JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIROMENTAL STUDIES

GIS-Based Physical Land suitability analysis for major Oilseeds: A case of Dawro Zone, Southwest Ethiopia

By:

Abebe Tadesse Kocho

A Thesis Submitted to Jimma University, College of Social Science and Humanity, Department of Geography and Environmental Studies in partial fulfillment of the requirement for the degree of Masters of Science (M. Sc) in Geographic Information System and Remote sensing

Major Advisor: Ajay Babu (PhD)

Co-advisor: Gemechu Debesa (M.Sc.)

August 2021

Jimma, Ethiopia

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M.Sc Thesis

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DECLARATION

This is to certify that this thesis entitled "*GIS-Based Physical Land suitability analysis for major Oilseeds: A case of Dawro Zone, Southwest Ethiopia*" is accepted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Geographic Information System and Remote Sensing by the School of Graduate Studies, Jimma University through the College of Social Science and Humanities done by Abebe Tadesse is a genuine work carried out by him under my guidance. The matter embodied in this thesis work has not been submitted earlier for the award of any degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it can be accepted as fulfilling the research thesis requirements.

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FINAL THESIS APPROVAL FORM

As members of the Board of examining of the final M.Sc thesis open defense, we certify that we have read and evaluated the thesis prepared by Abebe Tadesse under the title *"GIS-Based Physical Land suitability analysis for major Oilseeds: A case of Dawro Zone, Southwest Ethiopia"* and recommend that the thesis be accepted as fulfilling the thesis requirement for the Degree of Master of Geographic Information System and Remote Sensing in Jimma University.

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August 2021

Jimma, Ethiopia

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Acronyms

AHP	Analytic hierarchy process
APA	American Psychological Association
ATA	Agriculture Transformation Agency
ASTER	Advanced space borne Thermal Emission and Reflectance Radiometer
BOA	Bureau of Agriculture
DEM	Digital Elevation Model
DZANRDD	Dawro Zone Agriculture and Natural Resource Development department
DZFEDD	Dawro zone finance and economy Development Department
FAO	Food and Agriculture organization
GCP	Ground Controlling Points
GIS	Geographic Information System
GPS	Global Positioning System
IBC	Institute of Biodiversity conservation (Ethiopia)
ISRIC	International Soil Reference and Information Centre
LULC	Land Use Land Cover
M.a.s.l	Meter above Sea Level
MCDA	Multi criteria Decision Analysis
MOA	Ministry of Agriculture
RS	Remote Sensing
SNNPR	Southern Nation Nationalities People Region
UN	United Nations
UTM	Universal Transverse Mercator
USGS	United States Geologic survey

Acknowledgment

First, I am pleased to thank Almighty God for this assured opportunity by his permission.

Secondly, I would like to express my heartfelt gratitude to my advisors Ajay Babu (Ph.D.) and Gemechu D (M.Sc) for their contribution in reshaping, giving direction and comment until the final thesis work.

Thirdly, my thanks go to my loved wife Elshaday Gubela and my daughter Ephratha Abebe for their help, commitment and accompanying with me all around.

Finally, I would like to express thankful feelings for those who have possessed their knowledge without halting, especially Jimma university GeES staff members.

My last but not least delighting will be going to the massive internet horseback packages who carries a lot of immediate answers when asked any time.

Abstract

Identifying suitable land for agricultural activity is expected to change the lives of farmers and to play an important role in building the country's economy. Hence, to get the optimum benefit out of the land, the degree of land suitability has to be assessed. A GIS-assisted land suitability assessment will help farmers and institutions involved in crop development to decide which crop to use on which land. The focus of the study was to allocate how much suitable land is available for oil crops to enable local farmers in oilseed production. Thus, the study used eleven factors selected from climatic, topographic, socioeconomic, and soil parameters within weighted overlay in GIS spatial analyst tool to arrive at the final physical land suitability of oil crops. Factors that were considered in the study were altitude, rainfall, temperature, soil PH, soil drainage, soil texture, soil depth, LULC, slope, road accessibility, and market centers. The result indicated that 4%, 10%, and 1% of the study area were highly suitable for niger, flax, and sesame crops respectively. Moderately suitable area for niger, flax, and sesame accounts 64%, 57%, and 53% respectively. The marginally suitable land for niger, flax, and sesame covered 14%, 14%, and 28% respectively. As the degree of limitations increases, the lands needs additional soil improvement practices or goes through improved varieties to increase the productivity of the crops. The share of suitable land for oilseeds development in all eleven woredas has been shown. Small plots of land where the farmers expected to use oilseeds in shifts have been identified. As long as there is such suitable land, it will be effective if the farmer engages in oilseed farming. Thus, from this study, it is possible to correct the deficiencies in the development and production of oilseeds. This means that the identification of suitable potential land for farming is professionally supported by local agricultural development.

Keywords: **oilseeds, physical land suitability, GIS and RS, weighted overlay**

Chapter One

1. Introduction

1.1. Background

The world population is increasing from time to time and their activity on land is increasing. People use land resources every day. They use soil to produce crops, extract mining activity; industrialization activities and they use water from streams or from underground (Fischer et al., 2000), (D. Ayalew, 2008), and (Reta, 2019). Agricultural production is the basis of human survival and development. Oilseeds such as soybean, cottonseed, rapeseed (canola), sunflower seed and peanut, are the largest sources of vegetable oils in the World (Tadesse, 2013). It is adapted to a wide range of environments, with Canada, Argentina and India being among the world's largest producers (Casa et al., 1999). In Africa, Sudan, Nigeria, Somalia, Uganda, and Ethiopia are major oil crop producers (Kahsay et al., 2018).

Agriculture is a key driver of Ethiopia's economic growth and food security ((FAO, 2012), and (Johansson & Garedew, 2016)). It's important role is one of production, both of food for the rural and the urban population and of cash crops for the export market to earn foreign currency. Crop production plays a vital role in generating surplus capital to speed up the overall socio-economic conditions of the farmers (G. Ayalew & Selassie, 2015). Cereals, legumes and oilseed crops are major field crops grown in Ethiopia (Gebeyehu et al., 2001). Ethiopia has a considerable potential for oilseed production resulting from its diverse and favorable climate conditions as well as the existing large size of uncultivated land (*Multi-Stakeholder Platform Contribution to Value Chain Development, The Edible Oil and Oilseeds Value Chain in Ethiopia. Final Case Study Report*, 2011). The report of Institute of Biodiversity conservation of Ethiopia (FAO, 2012) confirms that major indigenous oilseeds (niger (Guizotia abyssinica), sesame (Sesamum indicum) and linseed (Linum usitatisimum L.)) displaying considerable diversity in the country. They are a mainstay of the rural and national economy in Ethiopia. After coffee oilseeds are the second largest export earner for the country and already more than 3 million smallholders are involved in its production (J.Wijnads et al., 2015). The government has indicated that the oil seeds such as sesame, niger and safflower seeds as high-priority export crops and ranks the second biggest export earner(Zerhun, 2012). On the other hands, oilseeds play an important role in the traditional nutrition of Ethiopian; they are a major source of energy and proteins (C.J.P.Seegeler, 1983).

The growing demand in the world market for these specialty products and the available capacity to expand production could make oilseeds turn into one of the engines of economic growth of Ethiopia (J.Wijnads et al., 2015).

One of the oil seed clusters allocated in southern nation nationalities and people region of Ethiopia is around the gorges of Gibe, Gojeb and Omo rivers (Terefe et al., 2016). Dawro zone is in this Omo river basin. Even though there were potentials for oil seed production; the level of oil seed production in the area is low in relation to cereal crops and yet not adopted well. Fifty two percent of the total area of Dawro zone is kolla agro ecology, which will be expected to use oil crop production and cultivation. Hence, there is a need to allocate suitable area for oil seed productions where agriculturalists will use the final findings to increase their economic development through oil crop production.

A GIS-assisted land suitability assessment will help farmers and institutions involved in crop development to decide which crop to use on which land. Because GIS and RS technology has an ability to analyze and present geospatial data in to the expected output for decision-making (Mendas & Delali, 2012). Thus, the study used physical land attributes such as climatic, topographic, soil and socioeconomic parameters, namely temperature, rainfall, altitude, slope, soil (soil depth, PH, texture, and drainage), land use land cover, accessibility to market and road accessibility as input parameters. Hence, the interpretation were made from spatial and non-spatial information analyzed with the most useful spatial analysis tools of GIS, which is weighted overly functions to get the final goal of the study.

1.2. Statement of Problem

It is important to identify research-based land suitability assessment before engaging in any agricultural activity. Studying which crops fit in which agro ecology will make farming activities more sustainable. To assess the degree of land suitability, the newly emerging GIS and remote sensing technology is being used wisely. Although different scholars on different types of crops are conducted crop suitability assessment around the globe, all crops have their characteristics and should be studied according to local conditions. Given the role that oil crop production plays in a country's economic growth, it is important to identify areas where oil crops can be grown. This is because of the growing demand for oil crops in the world market. In this regard, the identification and extraction of land suitable for oil crops with the help of GIS will help the development of the sector. Therefore, it is possible to improve the oil crop development by knowing how much lands are suitable for the cultivation of oil crops in the Dawro zone. Although Dawro zone is located in the Omo-Gibe basin, which has potentials for oilseed production, the level of oilseed production in the area is low. It is not known how much land there is. More than fifty-two percent of the total area of the Dawro zone is kola agro ecology, which will be expected to use oil crop production (Agize et al., 2013). This is a good opportunity for farmers to cultivate oilseeds, but no spatial information is available for selected crops. It implies that suitability assessment is required in driving spatial information for oil crops. The need of the study was to locate a suitable area for oilseed productions where agriculturalists will use the final finding to increase their economic development through cashes them gain from selected crops. According to (Abagyeh et al., 2016) assessing the land suitability will enable optimum performance and maximum productivity of the crop. However, the study area has not been assessed for oilseeds using GIS technology and farmers are not yet specialized in the activity of oilseed production. As of the report of Dawro zone agriculture department (DZANRDD, 2019), the cereal crops and root crops cover large parts of agricultural activities in the area whereas oilseed production covers the least. Therefore, there was a need to locate a suitable area for oilseed productions. The market value of oilseed is very encouraging from time to time. Hence, physical land suitability analysis was necessary to provide geospatial information on crop production.

According to (Jha et al., 2012) the research component for oilseed crops has to be strengthened further to evolve sustainable and viable technologies to increase its productivity. Thus, an important issue was providing spatial and non-geospatial information for oilseed production.

The crop agriculture in different parts of Ethiopia is dominated by numerous smallholder farmers in cultivating mainly cereals for both household consumption and sells the remaining (Tadesse, 2013). However, in order to improve the producer farmers' economy, it is important to invest in marketable and valuable crops such as oil crops. Therefore, determining the location of better land for agricultural activities using different attributes of land is necessary. Accordingly, the researches on land suitability for oilseeds in a different part of Ethiopia are not much enough in number and there have been very few GIS-based studies in the area.

One of the reasons for this study was to fill the gaps in identifying the areas that are suitable for oilseeds, though oilseeds are known to be the basis of their growth in the agricultural sector either national or international. Although previous studies have focused on agricultural conditions for oil-producing regions (Gurmesa, 2010), trade opportunities for oilseeds and value chains (Wijnands et al., 2007), it has been reported (Francom, 2018) that Ethiopia's oil crop sector needs to expand. In Dawuro zone, too, apart from studies such as a lowering of crop production due to land degradation, deforestation, soil erosion and decrease in soil fertility problems (Agize et al., 2013) and (Wolka et al., 2011), studies on oil crops are rare.

Therefore, it is necessary and essential to carry out scientific evaluation of land with the help of GIS and RS technologies for oilseeds (niger seeds, flax seeds, and sesame) in the area. Besides this, GIS-based suitability assessment for crop production has been very important and was not tried accordingly in this study area. According to (Guja, 2018), there is a need for future Land use allocation; Agricultural performance, and land suitability assessment. Therefore, with this study spatial information for oil crop production will be provided for better agricultural economic development activities in the area. Hence, the study is expected to fill the increasing demand for scientific reports in geographical information and remote sensing technologies.

1.3. Objectives of the study

1.3.1. The general objective of the study

The general objective of the study is to evaluate the current physical land suitability for major oil seeds (niger seeds, flax seeds, and sesame) using GIS and remote sensing technology in the Dawro zone, Southwest Ethiopia.

1.3.2. Specific Objectives of the study

- To identify factors that determine physical land suitability for selected crops
- Evaluating the current potential land for niger seed, flaxseed, and sesame in the area
- To produce suitability maps for the selected crops in the study area

1.4. The Research Questions

- What are the important evaluation criteria to classify potentially suitable lands for Oilseeds in the study area?
- How much the land is potentially suitable for the selected crops based on physical factors in the study area?
- How the suitability map will be developed for selected crops?

1.5. Scope of the study

Spatially, the study was undertaken in the Dawro zone, southwestern Ethiopia. Its focus was to analyze current physical Land suitability for the production and cultivation of Oil Seeds (Niger seeds, flax seeds, and sesame) in Dawro Zone, Southwest Ethiopia. The study was also to describe potentially suitable lands based on the range of physical constraints that influence selected crop productions in the area. Finally, the scope of the study was to model the GIS and RS approach by attempting and evaluating physical constraints for the selected crops.

1.6. Significance of the Study

Land suitability analysis is vital to support agricultural sustainability for economic growth. It will provide the local communities with relevant information on crop productions. Using the results, farmers will come up with new plans or may need to update the existing plans on crop productions, economic development activities, and benefits. The study will provide scientific knowledge to help the community in their crop production activities according to the potential of the land. All development partners including extension workers, technical assistants, NGOs, and others involved in agricultural development activities will understand the ranges of physical factors determining oil seeds. Therefore, the present study was intended to reveal the underlying physical factors and constraints that determine physical land suitability for oilseeds (niger seeds, flax seeds, and sesame) in the Dawro zone. Finally, the study will help in providing digital maps, reports, and research findings directly useful for decision-makers and researchers who require relevant data for their work.

1.7. Organization of the paper

The study was organized into five chapters. The first chapter deals with the introduction of the study, statement of the problem, basic research questions, objectives, significance, the scope of the study and operational definition. The second chapter presents a review of the literature and the third chapter includes the research methodology of the study. The fourth chapter is all about the presentation, analysis, and interpretation of data and the fifth chapter will present a conclusion and recommendation of the study. Finally, the list of reference materials were indicated under the reference as per APA style and the important information will be annexed in the appendices.

Chapter Two

2. Related Literature Review

2.1. Theories and Concepts on Land suitability study

Internationally recognized suitability classes outlined by FAO can be adapted and applied at both regional and local scale (FAO, 1976). This methodological framework is used to evaluate the suitability of specific crop in a specific location for producing a particular crop under a defined agricultural production system (Kassam et al., 2012).

Land suitability study for agriculture is a very important technique in deciding future agricultural cropping pattern, planning and activities (Singha & Swain, 2016). It is an assessment of an area to determine how proper or appropriate it is for a particular use of the land (such as growing a crop variety) in a particular location (Singha & Swain, 2016), (S.Bandyopadhyay et al., 2009). It also deals with the assessment of land performances for the specific use that is crop production (S.Bandyopadhyay et al., 2009).

2.2. Assessing suitable land for different crops

Land suitability analysis is a method of land evaluation, which measures the degree of appropriateness of land for a certain use (Halder, 2013). By using suitability analysis the appropriateness of a given type of land will be figured based land attributes and the growing conditions of a particular crop(Singh et al., 2018). Each plant species requires definite soil and site conditions for its optimum growth. However, most plant species need well drained, moderately fine to medium texture soils, free of salinity and having optimum physical environment (Mishra, 2007).

Table 1 FAO land evaluation Framework

Suitability Classes	Description
S1, Highly suitable	Land having no significant limitations, or only minor limitations. Nil to minor negative economic, environmental, health, and/or social outcomes.
S2, Moderately suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given land use. Potential negative economic,

	environmental, health, and/or social outcomes if not adequately managed.
S3, Marginally suitable	Land having limitations which in aggregate are severe for sustained application of a given use. Moderate to high risk of negative economic, environmental, health, and/or social outcomes if not adequately managed.
N1, Not suitable	Land having limitations, which may be insurmountable. Very high risk of negative economic, environmental, and/or social outcomes if not managed.
N2, Not suitable	Land having limitations, which appear so severe as to, preclude any possibilities of successful sustained use of the land in the given manner. Almost certain risk of significant negative economic, environmental, and/or social outcomes.

Once the physical factors that, determine the location of a crop production has been figured, the methodological flow is formulated and GIS technology will be used to derive land suitability in terms of suitability classes and its extent.

2.2.1. Oilseeds and its productivity

Oilseeds are crops in which energy is stored mainly in the form of oil and they are grown all over the world (Ahmed, 2017). Soybean, cottonseed, rapeseed (canola), sunflower seed and peanut, are the largest sources of vegetable oils in the World (Tadesse, 2013). Oilseed crops belong to numerous plant families and their seeds are used not only as a source of oil but also as raw materials for various oleo-chemical industries.

The Ethiopian government has indicated that the oil seeds such as sesame, niger and safflower seeds as high-priority export crops and ranks the second biggest export earner (Zerhun, 2012). The productivity of oilseed crops in Ethiopia can be explained by a variety of variables(Gurmesa, 2010).

A. Niger seed (Guizotia abyssinica (L. f.) Cass.))

Niger (Guizotia abyssinica (L. f.) Cass.) is an oilseed crop cultivated in Ethiopia and India for its edible oil(Heuzé et al., 2016). Niger is believed to have originated from Ethiopia where it was domesticated from about 2000 BC. It then spread to India. It is mainly cultivated in these two countries but is also present in other African and Asian countries (Sudan, Uganda, Zaire, Tanzania, Malawi, Zimbabwe, Nepal, Bangladesh, Bhutan), and in the West Indies. Niger was also tested in Russia, Germany, Switzerland, France and Czechoslovakia in the 19th century (Weiss, 1983 cited by Getinet et al., 1996)(Heuzé et al., 2016).

B. Flax seed (Linum usitatissimum L.)

Flax, Linum usitatissimum L., is an oil seed crop in the family Linaceae. Flax is adapted to a variety of climates across different geographic regions. According to (Ehrensing, 2008), flax oil yield and quality are generally better in higher latitudes. The optimum temperature requirement for growing flax varies from 60 to 75 °F (15.6 to 23.9 °C). Flax seedlings are believed to survive in temperatures ranging from 13 to 25 °F (-10.6 to -3.9 °C)(Sediqi, 2012). Flax does not tolerate poorly drained soils well (Ehrensing, 2008).

C. Sesame (Sesamum indicum L)

Sesame is an annual herbaceous crop grown for its oil-rich seeds. Sesame has been grown for the last over 2500 years. The crops ability to grow in adverse conditions such as dry weather and high temperatures has enabled its spread in many parts of the world. Because of its ability to survive adverse conditions, Sesame Crop can be planted using traditional methods. This has made it easy for many Somalia Farmers to draw value from the crop and to be able to produce it in large scale production systems (Bubbolini et al., 2016). Sesame is a broadleaf plant that grows to a height of 1.5 to 2 meters, depending on the variety and growing conditions. It is erect, branched, mostly annual, or long season plant with well-developed root system. It is a warm season annual crop and is considered drought tolerant, but needs good soil moisture for establishment and for high yield. Soil type and moisture influence growth and productivity of varieties. Sesame grown under irrigation often becomes much greater and yield higher than rain-grown crops(Terefe et al., 2016).

2.2.2. Importance of oilseeds

Oil seeds such as sesame, linseed, soybeans, corn, cottonseed, groundnut, sunflower, safflower and rapeseed are the largest sources of vegetable oils(Zerhun, 2012). In Ethiopia, niger is a major source of edible oil and provides about 50% of the country’s oilseed production. Ethiopian niger seeds contain about 40% oil (Getinet & Sharma, 1996).

Currently, oilseed flax is more economically important than fiber flax. Most world flax production is for linseed or flaxseed oil, flaxseed meal, and flax straw. Flax seeds are an excellent source of oil, containing from 40 to 45 percent oil(Ehrensing, 2008).

Apart from its leaves and seeds being eaten as food, Sesame crop has many uses. Its seeds contain Sesame Oil which is used for many things including but not limited to; Pharmaceutical industries in the manufacture of cosmetics such as Soap, Skin Creams, etc. It is also used in pyrethrum industry for the manufacture insecticides and human medicine to manage diarrhea, cough, asthma, ulcers etc(Bubbolini et al., 2016).

Sesame seed is consumed whole in bakeries or pressed for oil extraction. Light colored seeds are considered to yield better quality oil than dark. However, dark colored varieties have high oil content than light colored seed. White-seeded varieties are preferred when roasted and eaten. They also command the market premium over the dark seeds(Terefe et al., 2016).

2.3. Factors that affect the distribution of crop production

2.3.1. Climatic factors

Climate is the major physical factor in controlling agricultural land use (Prakash et al., 2007). Areas with too little rain or too much rain determine the growth of a given crop. The combined effect of the two climatic factors such as precipitation and temperature, which presents a range of favorable growing conditions for various major crops and determine the location of crops (Baker, N.T., and Capel, 2011). Thus, data on these elements are so important for sustainable local level land use planning processes.

2.3.1.1. Rainfall

Among the Climatic condition, annual precipitation is an important aspect of climate and key factor in plant growth for rain fed agriculture. Planting crops outside the specific climatic region will negatively influence crop yield (Günther Fischer, Harrij van Velthuizen, 2000). According to (Negash, 2012), while undertaking any level of land use planning, it is important to know the spatial reliability of the rainfall amount and distributions.

2.3.1.2. Temperature

Most plants cannot grow if the temperature falls below 6°C or the soil if frozen for five consecutive months. Temperature drives crop growth(GIZ, 2016). Extreme events of heat / cold wave cause enormous losses of standing crops. Consequently, the temperature suitability measures level of crop cultivation. The environmental factors most likely to affect crop yields were high temperature, due to its effect on development rate, and the consequent shortening of the growing cycle and perhaps water shortage(Casa et al., 1999).

2.3.2. Soils

The soils are natural three dimensional bodies occupying a characteristic part of the landscape(IUSS Working Group WRB, 2015). Soils provide the physical base for crop roots and are the principal source of nutrients. Plants need soil with certain characteristics. Soil depth is one of the important soil physical parameters. Soil depth determines roots growth as well as presence of volume of water and air in the soil(S.Bandyopadhyay et al., 2009). According to (Baker, N.T., and Capel, 2011), most crops need at least 100 centimeters of soil to grow, although some crops can be grown in shallower soils. Soil type will influence crop cultivation because different crops prefer different soils.

2.3.3. Topography factors

Topography is the physical feature of a landscape or terrain. Topographic factors influence accessibility, drainage, rate of erosion and costs of land development. The influence of topography on agricultural land use is many and varied. Steep slopes are subject to soil and nutrient loss. The slope of the landscape effects soil formation, climate, water drainage, and soil-water availability. Steep slopes are subject to erosion and soil loss(Baker, N.T., and Capel, 2011). In long terms, cultivation of slopes might result in losses of land productivity and consequently reduction of natural soil fertility and of available soil moisture (IIASA/FAO, 2012)

2.3.3.1. **Altitude**

Altitude affects temperature so it also affects farming. When temperatures are consistently high with sufficient precipitation high yield crops such as rise can be grown.

2.3.3.2. Slope

The angle of slope will affect the type, depth and moisture content of soil. It will also affect the rate of soil erosion(FAO, 2006).

2.4. Environmental requirements for oilseeds

A. Niger (*Guizotia abyssinica (L. f.) Cass.)*

Niger (Guizotia abyssinica L) is a group of oil crop that is mainly suitable under rain fed condition (Gogoi, 2019). Niger grows in moderate temperature ranging between 15°C and 23°C.It mainly grows in mid-altitude and highland areas (1600-2200 m.a.s.l) in Ethiopia (Getinet & Sharma, 1996). According to (Misteru, 2008), it mainly grown from 1600 m.a.s.l to 2500 m.a.s.l, within annual rainfall 500 mm to 1000 mm. However, according to (Heuzé et al., 2016) it can be grown from sea level up to an altitude of 2500 m where average daily temperatures range from 13°C to 23°C, and night temperatures are above 2°C. It uses optimal annual rainfall from 1000-1300 mm, and depresses its yield at 2000 mm. Niger does well on a wide range of soils, from poor sandy soils to heavy black cotton soils, at a pH varying from 5.2 to 7.3.

B. Flax crop (Linum usitatissimum L.)

Flax should be planted on the same type of land as wheat or oats, where good soil drainage is very important. Flax is adapted to most soil types, but especially to deep, fertile, loam soils. Oilseed flax is widely adapted to a broad range of soil and environmental conditions. Cool temperatures after flowering tend to increase oil (particularly linolenic acid) content. Flax generally does best on well-drained soils with good water holding capacity, such as silt-loams and clay loams. Flax does not tolerate poorly drained soils well (Ehrensing, 2008).

C. Sesame *(Sesamum indicum)*

Sesame varieties have adapted to many soil types. The high-yielding crops thrive best on well-drained, fertile soils of medium texture and neutral P^H. However, these have low tolerance for soils with high salt and waterlogged. It is a warm season annual crop, which is primarily adapted to areas with long growing seasons and well-drained soils. Sesame prefers slightly acid to alkaline soils (pH 5-8) with moderate fertility. Clay soils are more prone to water logging. Therefore, sesame will perform best on fertile and well-drained soils such as silt loams. It is adapted to sandy loam soils provided there is adequate moisture during seedling establishment and it has been grown satisfactorily on silty clay loam soils. Planting sesame is the most critical phase of its management.

Sesame (Sesamum indicum) is grown in areas with annual rainfall of 625-1100mm and temperature of >27^{0}C. The crop is tolerant to drought, but not to water logging and excessive rainfall. Sesame is well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams. In Ethiopia, sesame grows well in the semiarid areas of Amhara, Tigray, Benshangul Gumuz, and Somali Regions. Lowlands of Oromiya and Southern Nations nationalities and Peoples Regions also grow a significant amount(Terefe et al., 2016).

2.5. The Importance of GIS and RS Technologies in suitability analysis

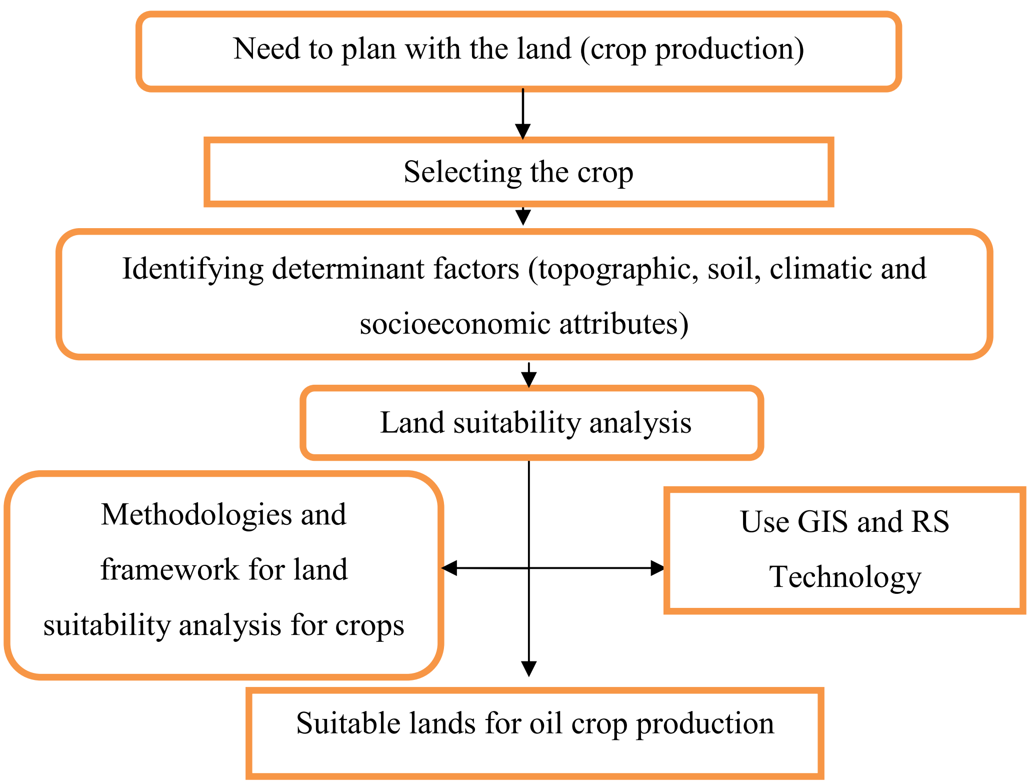
GIS is computer-based tool for mapping and analyzing geographic phenomenon that exist on Earth (Goodchild & Longley, 1999). It offers numerous possibilities to combine data sets of different sources for analysis and visualization(Jan Blo¨the and Lothar Schrott, Prasicek, 2018). Manipulation and analysis of various types of spatial information of delineation, measurement, mathematical operations, and creation of different maps and layers are possible within GIS environment. As a decision support system, GIS involves the integration of geographically referenced spatial data in addressing issues that have to do with resources location and allocation, crop and species suitability, conducting land capability assessment and land use suitability analysis, and among many others(climate change commission, 2016). GIS application plays an important role in identifying and studying land for various agricultural activities. In particular, it helps to create a favorable environment for farmers by identifying suitable areas for selected crops.

According to(Earls & Dixon, 2014), ArcGIS Statistical analyst has the capability to apply many types of spatial interpolation to input point data. Thus, the use geographical information systems (GIS) will lead to generate thematic maps and areas estimates, and enables many analytical operations in a spatial format, by combining different sets of information in various ways to produce overlay interpreted maps (Jan Blo¨the and Lothar Schrott, Prasicek, 2018).

Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Al-fares, 2013). Thus, the combined application of remote sensing and GIS effective tool in the delineation of watersheds and land use land cover classification. Therefore, the data from remote sensing will be used for the quantitative analysis of digital information where measurements can be made from ground, aircrafts or satellites. It is also used to monitor land features, natural resources and dynamic aspects of human activities for preparation of thematic maps.

2.6. Analytical Hierarchy Process (AHP)

Applications of the multiple-criteria decision methods applications especially popular in the last few decades. The method of analytic hierarchy process (AHP) is one of the most used methods in decision making processes, developed by Saaty (Atanasova-pacemska et al., 2014). Other researcher (Chandio & Matori, 2012) observed that AHP is proven as a developed decision making instrument in finding optimal land for development. It is a classical procedure, which gives a systematic approach in making proper decisions for site selection and allocation. The use of MCDA techniques such as analytic hierarchy process (AHP) by using GIS and remote sensing is a flexible and effective framework to assess and map several different criteria for the strategic placement of cropping (Seyedmohammadi et al., 2019).



igure 1 conceptual framework for land suitability analysis (own developed)

Chapter Three

3. Description of the study area and Research Methodology

3.1. Description of the study area

This study area, Dawro zone, is located in Southern Nations, Nationalities and Peoples Region (SNNPR) southwest Ethiopia. It is one of the 14 Zones in the region and bounded with Hadiya Zone in the North, Kembata & Tembaro Zone in the Northeast, Wolayta Zone in the East, Gamo Gofa Zone in the South, and Konta special Woreda in the West within SNNPR and south of Jimma Zone in Oromya Region. Gojeb and Omo Rivers demarcated the Dawro zone from Northwest to North and from South to North East respectively. Tarcha is the zonal town of about 507 kilometers Southwest of Addis Ababa across Shashemene and Wolayta, 282 Kilometers away from Hawassa, the town of SNNPR, and 180 km from Jimma (Agize et al., 2013), (Boyana et al., 2018). Gibe III manmade lake from Gibe III hydroelectric power project has attractive special land view site from Loma Bosa, Zaba Gazo, and Gena woredas. Chabara Churchura National Park (CCNP) has a boundary share from Dawro and Konta Special woreda in the Eastern location and it is a habitat for different wildlife with dense natural forests.

The elevation ranges of the Dawro zone starts from 538 to 2820 meters above sea level at the gorges of Omo river valley and Tuta ridges in Tocha woreda respectively. The lowest altitude is around Omo River valley in Disa woreda and the highest elevation is around the Tuta ridges of Tocha woreda. The agro-climatic zones are 43.45 % Woyna dega, 52.4 % kola and 4.15 % dega (DZADD, 2019)

The geographical extent of Dawro zone lies between 6°32'00" to 7°22'00" North and 36°40'00" to 37°35'00" East. The total area of the Dawro zone is 4403.51 square kilometers. Figure 2 below indicated the location map of the study area. There are 174 kebele, 10 woredas and one town administration in the area namely; (Mareka woreda, Mari Mansa woreda, Tocha woreda, Kechi woreda, Esara woreda, Disa woreda, Loma woreda, Zaba Gazo woreda, Gena woreda, Tarcha zuriya woreda , and Tarcha town administration)

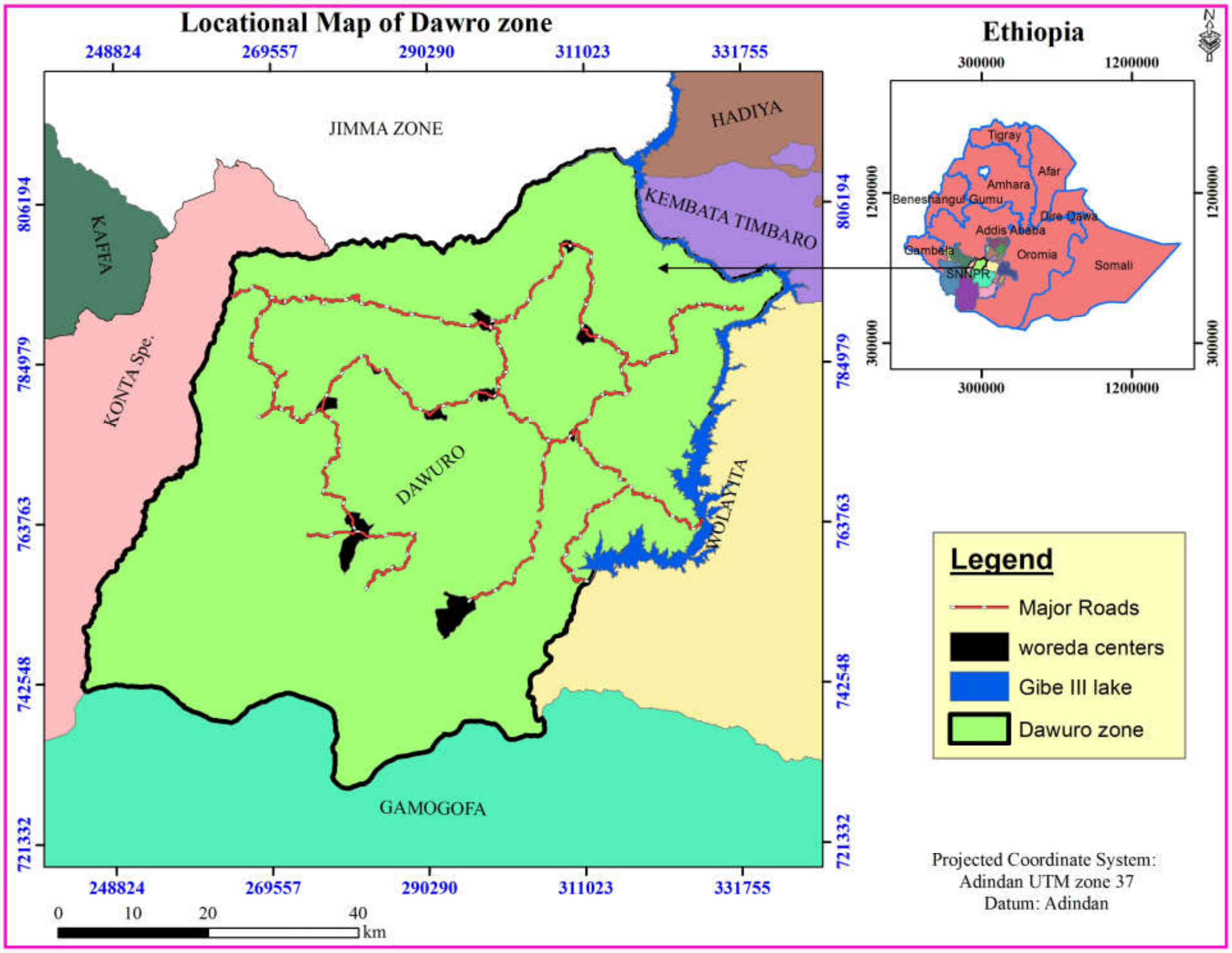


Figure 2 Location Map of the study area

3.1.1. Demographic Characteristics

According to the Dawro zone, Finance and Economic Development Department (DZFEDD, 2019), the total population of the Dawro zone has a total population of 715305, of whom 650843 were rural residents and 64463 or 9.01% were urban populations. The sex proportion of the Dawro zone is 364805 female and 350500 is male. The population density of the Dawro zone is 162.43.

3.1.2. Socio-economic Characteristics

Dawro zone has potential land for agricultural activity with diverse agro-ecologies, farming systems, socio-economic conditions, and cultures. Most of the livelihood strategies of the rural community depend on mixed agriculture with livestock husbandry. The major crops grown and used for consumption and cash exchange in the study area is dominated by cereals (maize, teff, wheat, barley, sorghum), pulses (haricot bean, chickpea, field pea), oil crops such as (sesame, niger, and flax seeds), root crops (Enset, potato, sweet potato) and fruits as well as cash crops like ginger and coffee (Agize et al., 2013).

Table 2 Reports of zonal oil seeds in Dawuro zone (DZADD, 2019)

woreda name	Sesame (ha)	niger (ha)	Cabbage (ha)	sunflower(ha)	Nuts(ha)	flax (ha)	Cabbage (ha)
Tarcha zuriya woreda	12	28	425		10	5	480
Loma woreda	4				20	5	29
Esara woreda	7	4		11	16	4	42
Tocha woreda			384		0	3	390
Zaba Gazo woreda	5		205		11	5	241
Tarcha Town admin	2	8	2		15	5	37
Disa woreda	32		36	5	10	5	106
Gena woreda						6	6
Kechi woreda		6	363	0	25	8	431
Mareka woreda			470			2	475
Mari woreda			105	4	20	2	131
sum	62	46	1990	20	127	50	2368

Even though there was potential oilseed production, table 1 indicates that 0.537 percentage of the total area is being practiced with oil crop.

Enset is the staple food in Dawro, particularly in mid and high-altitude areas (Boyana et al., 2018), while maize is the most important crop in the lowlands (Agize et al., 2013). The product of the Enset plant namely (kocho) is used for daily food consumption and is the most important food-securing crop in the area (DZANRDD, 2019)

Table 3 Reports of cereal crop production in Dawro zone (DZADD, 2019)

Woreda	Teff(ha)	barley(ha)	wheat(ha)	Rice(ha)	Rye (ha)	Dagusa (ha)	Total
Tarcha Zuriya	2015		62			62	2139
Loma woreda	3840	400	1760		4		6004
Esara woreda	1963.5	584.25	806	80	3.75		3437.5
Tocha woreda	201	601	525		36		1363
Zaba Gazo woreda	2404	58.75	141.5		15		2619.25
Tarcha Town admin	64						64

Disa woreda	1758	377.5	474		38.5		2648
Gena wordda	1288	86.25	206.5		30.125	924	2534.875
Kechi woreda	32.5	130.5	393.25			29	585.25
Mareka woreda	867	295	666				1828
Mari woreda	1046	300	916		6		2268
Sum	15479	2833.25	5950.25	80	133.375	1015	25, 490.875

The above table 2 showed that about 5.8 % of the total area of the study zone was being used for cereal crop productions.

Dawro zone has varied agro-climate that has agriculture potential ((Girma et al., 2019), (Agize et al., 2013)). The soil is fertile which has great potential for agriculture(Guja, 2018). The rugged topography particularly causes difficulties in road, irrigation and other infrastructure development. The steep slope mountainsides are not suitable for tilling and are vulnerable to soil erosion(Agize et al., 2013). The mountain areas are more suitable for livestock rearing. Cattle are indispensable for rural households both as a means of subsistence and source of cash income. In rural areas, the number of cattle owned and enset cultivated by a household usually determines the wealth status of the household.

In general, the people are dependent on subsistence agriculture for their livelihoods and the majority of the populations are involved in this sector, whereas the non-agricultural sectors contribute a smaller amount to the livelihoods of the people. The domestic animals found include cattle, horses, mules, donkeys, sheep, goats, and poultry((Agize et al., 2013). Landforms, rivers, gorges and mountains have cultural importance for the people of the study area. People living there have long years of experience of interaction with each other and the natural resources of their surroundings.

3.2. Research Design

This study was based on descriptive technical research. Thus, it described the current physical suitability of the study area based on the determinant factors and characteristics of the land to locate the suitable land for oil crop production and cultivation. Non-probabilistic purposive sampling technique was used in this study to target a specific objective. Thus, the study used mixed research design method by using both qualitative and quantitative method to evaluate physical land suitability for oil seeds.

Qualitatively, the study focused to determine the relationship between each determinant factors to develop suitability analysis based on GIS operation. This was to conclude on the existing theory in such a way that why each determinant parameters governs the suitability of the selected crops. Quantitatively the statistical conclusions made based on the parameters to make suitability decision for selected oilseeds. Hence, the numerical data was used in the analysis to find the land suitability. The quantitative values of all the parameters from physical factors of topographic data (slope and altitude ranges), soil data (Soil depth, Soil texture, Soil PH, and soil drainage), climatic data (rainfall and temperature), socioeconomic services (road and market accessibility) and LULC were discussed in how they influence the potential suitability ranges of selected crops. These factors are quantified based on crop suitability standards to evaluate the level of suitability for selected crops. Finally, the results from the overlay operations under GIS environment will be used to describe the expected goal of the study quantitatively and qualitatively.

3.3. Data types and sources

Both Primary and secondary data sources were used in the study. The freely available sentinel-2B images of the month December 2019-February 2020 were downloaded from https://earthexplorer.usgs.gov/ for LULC classification. Determining the topographic factor suitability was made from ASTER DEM with 30m resolution that was downloaded from https://earthexplorer.usgs.gov/ official web site. GPS data from was used to check the accuracy assessment and to validate land use land cover classification of sentinel images. Rainfall and temperature data were downloaded from the website of world climate data version 2 http://worldclim.org/version2. Statistical and socioeconomic data of crop production were collected from the study zone districts. Soil parameters were downloaded from open sources of ISRIC and FAO websites (https://www.isric.org/explore) and http://www.fao.org/soils-portal/soil-survey/soilmaps-and-databases/harmonized-world-soil respectively. Socioeconomic data for market and road accessibility were taken from offices of the study area and sites by collection. Finally, the related research articles, books, conference reports and organizational reports were used as a secondary source to attempt the current study.

Table 4 data types and sources

No	Data Type	Resolution(m)	Data Source
1	ASTER DEM	30	USGS
2	SENTINEL-2A image	10	USGS
3	Soil data	250	IRSIC
4	Meteorological data (climatic)	1km	Worldclim.com
5	statistical or socioeconomic data of crop production	-	Dawro zone agriculture department
6	GCP	-	Field observations

3.4. Software and tools

Arc GIS version 10.3 was used as the central processing software for main analysis in this study. All raw data acquisition, preprocessing, manipulation and analysis were undertaken through GIS environment. Secondly, ERDAS Imagine 2015 was used for land use land cover classification and for accuracy assessment. Google earth, GPS and digital camera were used for ground truth verification for accuracy assessment and capturing photos respectively.

Table 5 Data processing software and tools

Number	Name	Version	Function
1	Arc GIS	10.3	Data processing and analysis
2	Erdas Imagine	2015	Data processing
3	GPS	Garmin72H	Data collection
4	Google earth		Ground truth verification
5	Digital camera		Photo capturing

3.5. Methods of data analysis

3.5.1. Data preprocessing

Data preprocessing of the satellite images is very essential before the raw data be processed for image classification. Thus, after data preprocessing data were got ready for data analysis. The preprocessing steps included the conversion of all datasets to the same geographical projection that is a prerequisite to continue the spatial analysis procedure. Therefore, the raw ASTER DEM was projected from geographic coordinate system to projected coordinate system (Adindan UTM zone 37) to process slope and altitude ranges to allocate the suitable location of oil crop production. Secondly, the downloaded scenes of sentinel images from USGS web site, were checked to cover all the study area. The downloaded Sentinel-2 images were L1C_T37NBH, L1C_T37NBJ, L1C_T37NCH and L1C_T37NCJ of the year 2020 and mosaiced into one scene to cover the study area. The bands, which were composited and clipped to the study area, were band 2, band 3, band 4, band 5 and band 8. The clipped sentinel image were projected from geographic to the projected coordinate system for LULC classification. Thirdly, the soil parameters were preprocessed and reclassified based on crop suitability ranges. Fourthly, climate parameters from worldclim.com projected and reclassified according to oil seed suitability.

3.5.2. Evaluation criteria

Physical land potential analysis for agricultural crops needs the consideration of different environmental factors or criteria. Hence the set of evaluation criteria consisting of Soil parameters (depth, PH, drainage and texture); Climate parameters (Precipitation and Temperature); topography (slope and altitude ranges); socioeconomic (Roads and Market accessibility) and Current Land use land cover were integrated and analyzed to get the expected output or objective according to the methodological flow chart in figure 3. Accordingly, evaluation requirements and the range of suitability for each crops were set as shown in Table 5, 6 and 7.

3.5.3. Reclassification and description of evaluation factors

All the values of the required factors were reclassified in to suitability classes of selected crops according to the table 6, 7 and 8. Then all the reclassified factors were transformed to a common ratio scale before the combination of factors made into analysis.

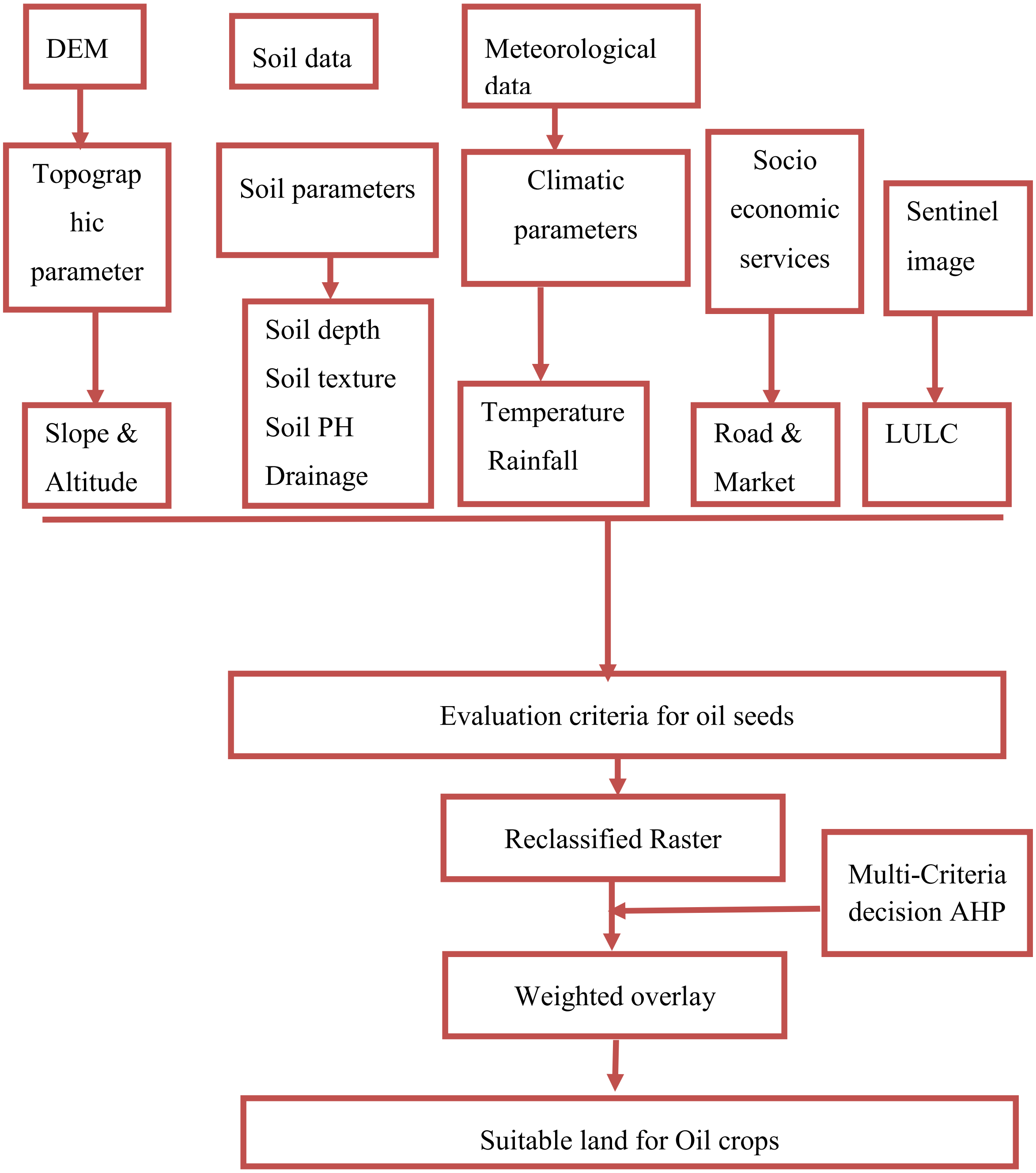


Figure 3 methodological chart

Table 6 Evaluation requirements rating for niger crop

Name of the crop	Decisive Factor / Criterion	Range of Suitability					sources
		Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Currently Not Suitable (N1)	Permanently Not Suitable (N2)	
Niger	Altitude (m)	1500-2000	1100-1500,	2000-2400	<1100, >2400		(Zerhun, 2012), (Misteru, 2008), (Heuzé et al., 2016), (Getinet & Sharma, 1996), (Taffesse et al., 2011), (FAO, 1992), (*Multi-Stakeholder Platform Contribution to Value Chain Development, The Edible Oil and Oilseeds Value Chain in Ethiopia. Final Case Study Report*, 2011), (Debesa et al., 2020), (Hurni, 1998), (Jacobsz & Merwe, 2012), (Landon, 1991)
	Rain fall (mm)	800-1100	600-800	1100-1500	<600, >1500		
	Temperature (c°)	17.5-22.5	15-17.5	22.5-25.0	<15.0, >25.0		
	Soil P^H	6.7-7.3	5.5-6.7	7.3-8.5	< 5.5, >8.5		
	Drainage (class)	MW, M	P-I	SE	VP, E		
	Soil texture	(L, SiC)	(SL)	Sandy soil,	(S, LS)		
	Soil depth	>50 cm	25-50 cm	20-25 cm	0-25cm		
	LULC	Agriculture	Grass land	Bare soil	Forest land, Bush land, built up area	Water body	
	Slope (%)	0-8%	8-15%	15-30%	>30%		
	Road accessibility (km)	0-2 km	2-4 km	4-7 km	>7 km		
	Market center (km)	0-4 km	4-8 km	4-12 km	>12 km		

Table 7 Evaluation requirements rating for Flax crop

Name of the crop	Decisive factor / Criterion	Range of Suitability					sources
		Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Currently Not Suitable (N1)	Permanently Not Suitable (N2)	
Flax crop	Altitude (m)	1500-2000	770-1500	2000-2400	<770, >2400		(PANDAY et al., 2014), (Taffesse et al., 2011), , (Ehrensing, 2008), (FAO, 2015), (FAO, 1992), (Debesa et al., 2020), (Hurni, 1998), (Jacobsz & Merwe, 2012), (Landon, 1991)
	Rain fall (mm)	1000-1250	750-1000, 1250-1500	1500-1600	<750		
	Temperature (°C	18-20	20-22	15-18			
	Soil P^H	6.0-6.5	5.5-6.0, 6.5-7.0	5.0-5.5	< 5.0, >7.0		
	Drainage (class)	Well drained soil					
	Soil texture	(SiL, CL, L)	(SL, SiC)	Sand, light clay (S)	Sandy soil , heavy clay, rocky (S, C)		
	Soil depth	>50 cm	25-50 cm	20-25 cm	<20 cm		
	LULC	Agriculture	Grass land	Bare soil	Forest land, Bush land, built up area	Water body	
	Slope (%)	0-8%	8-15%	15-30%	>30%		
	Road accessibility (km)	0-2 km	2-4 km	4-7 km	>7 km		
	Market center (km)	0-4 km	4-8 km	4-12 km	>12 km		

Table 8 Evaluation requirements rating for Sesame crop

Name of the crop	Decisive factors / Criterion	Range of Suitability					sources
		Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Currently Not Suitable (N1)	Permanently Not Suitable (N2)	
Sesame	Altitude (m)	0-1200	1200-1400	1400-1600	>1600		(Zerhun, 2012), (PANDAY et al., 2014), (Ehrensing, 2008), (Heuzé et al., 2016), (Kindu et al., 2009), (Debesa et al., 2020), (Hurni, 1998), (Jacobsz & Merwe, 2012), (Girmay, 2018) (Landon, 1991)
	Rain fall (mm)	500-700	400-500	700-1000	<400, >1000		
	Temperature (c°)	22.5-32.5	20-22.5	15-20	<15, >32.5		
	Soil P^H	5.5-6.7	5.0-5.5	6.7-7.3	< 5.0, >7.3		
	Drainage (class)	MW-W		SE	E, VP-I		
	Soil texture	SL-CL	LS	SiCL-SiC	S, Clay		
	Soil depth	>100 cm	50-100 cm	25-50 cm	<25 cm		
	LULC	Agriculture	Grass land	Bare soil	Forest land, Bush land, built up area	Water body	
	Slope (%)	0-8%	8-15%	15-30%	>30%		
	Road accessibility (km)	0-2 km	2-4 km	4-7 km	>7 km		
	Market center (km)	0-4 km	4-8 km	4-12 km	>12 km		

Where;

SiCL stands for silty clay loam, CL stands for clay loam, Si is silt, SiL stands for silty loam, SC is sandy clay, L is loam, SCL stands for sandy clay loam, SL is sandy loam, LS is loamy sand, LULC is land use land cover, MW moderately well drained, SE is somewhat excessively drained, E stands for excessively drained.

3.6. Weighted overlay analysis

A. Analytical hierarchy process (AHP)

AHP is Multiple-criteria technique which is based on the need of the complex problems branching into a hierarchical structure of specific elements that are objective (goal), criteria (sub-criteria) and alternatives (Atanasova-pacemska et al., 2014).

Table 9 Saaty scale

Importance	Definition	Explanation
1	Equally important	Both elements have equal contribution in the objective.
3	Moderately important	Moderate advantage of the one element compared to the other
5	Strong important	Strong favoring of one element compared to the other
7	Very strong and proven importance	One element is strongly favored and has domination in practice, compared to the other
9	Extreme importance	One element is favored in comparison with the other, based on strongly proved evidences
2, 4, 6, 8	Inter – values	

Source ((T.L.Saaty, 2002), (Tatjana et al., 2014), (Mathur, 2015))

According to (Chandio & Matori, 2012) observation, AHP is proven as a developed decision making instrument in finding optimal land for development. Land attributes parameters, climatic and socioeconomic parameters will be used through analysis. Hence, each factors are weighted for overly processes by using pair-wise comparison matrix shown on table 23.

Using the pair-wise comparison matrix, the analytic hierarchy process (AHP) calculates comparative weights for individual criterion layers (Yalew, 2016). The pair wise matrix could also be redesigned based on stakeholders' preferences and requirements for crop land suitability index (Aldababseh & Maghelal,2018).These pair wise comparisons are then analyzed to produce a set of weights that sum to one. The factors and their resulting weights are used as inputs for overlay operation.

Thus, pair wise comparison was made and the value of each factors filled in the way as shown in the table 23. The scales of importance according to the table 22 were made to weight the influencing factors. From the table 10 of pair wise matrix consistency index and consistency ratio are calculated as below for acceptance.

$$CI = \frac{(\lambda max - 1)}{n - 1}$$

Where

CI is consistency index

λmax Is lambda maximum where it value exceeds the number of factor in pair wise ranking and n is the number of factors

$$CI = \frac{(12.30103 - 1)}{11 - 1}$$

CI =0.130103703

$$CR = \frac{\mathrm{CI}}{RI}$$

Where CR is consistency ratio and RI is random consistency index, which will be taken as 1.51 from the table of (Wang et al., 2011).

$$CR = \frac{0.130103703}{1.51}$$

Therefore the value of CR= 0.08616139 shows that the level of inconsistency is acceptable. According to (L.Saaty, 1990), priorities given for the factors scaling from one to nine (1 to 9) is to get the weighted average for weighted overlay analysis. Therefore, weights of all factors after comparing with in pair wise matrix of the table 10 shows that elevation weighted 25%, rain fall is 17%, Temperatures is 14%, LULC is 11%, soil P^H is 10%, soil texture is 6%, soil drainage is 6%, soil depth is 4%, slope is 3%, road accessibility is 2% and market centers weighed 2%.

Table 10 Pair wise matrix of oil seed criteria

Factors	LULC	Rain fall	Temperature	altitude	soil depth	soil Drainage	soil P^H	soil texture	Slope	Road accessibility	Market centers
Elevation	1	3	3	3	3	5	5	5	7	7	9
Rain fall		1	3	3	3	3	3	3	5	7	7
Temperature			1	3	3	3	3	3	5	7	7
LULC				1	3	3	3	3	5	5	7
soil P^H					1	3	3	3	5	5	7
Soil drainage						1	3	3	5	5	7
soil texture							1	3	5	5	7
Soil depth								1	3	5	7
Slope									1	5	5
Road accessibility										1	5
Market centers											1

CHAPTER FOUR

4. Results and Discussion

4.1. Land use land cover classification (LULC)

Current land use and land cover is important to decide suitable land for agricultural activities. The process of land use and land cover classification is of two types that are supervised and unsupervised classifications. In this study, supervised classification method was used to extract land use and land cover type of the study area. The signatures were specified in ERDAS Imagine software using sentinel images of the year 2020. The signatures were assigned to extract current land use land cover as agricultural land, forestland, shrub lands, water body, grassland, bare lands and built up areas from the image. The classification comprises of three basic step which are training area, classification and statistics (Mason, 2016). Hence, signature extraction techniques were made to create the training site by creating statistical characterizations of each LULC. Finally, land use land cover classification with the assigned LULC classes was performed using maximum likelihood decision rule . With maximum likelihood classification algorithm, the software package judges the classes to which the pixels most probably belongs. Thus, the types of LULC and the percentages of each LULC of the area have been shown in table 11. Therefore, the study area consists of agriculture (25%) coverage, natural forest (12%), bush land (25%), grassland (29%), built-up areas (5%), bare land (2%) and the area covered by water body was 2% as shown in the table 9.

Table 11 land use land cover

S/N	LULC	area in hectare	percentage
1	Agriculture land	110088	25%
2	Built-up area	22017.6	5%
3	Forest land	52842.1	12%
4	Bare land	8807.02	2%
5	Shrub land	110088	25%
6	Grass land	127702	29%
7	Water body	8807.02	2%
Sum		440351	100%

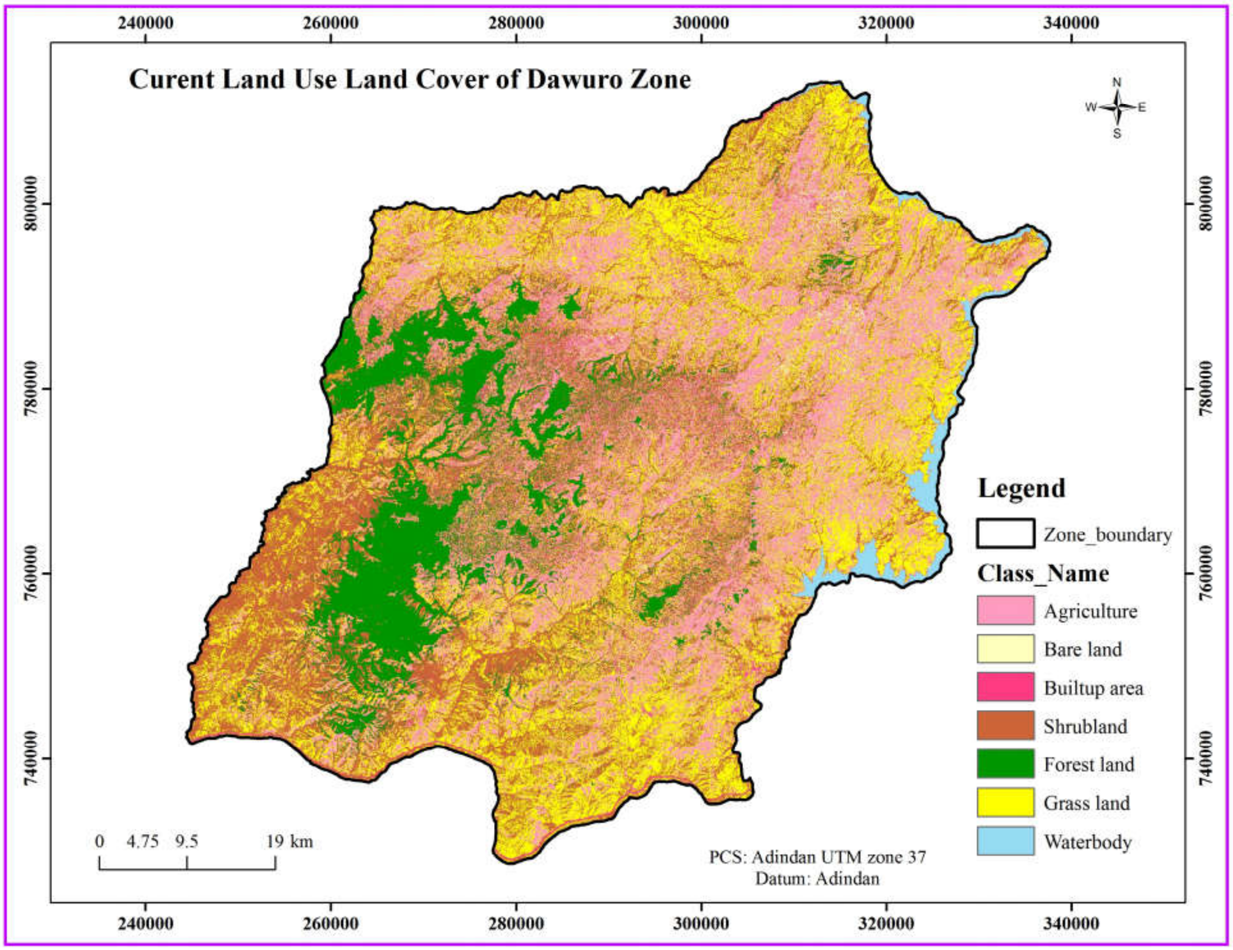


Figure 4 current land use land cover

Accuracy Assessment

Accuracy assessment is conducted to understand the quality of map information by identifying and assessing map errors (Congalton & Green, 1999). By using accuracy assessment the classified LULC map will be quantitatively assessed to check how effectively the pixels were sampled into the correct land cover classes (Rwanga & Ndambuki, 2017). In evaluating the classified image, table 29 the ground controlling (GCP) values were used. The most common accuracy assessment elements used to describe accuracy were overall accuracy, producer's accuracy, user's accuracy and kappa coefficient (Rwanga & Ndambuki, 2017). Thus, a thematic map of current land use land cover of the study area was derived as shown in figure 4 and a hypothetical error matrix for each class was done as shown in the table 9 below.

Table 12 Error matrix table year 2020

	water body	Forest	agriculture	bush land	built up area	grazing land	bare soil	total (user)
water body	33	0	0	4	0	0	0	**37**
Forest	0	78	1	1	0	0	0	**80**
agriculture	0	0	119	5	0	6	0	**130**
bush land	1	3	5	53	0	0	0	**62**
built up area	0	6	0	4	38	0	0	**48**
grazing land	0	2	0	0	0	45	0	**47**
bare soil	0	10		3	1	3	26	**43**
total (producer)	**34**	**99**	**125**	**70**	**39**	**54**	**26**	**447**

Therefore, the overall accuracy, producer's accuracy, user's accuracy and kappa coefficient calculated as below.

$$\text{Over all accuracy} = \frac{(\text{total number of correctly classified pixels in the table diagonally})}{\text{the total number of pixels of the reference data (row total)}} \quad \text{Equation 1}$$

$$\text{Over all accuracy} = \frac{(392)}{447} \text{X } 100$$

$$\text{Over all accuracy} = 87.69\%$$

The result 87.69% showed that it achieved the target accuracy level for thematic mapping via an image classification was an accuracy of > 85% (Wulder et al., 2006). The producer accuracy for each class in the column and the user accuracy for each class in the row were calculated as follows.

$$\text{Producer accuracy} = \frac{(\text{number of correctly classified pixels in each category})}{\text{the total number of pixels of the reference data (column total)}} \text{ ----Equation 2}$$

$$\text{The user accuracy} = \frac{(\text{number of correctly classified pixels in each category})}{\text{the total number of pixels of the reference data (row total)}} \text{ ---- Equation 3}$$

Table 13 Producer and user accuracy year 2020

	water body	Forest	agriculture	bush land	built up area	grazing land	bare soil	total (user)	user accuracy
water body	33	0	0	4	0	0	0	**37**	89%
Forest	0	78	1	1	0	0	0	**80**	98%
agriculture	0	0	119	5	0	6	0	**130**	92%
bush land	1	3	5	53	0	0	0	**62**	85%
built up area	0	6	0	4	38	0	0	**48**	79%
grazing land	0	2	0	0	0	45	0	**47**	96%
bare soil	0	10		3	1	3	26	**43**	60%
total (producer)	**34**	**99**	**125**	**70**	**39**	**54**	**26**	**447**	
producer accuracy	97%	79%	95%	76%	97%	83%	100%		
Sum of Correctly classified pixels (diagonal)	**392**								
over all accuracy	87.69%								

$$Kappa\ coefficient = \frac{N(\sum_{i=1}^{r} Xii) - ((\sum_{i=1}^{r}(Xi+.X+1))}{(N^2) - ((\sum_{i=1}^{r}(Xi+.X+i))}$$

Where, r = number of rows in error matrix

Xii = number of observations in the row i, and column i(diagonal)

Xi+ = total of the observation in the row i,

X+i = total of the observation in the column i,

N = total number of the observation included in the matrix

$$= \frac{(392 * 447) - ((34 * 37) + (99 * 80) + (125 * 130) + (70 * 62) + (39 * 48) + (54 * 47) + (26 * 43))}{(447 * 447) -)}$$

$$= \frac{(175224) - (139928)}{(199809) - 139928)}$$

$$\frac{35296}{59881} * 100$$

$$Kappa\ coefficient = \underline{58\%}$$

4.2. Topographic parameters

Among the topographic parameters, altitude and slopes are very influential parameters for agricultural activities. Therefore, the Slope and elevation ranges were generated from Digital Elevation Model (DEM) of ASTER image for oil crop suitability.

1. **Slope classes**

Flat or level land is preferable in terms of agricultural activities. Thus, the study area has been classified as shown in the table 14 according to (Grima & Kenate, 2017) used for capability classification for agricultural use.

Table 14 slope classes of Dawro zone

s/N	Slope classes	Area in hectare	percentage
1	0-3%	4046.44	1%
2	3-8%	22684.4	5%
3	8-15%	59185.1	13%
4	15-30%	152064	35%
5	30-50%	128181	29%
6	>50%	74189.2	17%
Total		440351	100%

As shown in the table 11, the slope class greater than 15% covers 81% of the area. Thus, according to the guidelines for soil description (FAO, 2006), major areas of Dawro zone was covered by the slope classes from moderately steep to very steep slopes. The slope classes from flat to gently sloping covered the rest 19% of the area.

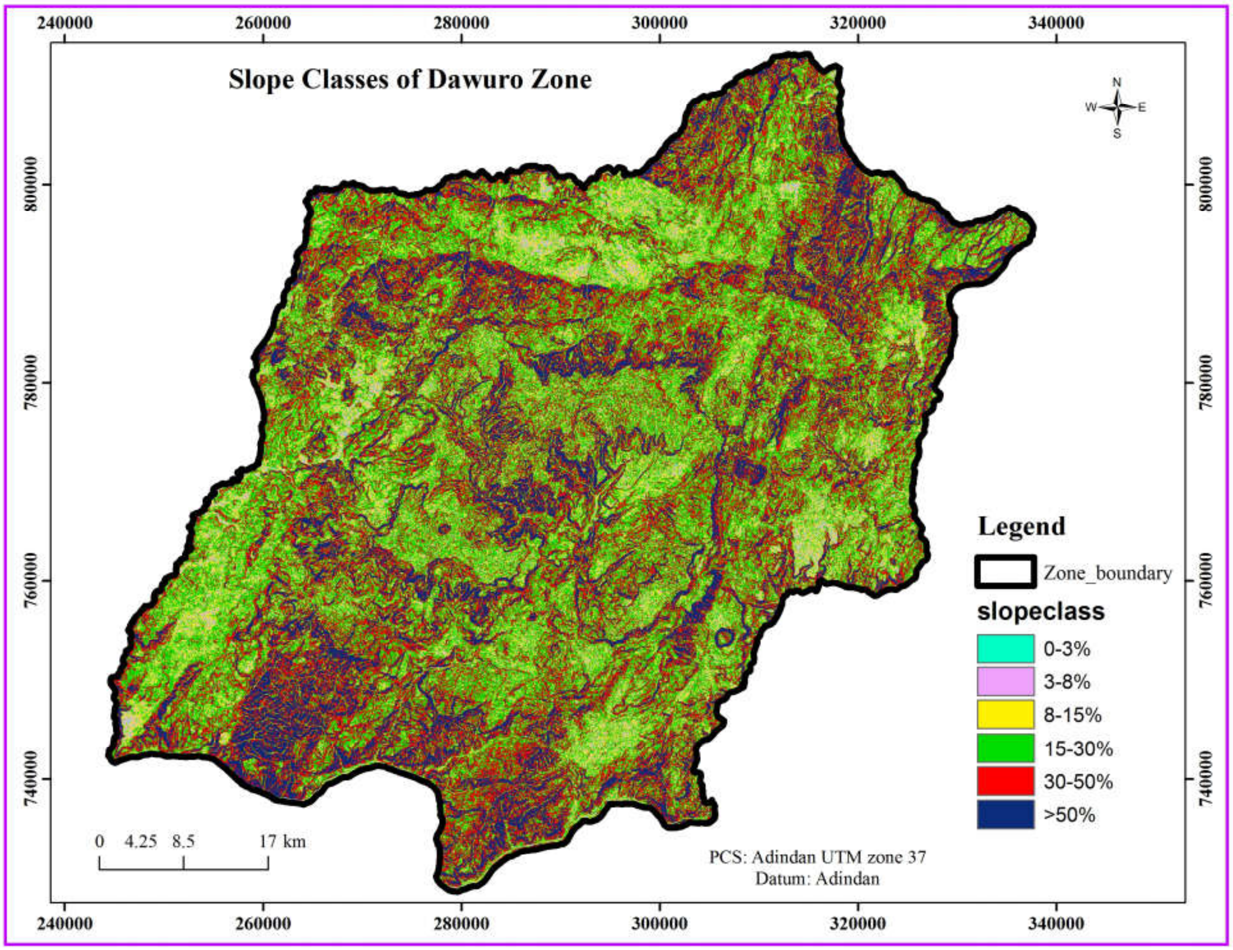


Figure 5 Slope Classes of Dawro Zone

2. Elevation ranges

The elevation ranges for the crops niger, flax and sesame in this study were identified according to the tables 15, 16 and 17 respectively, as all crops are grown in different agro ecologies, but not in all highlands.

Table 15 elevation ranges of niger crop

crop name	elevation ranges	suitability order	area in hectare	coverage in percentage
niger	<1100	4	92873.1	21%
niger	1100-1500	2	140410	32%
niger	1500-2000	1	141713	32%
niger	2000-2400	3	57247.7	13%
niger	>2400	4	8107.2	2%
			440351	100%

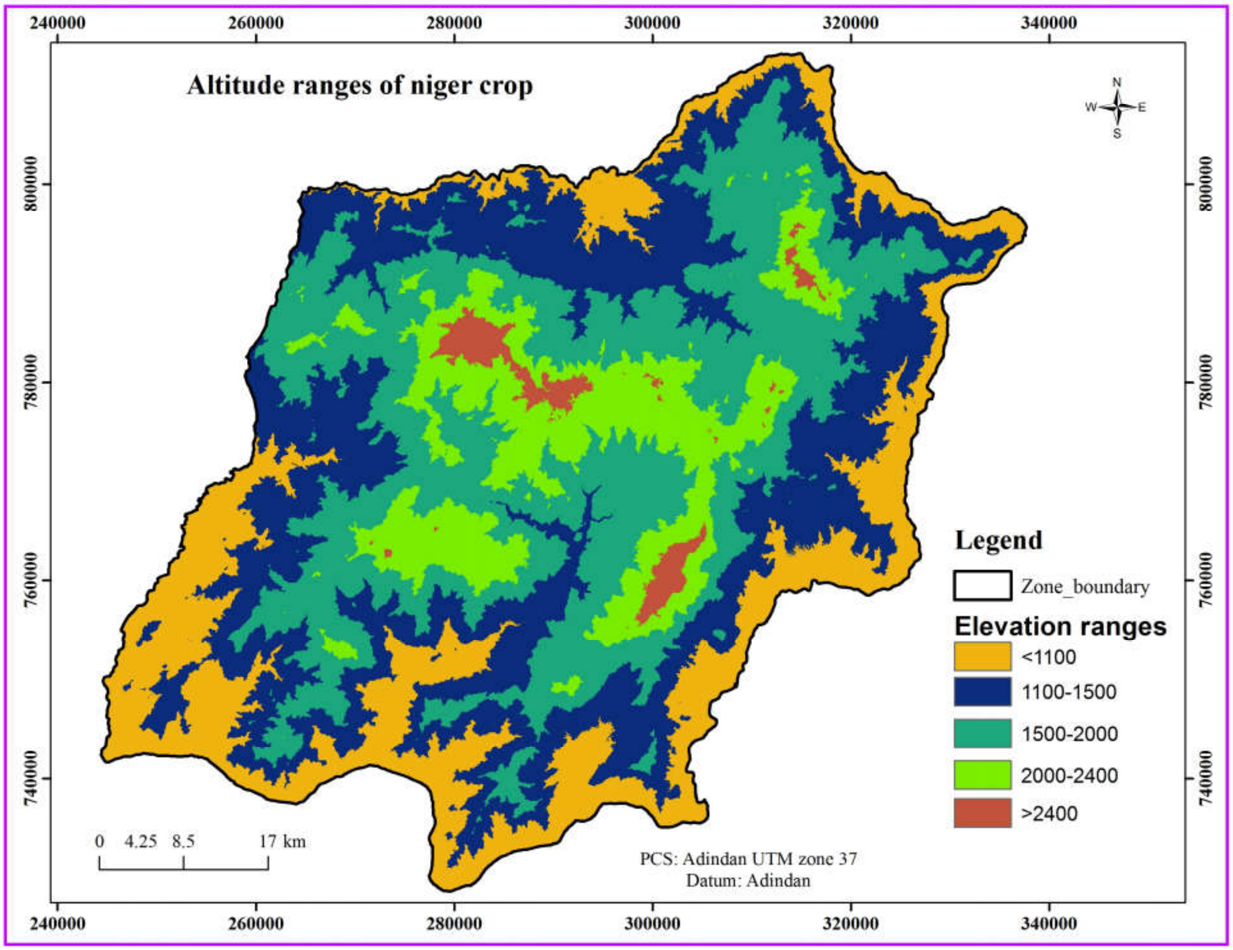


Figure 6 Elevation ranges of niger crop

Elevation ranges of flax crop

Table 16 elevation ranges for flax crop

crop name	elevation ranges	suitability order	area in hectare	coverage in percentage
flax	<770	4	13596.2	3%
flax	770-1500	3	219687	50%
flax	1500-2000	1	141713	32%
flax	2000-2400	3	57247.7	13%
flax	>2400	4	8107.1	2%
			440351	100%

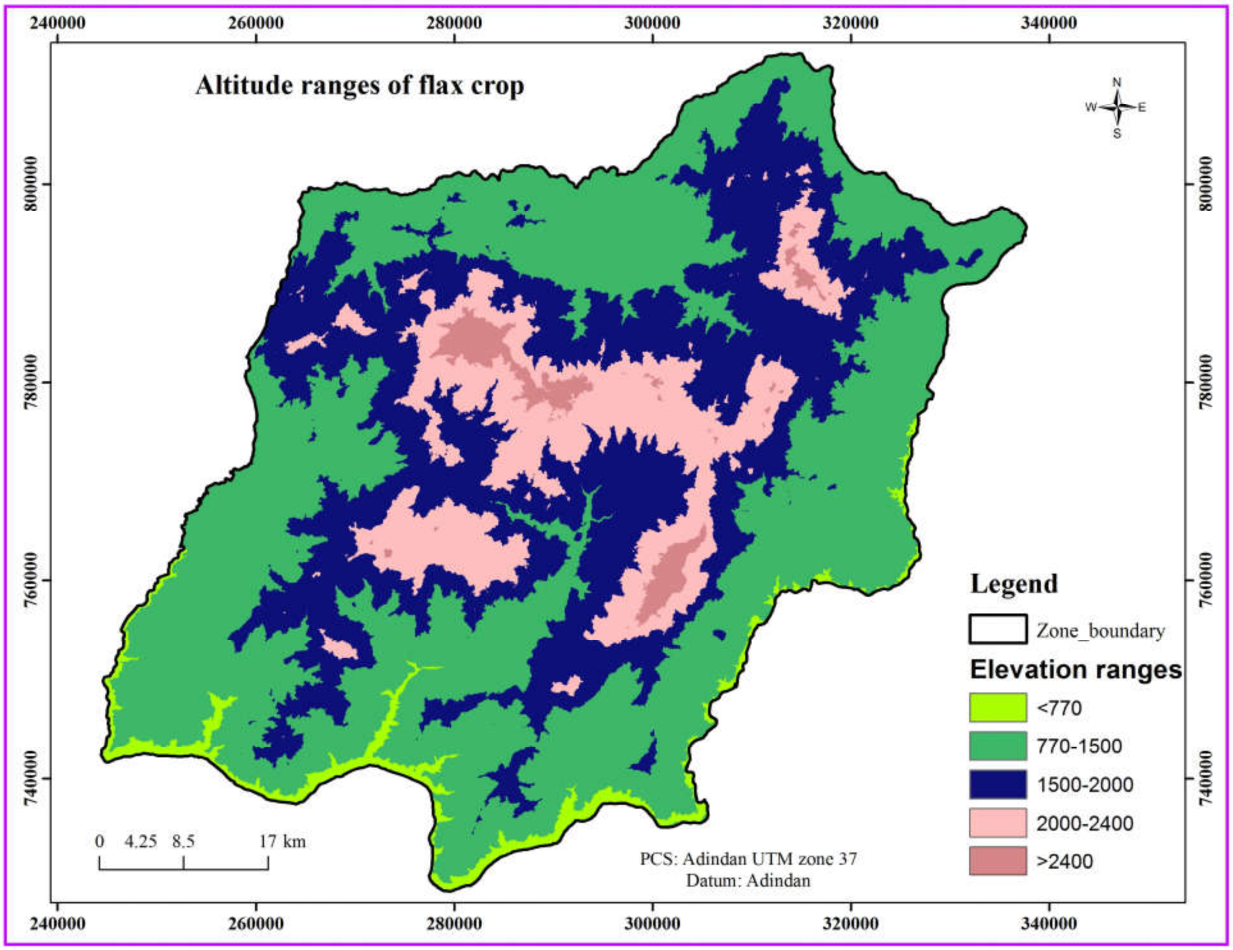


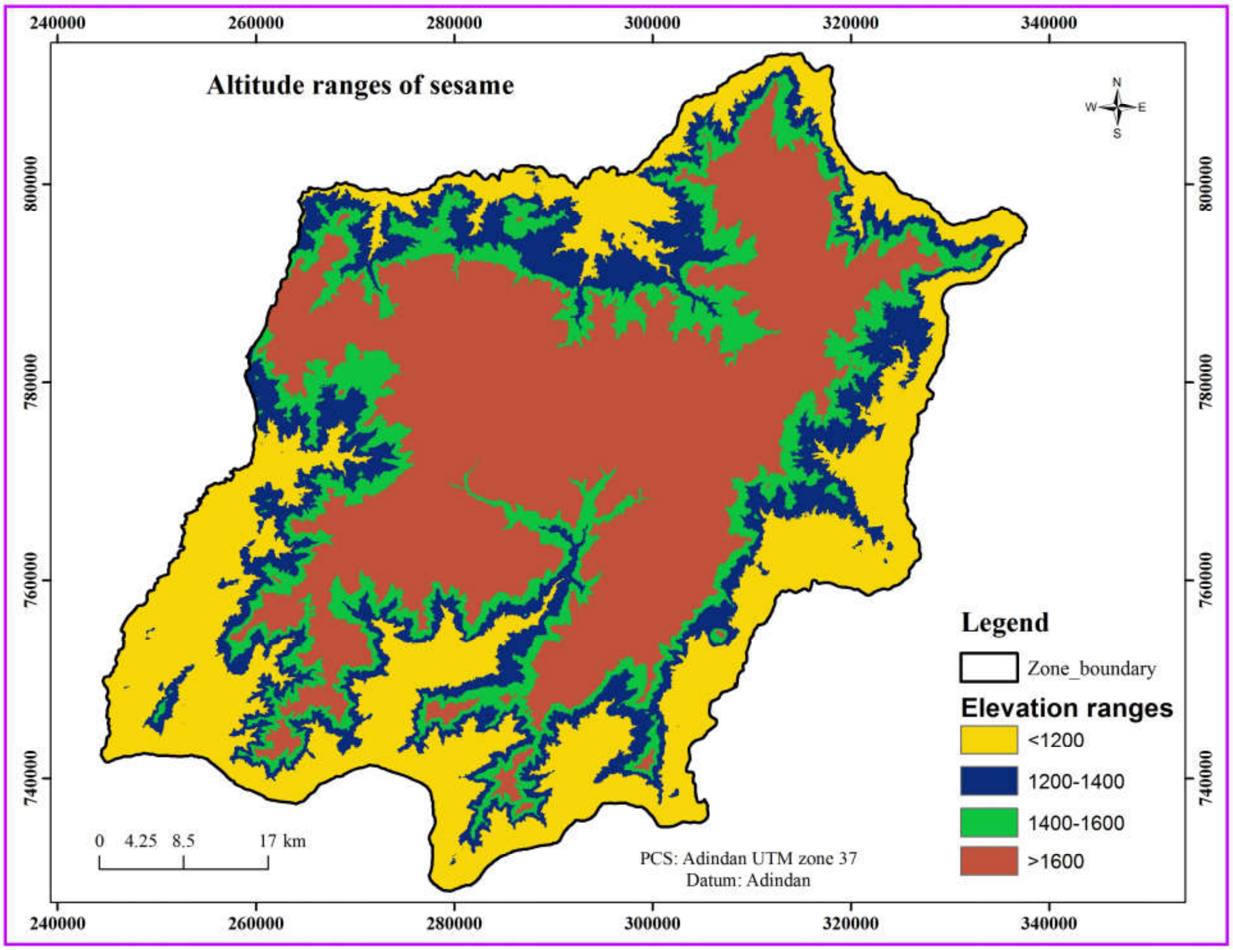
Figure 7 Elevation ranges of flax

Elevation ranges of Sesame crop

Table 17 elevation ranges of sesame

crop name	elevation ranges	suitability order	area in hectare	coverage in percentage
sesame	<1200	1	127541	29%
sesame	1200-1400	2	71662	16%
sesame	1400-1600	3	65656	15%
sesame	>1600	4	175492	40%
			440351	100%

Figure 8 Elevation ranges of sesame



4.3. Soil parameters

Soil is one of the most important and determinant factor for land suitability evaluation of agricultural crops. Soil parameters determine the suitability of crops in one place. Among the soil parameters, soil depth, soil texture and soil PH are the main soil factors that limit the crop suitability growing in crop production (El-Aziz, 2018). In terms of soil, soil having silty clay loam and sandy loam soils, soils having depth from shallow to deep soil depth, and well to moderately well-drained soil is ideal for oilseed production.

1. Soil type

Soil type will influence crop cultivation because different crops prefer different soils. According to (Schiefer et al., 2016) the soil groups in table 18 namely andosols, luvisols, acrisols and vertisols found at good soil depth more than 60cm. The Cambisol soil group found at medium soil depth between 30 and 60 cm where as the Leptosols found at lower altitudes with soil depth less than 30cm.

Table 18 soil types

S/N	soil type	Soil Group	area in hectare	percentage
1	vitric andosols	Andosols	22017.55	5%
2	vertic cambisols	Cambisol	40913.66	9%
4	Leptosols	Leptosols	123298.28	28%
5	vertic luvisols	Luvisols	171736.89	39%
6	orthic acrisols	Acrisols	74859.67	17%
7	pellic vertisols	Vertisols	8807.02	2%
	Sum		440351	100%

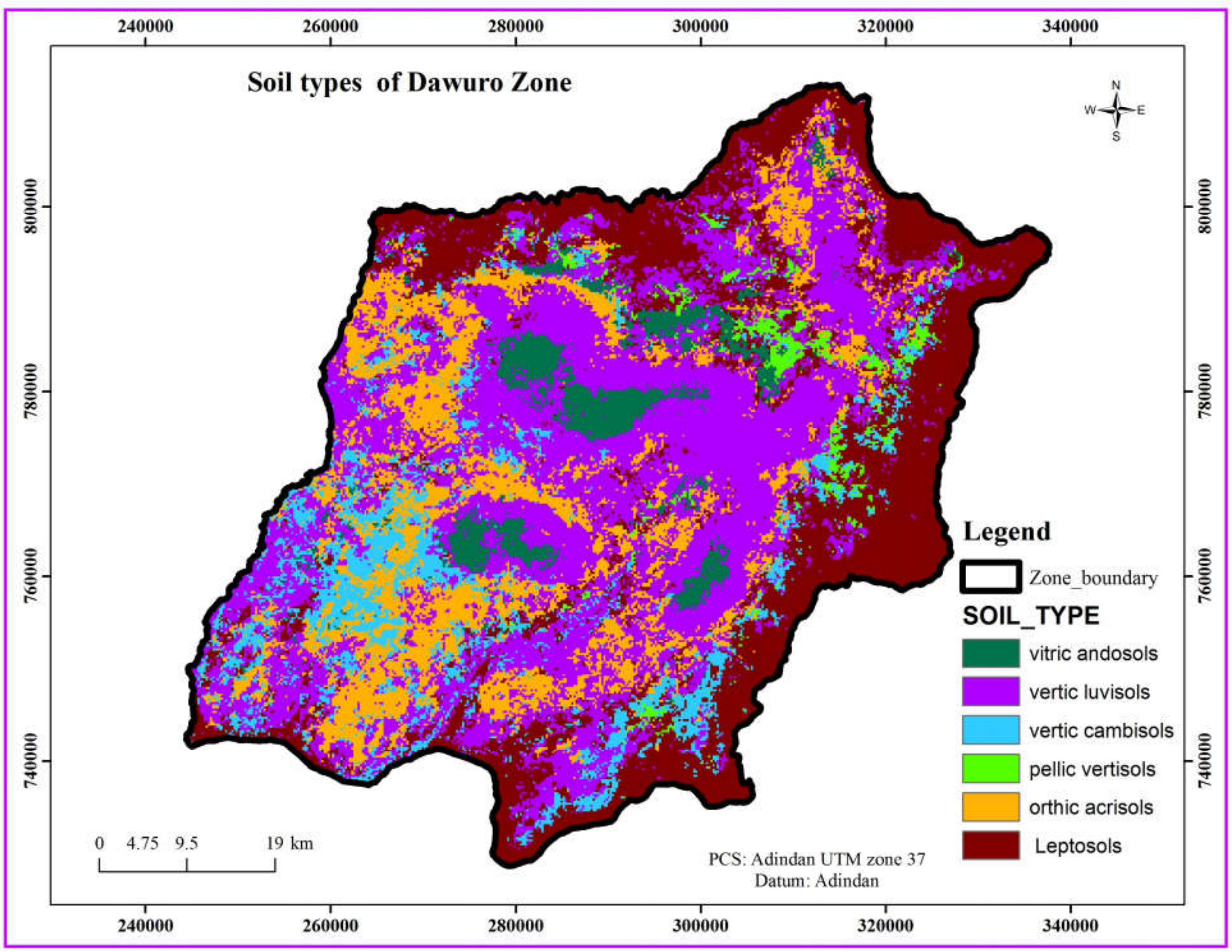


Figure 9 Soil types of Dawro Zone

2. Soil P^H

There is a direct effect of soil P^H on plant growth, regulates nutrient availability and microorganisms activity. Thus, the suitability of crops vary with P^H (Suarau Odutola Oshunsanya, 2018), (Harsh, 2017). The ranges of soil p^H in the study area have been shown in table 19.

Table 19 soil p^H

S/N	P^H	acidity classes	suitability	area in hectare	percentage
1	5.1-5.5	strongly acidic	S3	96877.2	22%
2	5.6-6.0	moderately acidic	S2	110088	25%
3	6.1-6.5	slightly acidic	S1	118895	27%
4	6.6-7.3	Neutral	S2	74859.7	17%
5	7.4-7.8	slightly alkaline	N1	35228.1	8%
		Sum		440351	100%

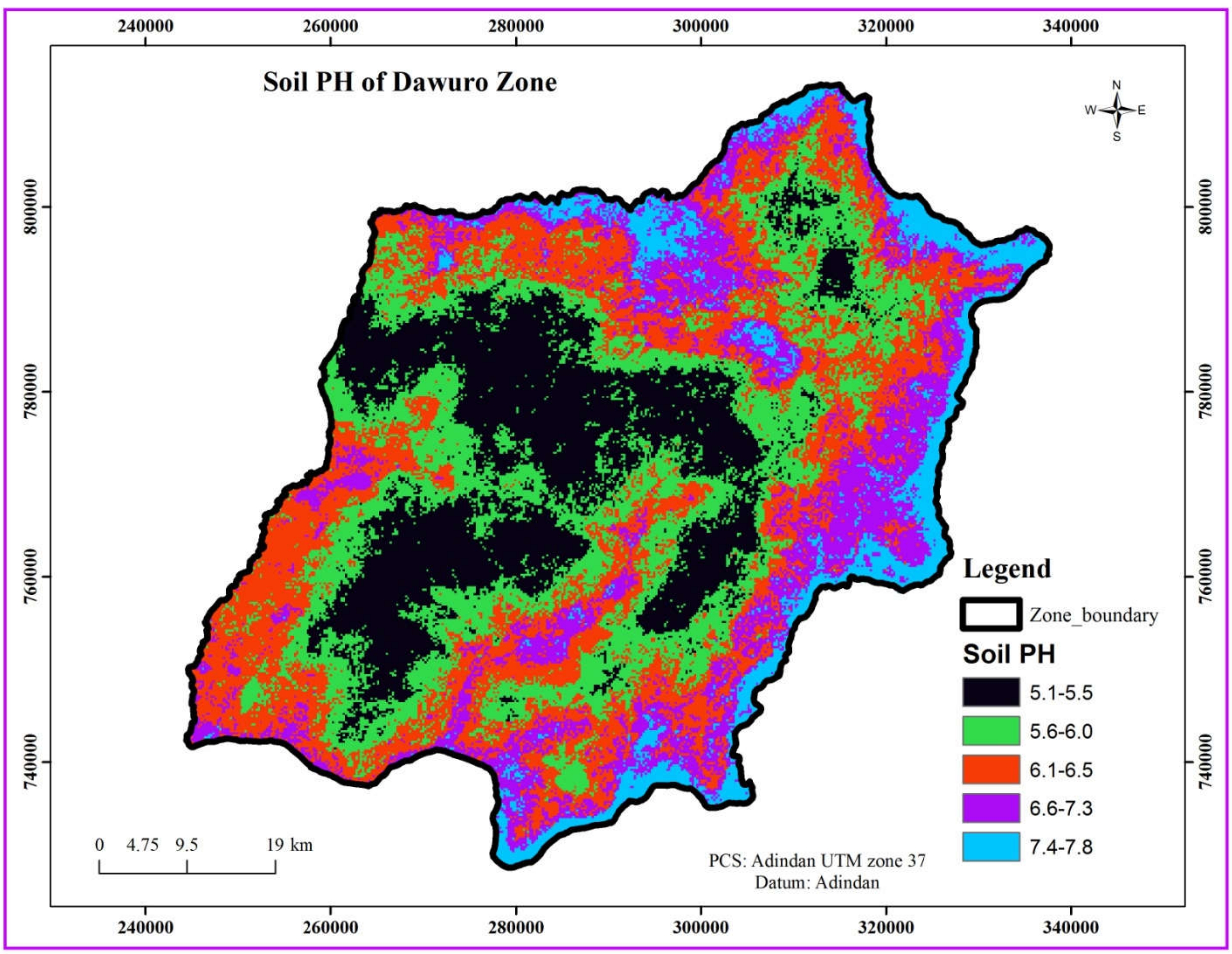


Figure 10 soil PH

3. Soil depth

Soil depth defines the root space and the volume of soil from where the plants fulfill their water and nutrient demands. According to (El-Aziz, 2018), crop suitability depends on soil depth and other soil factors. The soil depth facilitates the water storage at crop root depth. Accordingly, table 20 showed that 57% the study area covers soil depth greater than 50cm which is moderately deep to deep soil as classified as (Grima & Kenate, 2017) which is also crop exploitable depth (Arrouays et al., 2014) . The remaining 43% covered shallow depth that is bounded between 25-50 cm.

Table 20 soil depth

S/N	soil depth class	area in hectare	percentage
1	25-50	189351	43%
2	>100	127702	29%
3	50-100	123298	28%
	Sum	440351	100%

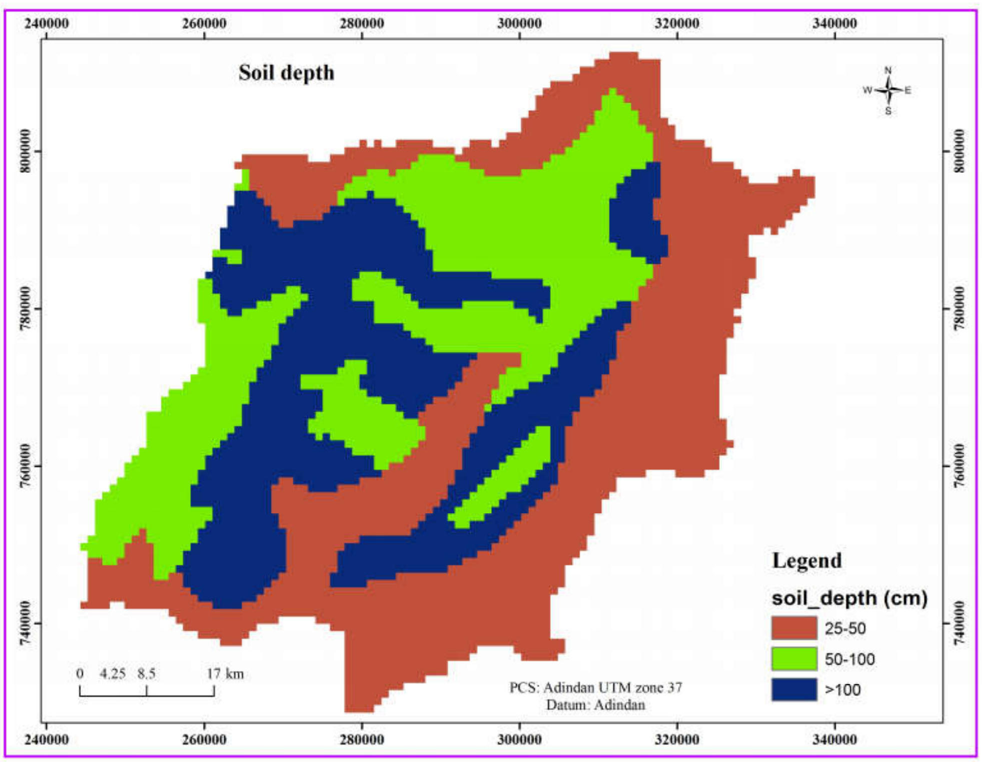


Figure 11 soil depth

4. Soil drainage

Soil drainage is a natural process in which water movement takes place in the soil where air movement also takes place when water leaves the soil (Fuasey, 2005). According to (USDA, 1993), drainage classes found in the area are moderately well drained and well drained classes covering the area 43% and 57% respectively. Well-drained soils are those soils with available water throughout growing seasons.

Table 21 soil drainage

S/N	drainage	suitability	Area in hectare	percentage
1	M		251000	57%
2	W		189351	43%
	Sum		440351	

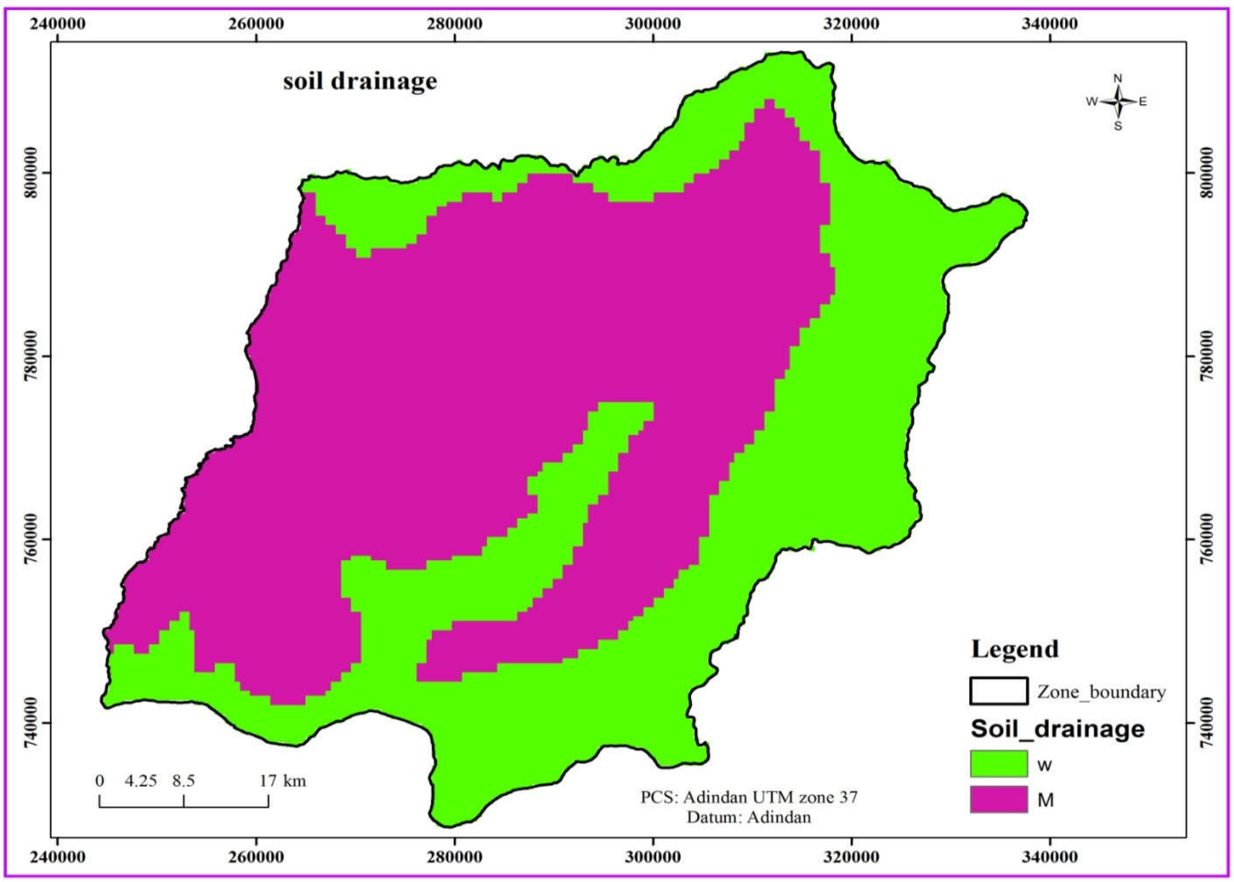


Figure 12 soil drainage

5. Soil texture

The soil structure and functioning is controlled by soil particle size distribution(Martín et al., 2017). The table 22 showed that loamy sand and sandy loam covered 43% of the total coverage. The clay loam and loam soil covered 37% where as 20% of the total coverage was silty clay loam.

Table 22 soil textural classes

S/n	Texture_ Class	area_ ha	percentage
1	Clay loam, Loam	163205	37%
2	Silty clay loam,	89483	20%
3	Sandy L, Loamy sand	187663	43%
		440351	100%

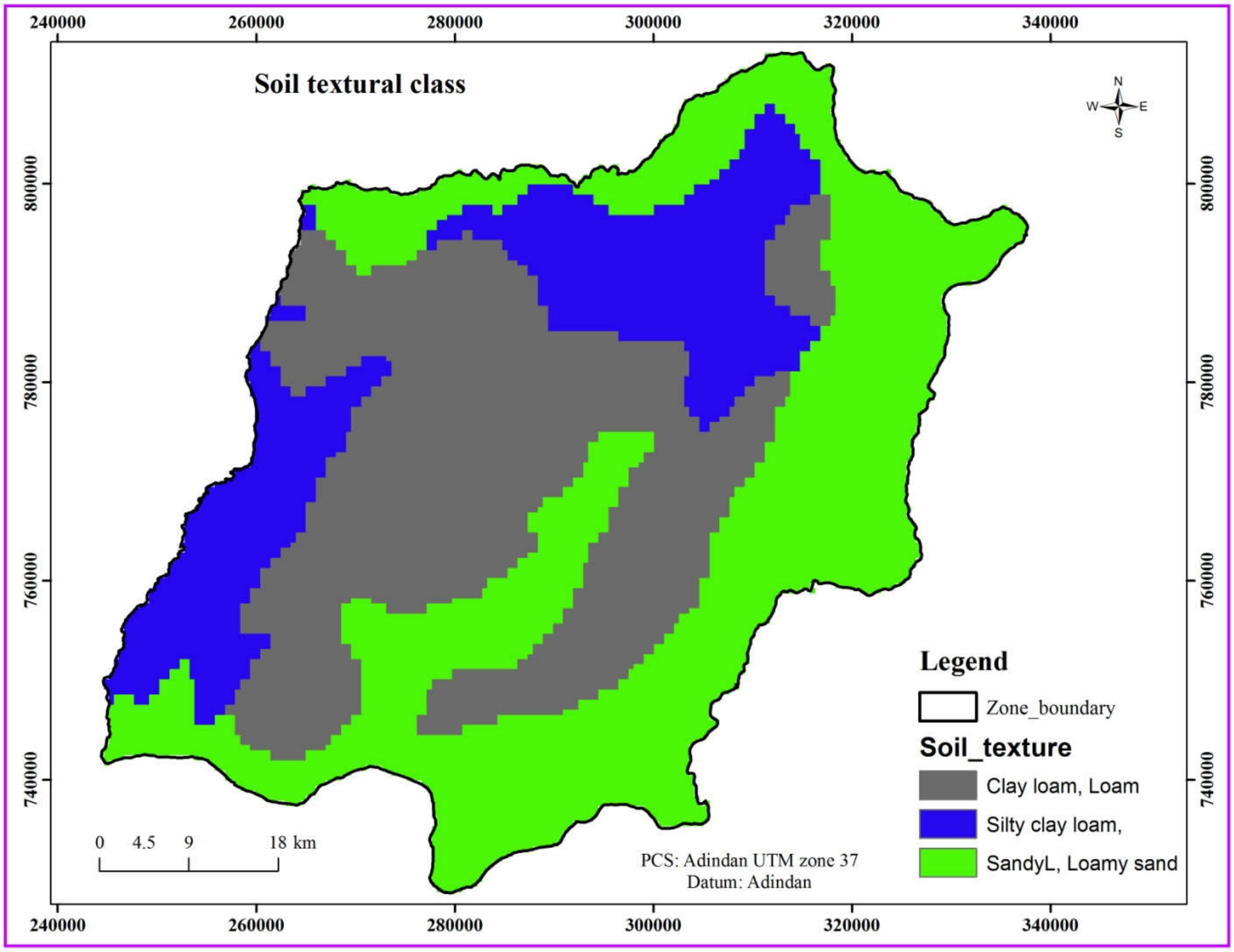


Figure 13 soil textural classes

4.4. Socioeconomic factors (Road and market accessibility)

The availability of road infrastructure and shopping malls plays an important role in transporting agricultural products to the market centers.

1. Road suitability

Road is the major access to transport agricultural production and to transport different input to connect with market centers in economic development. While it is not the first and most important way in giving more attention to road accessibility to produce any agricultural product, it is preferable to look for road accessibility in the area.

Thus, the road accessibility for the selected crops has been calculated using Euclidean distances from the existing roads. According to (Fungo et al., 2017) the People reside close to the road can easily access to the market with their crop productions, however the farmers far away from the road access can benefit less. Therefore, 46% the study area was far away 4km, which was taken as marginally to not suitable as shown in the table 23.

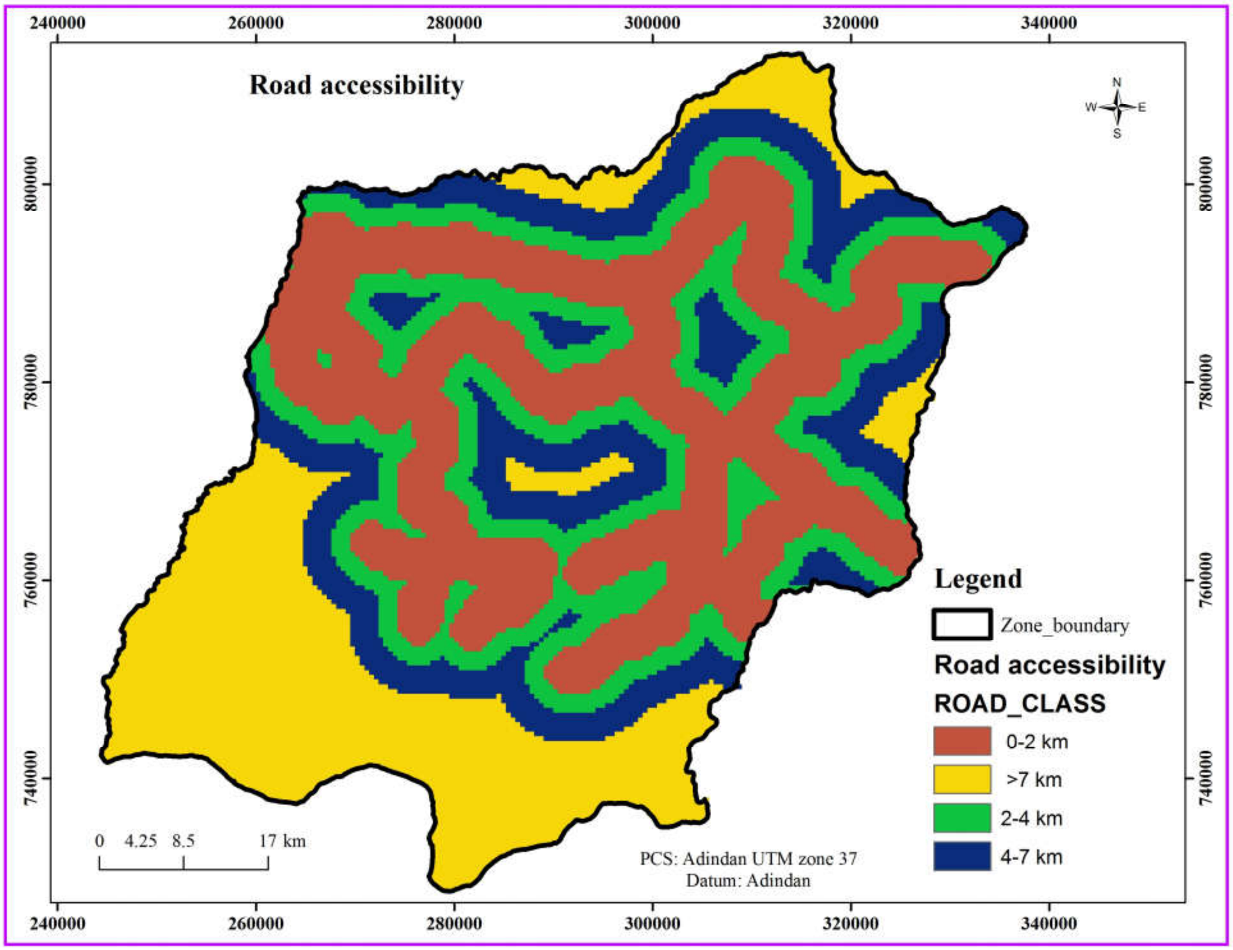


Figure 14 Road accessibility

To identify the suitability of distances from the road, distance raster were processed by using Euclidean Distance as shown in table 23. Thus, the table shows that 33% of the area was highly suitable for oil crops. The remaining 21%, 18% and 28% were moderately, marginally and not suitable respectively.

Table 23 Road accessibility

S/N	Road classes	road suitability	area in hectare	percentage
1	0-2 km	1	145316	33%
2	2-4 km	2	92473.7	21%
3	4-7 km	3	79263.2	18%
4	>7 km	4	123298	28%

Total	440351	100%

2. Market suitability

According to (Fadairo & Olutegbe, 2018) markets can play major roles in facilitating and sustaining rural urban linkages. The market access is essential in the identification of the places where agricultural products will be sold. It was important to assess the accessibility of market centers in study area for selected crop to connect with developmental activities where farmers can benefit from the crop productions. Village market centers were identified with GPS to select suitable areas for oil crops. Thus, as shown in table 24, moderately and marginally suitable area covers 30% and 37% respectively.

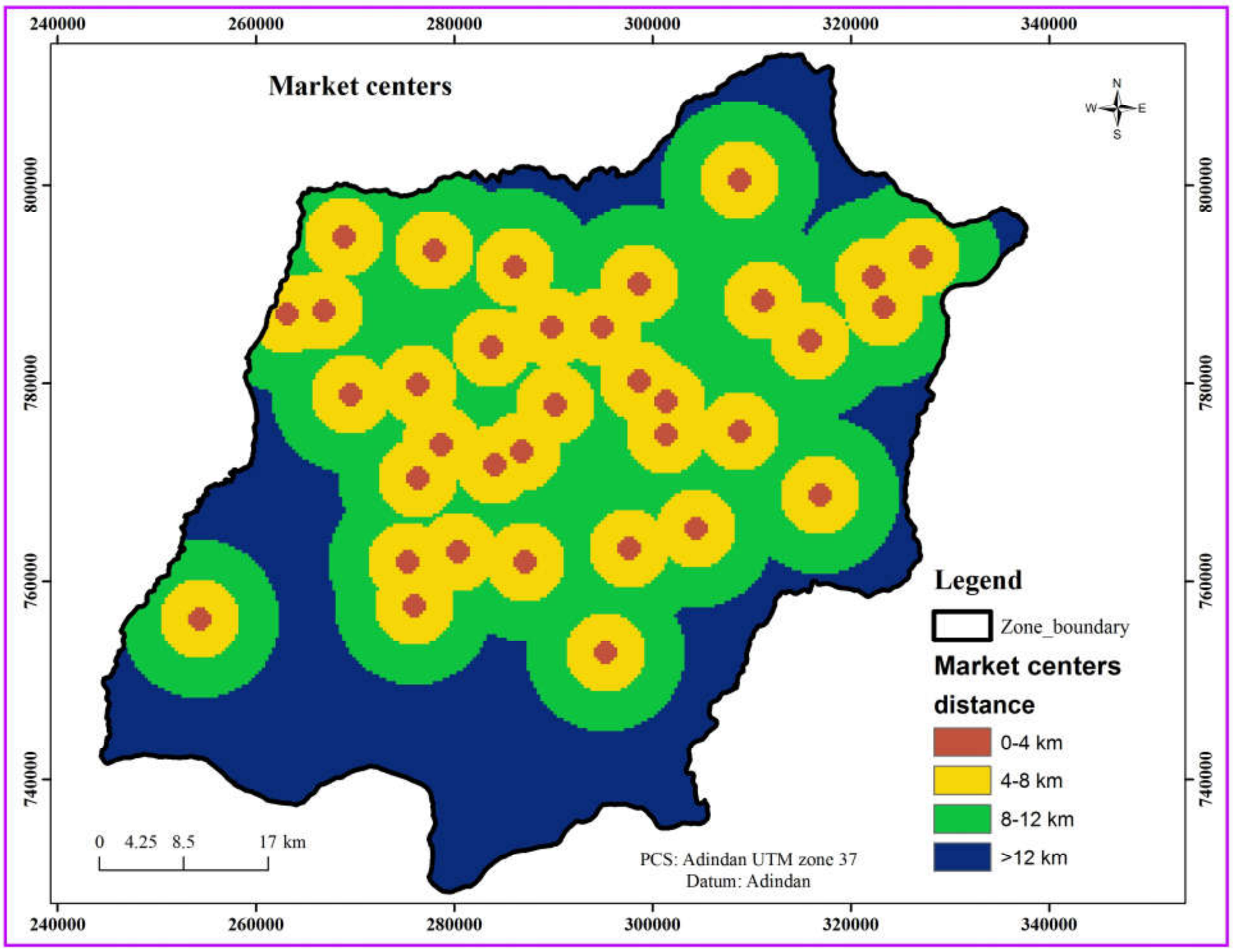


Figure 15 Market centers

Table 24 Market accessibility

S/N	distance in km	market suitability	area in hectare	Percentage
1	0-4 km	1	14813.5	3%
2	4-8 km	2	133931	30%
3	8-12 km	3	163714	37%
4	>12 km	4	127894	29%
	Total		440351	100%

4.5. Climatic factors

Climate is the major physical factor in controlling agricultural land use (Prakash et al., 2007). Among the climatic factors, rainfall and temperature can determine the types of crops that can be produced in a given location. Thus, the combined effect of the two climatic factors such as precipitation and temperature presents a range of favorable growing conditions for various major crops and determines the location of crops (Baker, N.T., and Capel, 2011). Therefore, rainfall and temperature conditions in the Dawro zone has been shown in figure 16.

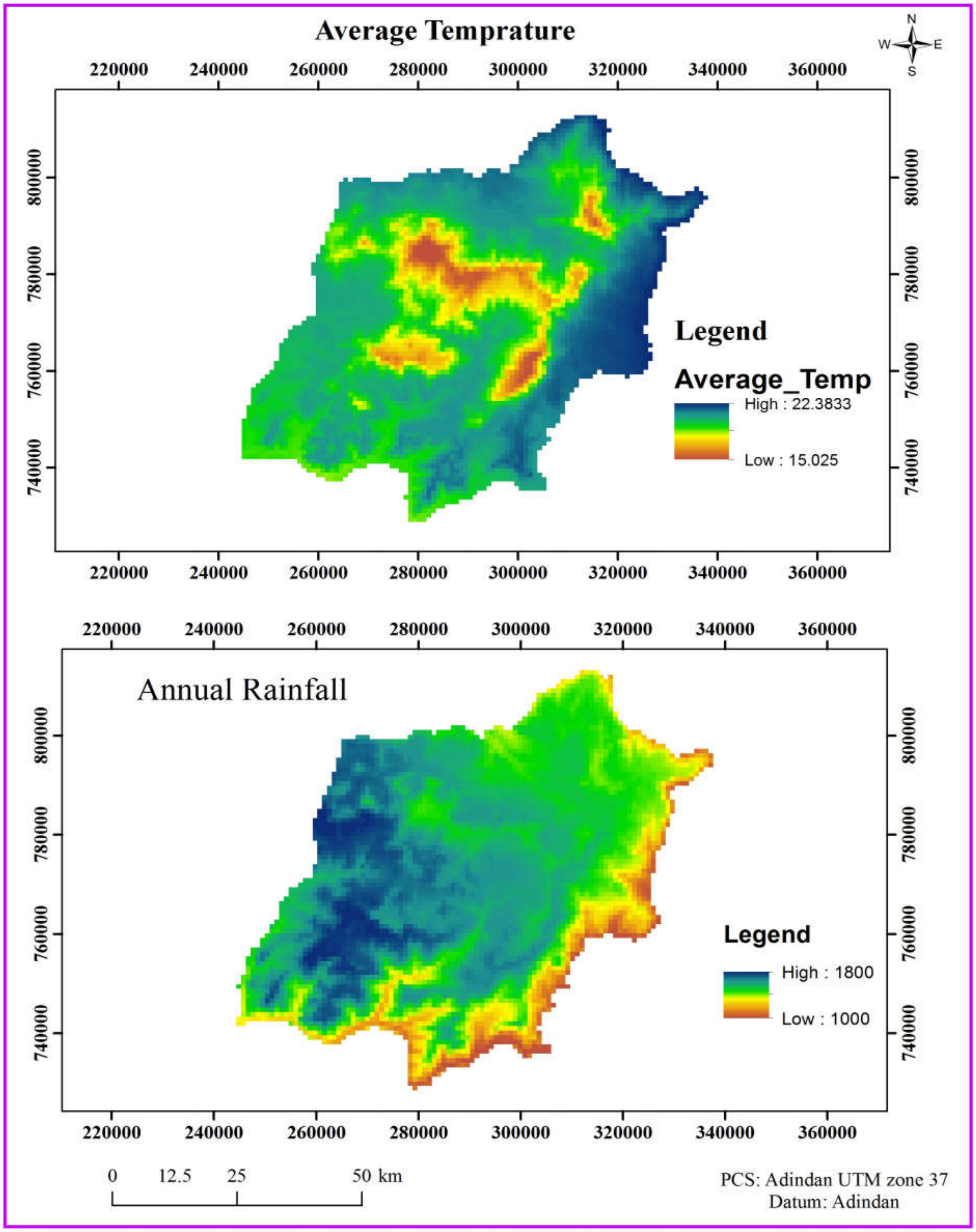


Figure 16 Climatic factors

4.6. Weighted Overlay analysis

A geographic problem often requires analysis of many different factors using GIS. Spatial Multi-Criteria Analysis (Weighted Overlay) is the most commonly used method in Land suitability evaluation, hence, the MCD procedure was conducted in this study. Overlay operation is part of spatial analysis processes based on the value of weights of each subclass within each thematic map. A weighted overlay will combine all factor layers into new information to produce individual value for each pixel and a new map was produced(Hezan, 2010.) The weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. For instance, finding suitable land for crops requires the weighting of topographic factors, soil parameters, land use, climatic parameters, and socioeconomic parameters (Yang Yi, 2003). The paired wise comparison was made by using the scales from 1 to 9 as shown in the table 10 (Atanasova–Pachemska et al., 2014), (Mathur, 2015)).

According to (Janssen and Rietveld, 1990), weighted overlay only accepts integer raster's as input. Therefore, the input raster of elevation ranges, slope classes, soil depth, soil PH, soil drainage, land use, precipitation, temperature and Euclidean distances of socioeconomic parameters (roads and markets locations) brought into weighted overlay function in GIS to get the expected suitable land. The parameters and the scale values assigned for each crops (niger, flax and sesame) with their subclasses used in final weighted overlay was shown in appendix table 34, 35 and 36 respectively. The final output map of the three-selected oil seeds were shown in the figure 17, 18 and 19.

4.7. Land suitability for oil crops

For countries like Ethiopia where their economy is based on agriculture, it is expected to work extensively in the development of oilseeds. With this study, GIS based research in identifying suitable cultivable land to meet oil seed production and linkage with the market opportunities as discussed by (Fila et al., 2018). As described in chapter three, a weight was made for soil properties, topographic factors, climatic and socioeconomic factors in MCDM for this specific study. These factors were LULC, elevation, rainfall, temperature, soil depth, soil drainage, soil PH, soil texture, slope percentage, road accessibility, and market center distances. Thus, the weighted overlay analysis was made in Arc GIS spatial analyst tool.

Topographic parameters like elevation ranges, seasonal cover, soil requirements, and weather conditions were all important factors in the study. However, parameter like the slope of the land was taken to have a low impact in considering the land can be leveled for farm practices by using various soil leveling machines. Similarly, road distances and market center accessibility were taken into lower weights.

Table 25 suitable land oil crops

S/n	Suitability	Crop					
		niger		Flax		Sesame	
		area in ha	percentage	area in ha	percentage	area in ha	percentage
1	Restricted area	79053.2	18%	79053.2	18%	79053.2	18%
2	Highly suitable	19059	4%	46021.2	10%	5708.75	1%
3	Moderately suitable	280819	64%	252207	57%	231600.1	53%
4	Marginally suitable	61420	14%	63069.4	14%	123989	28%
Total		440351.2	100%	440351.3	100%	440351.1	100%

Thus, as indicated in table 25 the study found that proportion of highly suitable for niger, flax, and sesame crops were 4, 10, and 1 percent respectively. Moderately suitable land for niger, flax and sesame were 64%, 57% and 53% respectively. Marginally suitable land for niger, flax and sesame crops were 14%, 14% and 28% respectively. On the other hand, 79053.2 hectare that was 18% of the study area which was the land covered by forestland, built-ups and water body restricted during the suitability analysis.

1. Suitable land for niger crop

The land which was potentially highly suitable for niger crop was 19059 hectare that covers 4% of the study area. The area that was highly suitable for the niger crop had moderately deep soil with soil pH 5.6 – 7.3 and favorable climatic conditions with rainfall range between 1100-1500 mm.

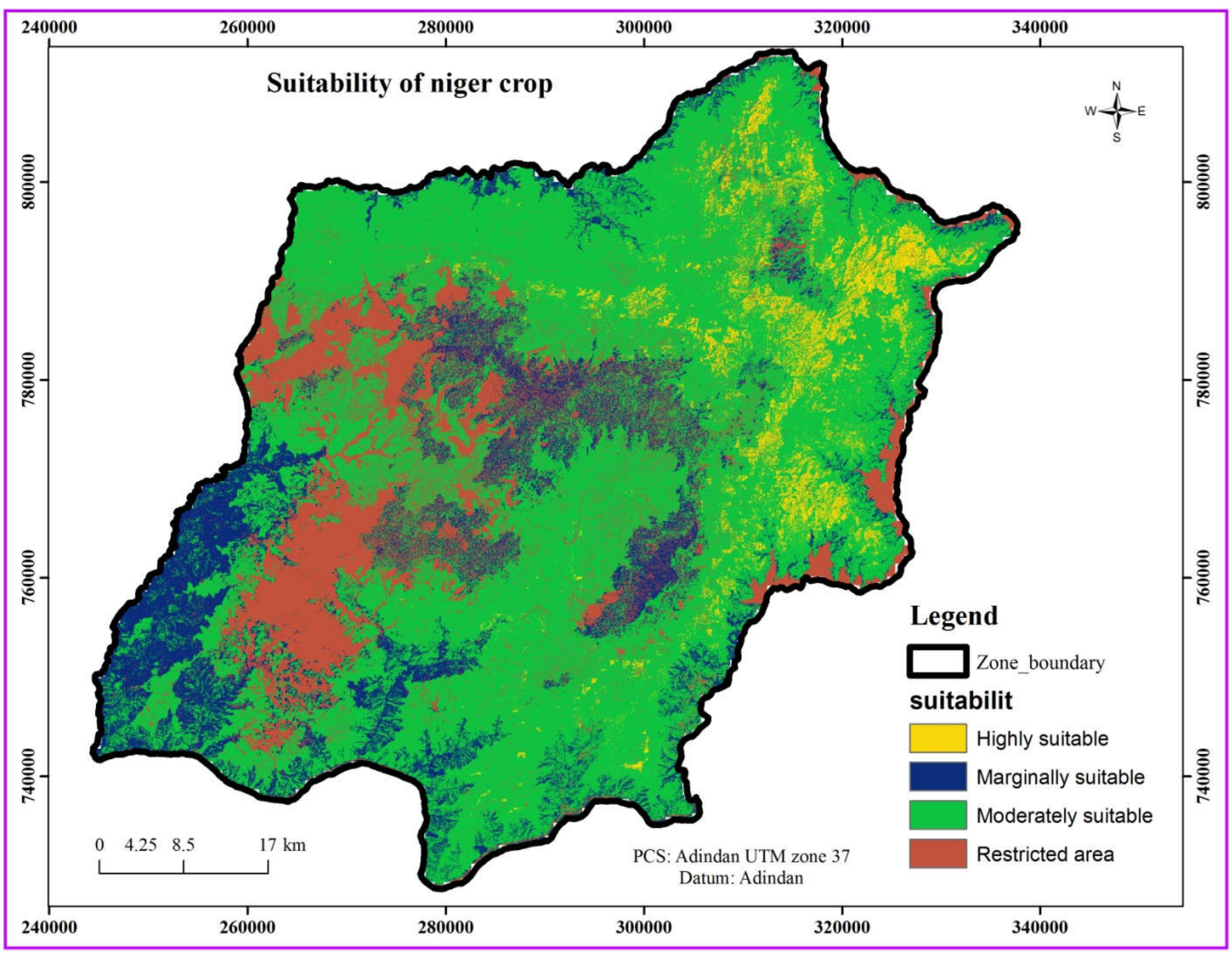
Table 26 Suitable land for niger crop

S/n	**Suitable land for niger crop**					
		Restricted area	Highly	Moderately	Marginally	sum

			suitable	suitable	suitable	
1	area in hectare	79053.2	19059	280819	61420	440351
2	percentage	18%	4%	64%	14%	100%

Hence, the study area had favorable growing conditions with topographic, soil requirements, and climatic requirements according to (Gogoi, 2019). The area under moderately suitable class covered 64% of the study area characterized by clay loam, silty clay loam, loam , and sandy loam soil texture whereas 14% of the study area that was marginally suitable land had clay loam and silty clay loam soil texture and characterized by soil pH value 5.1-5.5 and 6.1-6.5. However, according to the annual reports of the Dawro zone agriculture and natural resource department, the practice in oilseed crops was low and needs improvement.

Figure 17 suitability map of niger seed



2. **Suitable land for flax**

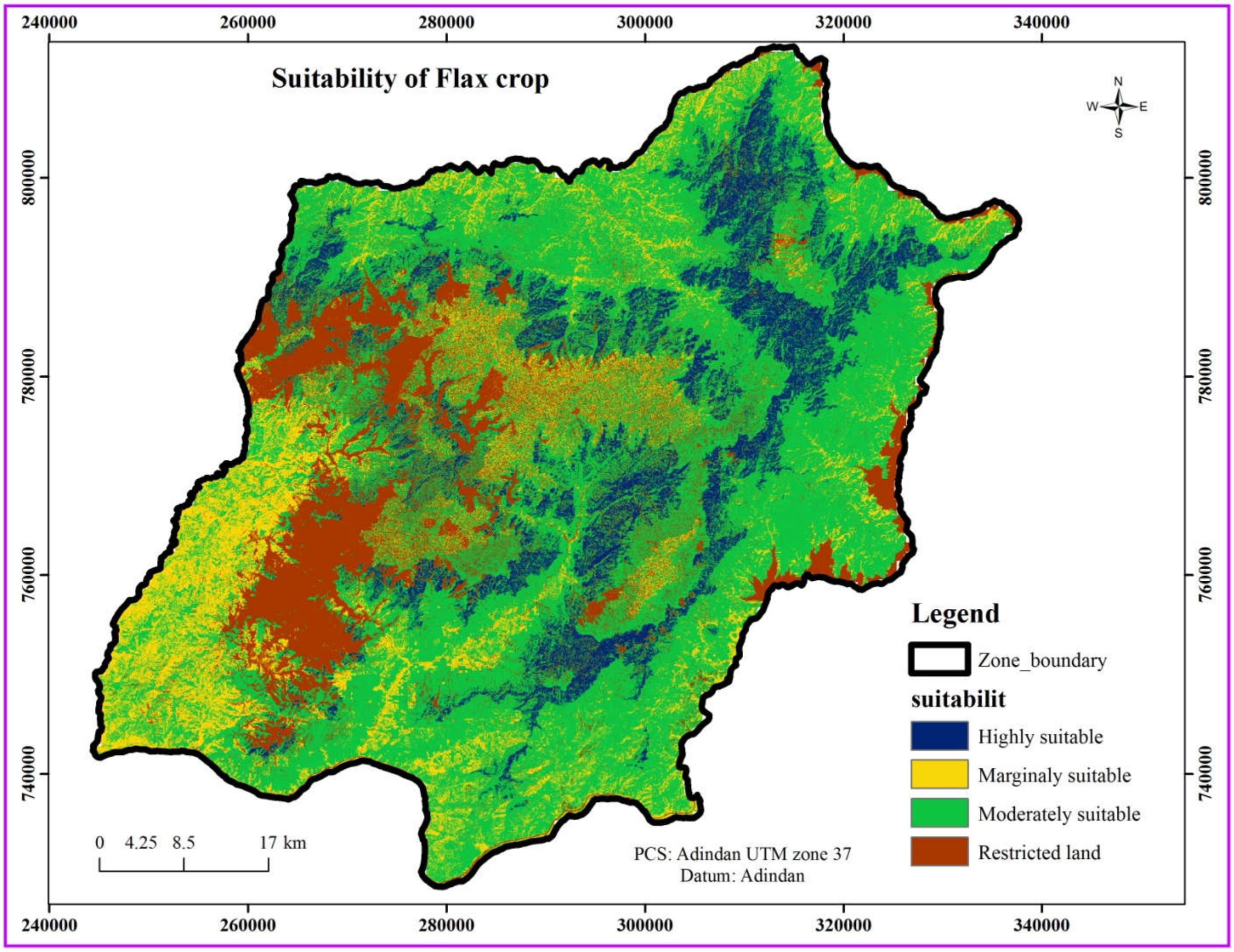
The extracted suitable land for flax crop was 46021.2 hectare covering 10% of the study area. The soil in the study area had fertile ground with well and moderate soil drainage. On the other hand, highly suitable land is located at an altitude of 1,500-2000 m and the soil is clay loam, loam, and silty clay loam.

Table 27 Suitable land for flaxseed

S/n	**Suitable land for flaxseed**					
		Restricted area	Highly suitable	Moderately suitable	Marginally suitable	sum
1	area in hectare	79053.2	46021.2	252207	63069.4	440351
2	percentage	18%	10%	57%	4%	100%

Moderately and marginally suitable land was 252207 and 63069.4 hectare, which covers 57% and 4% respectively. The weather data used by the study show that rainfall and temperature conditions are conducive to flax production. However, high-temperature areas were taken to marginally suitable for the reason of its effect on development rate and the consequent shortening of the growing cycle (Casa et al., 1999).

Figure 18 suitability ranges of flax crop



3. **Suitable land for sesame**

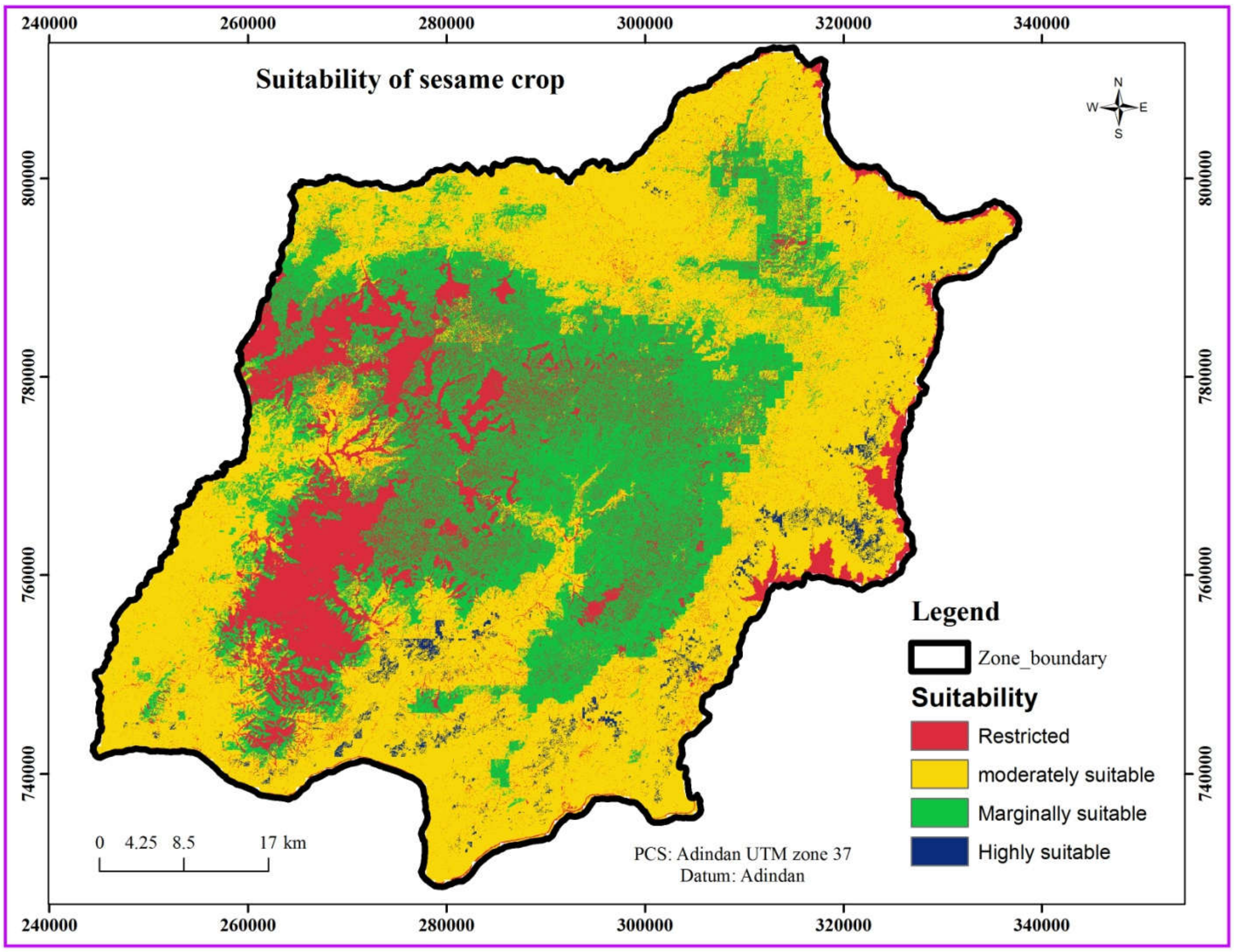
The suitable land for sesame crop was 5708.75 hectares covering 1 percent of the study area at lower altitude <1200m and annual rainfall less than 1100mm. As long as there is such fertile land, it will be effective if the farmer engages in sesame farming.

Table 28 Suitable land for sesame

S/n	**Suitable land for sesame**					
		Restricted area	Highly suitable	Moderately suitable	Marginally suitable	sum
1	area in hectare	79053.2	5708.75	231600.1	123989	440351
2	percentage	18%	1%	53%	28%	100%

The result conceded with (Bennett, 1993) as sesame crop adapted to tropical temperate condition with low rainfall and high-temperature region. The soil depth with shallow depth having the nature of sandy loam and loamy sand soil was accepted as a suitable region in the area. The area was well-drained optimum PH between 6.1-6.6 as sesame crops cannot tolerate water logging (Bennett, 1993).

Figure 19 suitability ranges of sesame



4.8. Suitability of oil crops at district level and the same parcel of land suitable for the three crops

The share of land suitable for the cultivation and production of oilseeds in all eleven woredas in the study area was shown in tables 30, 31, and 32. In this regard, highly suitable land for niger seed was found in Zaba, Loma, and Gena woreda covering 18%, 10%, and 10% respectively. Similarly, lands highly suitable for flax are widely available in Gena, Zaba, Loma, Mareka, Tarcha zuriya, and Tocha districts covering 21%, 17%, 15%, 14%, 13%, and 11% respectively. Sesame crop had highly suitable land in Disa, Loma, and Zaba districts while in Mareka, Mari Mansa, Tocha, and Kechi districts had no highly suitable lands as shown in the table 32. However, in terms of coverage, there is a large amount of moderately and marginally suitable land for niger, flax, and sesame production in the study area. As the degree of limitations increase, moderately suitable lands needs additional soil improvement practices or goes through improved varieties to increase the productivity of the crops. In fact, according to a research paper of (Slehak, 2007), marginally suitable land has been identified as having a lot of problems with limitations so severe that additional inputs needed to sustain the production.

As GIS's greatest potential is to select suitably locations by combining different factors, the same parcel of the land which is competing for two or more oil crops as an option has been shown in figure 18. The fact that the same land is suitable for the production of more than one crop will enable the farmer to select and produce it at any time of his choice. Nevertheless, most land is moderate to marginally suitable. Thus, table 29 shows that although there is no suitable land for the three oil crops at the time, there is suitable land for two of the three. Therefore, 11688.30-hectare land is highly suitable for niger and flax seeds at the same time. However, moderately suitable areas for niger and sesame covered 26% of the total area.

Table 29 the same parcel of land suitable for three crops

No	The same parcel of land suitable for oil crops	Area in hectare
1	Highly suitable for niger and flax seed	11,688.30
2	Highly suitable for niger and sesame	544.03
3	Highly suitable sesame and moderately suitable for niger	5,156.62
4	Highly suitable for niger and moderately suitable for sesame	16,584.53
5	Highly suitable for niger and marginally suitable for sesame	587.3
6	Moderately suitable for niger and sesame	118,298.10
7	Moderately suitable for niger and flax	47,630.27
8	Moderately suitable for niger marginally suitable for flax	22,693.24
9	Moderately suitable for sesame and marginally suitable for niger	35,978.26
10	Moderately for niger and marginally suitable for sesame	96,583.04
11	Marginally suitable for niger, flax and sesame	12,994.30
12	Marginally suitable for niger and sesame	25,362.77
13	Restricted land	79,053.2

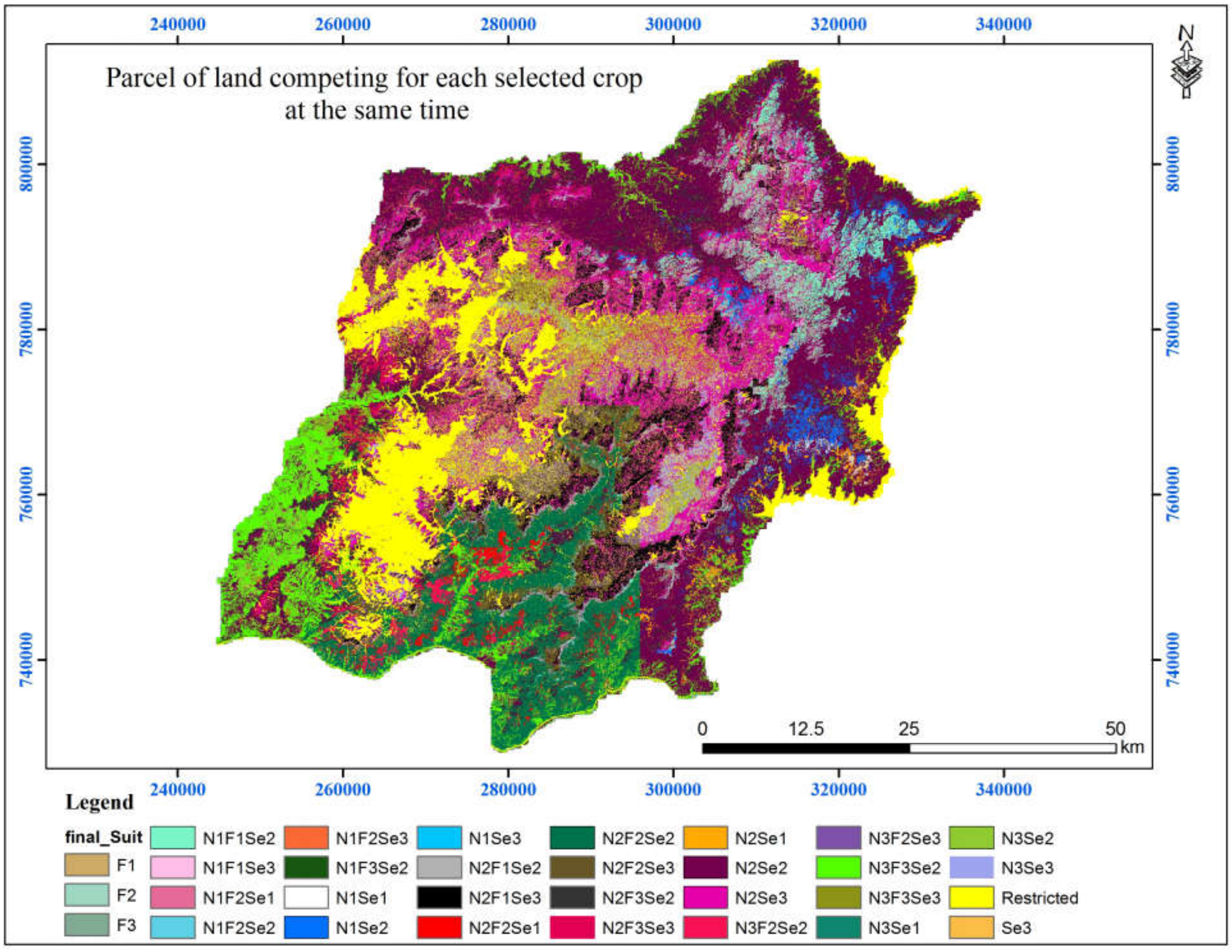


Figure 20 Parcel of land allocated for each crops

Where F is flaxseed, N is niger seed, Se is sesame seed, 1 stands for highly suitable land, 2 stands for moderately suitable land, 3 stands for marginally suitable land and restricted area are forest land and water body.

Table 30 suitability of niger seed at woreda level

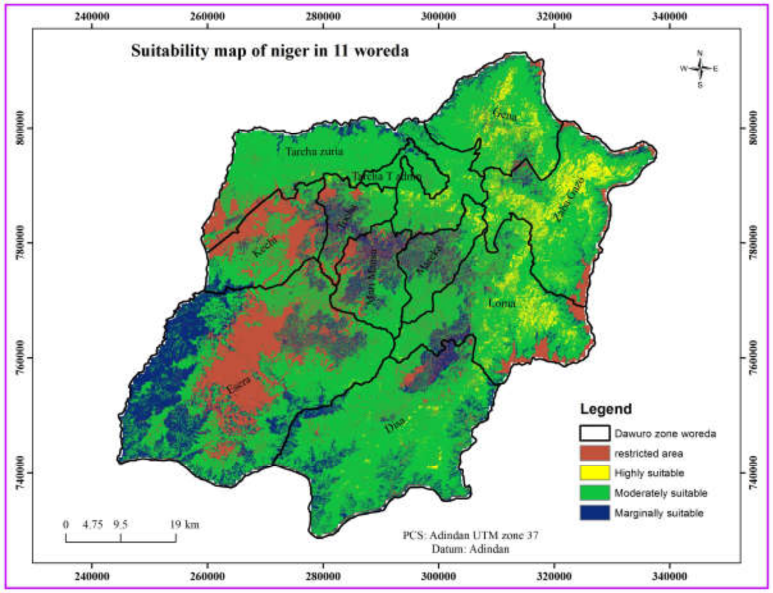
Nº	Woreda name	area in hectare	Selected oilseeds							
			Niger							
			S1		S2		S3		Restricted	
			ha	%	ha	%	ha	%	ha	%
1	Disa	74903	887.2	1%	57616.4	77%	10948	15%	5451.43	7%
2	Loma	48727.4	4856.09	10%	33484.1	69%	3888.32	8%	6498.93	13%
3	Zaba	44894.7	8041.61	18%	31232.5	70%	1928.74	4%	3691.88	8%
4	Gena	33222.3	3467.56	10%	26096.4	79%	1654.37	5%	2003.99	6%
5	Tarcha zuriya	52682.3	1012.18	2%	42957.7	82%	2374.59	5%	6337.79	12%
6	Tarcha town	6040.23	106.27	2%	5342.7	88%	315.39	5%	275.87	5%
7	Mareka	14898.7	435.31	3%	8923.61	60%	2784.38	19%	2755.44	18%
8	Mari mansa	18327.1	10.88	0%	8152.96	44%	4532.97	25%	5630.6	31%
9	Tocha	13303.2	172.45	1%	6394.81	48%	2601.25	20%	4134.69	31%
10	Kechi	25539.9	4.84	0%	11218.5	44%	2323.08	9%	11993.5	47%
11	Esara	107812	64.79	0%	49398.2	46%	28069.4	26%	30279.2	28%
Sum		440350.83	19059.2	48%	280818	64%	61420.5	14%	79053.3	18%

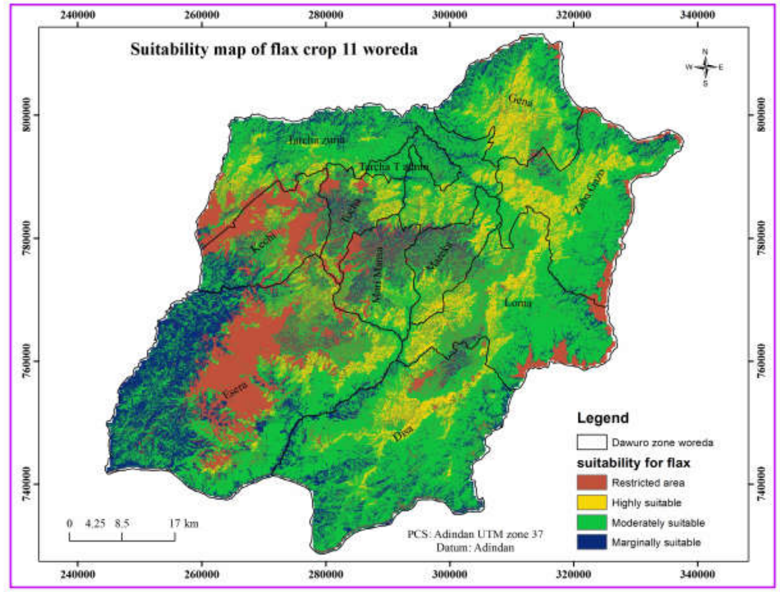
Table 31 suitability of flax seed at woreda level

N°	Woreda name	area in hectare	Selected oilseeds							
			Flax							
			S1		S2		S3		restricted	
			Ha	%	ha	%	ha	%	ha	%
1	Disa	74903	6360.2	8%	52000.48	69%	11066.27	15%	5476.05	7%
2	Loma	48727.4	7549.86	15%	31975.96	66%	2607.52	5%	6594.06	14%
3	Zaba	44894.7	7795.46	17%	30533.32	68%	2855.07	6%	3710.85	8%
4	Gena	33222.3	7007.2	21%	20942.41	63%	3269.90	10%	2002.79	6%
5	Tarcha zuriya	52682.3	5746.48	11%	34601.25	66%	6010.89	11%	6323.68	12%
6	Tarcha town	6040.23	135.24	2%	4676.06	77%	979.43	16%	249.499	4%
7	Mareka	14898.7	2081.41	14%	8066.16	54%	2022.06	14%	2729.07	18%
8	Mari mansa	18327.1	1433.5	8%	8313.32	45%	2976.05	16%	5604.23	31%
9	Tocha	13303.2	1755.05	13%	5427.49	41%	2012.34	15%	4108.32	31%
10	Kechi	25539.9	1218.4	5%	8953.33	35%	3388.94	13%	11979.2	47%
11	Esara	107812	4938.4	5%	46717	43%	25880.92	24%	30275.9	28%
Sum		440350.83	46021.2	10%	252207	57%	63069.40	14%	79053.7	18%

Table 32 suitability of sesame seed at woreda level

N°	Woreda name	area in ha	Selected oilseeds							
			Sesame							
			S1		S2		S3		restricted	
			ha	%	ha	%	ha	%	ha	%
1	Disa	74903	2043.04	3%	52344.0	70%	15064.5	20%	5451.43	7%
2	Loma	48727.4	1472.39	3%	23026.5	47%	17729.6	36%	6498.93	13%
3	Zaba	44894.7	678.41	2%	35824.1	80%	4700.3	10%	3691.88	8%
4	Gena	33222.3	146.75	0%	24367.9	73%	6703.6	20%	2003.99	6%
5	Tarcha zuriya	52682.3	4.64	0%	31569.6	60%	14770.3	28%	6337.79	12%
6	Tarcha town	6040.23	5.57	0%	5489.8	91%	269.0	4%	275.87	5%
7	Mareka	14898.7			1356.8	9%	10786.5	72%	2755.44	18%
8	Mari mansa	18327.1			752.5	4%	11944.0	65%	5630.6	31%
9	Tocha	13303.2			1214.2	9%	7954.3	60%	4134.69	31%
10	Kechi	25539.9			5535.6	22%	8010.8	31%	11993.5	47%
11	Esara	107812	1357.95	1%	50118.9	46%	26056.0	24%	30279.2	28%
Sum		440350.83	5708.75	1%	231599.9	53%	123988.9	28%	79053.3	18%





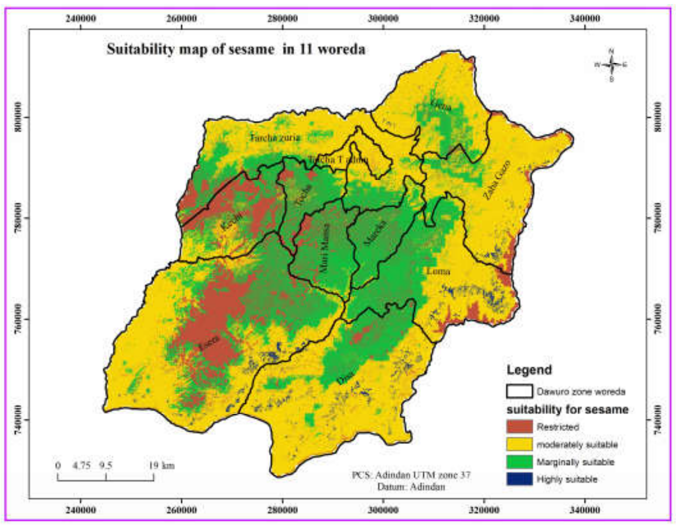


Figure 21 Oilseeds at woreda level (niger , flax and sesame)

4.9. Validity and Verifications

The reliability and validity of outcomes of this study was ensured as much as possible on the methodological aspect of past research findings and scholar articles focusing the techniques and consulting knowledgeable persons (experts, development agents, researchers) on issues that require detailed information. In the case of reliability of the research result, the researcher conducted a field survey by using GPS to collect ground control points (GCP) to verify assessment. GPS points were taken from the ranges of the suitability (highly suitable to low suitable areas) for the final validity. The final small fields identified in Table 26 are viewed on the ground in view of the need to survey the ground in order to verify the findings. Based on this, it has been proven that isolated fields are currently used for grain/pulse production and oil crops have recently been tested.

Table 33 GCP points Used for Validity and verifications

No	Shape *	X _ coordinate	Y _ coordinate	Elevation	Parcel
1	Point	315551	766846	1188	N1Se2
2	Point	309995	761095	1105	N2Se1
3	Point	309656	758660	1102	N2Se2
4	Point	294627	797333	973	N2Se2
5	Point	293237	797623	1078	N3Se2
6	Point	285255	792699	1500	N2Se2
7	Point	323414	786720	1390	N2Se2
8	Point	323351	786542	1400	N2Se2
9	Point	325078	763099	1055	N2Se1
10	Point	304503	753669	1146	N2Se1

Chapter Five

5. Conclusion and Recommendation

5.1. Conclusion

The research was intended to assess physical land suitability of oil crops with potentially available land for cultivation and production of oilseeds in Dawro zone by using GIS and RS technology. The study has also sought that GIS technology is effective and helpful in identifying the suitable potential area in the study. In summary, in terms of the purpose of the study, GIS and remote sensing technology identified potential lands from highly suitable to marginally suitable for the production and cultivation of oil crops. Thus, from this study, it is possible to correct the deficiencies in the development and production of oilseeds. This means that the identification of suitable potential land for farming is professionally supported by local agricultural development.

The main empirical findings of the study were presented in chapter four of the results and discussions. The findings shown in the summary result indicated that 4%, 10%, and 1% were highly suitable for niger, flax, and sesame crops whereas 64%, 57%, and 53% of the area were moderately suitable area for niger, flax, and sesame respectively. Marginally suitable for niger, flax and sesame were 14%, 14% and 28% respectively. As long as there is such fertile land, it will be effective if the farmer engages in oilseed farming. Although the report from the zonal agriculture bureau shows that oilseeds are not widely grown in the area for market value, it is effective if the farmer engages in the cultivation of oilseeds as long as such land is available.

All the data used by the study showed that the location of the study area is good climatic conditions, as well as the soil parameters permits the production and cultivation of niger, flax, and sesame.

5.2. Recommendation

- Using the results, farmers may come up with new plans or may need to update the existing plans on crop productions, economic development activities, and benefits.
- GIS and RS technology, multi-criteria evaluation method, is one of the appropriate ways to study land suitability assessment to increase crop production. Thus, a small

piece of farm fields studied and the field will get geospatial data for crop production activity to increase the crop yield.

Future study focus

- The parameters used in this study focused on the physical factors of soil parameters, topographic, climatic, socioeconomic factors like market and road accessibility. However, soil management activities and the influence of the population increase and density can be considered as additional variables that can influence land suitability analysis. Hence, further study that incorporates socio-economic variables (like income, preference, market, and yield) and nutrient composition for agricultural crops for the study area is necessary
- The gaps that need to be studied and expanded in the future were studying the availability and the deficiencies in soil nutrients and identifying the varieties of oil crops.
- Not only that, but there is a need for a GIS and remote sensing study by defining the productivity of the land as land productivity can be reduced due to various environments and other factors.

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7. Appendixes

Table 34 factors and scale values for niger crop

Niger crop				
Factors	Class range	Description	Scale Values	Weight
Elevation	1500-2000	S1	1	25
	1100-1500	S2	2	
	2000-2400	S3	3	
	<1100, >2400	N1	4	
Rain fall	<1100	S1	1	17
	1100-1500	S2	2	
	1500-1800	S3	3	
Temperature	.5-22.5	S1	1	14
	15-17.517	S2	2	
LULC	agriculture	S1	1	11
	Grass land	S2	2	
	bare land	S3	3	
	Bush land	N1	4	
	built-up area	restricted		
	natural forest	restricted		
	water body	restricted		
soil P^H	neutral	S1	1	10
	slightly acidic	S2	2	
	moderately acidic	S3	3	
	slightly alkaline	N1	4	
	strongly acidic	N2	5	
Soil drainage	w	S1	1	6
	M	S2	2	
soil texture	Clay loam, Loam	S1	1	6
	Silty clay loam,	S2	2	
	Sandy L, Loamy sand	S2	2	
Soil depth	deep	S1	1	4
	moderately deep	S1	1	
	shallow	S2	2	
Slope	0-8%	S1	1	3
	8-15%	S2	2	
	15-30%	S3	3	

	30-50%	N1	4	
	>50%	N2	5	
Road accessibility	0-2 km	S1	1	2
	2-4 km	S2	2	
	4-7 km	S3	3	
	>7 km	N1	4	
Market centers	0-4 km	S1	1	2
	4-8 km	S2	2	
	8-12 km	S3	3	
	>12 km	N1	4	

Table 35 factors and scale values for flax crop

Factors	Flax crop			
	Class range	Description	Scale Values	Weight
Elevation	1500-2000	S1	1	25
	2000-2400	S2	2	
	770-1500	S2	2	
	<770, >2400	S3	3	
Rain fall	<1100	S1	1	17
	1100-1500	S2	2	
	1500-1800	S3	3	
Temperature	18-20	S1	1	14
	15-18	S2	2	
	20-22.5	S3	3	
LULC	agriculture	S1	1	11
	built-up area	S2	2	
	natural forest	S3	3	
	bare land	N1	4	
	Bush land	restricted		
	Grass land	restricted		
	water body	restricted		
soil P^H	slightly acidic	S1	1	10

	neutral	S2	2	
	moderately acidic	S2	2	
	strongly acidic	S3	3	
	slightly alkaline	N1	4	
Soil drainage	w	S1	1	6
	M	S2	2	
soil texture	Silty clay loam,	S1	1	6
	Clay loam, Loam	S2	2	
	Sandy L, Loamy sand	S3	3	
Soil depth	deep	S1	1	4
	moderately deep	S1	1	
	shallow	S2	2	
Slope	0-8%	S1	1	3
	8-15%	S2	2	
	15-30%	S3	3	
	30-50%	N1	4	
	>50%	N2	4	
Road accessibility	0-2 km	S1	1	2
	2-4 km	S2	2	
	4-7 km	S3	3	
	>7 km	N1	4	
Market centers	0-4 km	S1	1	2
	4-8 km	S2	2	
	8-12 km	S3	3	
	>12 km	N1	4	

Table 36 factors and scale values for sesame crop

Factors	Sesame crop			
	Class range	Description	Scale Values	Weight
Elevation	<1200	S1	1	25
	1200-1400	S2	2	
	1400-1600	S3	3	
	>1600	N1	4	
Rain fall	<1100	S2	2	17
	1100-1500	S3	3	
	1500-1800	N1	4	
Temperature	>22.5	S1	1	14
	-20	S2	2	
	20-22.515	S3	3	
LULC	agriculture	S1	1	11
	built-up area	S2	2	
	natural forest	S3	3	
	bare land	N1	4	
	Bush land	restricted		
	Grass land	restricted		
	water body	restricted		
soil P^H	moderately acidic	S1	1	10
	slightly acidic	S2	1	
	strongly acidic	S2	2	
	neutral	S3	3	
	slightly alkaline	N1		
Soil drainage	w	S1	1	6
	M	S2	2	
soil texture	Clay loam, Loam	S1	1	6
	SandyL, Loamy sand	S2	2	
	Silty clay loam,	S3	3	
Soil depth	deep	S1	1	4

	moderately deep	S1	1	
	shallow	S2	2	
Slope	0-8%	S1	1	3
	8-15%	S2	2	
	15-30%	S3	3	
	30-50%	N1	4	
	>50%	N2	4	2
Road accessibility	0-2 km	S1	1	
	2-4 km	S2	2	
	4-7 km	S3	3	
	>7 km	N1	4	
Market centers	0-4 km	S1	1	2
	4-8 km	S2	2	
	8-12 km	S3	3	
	>12 km	N1	4	

Table 37 Ground controlling points (GCP)

S/N	Shape *	Id	True_ value	producer	x_ coordinate	Y_ coordinate
1	Point	1	1	1	312352	758726
2	Point	2	1	1	313681	759414
3	Point	3	1	1	314303	759454
4	Point	4	1	1	317608	760111
5	Point	5	1	1	317783	760746
6	Point	6	1	1	317957	761635
7	Point	7	1	1	318132	762730
8	Point	8	1	1	318767	759825
9	Point	9	1	1	320212	759603
10	Point	10	1	1	321577	759175
11	Point	11	1	1	323022	759492
12	Point	12	1	1	325322	760649
13	Point	13	1	1	325767	761808
14	Point	14	1	1	326735	762538
15	Point	15	1	1	326608	763538
16	Point	16	1	1	326052	765125
17	Point	17	1	1	324744	768527
18	Point	18	1	1	325961	775299
19	Point	19	1	1	331934	795918

20	Point	20	1	1	333606	796426
21	Point	21	1	1	325774	798585
22	Point	22	1	1	326896	798246
23	Point	23	1	1	317453	811163
24	Point	24	1	1	317684	811626
25	Point	25	1	1	317899	809493
26	Point	26	1	1	311781	812618
27	Point	27	1	1	312409	812767
28	Point	28	1	4	305312	808832
29	Point	29	1	4	304823	808724
30	Point	30	1	4	306360	809175
31	Point	31	1	4	303909	808407
32	Point	32	2	2	265327	753053
33	Point	33	2	2	266213	753331
34	Point	34	2	2	267840	754151
35	Point	35	2	2	266961	755599
36	Point	36	2	2	262046	756515
37	Point	37	2	2	263792	759425
38	Point	38	2	2	266719	764127
39	Point	39	2	2	269682	764339
40	Point	40	2	2	272751	766329
41	Point	41	2	2	274402	768636
42	Point	42	2	2	268920	767408
43	Point	43	2	2	263141	780608
44	Point	44	2	2	266360	782133
45	Point	45	2	2	269394	782066
46	Point	46	2	2	271992	780993
47	Point	47	2	2	262252	782603
48	Point	48	2	2	261126	784258
49	Point	49	2	2	262039	784338
50	Point	50	2	2	264513	786097
51	Point	51	2	2	285630	788119
52	Point	52	2	2	285738	788875
53	Point	53	2	2	286151	789408
54	Point	54	2	2	284855	788830
55	Point	55	2	4	283655	787263
56	Point	56	2	4	283658	787314
57	Point	57	2	3	283782	787363
58	Point	58	2	2	283496	787290
59	Point	59	2	4	283900	787379
60	Point	60	2	2	279403	788544

61	Point	61	2	2	279986	789031
62	Point	62	2	2	280351	789512
63	Point	63	2	2	281155	788269
64	Point	64	2	2	279430	787740
65	Point	65	2	2	294850	756844
66	Point	66	2	2	295123	756947
67	Point	67	2	2	295534	756659
68	Point	68	2	2	295955	757184
69	Point	69	2	2	293540	755364
70	Point	70	2	2	293663	755452
71	Point	71	2	2	293572	755550
72	Point	72	2	6	292631	755965
73	Point	73	2	6	292637	755987
74	Point	74	2	6	292663	756013
75	Point	75	2	6	292611	756073
76	Point	76	2	6	292545	756107
77	Point	77	2	2	303886	757191
78	Point	78	2	2	303825	757294
79	Point	79	2	2	303938	757429
80	Point	80	2	2	303725	757487
81	Point	81	2	2	305554	762997
82	Point	82	2	2	305370	762955
83	Point	83	2	2	305324	763089
84	Point	84	2	2	305653	762643
85	Point	85	2	2	305816	762819
86	Point	86	2	2	305807	762642
87	Point	87	2	6	307696	763801
88	Point	88	2	6	307645	763810
89	Point	89	2	6	307753	763839
90	Point	90	2	2	308589	772120
91	Point	91	2	2	308621	772273
92	Point	92	2	2	308270	772448
93	Point	93	2	2	313814	793884
94	Point	94	2	2	313705	793812
95	Point	95	2	2	313556	793830
96	Point	96	2	2	316130	793578
97	Point	97	2	2	316151	793676
98	Point	98	2	2	315815	793598
99	Point	99	2	2	316347	793727
100	Point	100	2	2	316355	793883
101	Point	101	4	3	257088	757445

102	Point	102	4	3	257112	757686
103	Point	103	4	3	256547	757502
104	Point	104	4	3	251915	760379
105	Point	105	4	3	251945	760208
106	Point	106	4	3	252615	759978
107	Point	107	4	2	258052	763914
108	Point	108	4	2	258013	764036
109	Point	109	4	4	258210	764177
110	Point	110	4	4	258055	764278
111	Point	111	4	6	260706	767531
112	Point	112	4	4	261278	767281
113	Point	113	4	4	329880	794198
114	Point	114	4	4	329908	794407
115	Point	115	4	4	329537	794375
116	Point	116	4	4	329582	794455
117	Point	117	4	4	329272	793887
118	Point	118	4	4	330784	795195
119	Point	119	4	3	331736	793881
120	Point	120	4	1	331838	795392
121	Point	121	4	2	322517	765452
122	Point	122	4	2	322566	765552
123	Point	123	4	6	322824	765611
124	Point	124	4	4	322474	765587
125	Point	125	4	2	322174	765498
126	Point	126	4	4	322284	765765
127	Point	127	4	4	322611	765850
128	Point	128	4	4	301117	782473
129	Point	129	4	4	301356	782442
130	Point	130	4	4	301169	782839
131	Point	131	4	4	301061	782353
132	Point	132	4	4	300766	782436
133	Point	133	4	2	296192	779762
134	Point	134	4	2	296215	779808
135	Point	135	4	2	295991	779776
136	Point	136	4	2	296090	779875
137	Point	137	4	4	296843	782759
138	Point	138	4	4	297040	782804
139	Point	139	4	4	296998	782962
140	Point	140	4	4	294715	784251
141	Point	141	4	4	295036	783897
142	Point	142	4	4	295208	784233

143	Point	143	4	4	294457	784211
144	Point	144	4	4	291460	783751
145	Point	145	4	4	291811	783909
146	Point	146	4	4	292044	784157
147	Point	147	4	4	290495	793194
148	Point	148	4	4	290368	793103
149	Point	149	4	4	290627	793423
150	Point	150	4	2	278244	749542
151	Point	151	4	2	278595	749793
152	Point	152	4	2	279114	749833
153	Point	153	4	2	279329	750388
154	Point	154	4	2	279491	750173
155	Point	155	4	4	277603	750008
156	Point	156	4	4	279266	749710
157	Point	157	6	6	292733	741768
158	Point	158	6	6	292348	742121
159	Point	159	6	6	293197	742676
160	Point	160	6	6	294339	745394
161	Point	161	6	6	293998	745719
162	Point	162	6	6	294101	746084
163	Point	163	6	6	292704	746275
164	Point	164	6	6	292632	746934
165	Point	165	6	6	315406	763472
166	Point	166	6	6	315421	763669
167	Point	167	6	6	315090	763610
168	Point	168	6	6	314472	763682
169	Point	169	6	6	314648	764016
170	Point	170	6	6	299323	798485
171	Point	171	6	6	299575	798669
172	Point	172	6	6	299103	798698
173	Point	173	6	6	295640	798031
174	Point	174	6	6	295708	798367
175	Point	175	6	6	295899	798753
176	Point	176	6	6	296327	798835
177	Point	177	6	6	314845	809715
178	Point	178	6	6	315351	810028
179	Point	179	6	6	315241	810181
180	Point	180	6	6	315306	810299
181	Point	181	6	6	314773	810405
182	Point	182	6	6	314671	809975
183	Point	183	6	6	314902	809647

184	Point	184	6	6	315097	809499
185	Point	185	6	6	315304	809721
186	Point	186	6	2	294603	771912
187	Point	187	6	2	294534	772168
188	Point	188	6	6	294500	772439
189	Point	189	6	6	294019	772426
190	Point	190	6	6	294565	772640
191	Point	191	6	6	325803	778190
192	Point	192	6	6	325497	778515
193	Point	193	6	6	325212	778674
194	Point	194	6	6	324985	779090
195	Point	195	6	6	326343	779249
196	Point	196	6	6	326482	779428
197	Point	197	6	6	326434	778777
198	Point	198	6	6	326160	778186
199	Point	199	6	6	325640	777928
200	Point	200	6	6	326009	777590
201	Point	201	5	5	298422	790528
202	Point	202	5	5	298388	790544
203	Point	203	5	5	298294	790535
204	Point	204	5	4	299178	791322
205	Point	205	5	4	299131	791389
206	Point	206	5	5	309288	800534
207	Point	207	5	5	309291	800608
208	Point	208	5	5	309260	800684
209	Point	209	5	5	309239	800736
210	Point	210	5	5	309384	800549
211	Point	211	5	5	309155	800580
212	Point	212	5	4	311214	789276
213	Point	213	5	2	311205	789202
214	Point	214	5	4	311378	789291
215	Point	215	5	4	311146	789251
216	Point	216	5	5	309150	775553
217	Point	217	5	5	309464	775573
218	Point	218	5	5	309415	775319
219	Point	219	5	5	309445	775392
220	Point	220	5	5	309075	775516
221	Point	221	5	5	309126	775570
222	Point	222	5	5	309004	775373
223	Point	223	5	5	309523	775626
224	Point	224	5	5	309341	775105

225	Point	225	5	5	308826	775059
226	Point	226	5	2	298115	780393
227	Point	227	5	2	298895	780657
228	Point	228	5	2	298888	780566
229	Point	229	5	5	298868	780490
230	Point	230	5	5	298779	780508
231	Point	231	5	5	298719	780543
232	Point	232	5	5	290387	777992
233	Point	233	5	2	290367	778210
234	Point	234	5	2	290352	778369
235	Point	235	5	5	290696	778153
236	Point	236	5	5	290858	778310
237	Point	237	5	5	290618	777865
238	Point	238	5	5	290548	777891
239	Point	239	7	7	330849	791883
240	Point	240	7	7	330844	791916
241	Point	241	7	7	330741	791900
242	Point	242	7	7	330706	791931
243	Point	243	7	7	329405	791664
244	Point	244	7	7	329416	791704
245	Point	245	7	2	329580	791707
246	Point	246	7	7	329424	791733
247	Point	247	7	2	329336	791857
248	Point	248	7	2	329306	791838
249	Point	249	7	2	328446	791699
250	Point	250	7	2	328171	791706
251	Point	251	7	7	327993	791739
252	Point	252	7	7	327890	791769
253	Point	253	7	2	314299	799411
254	Point	254	2	2	315148	799098
255	Point	255	2	2	314438	798443
256	Point	256	2	2	314184	798641
257	Point	257	7	6	299206	789536
258	Point	258	7	6	299148	789591
259	Point	259	7	6	299383	789477
260	Point	260	7	7	299490	789545
261	Point	261	7	7	295149	791352
262	Point	262	7	7	295141	791445
263	Point	263	7	7	295118	791551
264	Point	264	7	7	284898	792573
265	Point	265	7	7	284845	792583

266	Point	266	7	7	284904	792911
267	Point	267	7	7	284920	792886
268	Point	268	7	7	285273	792772
269	Point	269	7	7	269915	793531
270	Point	270	7	7	270027	793616
271	Point	271	7	7	270146	793777
272	Point	272	7	7	269899	793733
273	Point	273	7	7	269893	793565
274	Point	274	7	5	299938	758480
275	Point	275	7	2	299844	758490
276	Point	276	7	2	300025	758479
277	Point	277	7	2	299676	758318
278	Point	278	7	4	299655	758350
279	Point	279	7	4	299684	758279
280	Point	280	7	4	299715	758294
281	Point	281	7	2	295832	760844
282	Point	282	7	7	295905	760924
283	Point	283	7	7	295748	760890
284	Point	284	7	7	295621	760916
285	Point	285	3	4	258159	752886
286	Point	286	3	3	258028	752782
287	Point	287	3	4	258279	752774
288	Point	288	3	4	258262	752892
289	Point	289	3	3	258178	752949
290	Point	290	3	4	258744	753888
291	Point	291	3	2	258673	753896
292	Point	292	3	6	258876	754028
293	Point	293	3	6	258930	754029
294	Point	294	3	3	258536	754065
295	Point	295	3	4	258386	753995
296	Point	296	3	6	258571	753888
297	Point	297	3	6	258631	753797
298	Point	298	3	2	258919	754080
299	Point	299	3	3	261521	754442
300	Point	300	3	3	261274	754199
301	Point	301	3	3	261404	754383
302	Point	302	3	3	262082	754266
303	Point	303	3	3	262155	754537
304	Point	304	3	2	266772	757762
305	Point	305	3	2	266715	757771
306	Point	306	3	2	266536	757803

307	Point	307	3	3	266554	757695
308	Point	308	3	3	266733	757665
309	Point	309	3	3	286826	776038
310	Point	310	3	3	286783	776125
311	Point	311	3	3	286841	776238
312	Point	312	3	3	287028	776345
313	Point	313	3	3	287233	776109
314	Point	314	3	3	294201	772620
315	Point	315	3	3	294249	773536
316	Point	316	3	3	294408	774001
317	Point	317	3	3	293794	774128
318	Point	318	3	3	295561	772710
319	Point	319	3	3	295651	772980
320	Point	320	3	3	295466	773223
321	Point	321	3	3	295069	772361
322	Point	322	3	3	293635	772382
323	Point	323	3	3	292974	771985
324	Point	324	3	3	293053	772467
325	Point	325	3	3	307200	784412
326	Point	326	3	3	307086	784431
327	Point	327	3	3	305473	784279
328	Point	328	3	3	305016	783847
329	Point	329	3	4	305987	783123
330	Point	330	3	3	306362	783453
331	Point	331	3	3	308445	783948
332	Point	332	3	3	325924	791067
333	Point	333	3	3	326036	791189
334	Point	334	3	3	326242	791001
335	Point	335	3	3	326463	791507
336	Point	336	3	3	326079	791844
337	Point	337	3	3	325415	791884
338	Point	338	3	3	325223	791817
339	Point	339	3	3	323889	792665
340	Point	340	3	3	323960	792832
341	Point	341	3	3	323676	792581
342	Point	342	3	3	323876	792319
344	Point	344	3	3	321798	795158
345	Point	345	3	3	320222	793230
346	Point	346	3	4	320474	795711
347	Point	347	3	4	319703	795610
348	Point	348	3	3	282110	754277

349	Point	349	3	3	282050	754905
350	Point	350	3	3	282692	754799
351	Point	351	3	3	282311	755190
352	Point	352	3	3	281928	754171
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367	Point	367	3	3	312836	785640
368	Point	368	3	3	313077	785783
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371	Point	371	3	3	285786	760498
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376	Point	376	3	6	286596	759710
377	Point	377	3	3	284923	759112
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406	Point	406	2	2	313912	793354
407	Point	407	2	2	297115	758264
408	Point	408	2	2	296159	757984
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426	Point	426	3	3	309237	783538
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431	Point	431	4	4	260203	741168
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433	Point	433	4	4	247865	745503
434	Point	434	4	4	321530	777606
435	Point	435	5	5	301346	755443
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438	Point	438	5	5	301295	755405
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441	Point	441	5	5	304592	765450
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445	Point	445	6	6	298360	798715
446	Point	446	6	6	298135	798856
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