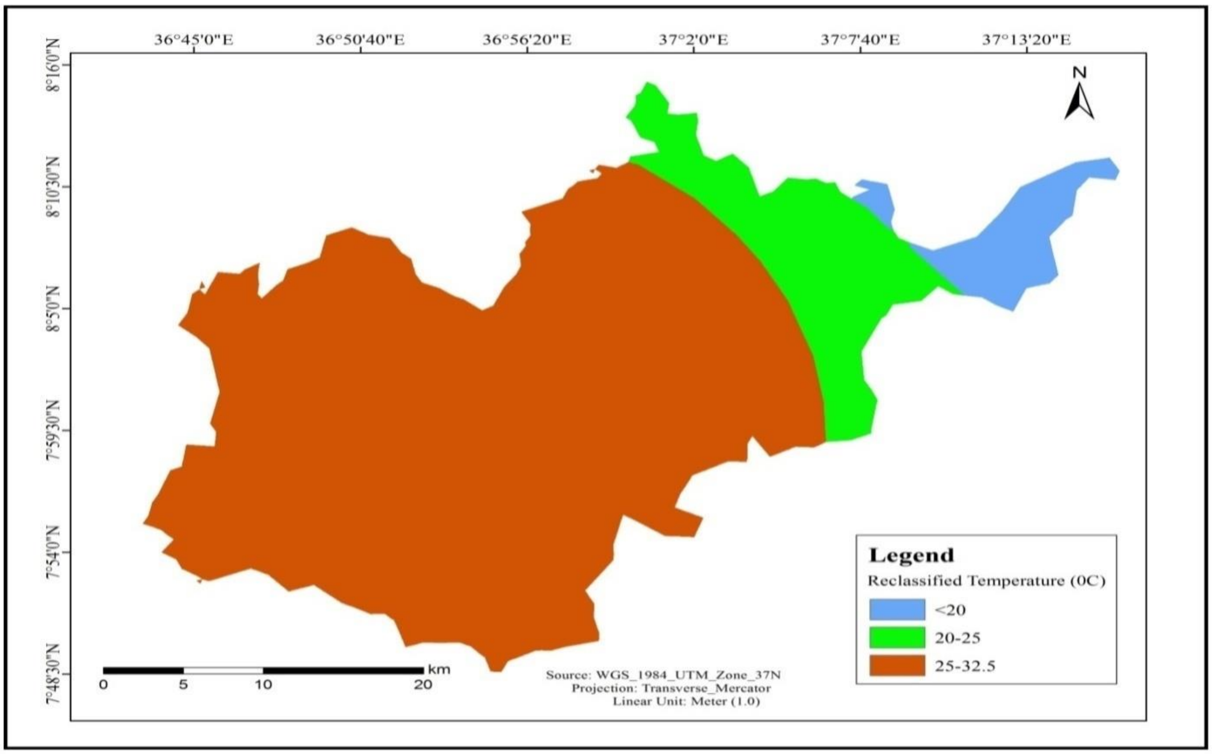


Figure 15: Temperature suitability map of the area

Table 13: Rainfall suitability class and area coverage of the study area

Rainfall suitability				
S/No	**Rainfall (mm)**	**Area (ha)**	**Area (%)**	**suitability classes**
1	600-900	45423.0	34.5	High suitable
2	900-1200	44075.8	33.5	Moderately suitable
3	>1200	42106.1	32.0	Not suitable
	Total	131605.0	100.0	

From the total area of the district highly suitable covered 34.5%, moderately suitable area covered 33.5% and not suitable covered about 32% of the area.

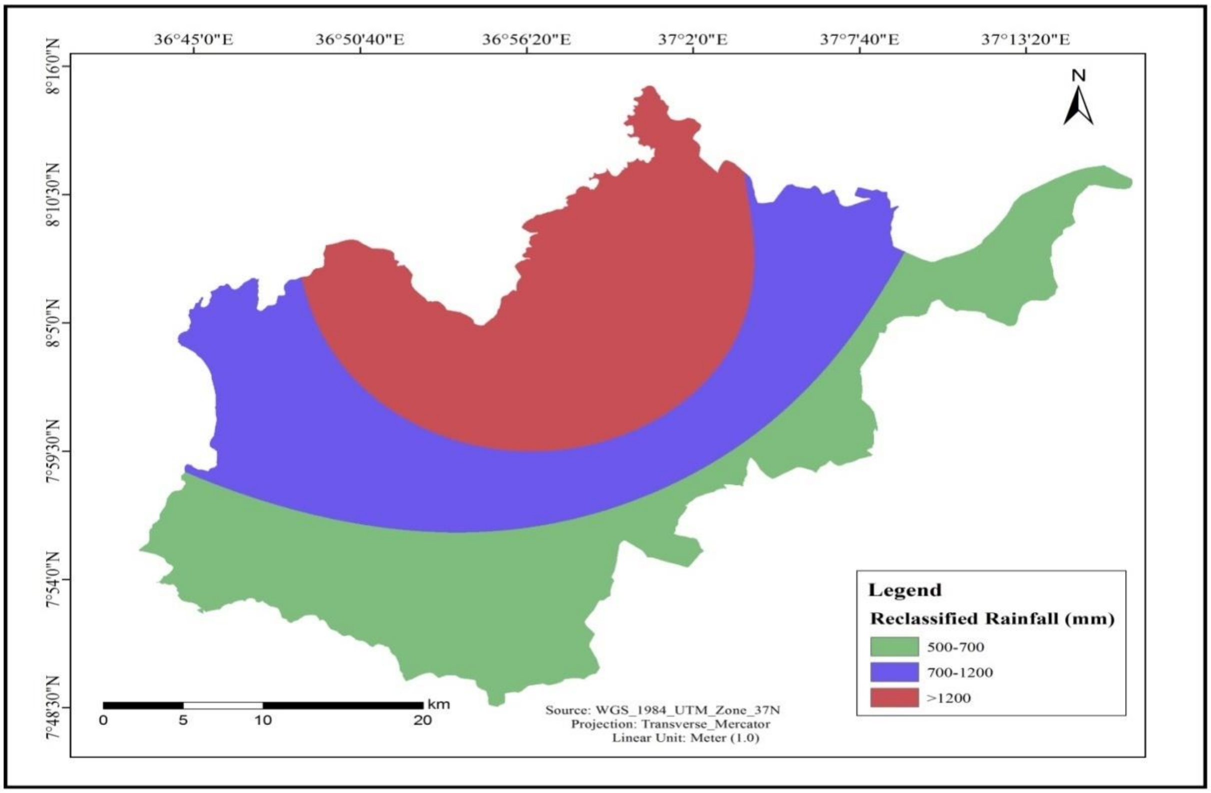


Figure 16: Rain fall suitability map

4.1.7. Land use/ cover suitability classification

The Landsat_8 satellite image was used to classify the land use or cover of the study area. The satellite image was classified by the supervised image classification technique by using ERDAS 2015. The area is classified in to six main classes. Those classes werecultivated land, forest land, water body, settlement, bare land, and grassland. The LULC classes of the study area reclassified based on different literature. Therefore,as clearly stated byShiferaw(2007) thecultivated land and grassland were classified as highly suitable and moderately suitable for surface irrigation respectively. Because of the assumption that the cultivated land will be used to irrigation without limitation and shrub grassland will be used with less limitation and the forested area, bare land, and water body were classified as moderately suitable, marginally suitable and not suitable for surface irrigation respectively. This is because of the forested area and bare land may be a choice when the cultivated and shrub grass land no more and the water body is not suitable. From the total land of the district, cultivated land covers about 57957.2ha (44%) of the total area, grassland covers 9766.6ha(7%) , forest area covers 58301.2ha (44.3%) of the total area and bare land,settlement and water body covers less present of the area, as shown in (figure 17).As presented in Table (14) the most class of land use land cover were classified with high accuracy.

Accuracy assessment

To determine classification accuracy, accuracy assessment is necessary to determine the classified output map meet or not meet certain predetermined classification accuracy criteria. Though, accuracy assessment is considered an integral part of any image classification. This is because image classification using different classification algorithms may classify pixels or groups of pixels to wrong classes. Thus, the error of omission or error of commission will occur while classifying an image. One of the most common methods used to assess classification accuracy is the use of an error matrix and also called a confusion matrix (Kefelegn et al., 2019)**.** So, this study was calculated overall, user accuracies and kappa coefficient with the help of ArcGIS 10.3 data management accuracy operation environment for the better quality of land cover classification. Accordingly an overall accuracy of **90%** was achieved with a Kappa coefficient of **0.86** for Landsat_8 of (2020) image.

Table 14: Confusion matrix of land us land cover classification of landsat_08

Land use/cover Classes	Forest	Grass	Cultivate	Water body	Settlem ent	Bare	Total	Producer accuracy	User Accuracy %
Forest	**21**	0	0	0	1	0	23	91.3	95.4

Grassland	0	**12**	1	1	0	1	15	92.3	80
Cultivate land	1	0	**19**	0	0	1	21	86.3	90.4
Water	0	1	0	**13**	0	0	14	92.8	92.8
Settlement	0	0	1	0	**19**	0	20	95	95
Bare land	1	0	1	0	0	**15**	17	90	88.2
Total	23	13	22	14	20	17	110		

Overall accuracy (OA) =90%

Kappa cofficiant (KC)= 0.86

Overall Accuracy

This is computed by dividing the total correct (i.e., a sum of Major diagonal by the total number of pixels in the error matrix. Which is (21+12+19+13+19+15)/110

Over accuracy =$\sum$ Xii/N---(2)

Where Xii is the number of correctly classified pixel or diagonal value and N is the entire numbers of pixels in the matrix. Thus, overall accuracy for this classification is (99/110) *100= 90%

Table 15: Land use land cover suitability and area coverage of the study area

S/No	LU/LC Types	Area (ha)	Area(%)	Suitability classes
1	Bare land	5114.7	3.9	Moderately suitable
2	Cultivated land	57957.2	44.0	Highly suitable
3	Forest	58301.2	44.3	Marginally suitable
4	Grass land	9766.6	7.3	Highly suitable
5	Settlement	423.0	0.3	Not suitable
6	Water body	42.3	0.002	Marginally suitable
	Total	131605.0	100.0	

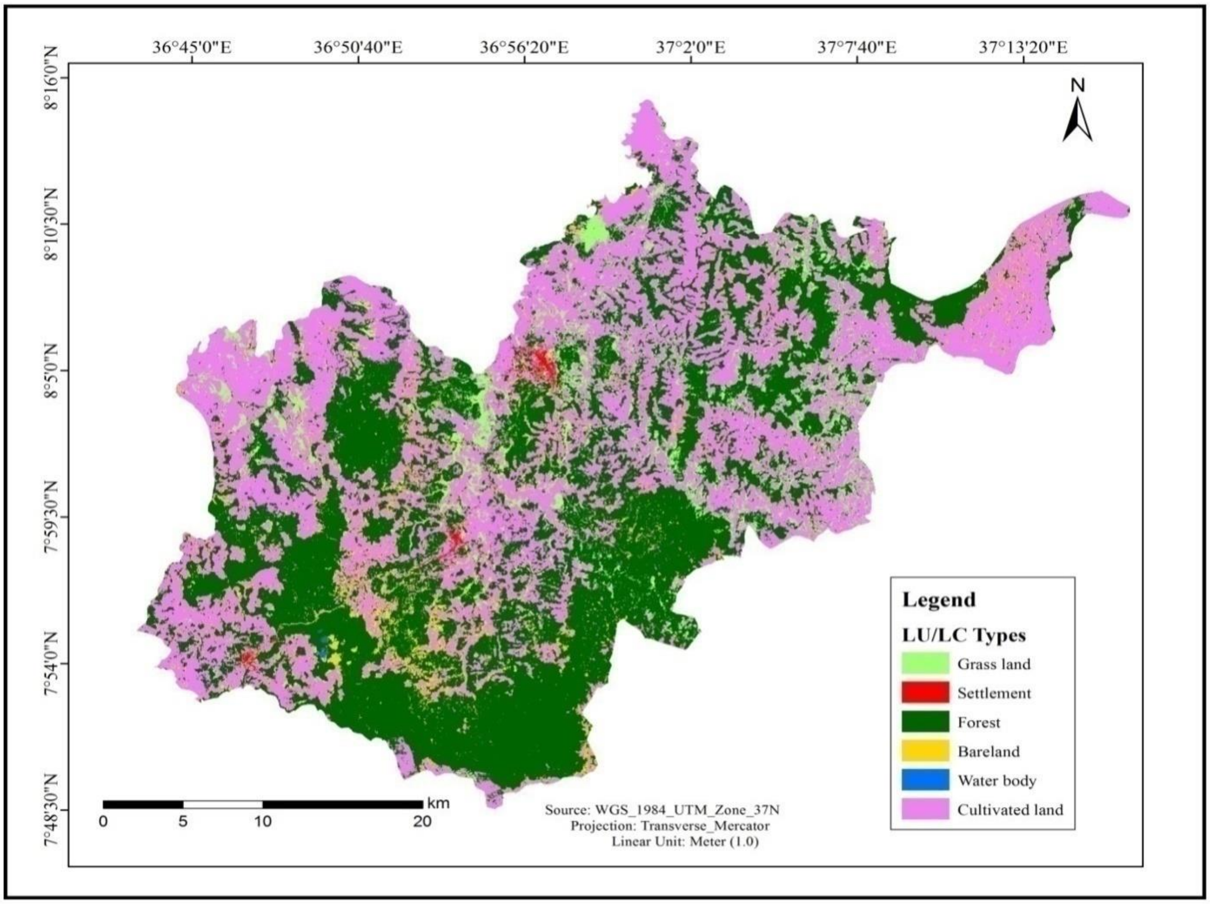


Figure 17: Land use land cover map of the district

4.1.8. Socio economic suitability

4.1.8.1. Market suitability

To analyze available market for irrigational agricultural product exchange the distance from specific potential surface irrigation area to market were measured by using multiple ring buffer tool of "proximity analysis". Then, market suitability was categorized according to its proximity in terms of distance (i.e. shorter the distance highly suitable than the far one) (frehiywet, 2019). Based on firehiywet (2019)standard, the distance radius of 5000 meters (5km) is classified as highly suitable, the range from(5km-8km) is suitable, (8km-10km) moderately suitable and (>10km) ware classified as not suitable for the exchange of the irrigation agricultural products respectively. The below figure shown the suitable market location class for surface irrigation agricultural product exchange.

Table 16: Market suitability class and area coverage of the study area

S/No	Distance from market(m)	Area (ha)	Area (%)	Suitability classes
1	5000m	20351.6	15.5	Highly suitable
2	5000-8000m	26632.8	20.2	Moderately suitable
3	8000-10000m	16036.9	12.2	Marginally suitable
4	>10,000m	68583.8	52.1	Not suitable
	Total	131605.0	100.0	

Most of the area dominated in not suitable range which estimated about 52% of the whole area coverage. Because, all of the market centers, were concentrated in the same area.

Market suitability map of the study area

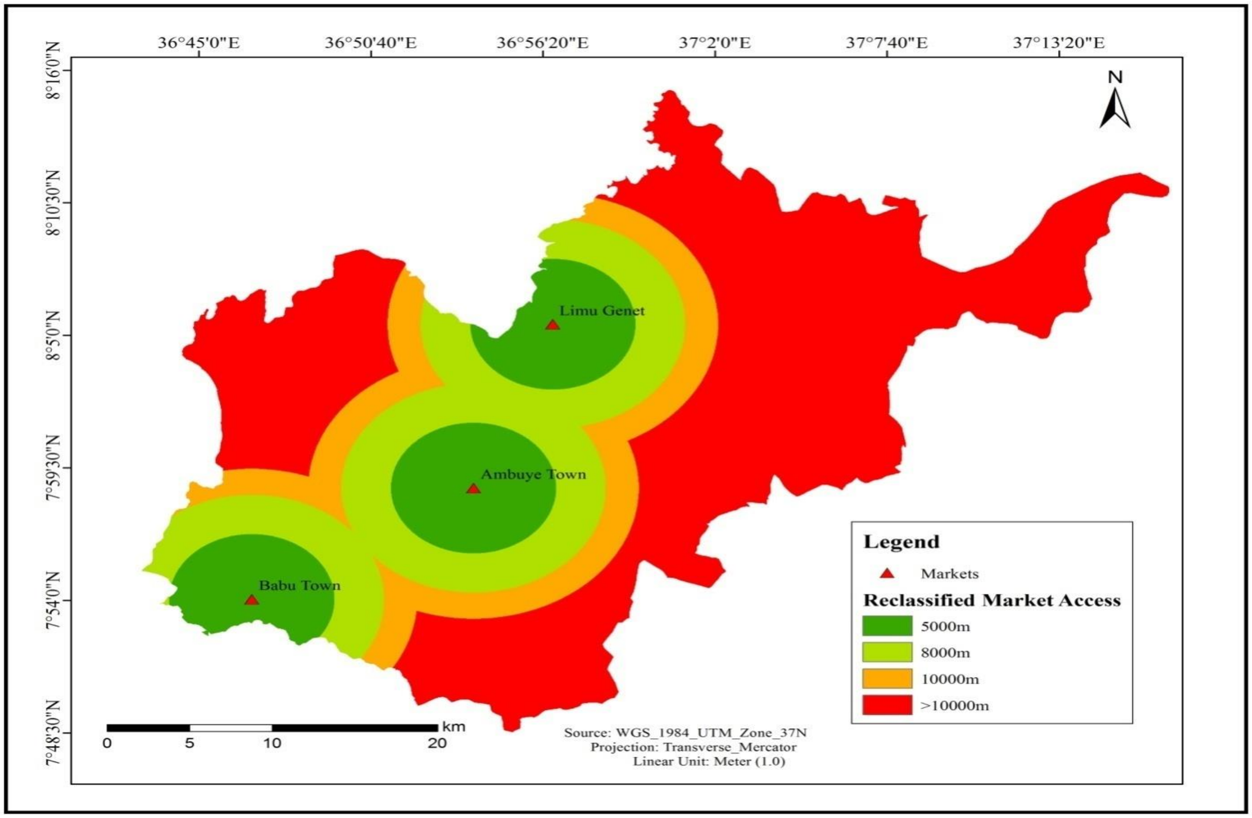


Figure 18: Market suitability map

4.1.9. Road suitability

Road is the major access to transport the output production and also to transport different input which necessary for irrigation potential and crop production development.

To analyze the available road for irrigational agricultural product transportation the distance from specific potential surface irrigation area to main road were measured by using multiple ring buffer tool of "proximity analysis". According to discussed by(frehiywet, 2019), the distance radius of 2000 meters (2km) is classified as highly suitable, the range from(2km-5km) is suitable, (5km-10km) moderately suitable and (>10km) ware classified as not suitable for the road suitability to transportation of the irrigation agricultural products to the market respectively. The below figure shown the suitability of road distance from irrigation agricultural product area to transport.

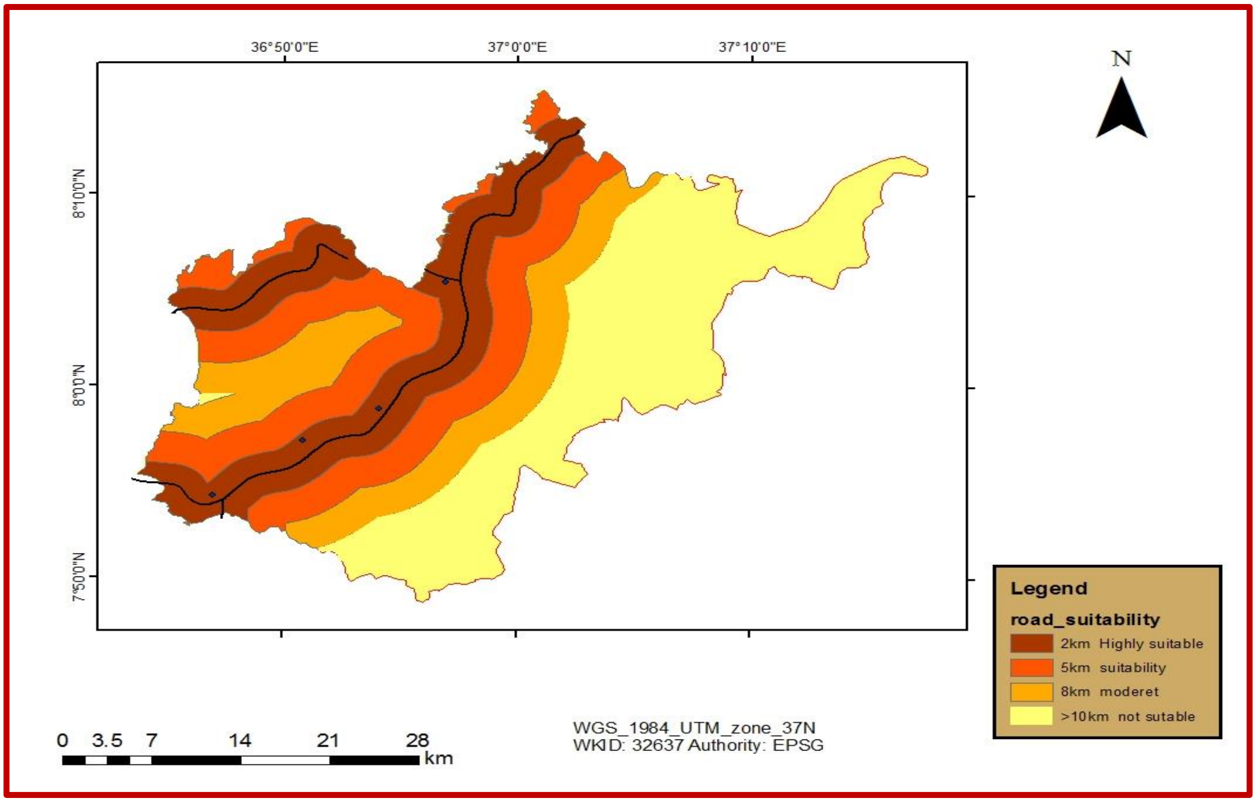


Figure 19: Road suitability map of the area

Table 17: Road suitability and area coverage of the study area

No.	Road suitability range	Area Share (ha)	Total area (%)	Suitability classes
1	2km	29207	22.19	Highly suitable
2	5km	32176	24.44	ModeratelySuitable
3	7km	23225	17.64	Marginally suitable
4	>10km	46997	35.71	Not suitable
	Total	**131605**	**100**	-

As expressed in the above table, Out of the total area of 131605 hectares 22% is highly suitable, 24% is suitable, 17% is moderately suitable and 34% of the total area is not suitable in order to transport the irrigation agricultural production to the target area.

4.2. Physical land suitability mapping for irrigation and selected crops

After evaluation of the physical land resource and socio economic factor of the area, it was necessary to examine the land suitability for crops production and irrigation potential in the study area. The base line to select types of crops, which are suitable for the land was, the types of crops which are widely product in the area and used by many farmers as commercial crops and for food. Maize and Groundnut were selected in order to evaluate the suitability of the land under the study area based on irrigation. Maize and Groundnut are widely grown in the study area.

4.2.1. Physical Land Suitability Mapping For Irrigation

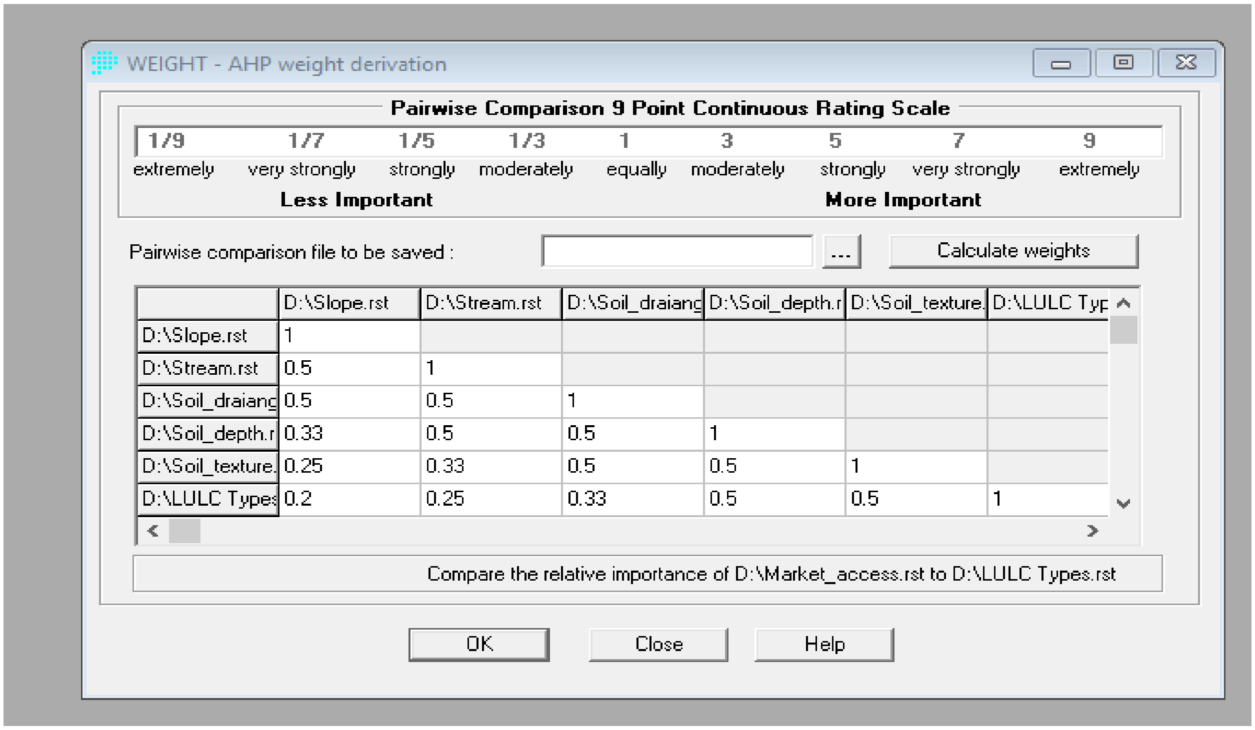
4.2.2. Multi-Criteria Decision method

This study was used multi criteria decision method (MCDM) technique of land suitability assessment with the use of several parameters such as climate, soil physical, socio economic, topography and land use land cover to delineate the potential area for irrigation and crop suitablity map. Multi criteria decision analysis (MCDA) involve the integration of several criteria into a single index of evaluation using analytical hierarchy process (AHP)(Science, 2018). Each of the criteria maps were integrated into the suitability classes based FAO (1996,1991,1984) Guidlines.

4.2.3. Assigning criterion weights

In this paper, factors, which were selected to evaluate the physical land resource of the district, were assign using IDRIS software in pair wise comparisons developed by (Saaty,T.L. 2008) in the context of a decision making process known as the Analytical Hierarchy Process(AHP). Pair wise technique was used for assigning weights of the factors.In pairwise comparison matrix, factors are compared two at a time in terms of their importance related to the stated objective. This process usually needs the different document and expert opinion in order to make the decision in assigning the important on each criterion. Within the comparison matrix, a bigger value implies that one of the criteria is more important than the other for a particular pair of. In this study the bigger value was given for slope. The percentage influence of slope map was asigned as 30% of the total layers of the study area maps. This is because of slope is the most limiting factor in the identification process of suraface irrigation development activities.Below Table shows pairwise comparison matrix.

Table 18: Pairwise comparison matrix of the factors for irrigation potential area specification



	D:\Slope.rst	D:\Stream.rst	D:\Soil_draiang	D:\Soil_depth.r	D:\Soil_texture.	D:\LULC Typ
D:\Slope.rst	1					
D:\Stream.rst	0.5	1				
D:\Soil_draiang	0.5	0.5	1			
D:\Soil_depth.r	0.33	0.5	0.5	1		
D:\Soil_texture.	0.25	0.33	0.5	0.5	1	
D:\LULC Types	0.2	0.25	0.33	0.5	0.5	1

Table 19: Factors weight rate

Parameters	Weightage
Slope	0.3034
Stream	0.2177
Soil drainage	0.1584
Soil depth	0.1127
Soil texture	0.0797
Land use land cover	0.0568
Market accesses	0.0297
Road accesses	0.0415

Consistency ratio =0.02

Consistency ratio is acceptable

4.2.4. Land Suitability Class Specification for surface irrigation

To specify the suitability class for surface irrigation, different factors identified, which affect the performance of the land use types.These factors include slope gradient, stream, soil drainage, soil depth, soil texture, distance from market, distance from road and land use of the district. Then the reclassified factors map was weighedand the final physical land suitability map of the district obtained.Accordingly, land suitability for irrigation potential was classified as highly suitable, moderately suitable, marginally suitable, and not suitable. From the total land of the district 10716.2 hectares (8.1%) which found around the rivers was highly suitable, 60821.2 hectares (46.2%) which covers northern, Eastern, western and more central parts of the area nearest to the rivers were moderately suitable, more of southern, southwest and southeastern pats which cover about 52236.0 hectares (39.7%) marginally suitableand a few parts of south border and eastern which cover about 7831.6 hectares (6.0%) was not suitable for surface irrigation

Table 20: Irrigation potential suitability class and area coverage (own process)

	Irrigation potential area		
S/No	**Suitability classes**	**Area (ha)**	**Area (%)**
1	Highly suitable	10716.2	8.1
2	Moderately suitable	60821.2	46.2
3	Marginally suitable	52236.0	39.7
4	Not suitable	7831.6	6.0
	Total	**131605.0**	**100.0**

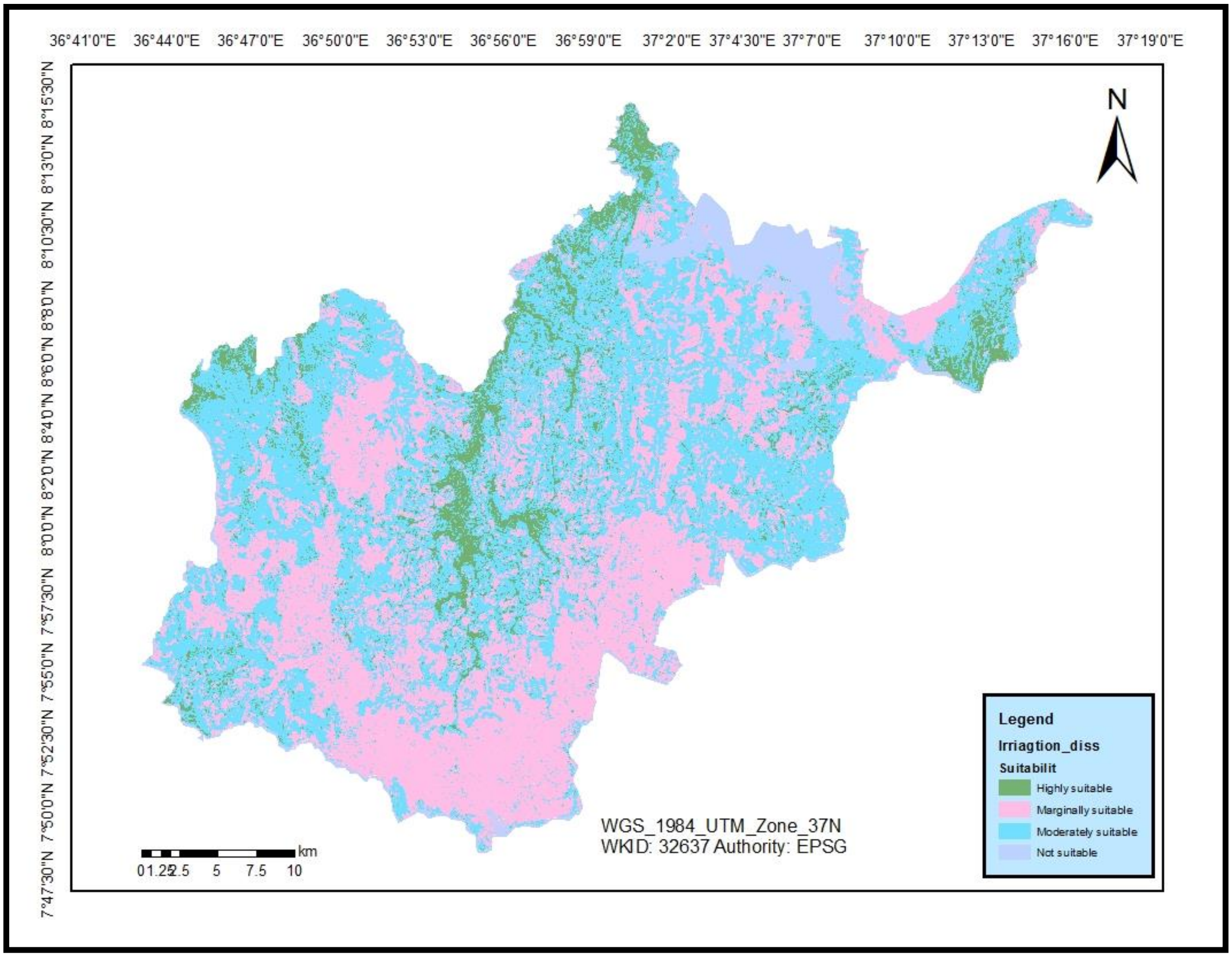


Figure 20: Irrigation potential map of the study area

4.2.5. Selected Crops Suitability Mapping

After evaluation of the physical land characteristics of the land for surface irrigation, it is very necessary to examine the land capability for crops production in the study area. Therefore the study aimed at to evaluate suitable crops in the study area. The base line to select types of crops, which are suitable for the land, was types of crops which are widely grown in the area and used by many farmers as commercial crops. Maize and groundnut were selected in order to evaluate the capability of the land under the study area. Maize is widely grown in the study area. The farmers are using it. The scale production is carried out in low management and investment level. Water resource used for maize is mainly rain fed. Groundnut is not widely used by many farmers like maize, but there are some people who harvest the groundnut in the study area. Its production is also good with in small plot of land. Therefore if it is widely grown with good management and investment level, it can be one of the major export items and the importance one in developing farmer's economy.

4.2.6. Evaluation of Physical Land of the district for selected Crops

Suitability Land evaluation provides information and recommendations for deciding which crops suitable to product where. Land evaluation is the selection of suitable land, and suitable cropping, irrigation and management alternatives. The evaluation and suitability classification system described in this paper was based on A Framework for Land Evaluation FAO (1976) and FAO (1996). The evaluation of soil depth, soil drainage, soil texture, LULC, climate and topographic conditions used to describe the performance of land qualities for maize and groundnut production.

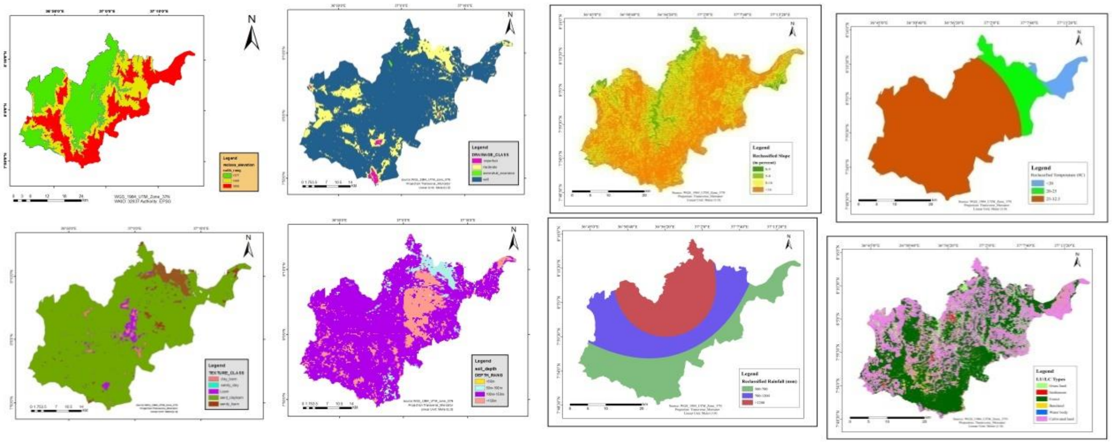
4.2.7. Crop requirement

The factors, which are mentioned above, are the major physical factors, which were considered to determine the production of crops in a specified area. All these factors have not the same impacts on crops. Some crops need one factor more than the others. However the factors bring different effects on production. Therefore weight given for the two crops were different based on their requirements. The physical properties of soils such as depth, texture, soil drainage are the important soil characteristics in land evaluation that affect the yields under specific climatic and site conditions. In this paper physical land properties were evaluated based on the crops requirements. The physical land resource of the district, which were evaluated, include drainage, slope gradient, soil texture, soil depth topography and land use According to FAO (1984) the Groundnut requires, well to somewhat excessive drained, gentle sloppy, soils texture with SL-SCL and L-Sand, depth of >100 are most preferred soil environments for the growth of Groundnut. The Maize requires, altitude 400-1800meter above sea level, gentle slope, soil texture from L-SC to LS-SL, soil depths of >100 are most preferred environments for the growth of low land maize.

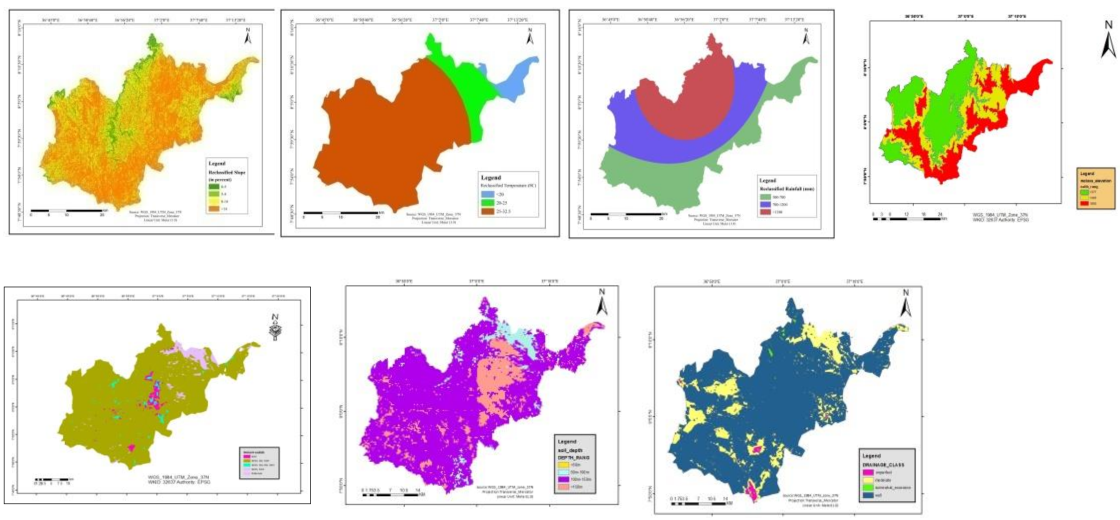
Table 21: Crop suitability requirement of FAO (1984)

Crop	factors	Unit	Range of suitability		
			Highly suitable(S1)	Moderately suitable (S2)	Not suitable (N)
Groundnut	Altitude	M	0-1000	1000-1600	>1600
	Mean temperature	C^0	25.0-32.5	20.0-25.0	below 20.0
	Rain fall	Mm	500-700	700-1200	>1200
	Drainage	Class	W-SE	MW	VP-I
	Texture	Class	SL-SCL	LS	S
	Depth	Cm	>100	50-100	0-50
	Slope angle	%	0-8	8-30	>30
Maize	Altitude	M	400-1400	1400-1800	>1800
	Mean temperature	C0	20-30.0	30.0-32.5	below 20.0 and over 32.5
	Rain fall	Mm	600-900	900-1200	>1200
	Drainage	Class	MW	SE	E
	Texture	Class	L-SC	LS-SL	S
	Depth	Cm	>100	50-100	0-50
	Slope angle	%	0-8	8-30	>30

Factors reclassified for maize suitability analysis



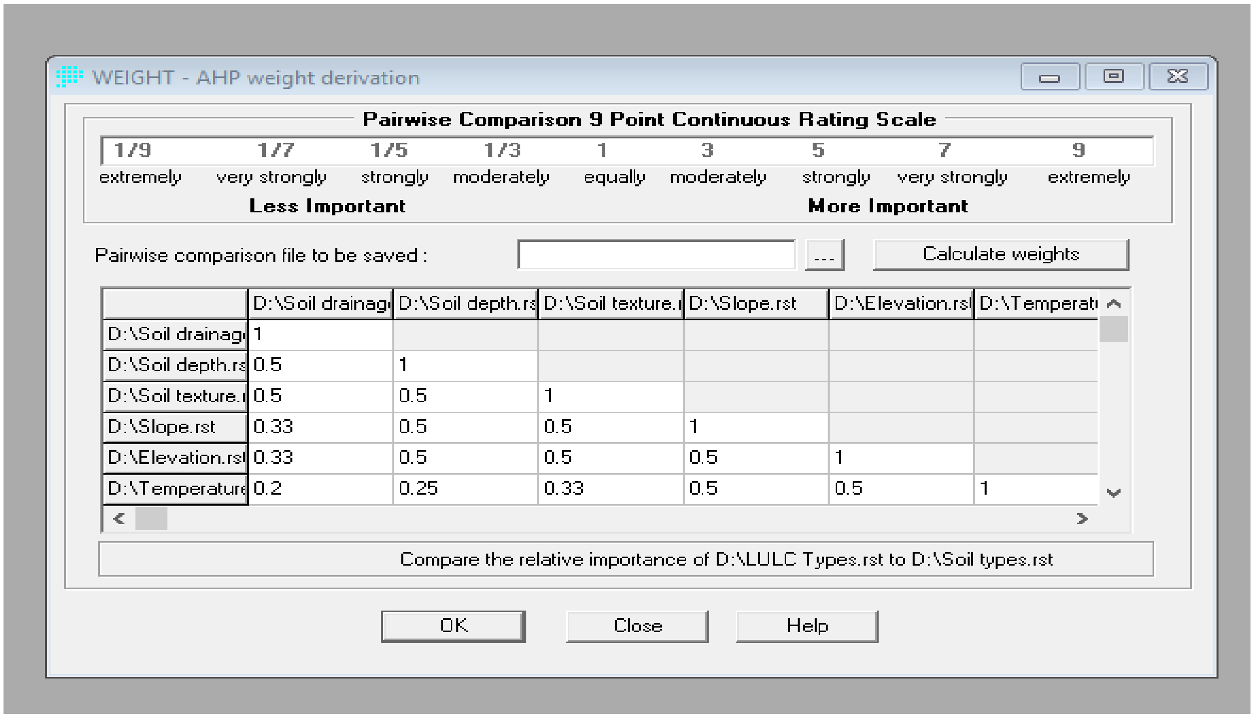
Factors reclassified for groundnut suitability analysis



4.2.8. Approaches Used to develop Suitability Map for selected Crops

The same procedure used to evaluate for surface irrigation potential was used for suitability of crops mapping of the study area. This method was multi-criteria decision evaluation (MCDE).Multi-criteria decision evaluation (MCDE) method in GIS environment is the best technique to evaluate different factors for a specific objective. Therefore, in this paper, MCDE was also used to evaluate the physical land characteristics and socioeconomic of the district for developing suitability map for both Maize and groundnut, based on FAO land evaluation framework (1976, 1996). In order to develop the suitability map for maize and groundnut, the crop requirements of FAO (1984) was reviewed.To evaluate the factors for the selection of the physical land for suitability of maize and groundnut, the factors values were assigned based on the crops requirements. Pair wise comparison technique was used in IDRIS software to assign the factors weight.

Pairwisecomparison for maize



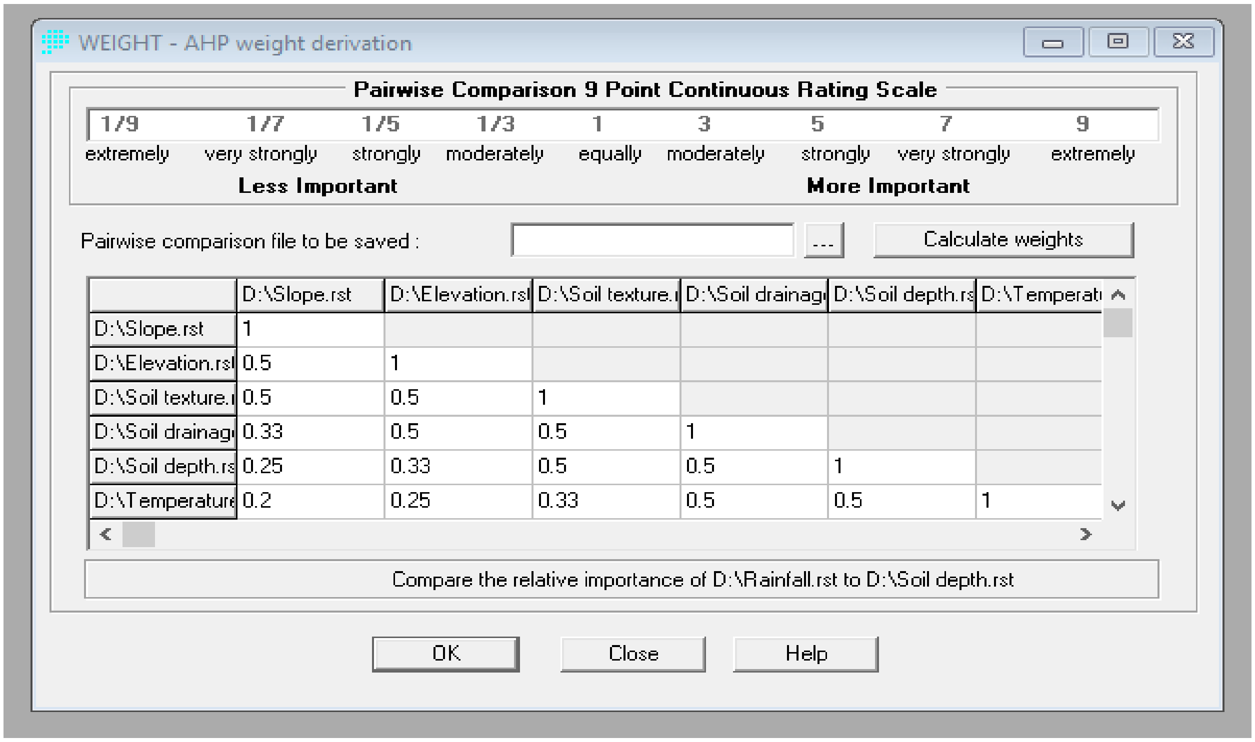
Factors weight rating for maize

Parameters	Weightage
Soil drainage	0.2812
Soil depth	0.2043
Soil texture	0.1489
Slope	0.1048
Elevation	0.0825
Temperature	0.0594
Rainfall	0.0506
Land use land cover	0.0614

Consistency ratio = 0.02

Consistency is acceptable

Pair wise comparison for groundnut



	D:\Slope.rst	D:\Elevation.rst	D:\Soil texture.r	D:\Soil drainag	D:\Soil depth.rs	D:\Temperatu
D:\Slope.rst	1					
D:\Elevation.rst	0.5	1				
D:\Soil texture.r	0.5	0.5	1			
D:\Soil drainag	0.33	0.5	0.5	1		
D:\Soil depth.rs	0.25	0.33	0.5	0.5	1	
D:\Temperature	0.2	0.25	0.33	0.5	0.5	1

Factors weight rate for groundnut

Parameters	Weightage
Slope	0.3187
elevation	0.2233
Soil drainage	0.1591
Soil depth	0.1096
Soil texture	0.0817
Temperature	0.0592
Rainfall	0.0483

Consistency ratio = 0.02

Consistency is acceptable

4.2.9. Suitability Class Specification for selected crops

The final crops suitability maps for maize and groundnut were developed by using AHP weight derivation in IDRIS. Accordingly each of the reclassified factors map were weighted and the final crop suitability maps developed. Both maize and groundnut crops suitability map were classified in to three suitability classes. These were very suitable, moderately suitable, and not suitable.

4.2.10. Suitability classes of maize

Suitability classes of Maize From the total land of the district,65332.6hectare (49.6%) was very suitable, 58414.3hectare (44.4%) moderately suitable, and 7858.1hectare (6%) was not suitable for maize production. Accordingly most of the northern and central part of the district was suitable to Maize production.

Table 22: Maize production potential and area coverage

Maize production potential area			
S/No	**Suitability classes**	**Area (ha)**	**Area (%)**
1	Highly suitable	65332.6	49.6
2	Moderately suitable	58414.3	44.4
3	Not suitable	7858.1	6.0
	Total	**131605.0**	**100.0**

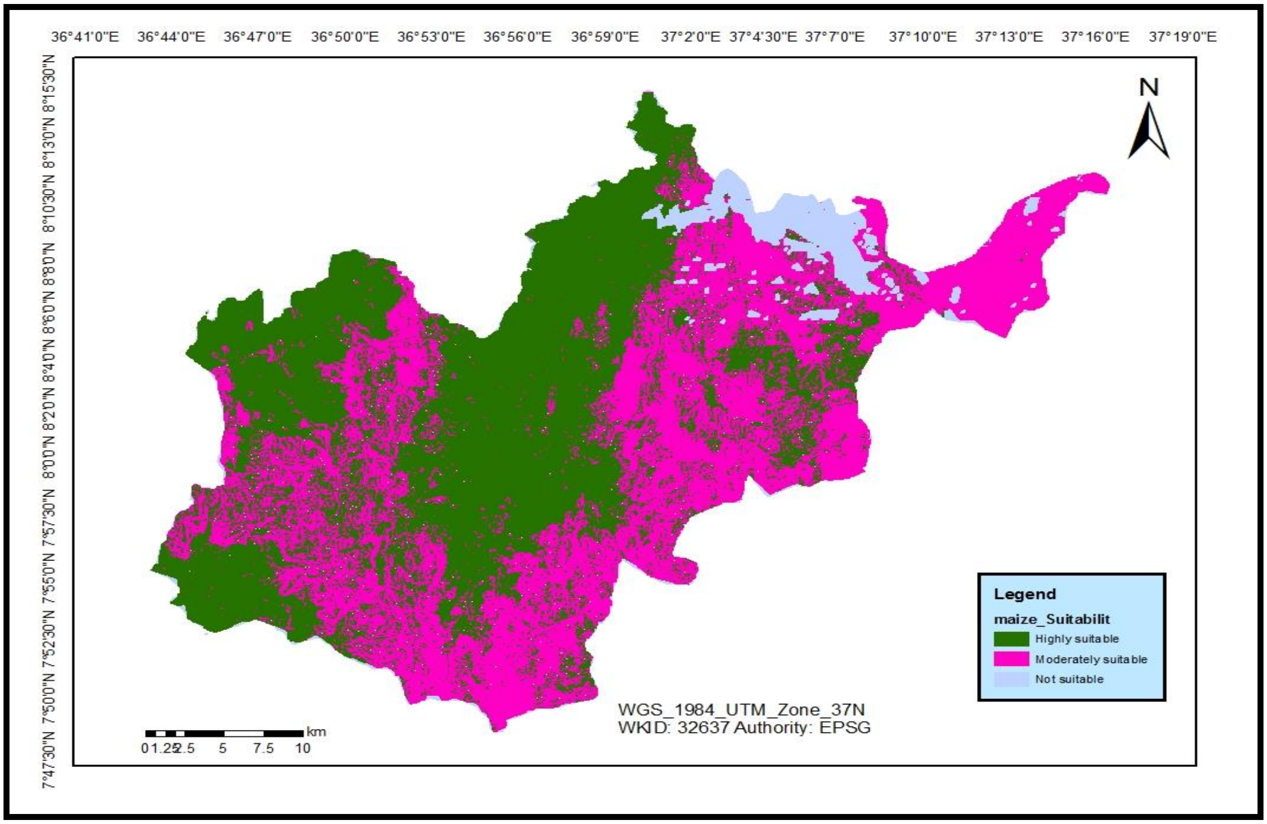


Figure 21:Maize production potential map of the district

4.2.11. Suitability classes of groundnut

From the total land of the district,63963.2hectare (48.6%) was very suitable, 59784.4 hectare (45.4%) was moderately suitable and 7857.4 hectare (6%) not suitable for groundnut crops.

Table 23: Groundnut production potential and area coverage

Groundnut production potential area			
S/No	**Suitability classes**	**Area (ha)**	**Area (%)**
1	Highly suitable	63963.2	48.6
2	Moderately suitable	59784.4	45.4
3	Not suitable	7857.4	6.0
	Total	**131605.0**	**100.0**

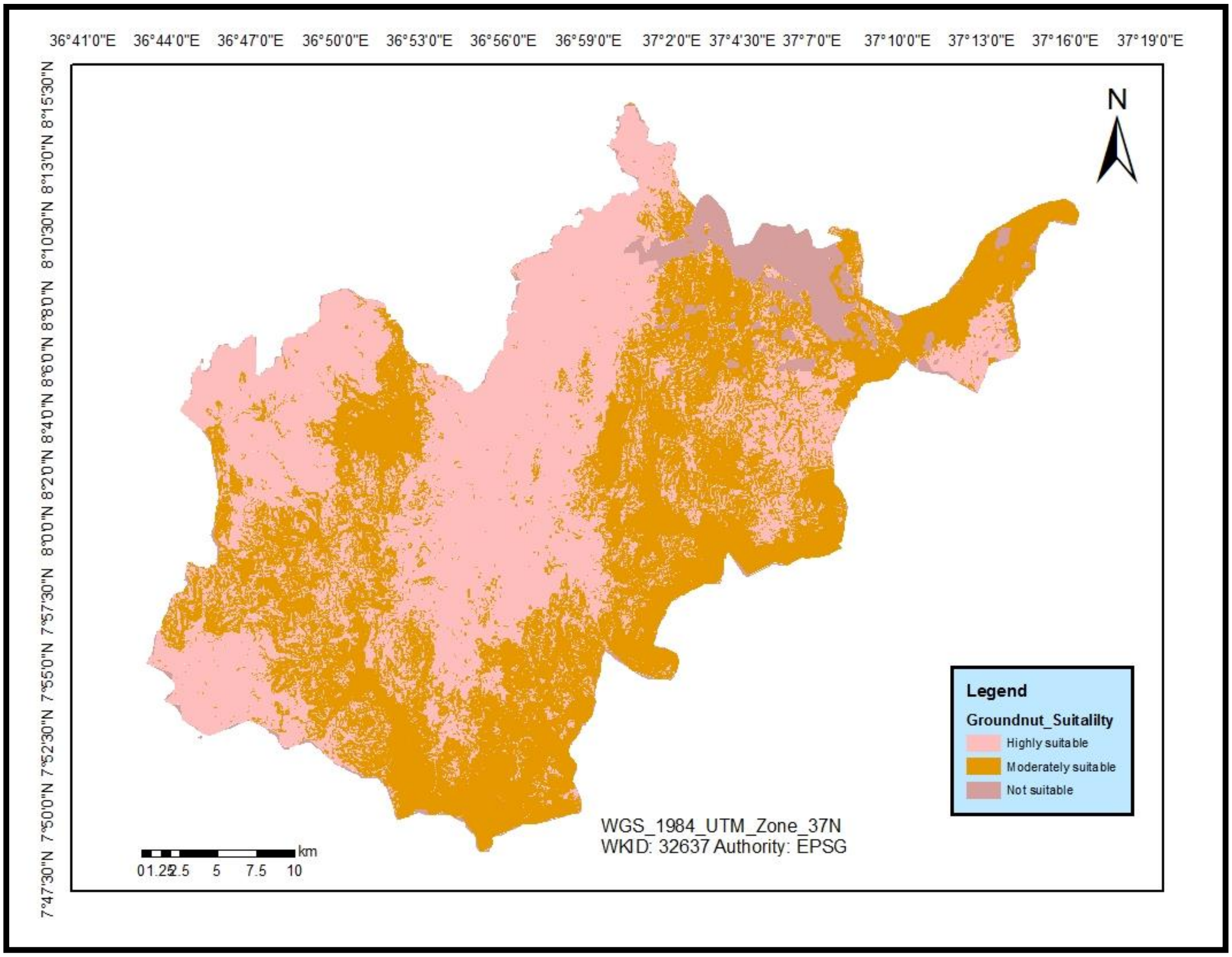


Figure 22:Groundnut production potential map of the district

4.3. Discussion

In Ethiopia, as in many developing countries, current land-use practices are not based on suitability analysis. As mentioned by (Hailu 2008, Girma and Kenate 2017) One of the most important and urgent problems to improve agricultural land management is increasing the efficient use of land resources. As stated by(Dula, 2010)GIS is the best tool to integrate the different land characteristics that differ spatially and dynamic tool for the multidimensional process of land use.Thus, to identify suitable land for irrigation potential for crop production,various study uses GIS with spatial decision making such as (Asrat& Yildiz 2019,Ayehu, 2015, Meier et al., 2018, Awulachew et al., 2011, Dula, 2010 and shiferaw 2007) considering different factors. The researchers tried to include two criteria and ten-factor maps. Namely: landscape (land use land cover map); topography (elevation and slope map); soil (drainage, depth, texture) accessibility (road and market) climate (rainfall and temperature). MCE is done based on those factor maps to produce the suitable area for irrigation potential for maize and groundnut crops. The results of this research findings and analysis were performed based on multi-criteria evaluation methods. The AHP method was applied to determine the relative importance of all selected factors. Analytic Hierarchy Process (AHP) is one of multi-criteria decision-making method used to derive ratio scales from paired comparisons that was originally developed by Saaty (1980). The influence of identified factors for the analysis is not equally important to analysis irrigation potential for selected crop production.This difference can be managed by multi-criteria evaluation. With this study, pairwise comparison technique was applied for weight calculation of each factor based on their relative importance. Accordingly, in this study among selected factors slope gain the highest weight and important factors than other factors in identifying land suitability for irrigation potential. Some writers also used this procedure in their irrigation potential suitability analysis (Shiferaw 2007, Ayehu, 2015,Awulachew et al., 2011, and Dula, 2010). Therefore, an important factor has a greater impact on the outcome than other factors. Each factor map was reclassified and standardized to a common numeric range based on their importance ranging from 1 to 4, indicating a variation from highly suitable to not suitable area. Then the weight is assigned based on pairwise comparison to all factors map. This study was used pairwise comparison to assign AHP weight derivation with in IDRISI software. Finally, based on FAO's (1991, 1984, 1996 and 1976) suitability range, the irrigation potential suitability for maize and groundnut map was generated. In general the geospatial techniques are a great tool to analyze, generate and identify irrigation potential for the study area.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The study was assessed the potential irrigable land for surface irrigation for selected crop suitability in Limmu Kossa district by using multi criteria decision making method. The land evaluation of physical land qualities of the study area indicates that the district has great potential for surface irrigation. The parameters which were considered for evaluation of the surface irrigation potential for selected crop suitability were Slope, Soil depth, soil drainage, soil texture, LULC, stream flow and socio economic factors such as, market distance, and road distance. Most of the parameters used in this study are essential but slope and soils has high influence in determining the Land suitability of the area rather than the others. About half percent of the district was characterized by gentle slope, which is less than 8%. This indicates that more of the district is classified under suitable for surface irrigation. In terms of soil, most types of crops require deep soil depth for their growth. The district's soil depth is between 50cm to 150cm. Those places having soil depth greater than 100cm is very suitable for crops based on the requirements of crops. Accordingly soil depth, which can be classified as very suitable for maize and Groundnut, which is above 100cm is there in the study area. The land having greater than 50cm soil depth in a specified area can be recommended suitable for surface irrigation. Us a result, the district has great potential for irrigation. Regarding to soil texture, the district is dominated by fine soil texture or most of the soil texture found in the district are clay loam and sand clay loam. Texture of a given soil affects infiltration capacity and water retention capacity. Fine textured soils have high water holding capacity and low infiltration rate. Therefore, more than 90% of the land of the district is characterized by less infiltration rate and these types of soil texture are suitable for more crop production. In general most of the prioritized factors result shown that the most part of the district is suitable for surface irrigation and for selected crop production, except accessibility factors. Because, there are no excess asses in the district or the road and the town in the districts concentrated in the some part of the area. Furthermore the accumulative results of this study show that more than 91% of the study area were suitable for surface irrigation potential for selected crop production.

5.2. Recommendation

- Decision makers and farmers should be aware which area is highly suitable for which types of crops in order to improve the potential of farmer's productivity with knowledge.
- The surface irrigation potential for crop suitability was carried out in this research by considering only physical and socio economic factors considered. But the effects of other factors such as chemical, environmental, and economic factors should be assessed as parameters to get sound and reliable result.
- Most of the farmers in the district, product once in a year, and have small plots of land with poor management. But Limmu kossa has a lot of rivers with high amount of rainfall annually. So irrigation potential should be considered as an important investment to improving rural income through increasing agricultural production in the area.
- As the result of this paper shows, most parts of the districts land were suitable for groundnut production, but in this study validation is note done. So other researcher should validate to realize the potential area.

References

AMOSRN, & Resource, N. (2011). Ministry Of Agriculture Natural Resource Sector Irrigation Agronomy Guideline.

Anane, Bouziri, L., Limam, A., & Jellali, S. (2012). Ranking suitable sites for irrigation with reclaimed water in the Nabeul-Hammamet region (Tunisia) using GIS and AHP-multicriteria decision analysis. *Resources, Conservation and Recycling*, *65*, 36–46. https://doi.org/10.1016/j.resconrec.2012.05.006

Asmerom, A. (2015). Assessing Surface Water Potential and Water Demand in Genale Dawa River Basin A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Hydraulic Engineering School of Civil and Environmental Engineering Addis Ab.

Asrat, D., Anteneh, A., & Yildiz, F. (2019). The determinants of irrigation participation and its impact on the pastoralist and agro- pastoralists income in Ethiopia : A review study. *Cogent Food & Agriculture*, *5*(1), 1–10. https://doi.org/10.1080/23311932.2019.1679700

Awulachew, & Ayana, M. (2011). Performance OF irrigation: An assessment at different scales in ethiopia. *Experimental Agriculture*, *47*(S1), 57–69. https://doi.org/10.1017/S0014479710000955

Ayehu, G. T., & Besufekad, S. A. (2015). Land Suitability Analysis for Rice Production : A GIS Based Multi-Criteria Decision Approach, (https://doi.org/10.5923/j.ajgis.20150403.02

Bengal, W. (2018). Land suitability assessment for potential surface irrigation of river catchment Land suitability assessment for potential surface irrigation of river catchment for irrigation development in Kansai watershed , Purulia , West Bengal , India. *Sustainable Water Resources Management*, (July 2017). https://doi.org/10.1007/s40899-017-0155-y

BORTSC. (2005). Technical Guidelines for Irrigation Suitability Land Classification Technical Guidelines for Irrigation Suitability Land Classification, (June). Retrieved from https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/TechnicalGuidelinesForIrrigationSuitabilityLandClass_2005.pdf

Congalton, R. G. (2001). Accuracy assessment and validation of remotely sensed and other spatial information. *International Journal of Wildland Fire*, *10*(3–4), 321–328. https://doi.org/10.1071/wf01031

Douh, B. (2016). Subsurface drip irrigation and water management under semiarid climate.

Dula. (2010). Gis And Remote Sensing Based Land Suitability Analysis For Agricultural Crops In Mojo Watershed, Upper Awash Sub-Basin, Ethiopia.

El-aziz, S. H. A. (2018). Evaluation of land suitability for main irrigated crops in the North-Western Region of Libya, *7*(1), 73–86. https://doi.org/10.18393/ejss.337218

Engdaw, K. (2016). *ASSESSMENT OF SURFACE WATER POTENTIAL AND Addis Ababa* Institute of Technology School of Graduate Studies School of civil and environmental engineering Assessment on Surface Water Potential and Demands of Wabishebele Basin in Ethiopia.

FAO. (1976). FAO (1976). A Frame Work for Land Evaluation .Rome: FAO.

FAO. (1984). Assistance To Land Use Planning Ethiopia Land Evaluation Part Three: Crop Environmental Requirements •.

FAO. (1985). Guidelines: land evaluation for irrigated agriculture. *FAO Soils Bulletin*, *55*(55), 231.

FAO. (1995). food and agriculture organization of the united nation Rome, 1995/ the state of food and agriculture 1995. *The State of Food and Agriculture*.

FAO. (1996). Guidelines for land-use planning .

FAO. (2015). FOOd And AgrICulturE OrgAnIzAtIOn OF thE unItEd nAtIOns rome, 2015.

FAO. (2016). Ethiopia Climate-Smart Agriculture Scoping Study.

FAO. (2016). Guidelines on irrigation investment projects 2016.

FAO, 1997. (1997). food and agriculture organization of the the united nations Rome, 1997.

firehiywet. (2019). Assessment of Physical Land Suitability for Surface Irrigation by using GIS and International Journal of Current Research Assessment of Physical Land Suitability for Surface Irrigation by using GIS and RS. https://doi.org/10.20546/ijcrar.2019.701.004

GAEZ. (2012). Global Agro-ecological Zones User ' s Guide.

Ganole, (2010). Gis- Based Surface Irrigation Potential Asssessment Of River Catchments For Irrigation Development In Dale Woreda, Sidama Zone, Snnp.

Girma & kanate. (2017). GIS Based Land-Use Suitability Analysis for Selected Perennial Crops in Gumay Woreda of Jimma Zone, South West Ethiopia. Ethiop.j.soc.lang.stud. 4(1), 3-18. eISSN:2408-9532; pISSN: 2412- 5180. ISBN 978-99944-70-78-5. W, 3–18.

Haile, G. (2015). Hailegebriel Shiferaw, (2007) Irrigation Potential Evaluation And Crop

Suitability Analysis Using Gis And Remote Sensing TechniqueS, *5*(15), 141–148.

Harrison,& Reilly, T. M. (2011). Mixed methods designs in marketing research, *14*(1), 7–26. https://doi.org/10.1108/13522751111099300

Hezan, M. (n.d.). Remote sensing and GIS aplication for assesmnent of land suitability potential for agricaltur in the IBB Governorate, the ripublic of yemen (2010).

Kebede, T., & Ademe, Y. (2016). Evaluating land suitability for irrigation purpose in Abaya district , Borena zone , Ethiopia, *11*(46), 4754–4761. https://doi.org/10.5897/AJAR2016.11438

Kefelegn. (2019). Using Geospatial Techniques in the Selection of Potential Ecotourism Ghana Journal of Geography Vol. 11(1), 2019 pages 201 – 227 DOI: https://dx.doi.org/10.4314/gjg.v11i1.12, *11*(1).

Kolajo, T., Daramola, O., & Adebiyi, A. (2019). *Big data stream analysis : a systematic literature review*. *Journal of Big Data*. Springer International Publishing. https://doi.org/10.1186/s40537-019-0210-7

Maniyunda, L. M., & Gwari, M. G. (2014). Soil suitability assessment of Haplustalfs for maize and groundnut in sub-humid environment of Nigeria, *3*(2), 393–403.

Meier, J., Zabel, F., & Mauser, W. (2018). A global approach to estimate irrigated areas - A comparison between different data and statistics. *Hydrology and Earth System Sciences*, *22*(2), 1119–1133. https://doi.org/10.5194/hess-22-1119-2018

Meron. (2007). Surface Irrigation Suitability Analysis Of Southern Abbay Basin By Implementing Gis.

MoA, 2011a. (2011). Ministry Of Agriculture Natural Resources Small-Scale Irrigation Situation Analysis And.

Mosissa, T. (2017). Review on participatory small-scale irrigation schemes and small-scale rainwater harvesting technology development and its contribution to household food security in Ethiopia, (October). https://doi.org/10.5897/IJWREE2016.0700

Neameh, J. B. (2003). Land evaluation for Land Use Planning with especial attention to sustainable fodder production in the Rouzeh Chai catchment of Orumiyeh area - Iran, (January).

Neves, Gonçalves, S., Morais, C. De, & De, T. F. (2014). Analysis of the difference between the Euclidean distance and the actual road distance in Brazil. *Transportation Research*

Procedia, *3*(July), 876–885. https://doi.org/10.1016/j.trpro.2014.10.066

Ntai, (2011). Critical factors determining successful irrigation farming in Lesotho 2011.

Saaty, (2014). Analytic Heirarchy Process, 1–11.

Saaty, R. W. 1980. "The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation (Decision Making Series)." *Mathematical Modelling*.

Saaty, T. L. (2008). (2008). Decision making with the analytic hierarchy process, Int. J. Services Sciences, Vol. 1, No. 1, pp.83–98. Biographical. *Omega*, *15*(4), 283–290. https://doi.org/10.1016/0305-0483(87)90016-8

Science, E. (2018). Multicriteria land suitability assessment for growing underutilised crop , bambara groundnut in Peninsular Malaysia.

Seri, R. (2014). The Analytic Hierarchy Process and the Theory of Measurement, (January 2009). https://doi.org/10.2307/27784145

Shiferaw, H. (2007). Irrigation Potential Evaluation And Crop Suitability Analysis Using Gis And Remote Sensing Technique In Beles Sub Basin, Beneshangul Gumez Region.2007.

Svendsen, M. (2009). Measuring Irrigation Performance in Africa.

Swamy, Inayathulla, M., Thabrez, M., & Shashishankar, A. (2017). Land Suitability Evaluation of Soils for Crop Production. https://doi.org/10.15680/IJIRSET.2017.0609083

Tadesse Hunduma. (2012). School of Graduate Studies Department of Earth Sciences GIS and Remote Sensing Based Fertilizer Suitability Mapping for Wheat (Triticum aestivum) at Lume Micro Watershed , Central Ethiopia The School of Graduate Studies of Addis Ababa University in Part.

Tegegn, D. . (2017). Historical Survey Of Limmu Genet Town From Its Foundation Up To Present, *6*(07).

Tudy. (2015). GIS based irrigation suitability analysis : A case study of abaya-chamo basin , southern rift valley of Ethiopia.

Velthuizen, H. Van, & Nachtergaele, F. (2002). *Global Agro-ecological Assessment for Agriculture in the 21st Century : Global Agro-ecological Assessment for Agriculture in the 21st Century : Methodology and Results*.

Wijngaart, R. Van Der, Helming, J., Jacobs, C., Andrés, P., Delvaux, G., Hoek, S., & Gomez, S. (2019). *Irrigation and irrigated agriculture potential in the Sahel : The case of the Niger River basin*. https://doi.org/10.2760/725906.

Winnie, M. (2015). Factors Influencing Crop Production In Irrigation Schemes In The Arid And Semi-Arid Lands Of Kenya : The Case Of Hola Irrigation Scheme , Tana River County , By Winnie Mugera A Research Project Report Submitted In Partial Fulfillment Of The Requirements.

Worqlul, A. W., Jeong, J., Dile, Y. T., Osorio, J., Schmitter, P., Gerik, T., … Clark, N. (2017). Assessing potential land suitable for surface irrigation using groundwater in Ethiopia. *Applied Geography*, *85*, 1–13. https://doi.org/10.1016/j.apgeog.2017.05.010

Yizengaw M. N. (2017). Gis- based surface irrigation potential asssessment: case study of temicha watershed in east gojam zone of amhara region.

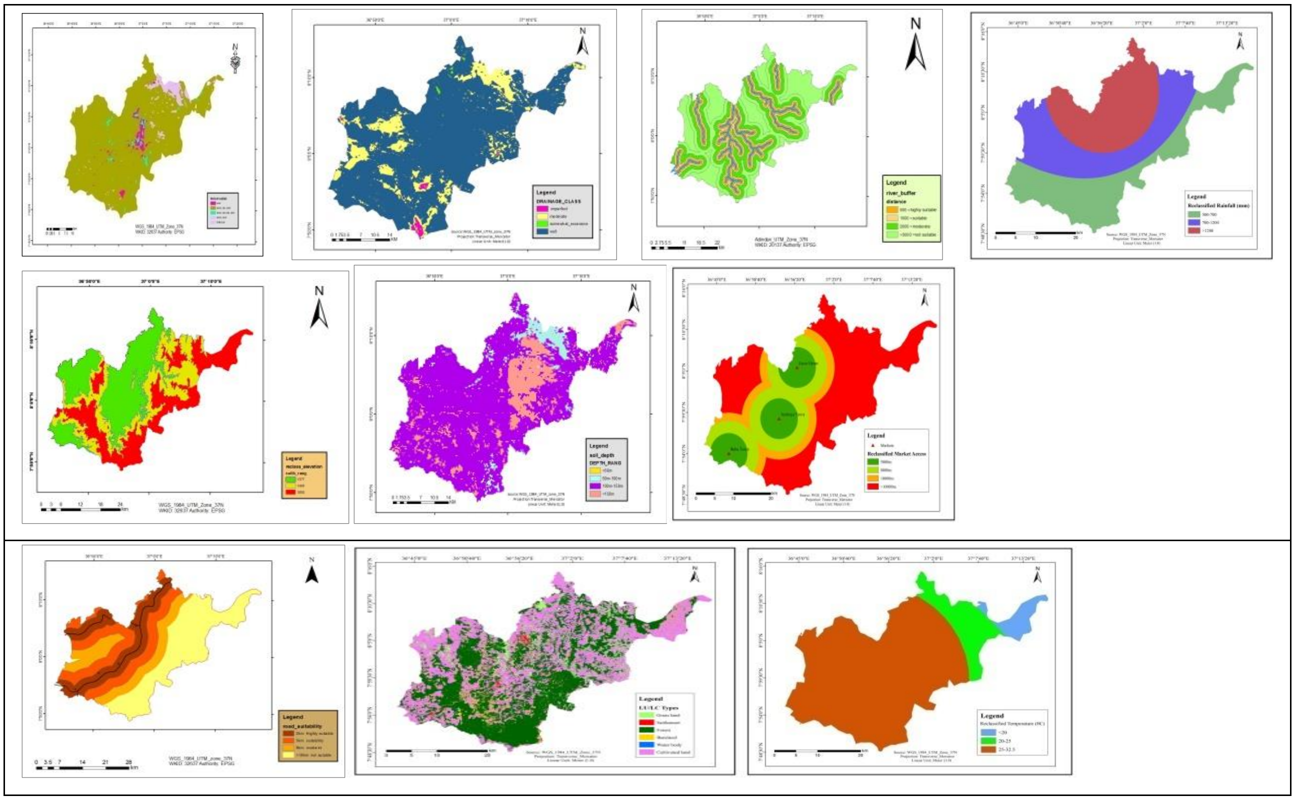
Zolekar, Rajendra Bhausaheb, And Vijay Shivaji Bhagat. 2015. “Multi-Criteria Land Suitability Analysis For Agriculture In Hilly Zone : Remote Sensing And Gis Approach.” *Computers And Electronics In Agriculture* 118: 300–321.

http://www.earthexplorer.usgs.gov/.

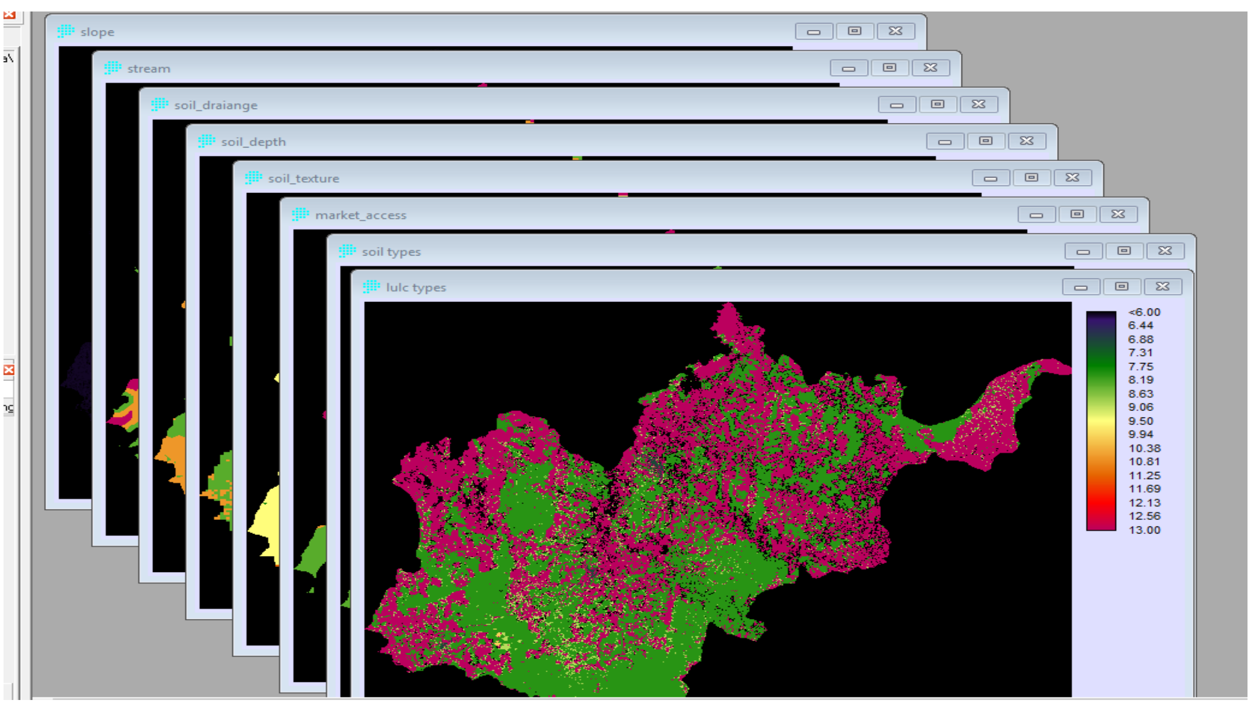
https://www.isric.org/projects/soil-property-maps-africa-250-m-resolution.

Appendix

Factors reclassified for surface irrigation potential suitability for selected crop



Factors weighted for irrigation potential suitability by IDRIS



GPS points collected from field

No.	Coordinate point		Land use land cover category
	X	Y	
1	260427	874411	Water body
2	260301	874464	Water body
3	200212	874606	Water body
4	260367	874712	Water body
5	260523	875608	Water body
6	260441	875456	Water body
7	260681	875645	Water body
8	261644	875317	Water body
9	260332	876283	Water body
10	260229	876228	Water body
11	256295	876849	Cultivated land
12	255457	876329	Cultivated land
13	259541	87493	Cultivated land
14	265990	881453	Cultivated land
15	268216	881933	Cultivated land
16	268355	879594	Cultivated land
17	273191	884302	Cultivated land
18	271842	884244	Cultivated land
19	275839	888921	Cultivated land
20	262676	900040	Cultivated land
21	255745	893061	Cultivated land
22	302062	897441	Cultivated land
23	292447	895228	Cultivated land
24	292539	892357	Cultivated land
25	291283	886483	Cultivated land
26	290595	885471	Cultivated land
27	285019	888018	Cultivated land

28	284886	890849	Cultivated land
29	283901	894904	Cultivated land
30	287373	893806	Cultivated land
31	275785	890524	Grass land
32	278256	891725	Grass land
33	277084	890288	Grass land
34	270160	899439	Grass land
35	268662	889635	Grass land
36	263891	877619	Grass land
37	274095	897959	Grass land
38	278599	866021	Grass land
39	276007	897053	Grass land
40	275854	900129	Grass land
41	277118	903833	Grass land
42	277462	804646	Grass land
43	281839	906359	Grass land
44	278672	906115	Grass land
45	270693	880470	Grass land
46	281193	906413	Grass land
47	279722	884263	Forest area
48	279074	883198	Forest area
49	775878	883986	Forest area
50	262725	889509	Forest area
51	269121	893718	Forest area
52	291464	898842	Forest area
53	297012	897055	Forest area
54	274003	870133	Forest area
55	265650	870014	Forest area
56	259311	879943	Forest area
57	261036	876811	Forest area
58	258426	877617	Forest area
59	255180	880449	Forest area

60	256399	880799	Forest area
61	273615	891139	Forest area
62	268629	882767	Settlement
63	268626	882860	Settlement
64	268620	882568	Settlement
65	268591	882907	Settlement
66	268461	882221	Settlement
67	268720	882337	Settlement
68	269135	882431	Settlement
69	268969	882737	Settlement
70	268521	879101	Settlement
71	262496	879839	Settlement
72	286212	906107	Bare land
73	287051	906591	Bare land
74	261140	874107	Bare land
75	260908	874183	Bare land
76	261193	875321	Bare land
77	261034	875856	Bare land
78	262364	874841	Bare land
79	274211	884771	Bare land
80	272769	885671	Bare land
81	281037	889771	Bare land
82	284293	890261	Bare land
83	297156	895684	Bare land
84	294657	902117	Bare land
85	286341	896208	Bare land
86	283302	900326	Bare land
87	284643	904334	Bare land
88	285169	903919	Bare land
89	285286	903569	Bare land
90	283456	904429	Bare land
91	284582	904232	Bare land