JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCE AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

SUITABILITY ANALYSIS FOR *ENSET* (*ENSETE VENTRICOSUM CHEESMAN (WELW))* CULTIVATION IN MAREKA DISTRICT, DAWURO ZONE, SOUTH WEST ETHIOPIA

ASNAKE BOYANA

JUNE, 2017

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I declare that the thesis entitled "Suitability Analysis for *Enset* (*Ensete Ventricosum Cheesman (Welw))* Cultivation in Mareka District, Dawuro Zone, South West Ethiopia" has been conducted by me under supervision of Dr. Kefelegn Getahun and Ashenif Melese in Jimma University, school of post graduate studies, college of social science and humanities department of geography and environmental studies during the year 2016-2017. It is submitted for the partial fulfillment requirement for **Master of Science degree** in Geographic information system and remote sensing. I further confirm that the thesis work has not been submitted earlier to other universities for award of degree or diploma.

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

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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 Asnake Boyana under the title "Suitability Analysis for *Enset* (*Ensete Ventricosum Cheesman (Welw))* Cultivation in Mareka District, Dawuro Zone, South West Ethiopia", and recommend that the thesis is accepted as fulfilling the thesis requirement for the Degree of Master Science in Geographic Information System and Remote Sensing in Jimma University.

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I hereby certify that all the correction and recommendation suggested by the board of examiners are incorporated into the final thesis entitled **“**Suitability Analysis for *Enset* (*Ensete Ventricosum Cheesman (Welw))* Cultivation in Mareka District, Dawuro Zone, South West Ethiopia”, by **Asnake Boyana.**

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Abbreviations

AAT: Average Annual Temperature

AEZ: Agro Ecological Zone

AHP: Analytical Hierarchy Process

APPT: Average Annual Precipitation

CSA: Central Statistical Agency

DAs: Development Agents

DEM: Digital Elevation Model

Et.al. and Others

EMA: Ethiopia Mapping Agency

ERDAS: Earth Resource Data Analysis System

ETM+: Enhanced Thematic Mapper plus

FAO: Food and Agricultural Organization

GIS: Geographic Information System

GPS: Global Positioning System

Ha: Hectares

i.e. That means

ISRIC: International Soil and Research Information Center

KII: Key Informants Interview

LGPs: Long Growing Periods

LU/LCC: Land Use Land Cover Change

LUTs: Land Use Types

MDFEDO: Maraka District Finance and Economic Development Office

m.a.s.l: Meter above Sea level

MoA: Ministry of Agriculture

MoFED: Ministry of Finance and Economic Development

NMA: National Meteorological Agency

NRC: National Research Council of United States of America

PPT: Precipitation

PWCM Pair Wise Comparison Matrix

RS: Remote Sensing

SARI: Southern Agricultural Research Institution

SMCDM/A: Spatial Multi-Criteria Decision Making (Analysis)

SNNPRS: South Nation Nationalities and Peoples Regional State

SRTM: Shuttle Radar Topographic Mission

UTM: Universal Transverse Mercator

Symbol and signs

%	Percent
^{0}c	Degree centigrade/Celsius
^{0}	Degree
'	Minutes
"	Seconds
>	Greater than
<	Less than

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Abstract

This study was conducted out in Mareka District, Dawuro Zone South West Ethiopia with topic of suitability analysis for enset (ensete ventricosum cheesman (welw). GIS based agricultural suitability analysis is very important for cultivation of given crop type. Environmental factors like land use /land cover, temperature, rain fall, soil type and altitude were classified based on suitability evaluation methods of FAO and experts opinion. Multi-criteria decision making methods of ranking and prioritizing the importance of criteria based on their weight of influence formulated for suitability analysis by employing analytical hierarchy process IDRISI software extension. GIS and spatial MCDM evaluation was used to get importance of GIS based MCDM evaluations and solve environmental decision making problem. The factor maps were reclassified and standardized in GIS soft were extension tools, which led to the preparation of suitability analysis map of the enset plant suitability classes. As part of spatial MCDM, AHP pair wise comparison module was used to derive internal and external weights for each individual factors and parameters respectively. More weight was given for rain fall automatically by AHP algorithm for the reason that enset cultivation needs availability of rain fall more than any other factors. Consequently, suitability analysis was done and weighted overlay suitability map was visualized with integration of GIS. The findings show that among total area of 46,724 hectare, 30.4% is highly suitable for enset cultivation and production. About 53.7% of the study area is moderately suitable, 12.1% is marginally suitable and 3.8% is currently not suitable to enset crop cultivation of study area. The suitability Analysis of criteria evaluation on the study area showed that the area has greatest potential of enset cultivation. The final suitable open area that can be used for enset cultivation is 635.3ha. This accounts for about 1.4% of the total study area and 4.5% of available open area with in highly suitable order. Based on finding, it could be recommended that this work would be used as policy guide for planners; enset investment could be successful in the District, further suitability research works should be carried out in order to optimize the enset crop cultivation and production.

Key words: Suitability analysis, *Enset* suitability, Spatial MCDM, AHP, and Weighted overlay analysis

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

According to MoFED (2010), agriculture is the bases for the economy of Ethiopia. Employ 85% of its population, over 43% of the country's gross domestic product (GDP) and over 80% of foreign exchange earnings. Irrespective of this fact, production method is dominated by small-scale subsistence farming system mostly based on low-input and low-output rain-fed agriculture (Gizachew, 2014). Agricultural production lags behind the food requirement of the fast-growing population, this needs advanced approach improving agricultural production.

According to (Tsegaye and Struik, 2002) the farmers believe '*enset* is the shield to protect hunger, and life of human and animal is impossible without it '. Regardless of its significance for food security and ecological sustainability, however, little research and development work has been done on *enset* cultivation and production systems. The Ethiopian government has paying attention for its agricultural research and development efforts mainly on different types of crops. The awareness of the government towards encouraging the acceptance of these new technologies has resulted in a shift from *enset* to cereal based agriculture. This caused decline in production and some *enset* growing areas have faced famine in recent years (Tsegaye and Struik, 2002).

Some researchers and organizations such as Solomon and Mohammed (2016), FAO (1996) have tried to prepare a standard framework for suitable and optimal agricultural land use and classified into five suitability classes by following Food and Agricultural Organization (FAO) agricultural potential classes. FAO (1996) classifies agricultural potential based on soil and environmental characteristics into five classes including highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable. Another researcher like Kassa and Mulu (2012), classify crop and fruit producing surface into four suitability classes (highly suitable, moderately suitable, marginally suitable and not suitable) based on its suitability classes or modifying factors.

The problem of selecting the correct land for the cultivation of a certain agriculture product is a long standing and mainly empirical issue (Pirbalouti et al., 2011). Although many scholars and organizations have tried to provide a framework for optimal agricultural land use, it is supposed that much agricultural land used currently is below its optimal capability in different parts of the world. The classification of land into different suitability classes is useful in that some soil, climate, topographic and other characteristics of land can be suitable for specific crops and unsuitable for others; therefore, precision of land utilization type is very important (Ebrahim, 2014).

There are four farming schemes in Ethiopia. These are Pastoralist, shifting cultivation, the seed-farming and the *enset* (*Ensete ventricosum*) planting complex in south west highlands (Westphal, 1975 and Almaz and Anke, 2004). These scholars also indicated that, the field preparation for *enset* with the plough or the hoe is carried on during the months of October to December. For the reason that farmers use a parcels of different plots for the production of suckers and practice relocating several times until the plants are in their final plots within the boundaries of the homestead of twice or more at a year.

Enset (*Ensete ventricosum Cheesman (Welw)*) is a perennial crop belonging to the *Musaceae* family. *Enset* has been used as a food crop for long period of years only in Ethiopia, where it was once domesticated (Brandt et al., 1997). In outward appearance, *enset* looks like the banana plant, but the edible parts of *enset* are the pseudo stalk and the underground corm, not the fruit (Westphal, 1975). The scholar also stated that, *enset* is mainly vegetative circulated as it usually grown in humid mid altitude and highland environments and its natural center of the dispersal of *enset* is located in the higher areas of Kaffa, southern Ethiopia.

The Dawuro zone agricultural office report of (2016) shows that, Mareka District has large areal coverage in Dega and Woina dega agro-ecological classification. However, there was less investigation about *enset* suitability analysis and classification of land use either by local or regional government. This might be due to little attention given for *enset* crop and its benefit by local government. Another issue is that, *enset* has not been known throughout the country as important staple food crop except in south and southwestern part of Ethiopia.

Finally, to overcome uncertainties of suitable land areas for *enset* crop cultivation and to optimize land utilization in Mareka District, this study was carried out. This study employed GIS and remote sensing for analyzing potential *enset* crop suitable land area using input factors. In addition, the study attempted to assess *enset* crop potentially suitable area in the District and identified and mapped the classified area of *enset* crop suitable cultivation in the order of highly, moderately, marginally and not suitable aspect.

1.2 Statement of the problem

There have been occurrences of frequent crop failure causing severe socio-economic impacts that include food insecurity, famine, deaths, epidemic diseases, pests and economic losses among others issues in different country. These impacts seem to spread over large areas and differ in severity, magnitude and duration. The problem has caused public outcry for good information on agricultural farming practices for land suitability planning and management purposes (Mark et al., 2015).

Enset is an indigenous; little researched staple food crop known for its tolerance to temporary drought, high yield and environmental sustainability (Brandt et al., 1997). According to these scholars *enset* is a multipurpose plant with a range of utilities including food source for human and animals, soil and water conservation, construction and medicinal uses. K*ocho*, a fermented starch resulting from crushed pseudo stalk and corm, is the most important product, which is often baked into bread. *Enset* thread is the main bye product resulting from decortications of the thickset tissue from leaf sheathes of the pseudo stem. *Enset* also plays an important role as diet for animals during dry season. Fresh *enset* leaves are selectively cut from the standing crop and fed to livestock throughout feed shortages. Leaves for livestock feed can also be obtained as bye product during the entire *enset* plant harvest (corm and pseudo stem processing and fermentation into starch food). Among all other agricultural practices, *enset* farming systems support the largest human population concentration in Ethiopia, which in some areas it exceeds 1000 persons per square kilometer (SARI, 2014).

Enset is also the biggest vegetable having number of advantages to farming and consuming society. It is known in maintaining soil fertility, reducing land degradation, providing a long term sustained food supply by minimum inputs of effort, requiring a given parcel of field size, supporting large number of human and animal population. *Enset* is also characterized with highest amount of production with in small parcel of land, intercropping with other plants or crops, continued production of parcel of a field for decades or even for a centuries and still remain productive, stable and reliable (NRC, 2006).

According to Prakash (2003), now a day the number of human population of this world is increasing in an alarming rate. This is also a real condition happening in the study area, Mareka District. To feed fast growing population, it needs wise usage and planning of land to boost food crops production potential of an area. *Enset* represents about 65% of the total crop production and cultivation in the SNNPRS of Ethiopia (Shank and Chernet, 1996, Amare and Daniel, 2016).

To increase food production capacity of the area, it is very important to identify suitable areas for agricultural activities. Based on this, a given land could be assigned with regards of suitability for particular practices there by to regulate for efficient and effective land use utilization systems. Suitability analysis of an area using GIS that incorporate choice of the decision makers could bring long standing solutions in distinguishing appropriate land for potential productivity (Malczewski, 2006). As elaborated Rono and Mundia (2016), GIS tool has a unique ways to the analyses of suitability by involving all factors that influence land suitability to be combined and weighted under the single theme.

There are a number of factors that determine the growth and intensive cultivation system in the Mareka District Compared with other type of crops, *enset* can support large number of human and animal population with in small piece of agricultural field. This is why *enset* can yield larger quantities of food crop production in the small land surface.

Little attention has been paid towards *enset* production as well as utilization at local, regional and national scales. This can be mentioned with regard of the application of modern technologies including the usage of chemical fertilizer (Tsegaye and Struik, 2002). According to Genet (2004), due to less scientific investigation regarding the *enset* crop suitability, there has not been gained much importance that can be obtained from *enset* crop.

The study, area has also high potential of suitability than the present condition if it is used in a planned way for *enset* cultivation. The study area has more *enset* production potential than what currently exists, but little attention has been given towards to assessment of potential the suitability of the District for *enset* cultivation. For this reason, GIS based land suitability analysis study is necessary to solve problem.

1.2.1 Identified Gaps of *Enset* related works

The gaps identified from the reviews of different literature are that most of the research works done with respect to *enset* limited in its areal extent to the central and northern parts of southern Ethiopia especially Sidama Gurage, Hadya and Kambata tambaro Zones for instance (W/Michael et al., 2008a). Most of the agricultural research centers know existing are in Hawasa (SARI), Wolayta (Areka) and Bonga. In general talking, there were fewer researches done concerning *enset* and *enset* suitability particular in this study area (Mareka District). The other gap was most of research works related to *enset* themes focus on issues like land races (Assefa and Fitamo, 2016), indigenous knowledge (Olango et al., 2014), diversity and conservation (Negash, 2001), production estimation (Shank and Chernet, 1996), diseases of *enset* cultivation (SARI, 2013, 2014).

Although, these are important themes to be considered for *enset*, the physical or environmental land suitability must be at the core of *enset* cultivation which was overlooked or either under mined by the researchers. There are a few investigations on GIS based suitability analysis for cereal and cash crops cultivation, and very few researches concerning GIS based crop suitability in the study area. The present study has initiated in suitability analysis of *enset* crop cultivation. This is the main gap which needs great attention from researchers, land use planners, agricultural offices and from any other concerned bodies. The sector needs great attention since modern system of farming is very important to boost production potential. Land use planning information must be integrated for this endeavor. The above explained problem initiated the birth cry of this work.

1.3 Objectives

1.3.1 General objective

The general objective of this study is to assess the physical environment suitability for *enset* cultivation in Mareka District.

1.3.2 Specific Objectives

The following further particular objectives are prepared to guide the study in efficient way. These are to:

- ✓ Differentiate the current land use or land cover distribution types in Mareka District
- ✓ Identify and analyze biophysical factors that determine cultivation of the of *enset* crop.
- ✓ Produce map of the potentially suitable land area for *enset* cultivation

1.4 Research questions

- ✓ What are the current land uses or land covers distributions in Mareka District?
- ✓ Which biophysical factors determine *enset* crop cultivation?
- ✓ How to produce map of potentially suitable cultivation area for *enset* crop?

1.5 Significance of the study

Physical factors like climate, elevation and soil type can be considered the determinants of *enset* cultivation in study area. For this purpose, analysis of suitability can be very important tool to agricultural development planning. Because this enables to analyze suitability and capacity of cultivation in terms of land use land cover, climate, altitude and soil type. This could be implemented in both local and regional planning in the process of *enset* cultivation. Primarily this study analyzes potential cultivation area of *enset* crop. It evolves future plan of action including modernizing and determines suitability of *enset* cultivation for maximizing land use and productivity.

This study fills the gap by providing information to planners and policy makers for the field of *enset* crop production by using its spatial suitability analysis. Furthermore, *enset* crop dependent especially local communities can use the work to expand cultivation and production capacity of *enset* crop in the Mareka District.

1.6 Scope of the Study

Geographically, the study undertook in Mareka District, Dawuro Zone, South west Ethiopia. Content wise, the study was focused on GIS based *enset* suitability analysis through different environmental factors. Under GIS suitability analysis, there is most important method that could be used in multi criteria decision making system which was employed in this study. AHP is the sub methods of MCDM that was employed in the study to prioritize the influence of factors on the suitability of an area by giving weight for each of criteria according to their influence automatically.

1.7 Validity and Reliability of Data

For more examining of the findings, before performing weighted overlay suitability analysis map of study area prepared, sixty nine random points that has sampled with their coordinates were over laid to assess the accuracy of LU/LC classification and make fit suitability analysis model map. The study was also incorporated different methods standards and concept from different reviews of articles; selected farmers, experts, and Webs catalogs so on in order to come across on reliable and dependable research work.

1.8 Ethical Consideration

As described in Gatrell et al., (2012), scientists that deal with spatial phenomenon of earth's surface must follow every guiding principle formulated to human study fields. This should also go back into any efficiency to respect the dignity and well being of society that participates in geographical science investigations. The research code of ethics for professionals declares that conducts environmental investigation must make every effort to closely follow any guidelines established for human subjects' research and, beyond these, to make every effort to ensure the dignity and welfare of human participants in spatial science. The researchers get informed consent from the town administrative workers, community and key informants by clearly stating the objective and relevance of undertaking the project.

1.9 Organization

This paper is presented in five chapters and different subsections. Chapter one deals with an introduction, under this background, statement of the problem, objectives, research questions, significance and scope of the study, validation and reliability of data, ethical consideration and organization of the study were discussed widely about general overview of *enset* crop information in relation to the current study. Chapter two covered review of related literature that provided hypothetical and conceptual skeleton of work of other in scholars' writings. In chapter three the study has incorporated methods and materials and subsections like location description, agro ecological settings, about population, livelihood, research design, data source, type and collection methods, suitability analysis evaluation, and weighted overlay. Chapter four engaged in results and discussions. Chapter fives deals with conclusion and recommendations'.

CHAPTER TWO

RELATED LITERATURE REVIEW

2.1 Concept and Definition of Suitability Analysis

In suitability analysis a GIS based process applied to determine the suitability of specific area for substantial land application, i.e. it tells the suitability analysis of an area regarding its fundamental distinctiveness (fit or unfit). In addition, this analysis involves with considering wide ranges of criteria including environmental or physical factors. Appropriate handling of such large and heterogeneous maps requires applying a flexible tool. The Spatial Analytical Hierarchy method was introduced by Saaty in the mid-1970s and developed in 1980s is among the best method, which is suitable for carrying out these kinds of analysis as in (Saaty, 2000).

2.2 Definition of suitability Analysis

Suitability analysis is defined as the capacity of surface area of a particular land to support predetermined land use type. The process of classification includes assessment and assigning of particular land area in terms of their potential and current suitability for defined land use (Prakash, 2003). The suitability is a function of crop physical requirements and land characteristics and it is determinant of how well the qualities of land unit and environmental suitability factors counterpart with requirements of a particular form of land utilization (FAO, 1976).

The study by Gizachew (2014), described that GIS technique was found to be most necessary tool for the cropland suitability assessment of the given area. It was understandable that the same parcel of land was suitable for all crops bringing challenging nature of crop land use types (LUTs). To validate the variations observed in the spatial analysis, other empirical research need to be carried out. The current limiting factors for all crop suitability were soil type, altitude, rainfall, and temperature limits.

Enset is an orphan or little researched food crop cultivated merely in Ethiopia. *Enset* serves as staple or co-staple food for about 20 million people in Ethiopia, which accounts for 20% out of the more than 95 million people (Tsegaye 2002). The edible parts of the plant are the underground stem (corm) and pseudo stem, which are crushed and fermented into a starch-rich product called *kocho*. *Kocho* is mainly consumed after making pancake-like bread. The corm can be harvested at almost any age of the crop, and boiled and consumed in the same way with other root and tuber crops alleviate hunger during periods of critical food shortages. *Kocho* can be kept for a long time (for 10 years and even more) without being spoiled (Brandt et al, 1997).

Ministry of agriculture (MOA) (1989), argued that *enset* is a specialized and distinctive food crop cultivated in different areas of the Southwestern highlands, where it is a significant part of the crop mix in the farming system distribution reflect in the results of land evaluation. That show having the most suitable land for *enset* plant is area that has long growing periods (LGPs). Conversely, areas having short growing periods are the major constraint to *enset* cultivation in the lower areas, and poor soil drainage limits the suitable area in some parts of the *enset* dependent community, this is also true for study area.

2.3 Environmental Requirements for *Enset* Plant

Productive potential of *enset* is higher than any other crops cultivated in the region. However this can be determined by soils rain fall, temperature, LU/LC, altitude so on (Shank and Chernet, 1996, Amare and Daniel, 2016).

According to Olango et al. (2014), agronomical advice is needed which requires increased knowledge and understanding of management techniques of *enset* crop cultivation. This is important to integrate indigenous knowledge of *enset* and its cultivation system from farmers, experts and DAs.

There are no clear investigations made on the effects of environmental suitability analysis that determine the cultivation and production systems of *enset* crop. As taken from National Research Council (NRC) (2006), most of scholars claim that the following conditions are best suitable for the *enset* crop in general factors such as rain fall, altitude, temperature and soil.

2.3.1 Altitude

Altitude as a topographic factor strongly influences local environment weather conditions. This in turn also affect climate particularly temperature and rain fall of the given area. This eventually determines the suitability of *enset* cultivation (Smith et al, 2008). The study area has broad agro ecological zone based on topography that lies among Kola or hot lowland (‹1500m.a.s.l), Woinadega or mid highland (1500-2500m.a.s.l) and Dega or cool temperate highland (› 2500m.a.s.l) (MOA, 2000 and Hailu ,2014)

Generally, *enset* can be planted at elevation height extending from 1,100m to above 3,000m.a.s. l. It is particularly believed to be best suitable 2,000m and 2,750m.a.s.l elevation. Temperature as elements of climate and weather is one factor for any crop generation can be discussed in terms of average of low and high temperature or mean temperature conditions (MOA, 1989, Westphal, 1975).

2.3.2 Rainfall

Most *enset* growing areas receive annual rainfall amount ranges mainly from 1,100mm in march more than 1,500mm in September. Even though this amount of rainfall is not a demarcating boundary for *enset* plantation, growth and production of crop, the areas that gain little amount of rain fall is also cannot support the cultivation of *enset* crop, but it is taken as an ideal size of rainfall for the optimum usage (MoA, 1989).

2.3.3 Temperature

As described in MoA (1989) and Brandt et al. (1997), the mean annual temperature of *enset* plant growing environment is from 10 to 21^0c with relative humidity having 63 to 80 percent. The minimum and maximum amounts of temperature extent are 18 to 28^0c. From preliminary overview, it can be understood that *enset* cannot survive in both desert and frost area. Freezing destroys upper leaves of *enset* which can be best experienced in an altitude higher than 2,800m.a.s.l. This phenomenon becomes more series and can result in reduction of minerals that are important for *enstet* growth at altitude more than 3,000 m.a.s.l any determinants of *enset* plant growth is associated with amount of water or rain fall than that of temperature. *Enset* crop is considered as subtropical rather than tropical as result of the present growing locations are revealing the characteristics of subtropical climatic condition or in high altitude.

2.3.4 Soil type

E*nset* can be planted in many different soil types, as far as the soil is adequately suitable for *enset* roots and corm does not survive in deficiency of water. Consequently, the crop plant grows in well drained soils having normal water tables. The suitable soil investigated to be a moderately acidic to slightly alkaline with PH (potential hydrogen) value ranging from 5.6 to 7.3 (MoA, 1989). As described by Brandt et al. (1997), *enset* can potentially grows in most soil types as far as the soil has adequate fertility and well drained, but nitosols are most preferable than that of vertisols.

It is also physically existing matter that has a profile of minerals like organic and inorganic contents of different size that differ from each other depending up on type, soil structure, mechanical, chemical mineralogical and life system properties (FAO 1986).

2.4 Application of GIS in Crop Suitability Analysis

The importance of crop suitability goes beyond analysis of environmental factors, but also can include socio-economic suitability decision making. GIS includes different elements of data that begins with the integration of spatial data from RS based image data and is then standardized into computer system. This information can be controlled and various data topics such as agro ecology, climate, land use and soil categories overlaid for analytical manipulation. The strong question, analysis and syntheses of GIS were created model of rational tool to analyses cropland utilization decision (Baniya, 2008).

The capacity of GIS can play a major role in cropland suitability analysis decision-making processes. Considerable effort was employed in data gathering for the suitability analysis of *enset* crop production. This information can give hint both opportunities and drawbacks to the planning bodies (Ghafari et al, 2000). GIS have capacity to execute several works by using geographical and non- Geographical or attribute (both) data was saved in the system. It has the ability to combine many of geographic information technology advancements such as GPS, Remote sensing etc. The overall goal of GIS is to provide support spatial decision making system (Foote and Lynch, 1996). In multi-criteria analysis, many data segment could be managed in order to arrive at the suitability analysis, which can be achieved successfully through GIS.

Remote sensing provides the information about the various spatial factors under the study consideration. Remote sensing provides us with information's like land use /land cover change, drainage density, topography etc. Many non- parameters were also inferred looking several geographical procedures. Remote sensing together with GIS becomes a strong tool to integrate and interpret real world phenomenon in most realistic and understandable manner (Prakash, 2003).

2.4.1 Analytical Hierarchy process (AHP)

Analytical Hierarchy process is most commonly applied technique in complex issues decision making. AHP was introduced by Saaty (1977), with fundamental assumption that comparing of two components derived from their real time importance. AHP technique is the base of this assessment, because careful organization of sub criteria of main criteria if weight properly, represent perfect suitability order and fulfills the goal. After all, AHP is the weighting and comparing procedure (Baniya, 2008).

2.4.2 Evaluation Criteria.

According to Wanjohi (2008) in the spatial framework, evaluation criteria are associated with environmental things and interactions between things, and can be symbolized in the form of maps. A criterion map simulates the preferences of the decision maker concerning a particular concept, while a simple map layer is a representation of some spatial real data. A criterion map represents personal preferential information. Two different individuals possibly could allocate different standards to the same mapping unit in a single criterion map. After all factors standardized by expert knowledge, AHP is used for final evaluation of criteria with acceptable level of consistency ratio.

2.5 Importance of suitability analysis

GIS is an instrument to enter, store and recovery, management and analysis, and outcome of spatial information (Marble et al., 1984). Prakash (2003) argued that, in reality the main target of farming activity is all about maximizing the agricultural productivity and optimal use of land resources. GIS suitability crop suitability analysis provides guiding plan for proper utilization of land for cultivation practices.

It has been accepted that land crop suitability analysis is a real classification of agricultural land utilization and maximizing land usage must be depending up on the characteristics of land surface (FAO, 1976). Land use may also be considered in terms of current and potential suitability. Analyzing suitability of land for cultivation needs substantial work about data for explanation of prospects and restrictions to decision making bodies. GIS is important tool in describing relationship among crop characteristics and quality of land suitability.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Description of the Study Area

The study was conduct in Mareka District, Dawuro Zone that is located in SNNPRS where *enset* crop is a predominant staple food crop. It is situated to the southwest of Ethiopia at a distance of about 445k.m from Addis Ababa across Butajira- Hosana and 510km through Jimma via Tarcha. Astronomically Mareka District extends from $6^0$56' 00" to 7^0 04' 00" North and 37^0 02' 00" up to 37^0 16' 00" East. In its relative location Mareka District is found south west of Gena Bosa, north west of Loma, north of Esera and east of Tocha Districts. The total land surface area of the district is about 46.724 square km. The overall elevation of the District ranges between 947 and 2546 m.a.s.l.

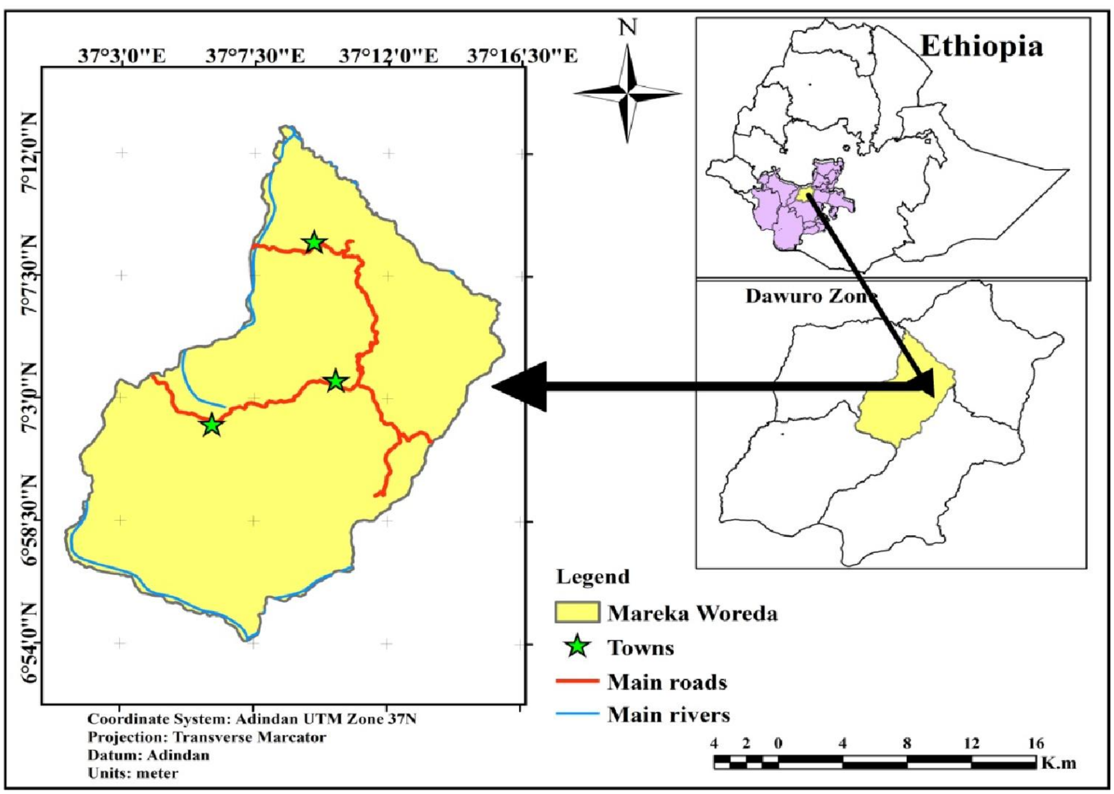

Figure 1: Location of the study area in Dawuro Zone

3.1.1 Agro ecology

According to MoA, (2000) traditional classification, agro-ecology of Ethiopia is classified as Kur, Wurch, Dega, Woina-dega, Kolla and Bereha. Based on the agro-ecological classification, the agro-ecology of the Mareka District, out of the total land size which is about 46,724 meter square (hectare); 8.23% is Kola (500-1500m.a.s.l), 50% Woinadega (1500-2300 m.a.s.l) and 41.77 % Dega (>2300 m.a.s.l). The minimum and maximum temperature ranges between 16^0c to 23.4^0c and the minimum and maximum rainfall amount is about 1314mm to 1516 (MoA, 2000).

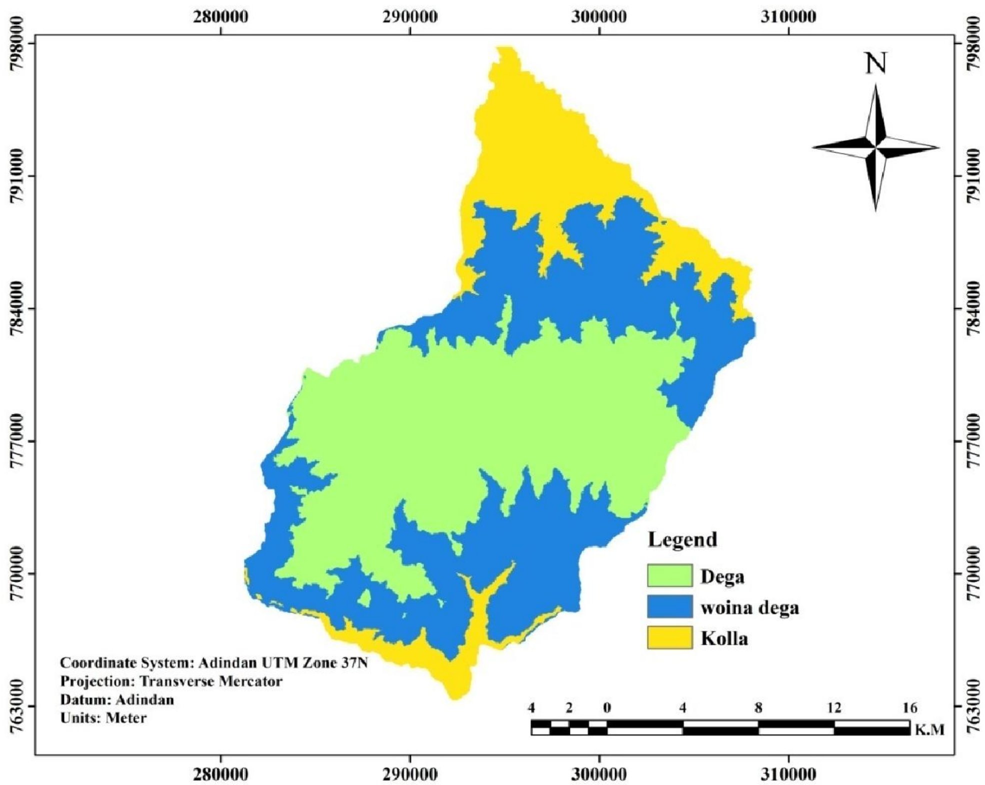

Figure 2: Agro ecological zones of Mareka District (Mareka District office of agriculture, 2014)

3.1.2. Land Use

Land use/land cover map of the study area divides into four major classes. These are crop land, settlement area, forest cover and open area. Crop land classification is dominant covering about 56.28 percent of total area. *Enset* which covers about 9,860ha and maize are major subsistence crops for highland and lowland inhabitants respectively as explained (Mareka District Agricultural office, 2016).

3.1.3 Population

According to Maraka District Finance and Economic Development Office (MDFEDO) (2014), the total population of Mareka District is estimated to be 147,913 from the total population 72,686 (49.2%) male and 73,269 (50.8%) were females based on data collected from the annual report of the office. The population density of the study area is 73 people per square km. From these 15% are lives in urban area. The remaining 85% are agrarian lives in rural parts of District (MFEDO, 2014).

3.1.4 Livelihood Conditions

According to SNNPRS livelihood profiles regional overview (2005), patterns of livelihood clearly vary from one area to another. Local factors such as climate, soil, access to market etc. all influence livelihood patterns. In the District the main food crops and live stocks are: maize, *enset*, sweet potatoes and cattle, sheep and goats respectively. There are no specialized cash crops but households sell some maize and one-half to two-third of the *enset*, *teff* and pulses they produce. Coffee is secondary sell item. Livestock, especially cattle are important source of income by providing the 45-60% of the household cash income annually.

3.2 Methods and materials

3.2.1 Research design

The research approach was semi mixed sequential dominant quantitative (technical) analyzation followed by qualitative interpretation. This research was based on the crosssectional study design. It was relied more on quantitative or technical logical procedures while concurrently recognizing qualitative explanations (Burke et al., 2007).

3.2.2 Data types and Source

1. Biophysical

The major data types used in this study include climate (average temperature and rainfall) data, ASTER (DEM) to derive altitude, soil. Likewise, Land sat 8 satellite image of 2017 was accessed freely from USGS to produce land use or land cover map of the study area

The primary source of ground control truth points that were collected from the study area. The secondary sources of data like DEM obtained from open source of (http://srtm.csi.cgiar.org), raster dataset of climate freely accessed from worldclim open source up dated climate data provider from 1970-2000 (30 years average precipitation and temperature) and shape file of soil from FAO. These basic data were resampled and clipped into study area boundary extent and were changed in to similar raster format.

2. Key Informants Interviews (KII)

Non probability sampling technique used to gather qualitative data from key informants. From this non probability sampling, purposive sampling method was used to conduct interview. KII was prepared to classify, analyze, assess and evaluate the factors that determine physical environmental condition for *enset* cultivation in the study area. As mentioned all KII were selected purposefully from different places, position and fields who acquired experience or knowledge related to agricultural practices in general and *enset* cultivation in particular. Accordingly five Developmental Agents (DAs) and five *enset* cultivation model farmers informed by DAs were used from Kebele levels. Three experts selected from office of the District, namely soil and plant science, land use administration experts. KII also conducted with soil and plant experts from Dawuro office agriculture. One *enset* plant expert from Southern Agriculture Research Institute (SARI), in total sixteen (16) different individuals from different position and field interviewed with written form of questions prior to made suitability evaluation and classification. The *enset* suitability classification was based on the information obtained from KII and supported by literature.

Table 1: Data types, sources and resolutions

No	Variables	Data type	Resolution (m)	Resample (m)	Data source	Remark
1	Elevation	DEM/raster	30*30	Original	USGS	
2	Soil data	Vector	-	30*30	FAO	
3	Meteorological data	Raster	1km	30*30	Worldclim .com	
4	Landsat8 2016 image	Raster	30*30	Original	USGS	
5	KII	Qualitative description data from Key informants				

2.2.3 Data Processing and transformations

1. Re-sampling of data

Data types that had accessed from different source possess various spatial multispectral resolutions with as well as with different format needs to be calibrated in to similar form and resolution before further processing. Here soil data which was in polygon clipped and changed in to raster format of the study area prior to any process. Interpolation technique was performed to get study area average annual rain fall and temperature data of worldclim. This data were validated by using the meteorological data that obtained from station near the study area. Due to absence of station with in study area, meteorological data gathered from neighbor station were interpolated by IDW and the pattern value was compared with that of worldclim data value.

All data sets changed into similar raster data resolution merge of 30 by 30 by resample extensions of raster data management tool. Clipping of the data to maintain the extent of the study area was also performed by using ERDAS for Land sat 8 image and Arcgis for the remaining data such as rain fall, temperature, altitude, soil by using study area boundary shape file. Bilinear resample technique was used for it performs a bilinear interpolation and determines the new value of a cell based on a weighted distance average of the four nearest input cell centers. It is useful for continuous data like rainfall, temperature and soil data and can cause some smoothing of the data using Arcgis 10.3.

2. Land use land cover

The ETM+ of 2017 January months ETM+ image of path 169 and row 055 was accessed from www.earth explorer.usgs.gov web site with 900m square spatial resolution. ERDAS imagine 2014 software was used to produce LU/LC map of the study area.

Land use land cover classification

GIS has been efficient and powerful tool in providing reliable information on natural resource classification and mapping of land use/ cover change over space and time (Teshome, 2016). Image classification was based on unsupervised and supervised image classification algorithms of ERDAS imagine 2014. The area was classified into four major different categories of land use types practiced based on experts from Mareka District office of agriculture. The categories are cropland settlement, forest, and open area as discussed detail. These all land use or land cover were classified with high level of accuracy. But some points classified as interrupted by crop land from open area, and forest cover.

Accuracy assessment

Land use/ land cover map of the study area accuracy of classification were cross checked by using ground control points obtained from the study area. Over all accuracy assessment was calculated. The Kappa coefficient expresses the error of a completely random classification (Congalton and Green, 1999).

K-hat computation

$$\hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}$$

Where N=total number of samples, r=number of classes, xii=diagonal (correctly) classified values in matrix, xi+=total row samples in row i, x+i=total sample in column i as adopted from (Congalton and Green, 1999).

Area which covered with restricted forest which is located on the north western border of the study area is prohibited from other land uses. The geographical coordinates of an area is $7^0$01'23"N up to $7^0$03'42" North and 37^0 03'07" up to 37^0 03'20" East .There are also other very small parcels of land which are restricted to use including cultivation of *enset.* So these are also considered in the classification process.

3. Climate Data

Crops cultivation requires particular amounts of rainfall and temperature. The study area lies within three classes namely Kola, Woina dega and Dega ecological zones as classified in traditional AEZ of Ethiopia (MoA, 2000). Worldclim data of average temperature and average rain fall from (1970_2000) which were obtained from Worldclim data were clipped by the shape of the study area to come up with the all over District map of temperature (average annual temperature) and rainfall (average annual rainfall).

4. Altitude

The elevation of study area was taken from DEM 30m resolution. The altitudinal range of the study area varies between 947 to 2,546masl (Jarvis, et al., 2008).The traditional agro ecology classification of the study area was reclassified in to four suitability classes based on office of agriculture agronomy and land use planning experts as highly, moderately, marginally and not suitable from highest to lowest altitude.

5. Soil Types

The soil type also influences suitability potential of the area for *enset* cultivation. Due to this soil type is considered as of parameter in suitability analysis of *enset* crop. Under soil data, there are different sub factors; this study considered soil type.

The property of soil type varies from one area to another that influence both up growth of plant as well as down extending of roots which in turn determine the survival and productivity (Henok, 2010). Soil types found in study area are orthic acrisol, eutric cambisols, dystric nitosols, dystric gleysols and dystric fluvisols.

Dystric fluvisols formed through erosion from elevated area to lower place and deposited in lower place. As classified by FAO (1977), fluvisols were categorized under moderately suitable for cultivation of crops. Whereas cambisols and acrisols were marginally suitable for agricultural practice if only factors like climate conditions allows for cultivation process. The remaining gleysols and histosols are not potentially suitable under current condition for agricultural development. Soil classification was supported with both literature and soil experts. The soil types identified from the data obtained from FAO and its productive quality description was gained from different literatures including FAO guidelines. Finally soil, plant and crop experts classified the soil types of the study area into four classes based on their productive potential. Namely highly, moderately, marginally and not suitable classes

3.3 Crop Suitability Evaluation

When a given crop suitability was carried out; area coverage, importance of the crops in the livelihood of the concerned community, suitability of soils and agro-climatic conditions of the study region is always considered. The cropland use requirement (LURs) was also selected based on agronomic knowledge of local experts and FAO (1998) guidelines. FAO establishes the following six fundamental guidelines for any type of land uses.

These basic principles are as follows:

> *"I. Land suitability is assessed and classified with respect to specified kinds of use; this principle embodies recognition of the fact that different kinds of land use have different requirements. ii. Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land: iii. A multidisciplinary approach is required: the evaluation process requires contributions from the fields of natural science, the technology of land use, economics and sociology. iv. Evaluation is made in terms relevant to the physical economic and social context of the area concerned: v. Suitability refers to use on a sustained basis: The aspect of environmental degradation is taken into account when assessing suitability.vi. Evaluation involves comparison of more than a single kind of use: This comparison could be, for example, between agriculture and forestry, between two or more different farming systems, or between individual crops."*

Digital data of selected land characteristics (LCs) of the region and classifier tables for crop LURs were properly encoded to the Microsoft office Excel sheet as database file was used in Arcgis for spatial suitability analysis. The land characteristics were reclassified based on cropland use requirement (Gizachew, 2014). Dawuro Zone and Mareka District offices of agriculture agreed on the following class description of crop suitability could be used for *enset*. The suitability classification considers both experts and literature.

Table2: Description of *enset* crop suitability (based on experts knowledge and Gizachew, 2014)

Code	Class	Description
S1	Highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
S2	Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
S3	Marginally suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
S4	Not suitable	Land that cannot support the land use on a sustained basis, or land on which benefits do not justify necessary inputs.

Where S1=highly suitable, S2=moderately suitable, S3=marginally suitable, S4=Not suitable

3.4 Spatial Multi-Criteria Decision Making process

Multi criteria decision making is defined as a process that combines and transforms a different spatial data inputs into a resultant decision output as described in (Drobne and Lisec, 2009). MCDA is a set of guiding line designed to facilitate decision-making. The basic purpose is to investigate a number of choice possibilities in the light of multiple criteria and conflicting objectives. Accordingly, this research used MCDM for factors and lastly prioritized each of factors based on the weight that was given by AHP calculation. Spatial (MCDM) is a process where geographical data is combined and transformed into a decision. Multi-criteria decision-making involves input data and the decision maker's preferences and operations of information by using particular decision system (Henok, 2010).

Spatial MCDM is more complicated and hard in contrast to conventional MCDM, as large numbers of factors need to be identified and considered, with high association of relationships among the factors (Malczewski, 1999). He also explained that the spatial decision problem is the difference between the desired state in a geographical system and an existing state in real world.

Spatial MCDM aims to attain solutions for spatial decision problems, resulting from multiple criteria. These criteria, also called attribute must be known carefully to arrive at the objectives and ultimate goal. The performance of an objective is measured with the help of these attributes. These objectives and fundamental attributes form a structure of evaluation criteria for a particular decision problem. These evaluation criteria should be comprehensive and measurable (Henok, 2010).

Being an issue of multi-criteria decision-making process, *enset* suitability demands for visualization of the impact of the alternatives and criteria in the form of maps. This requires can be accomplished effectively by the integration of spatial analysis and conventional multi-criteria evaluation techniques. Moreover, environmental decision problems are characterized of having multiple and often contradictory objectives. When evaluating such a complex phenomenon, the spatial dimension seems to be the big hurdle. Here, the integration of GIS and MCDM techniques becomes useful.

3.4.1 Analytical hierarchy process (AHP)

Analytical Hierarchy process is most commonly applied technique in complex issues decision making. AHP was introduced by Saaty (1977), with fundamental assumption that comparing of two components derived from their real time importance. AHP technique was the base of this assessment, because careful organization of sub criteria of main criteria if weighted properly, represent perfect suitability order and fulfills the goal. After all, AHP is the weighting and comparing procedure (Baniya, 2008). The Analytic Hierarchy Process (AHP) in MCDM exercises was found to be a useful method to determine the weights for each individual factor. It shall deal with inconsistent judgments and provides a measure of the inconsistency of the judgment of the factors. The GIS was employed as a technique that provides greater flexibility and accuracy for handling digital spatial data. The combination of AHP method with GIS in our experiment proved that it was a powerful combination to apply for land-use suitability analysis (Mustafa et al., 2011).

To come up with relative influence of weights of criteria and sub criteria, Analytical Hierarchy Process (AHP) approach in MCDM was used. In order to calculate the weights for criteria and sub- criteria, pair wise comparison matrix was structured by using data obtained from different experts and literatures; each and every factor were compared with the other factors relative to its influence on a scale from 1/9 to 9 in tabular format that was introduced by Saaty (2008).

Table3: Saaty scale of rating influence of factors

No	Intensity of influence	Definition	Explanation
1	1	Equal importance	Two factors influence equally to objective.
2	3	Somewhat more important	Experience and judgment slightly one over the other
3	5	Much more important	Experience and judgment strongly favour one over the other
4	7	Very much more important	Experience and judgment are very strongly to favour one over the other. Its importance is demonstrated in practice.
5	9	Absolutely more important	The evidence favouring one over the other is of highest possible validity
6	2,4,6,8	Intermediate values	When compromise is needed

3.4.2 Criteria standardization

The evaluation choices could be expressed according to different scales. The large value of multi criteria method needs that all criteria are expressed in the same scale. Standardization of criteria allows the rescaling of evaluation dimensions between 0 and 1 where o indicates not suitable and value 1 indicates suitable. This allows comparisons among criteria as described in (ILWIS User's Guide, 2004).

Following the processing and preparation of data, the factors were organized in the class of fit to their weight of importance. In AHP approach, the criteria are standardized, by using pair wise comparison methods. The standardization of factors or criteria brought about in ratings.

3.5 Weighted Overlay Analysis

Land suitability overlay mapping units

Land Mapping Unit (LMU) is an area of land demarcated on a map and possessing specified land characteristics and qualities (FAO, 1976). Land mapping unit were defined and map by natural resource surveys (e.g., soil survey, forest inventory). It was the analysis unit about which statements were made regarding its land suitability (Rossiter, 1996). The spatial unit of analysis for suitability evaluation is the land mapping unit. The delineation of this unit should, ideally depend on land qualities that have the most influences on the land uses under consideration. Thus, depending on the objectives of the evaluation, relevant 'core' data sets may include soils, elevation, climate, vegetation, and surface rainfall and temperature. In practice, Geographic Information Systems (GIS) are commonly used to overlay pertinent data sets in order to derive land mapping units (George, 2001).

A land unit must be drawn on the map defined by polygon of specific area. It must ensure the homogeneous characteristics of the land and also have to be supported specifically by the description of attribute data. Land units were determined by simple measures based on features that were observed directly on the field or remote sensing or others (Baniya, 2008).

According to Rabia and Terribile (2013), land suitability analysis desires a multi criteria decision making process as the analysis is guide of a decision makers regarding problem considers a number of parameters. Land suitability analysis was based on the functions of physical factors.

IDRISI software decision wizard software component was used to support multi criteria in which evaluation process multilayer were aggregated to yield a single out suitability overlay map. The weights were developed by providing a serious of pair wise comparison matrix of the relative importance of the factors to the suitability of pixels for the activity was analyzed. The pair wise matrix comparisons were then analyzed to produce a set of weights that sum to one. The procedures by which the weights were produced follow the logic developed by Saaty under the analytical hierarchy process (AHP).

$S = f(x_1, x_2 \ldots\ldots\ldots x_n)$

Where, S is land suitability level and x_1. $x_2\ldots$, x_n are the factors affecting land suitability for a given crop type in particular geographical set of an area.

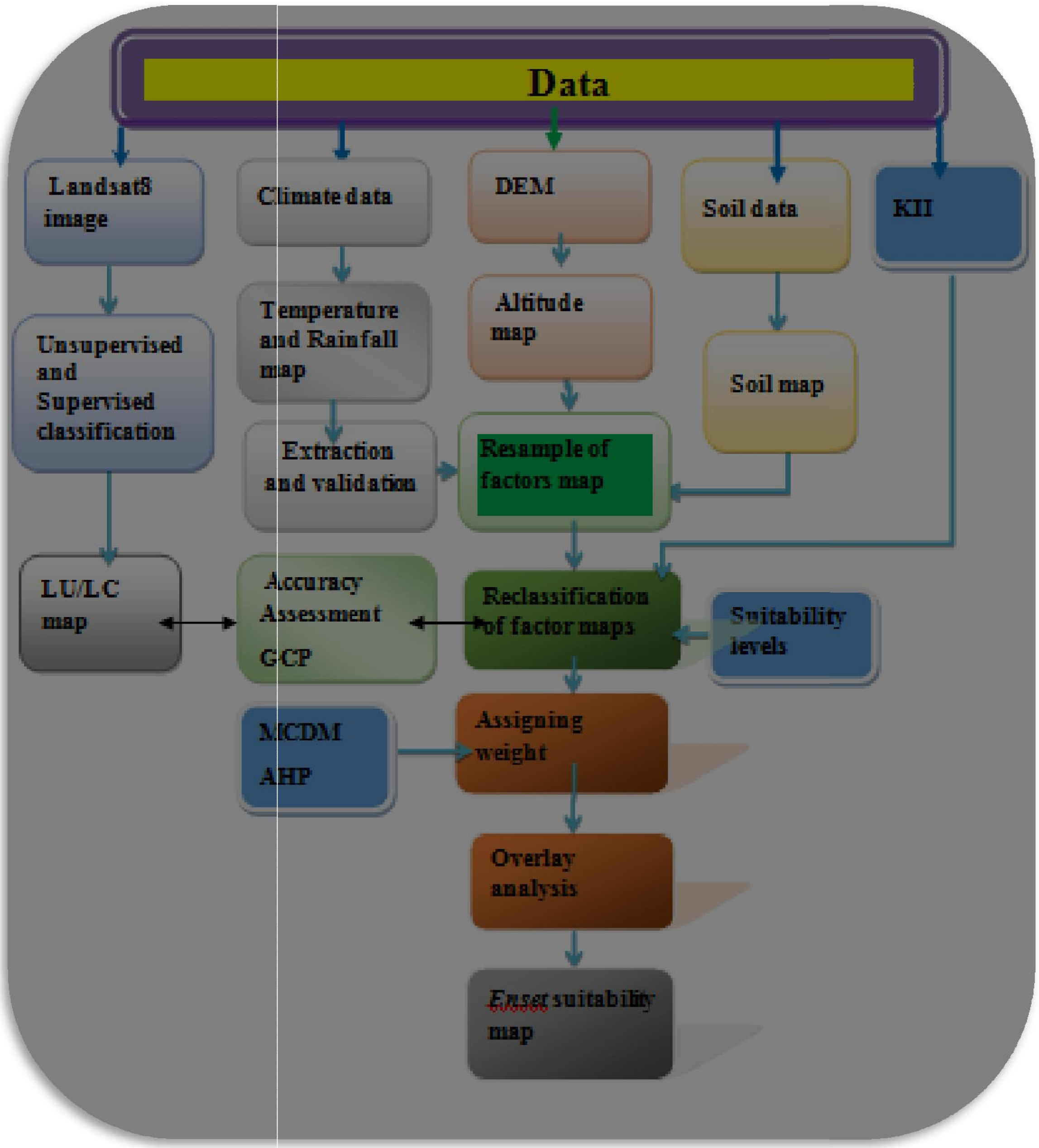

Figure 3: Overview of methodological flow chart

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Land Use or Land cover classification

Classification is the process of arrangement of pixels into a predetermined number of individual classes or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria. The result of training site is a set of signatures, which are criteria for a set of proposed classes.

Image was classified by the ERDAS imagine 2014 using supervised and unsupervised classification technique were used. The area was classified into four major different categories of land use types exercised. This is to classify image pixel into its belonging spectral resolution class. The unsupervised classification of image was carried out to understand the general land use/cover classes of the study area. Depending on the result of unsupervised classification the identification of training site were done. The categories are Cropland, settlement, forest and open area as written in table 4 below. These all LU/LC were classified with high level of accuracy. But some points classified as interrupted by agriculture from open area, and forest cover. The land use land cover of study area was classified with over all accuracy of 85% and kappa coefficient of 0.82. The calculated value of the kappa coefficient 0.82 of land use land cover classification of the study area was acceptable to proceed for the next steps of the work.

The following table was constructed to represent the classes of LU/LC of the study area. Then the quality of classification assessed was done by using over all accuracy and kappa coefficient.

Table 2: Accuracy assessment of landsat7 ETM+ 2017 classification

No.	Land use/ land cover class	Forest	Settlement	Open area	Agriculture	Total
1	Forest	**11**	0	0	0	11
2	Settlement	0	**12**	0	1	13
3	Open area	0	2	**16**	2	20
4	Agriculture	2	0	3	**20**	25
	Total	13	14	19	23	**69**

Overall all accuracy 0.85

Kappa coefficient 0.82 acceptable

The diagonal number value shows correctly classified land use pixel where as zero tells about the absence of interferences in the classification. The overall accuracy was calculated by dividing the total sum of correctly classified pixels by total sum of to pixel value in the error matrix. This value is 0.85or 85% when multiplied by 100%. Kappa coefficient measures the agreement between the classifications on map and the reference data or GCP. The Classifications is acceptable then can proceed to the next further for work. The kappa coefficient calculation resulted in 82% after multiplying by 100%. According to Adam et.al (2013), the kappa coefficient calculation result of LU/LC classification in the study area represents a strong corresponding agreement.

Table 3: LU/LC classifications of the study area

No.	Land use type	Area cover in (ha)	Area in (%)
1	Cropland	26,296.3	56.28
2	Settlement	96,83.2	20.72
3	Forest	29,46.8	6.31
4	Open area	77,97.7	16.69
Total		46,724	100

1. Cropland

Crop land cover class is the largest of all other type LU/LC type in the study area covering about 26,296.3ha which is 56.28 % of the total area. Most area of Dega and Woinadega agro ecological zone grows different types of crops. The major crops cultivated in these two zones are *enset* which has 9,860 ha or 21.1%, bean, peas, wheat, *teff*, maize, different roots and vegetables. In the Kola agro ecology maize, *teff, and* roots are cultivated.

2. Settlement

Settlement considered different categories of human settlement and construction areas like road, buildings, village, and towns that cover 9,683.2ha this is about 20.72% of the total area. There are major towns or settlement in the central and northern tip of the study area. The central part of the study area is densely populated.

3. Forest cover

The forest cover area includes both private and public forest surface this cover about 16.69% of the study area. The forest cover distributed in the study area, however, highest density of natural forest cover is located to the western parts of the study area. This is restricted from any type usage.

4. Open area

This stands for the area that is currently free from any kind of LU/LC. It covers about 7797.7ha which is about 16.89. Open areas situated to the south east and northern parts of the study area. But there is significant size of open area unevenly distributed in different parts of the study area.

Based on classification of the image from the total area of Woreda is 46,724.1hectare, of which agriculture accounts for about 56.28%, settlement 20.72%, Forest 6.31% and open area 16.68%.

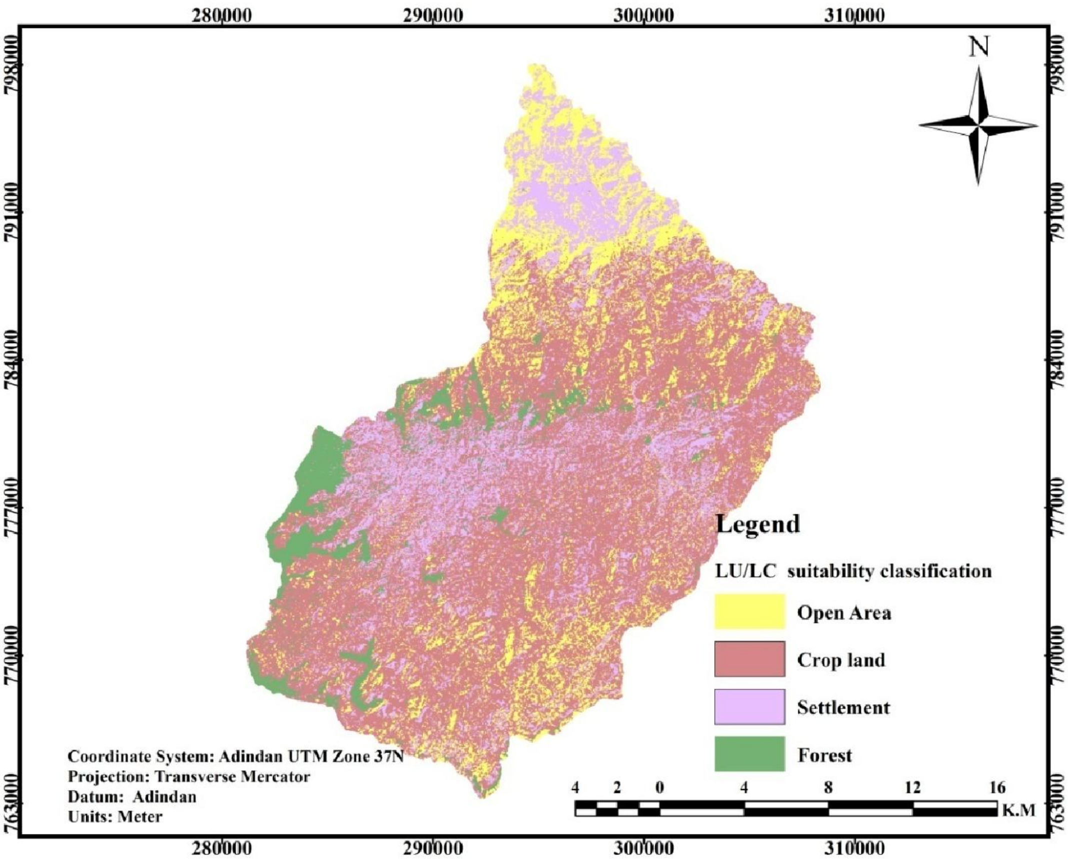

Figure 4: LU/LC classes of the study area.

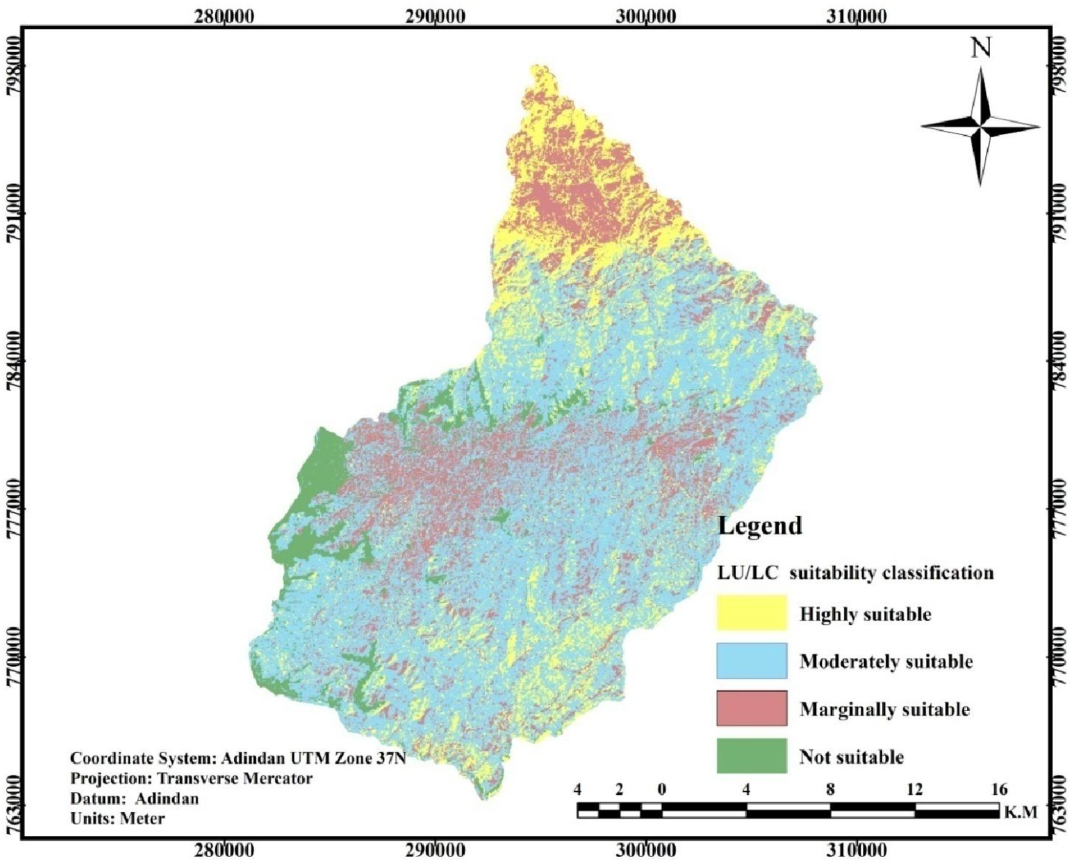

Figure 5: LU/LC suitability of the study area

Open area is considered highly suitable due to lower socio economic value when compared with other types of land use land cover in the study area. This why it is easy to implement the cultivation of *enset* in the area without incurring maximum in put economic cost.

4.1.1 Land use or land cover suitability Evaluation

Based on knowledge of experts, the LU/LC type the study area further reclassified into highly, moderately, marginally and not suitable classes. According to land use land cover, open land 7,794.7 hectare or 16.88 % which is located as distributed on southeastern and north central parts of the study area is highly suitable for *enset* cultivation. The agricultural area that is about 26,296.2 hectare or 56.3% of total area that lies widely in the center of the study area is classified as moderately suitable for *enset* agriculture. The remaining settlement and forest which covers the total area by 9,683.3 and 2,946.8 or 20.7 and 6.3% are classified as marginally and not suitable for *enset* cultivation respectively.

Table 4: LU/LC class description (based on experts knowledge)

LU/LC	Area in (ha)	Area in (%)	Suitability classes
Open area	7,878.06	16.86	Highly suitable
Crop land	26,356.68	56.41	Moderately suitable
Settlement	9,464.76	20.26	Marginally suitable
Forest	3,024.36	6.47	Not suitable

Here open area represent the surface that is currently remain free from any activity. According to experts opinion *enset* cultivation can be highly suitable on open area that is located on northern and southern tips of the study area than another type of land use in the study area**.**

4.2 Climate Data

The climate data of average temperature and average rainfall from (1970-2000) calculated from Worldclim data of thirty years. The thirty years average temperature and rainfall were reclassified with four classes according to their average value of places categorized by the Mareka District agronomist office of agriculture independently. The climate from both meteorological agency and worldclim had similar surface result when evaluated at data validation process.

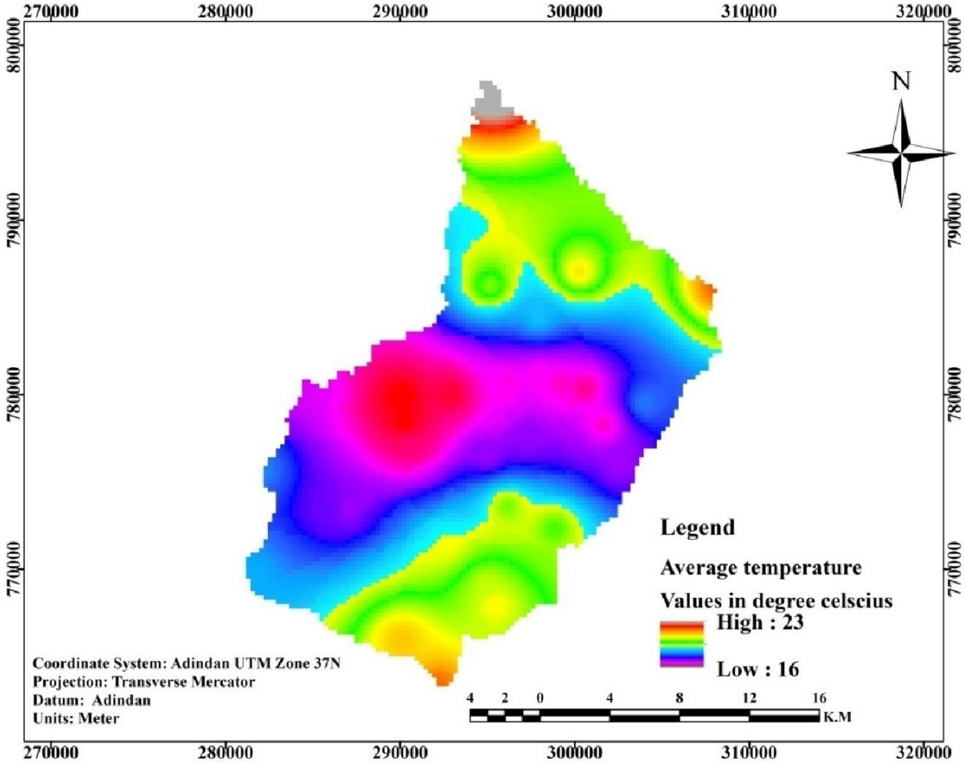

Figure 6: Average annual temperature of the study area

The highest and lowest average annual temperatures of the study area are 16.0 and 23.3^{0}c respectively. The lowest temperature and the highest rainfall experiencing area was known to be highly suitable and the area characterized by having high temperature and low rainfall classified not suitable for *enset* crop production in the study area. This finding is only based on the perpective of temperature the other factor has also their own influence.

4.2.1 Temperature suitability evaluation

Table 5: Average annual temperature (based on experts knowledge)

Average annual temp.(^{0}c)	Area in (ha)	Area in (%)	Suitability classes
< 17.5	14,211	30.4	Highly suitable
17.5up to 18.7	26,573	56.8	Moderately suitable
18.7 up to 20	4,743	10.2	Marginally suitable
> 20	1,197	2.6	Not suitable
Total	46,724	100	

The place with lowest value of temperature distribution with area coverage of 14,211hectare or 30.4% of total area was classified as highly suitable for *enset* cultivation. Highly suitable class of the study area has the temperature extent from 16.0 to 17.5^{0}c. According to Alemayehu (2017), the highly suitable area is situated to the Dega which is similar with result found under this study. The hinterlands of the study area exhibit this character.

This area has adequate rainfall occurrence probability when compared with other geographical setting. The remaining area that accounts 26,573, 4,743 and 1,197 hectare or 56.8, 10.2, and 2.6 % of total area was classified as moderately, marginally and not suitable for *enset* crop cultivation in the study area respectively. The average annual temperature of *enset* growing environment is from 10 to 21^{0}c (MoA, 1989 and Brandt et al., 1997).

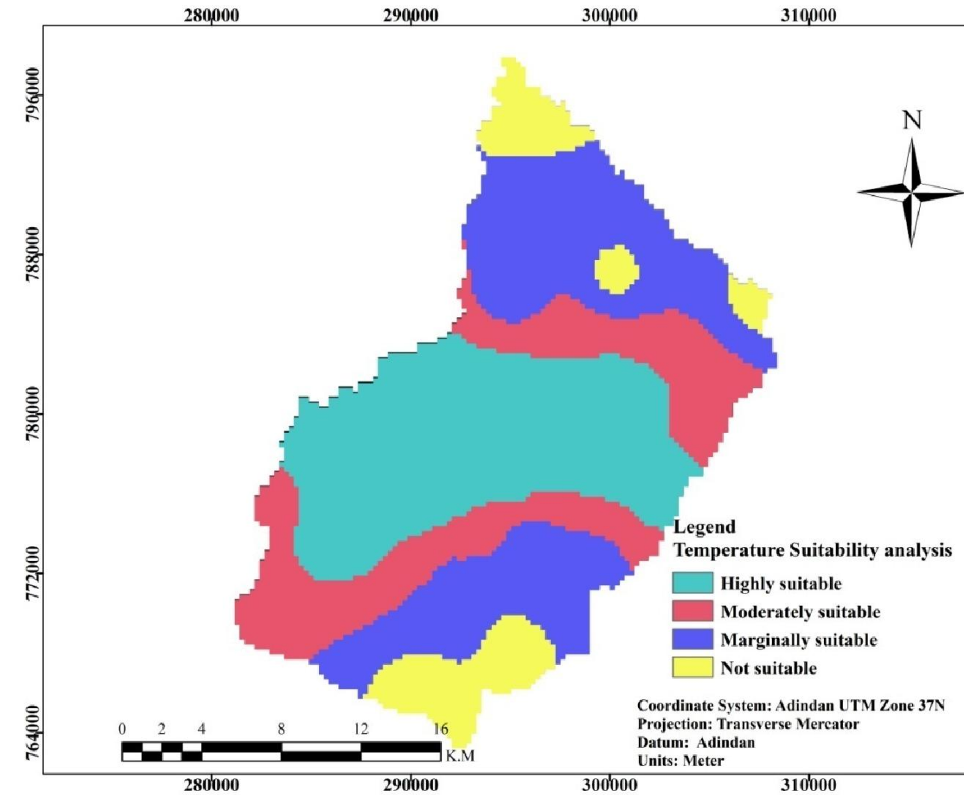

Figure 7: Average temperature suitability of the study area

The area with average annual temperature range from 16.0 to 17.5^{0}c which situated to the central part laying from east to west classified as highly suitable.

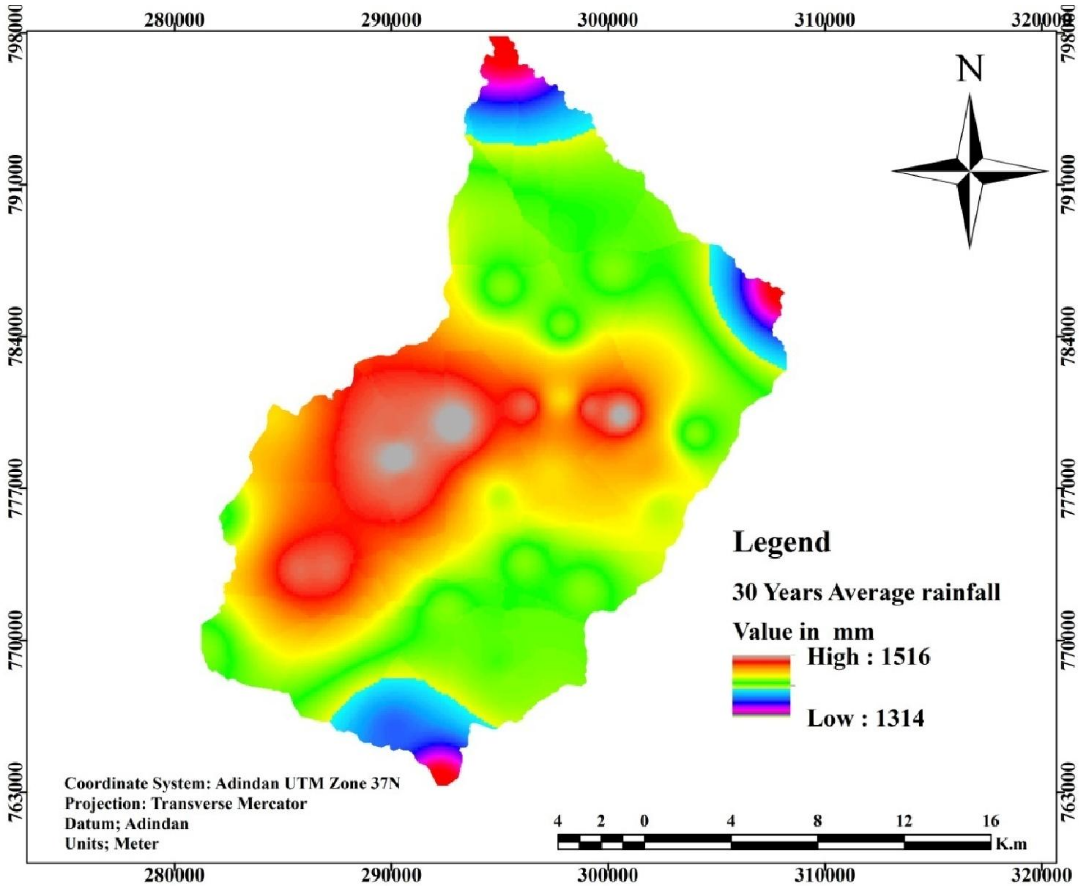

Figure 8: Average annual rainfall

The above figure represents thirty years average highest and lowest rainfall of distribution in the study area. The place with highest rainfall is Dega, medium is Woina dega and lowest is known to be Kolla. Dega area has high potential of *enset* cultivation than that of Kolla. This is further discussed in proceeding sections.

4.2.2 Rainfall suitability evaluation

Rainfall and temperature are inversely related with each other when examining the climate data of the study area. Rainfall is a dominant factor that determines the suitability of *enset* cultivation in the District composing the large share of the influence which is about 55.8%. The potential final suitable area still cannot be selected; this selection is based on only suitability of temperature only. The suitable condition of temperature itself cannot guarantee for final suitability is a combination of all factor.

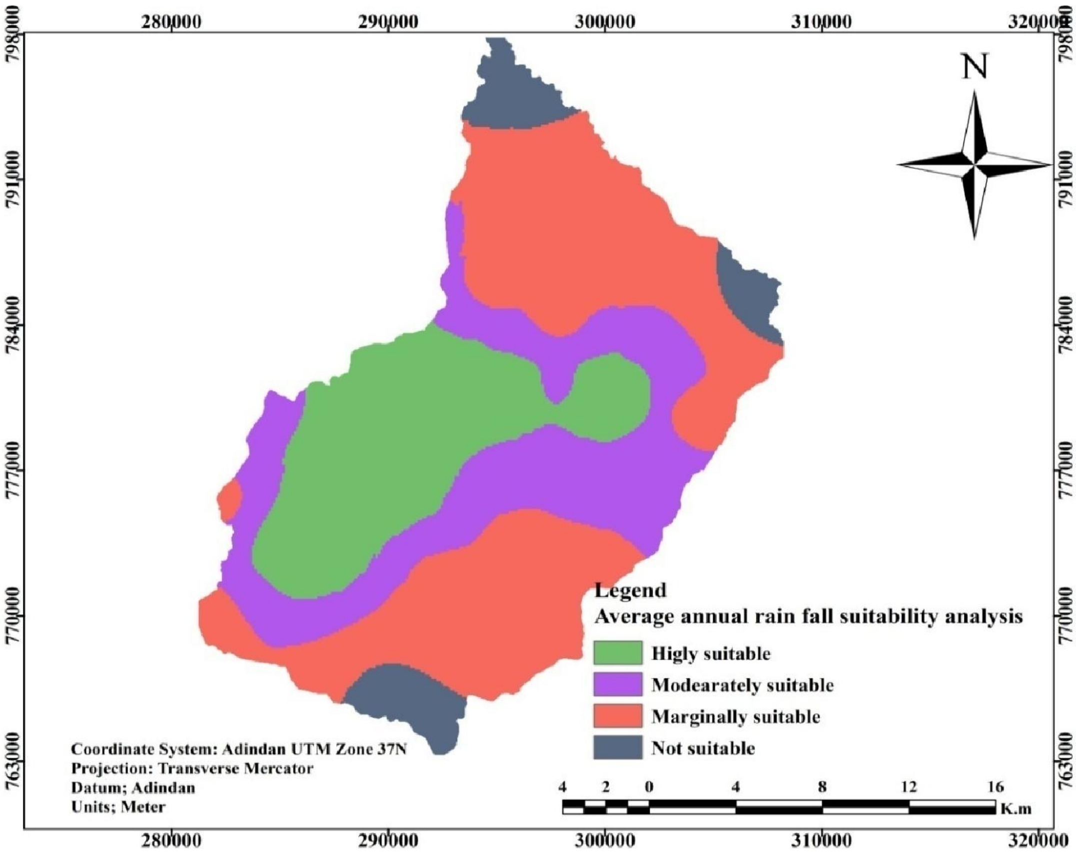

Figure 9: Average rainfall suitability of the study area

Table 6: Rainfall suitability (based on experts knowledge)

Average annual rainfall range (mm)	Area in (ha)	Area in (%)	Suitability class
> 1,455.7	16,677.5	35.7	highly suitable
1,413.8-1,455.7	23,228.3	49.7	Moderately suitable
1,369.4-1,413.8	5,197	11.1	Marginally suitable
< 1,369.4	1,621.2	3.5	Not suitable
Total	46,724	100	

According to local expert opinion, unlike average temperature distribution the highest rainfalls preferable to *enset*, the area with highest distribution of rainfall which is about 16,677.5 hectare or 35.7 % of total area was classified as highly suitable for *enset* agricultural practices. The remaining 23,228.3, 5,197 and 1,621.2 in hectares or 49.7, 11.1 and 3.5 % are moderately, marginally and not suitable for *enset* cultivation in study area respectively. According to MoA (1989), areas that receive highest amount of rainfall are highly suitable for *enset* cultivation than areas that gain less amount of rainfall. The lowest average annual rainfall recorded in the northern tip of the study area is not suitable for *enset* cultivation.

4.3 Altitude

The elevation of study area was taken from DEM having 30m resolution. The altitudinal range of the study area varies between 947 to 2,546masl. According to traditional agro ecology classification of Ethiopia, agro ecology range of the Woreda ranges from Kola to Degas. Kola 500-1,500masl is about 8.23%, Woinadega 1501-2,300masl is about 50% and Dega above 2,300msl is about 41.77%.

Generally, *enset* can be planted at elevation height extending from 1,100m to above 3,000m above mean sea level. It is particularly believed to be best suitable 2,000m and 2,750masl elevation. Temperature as elements of climate and weather is one factor for any crop generation can be discussed in terms of Average of low and high temperature or mean temperature conditions (MOA, 1989, Westphal, 1975).

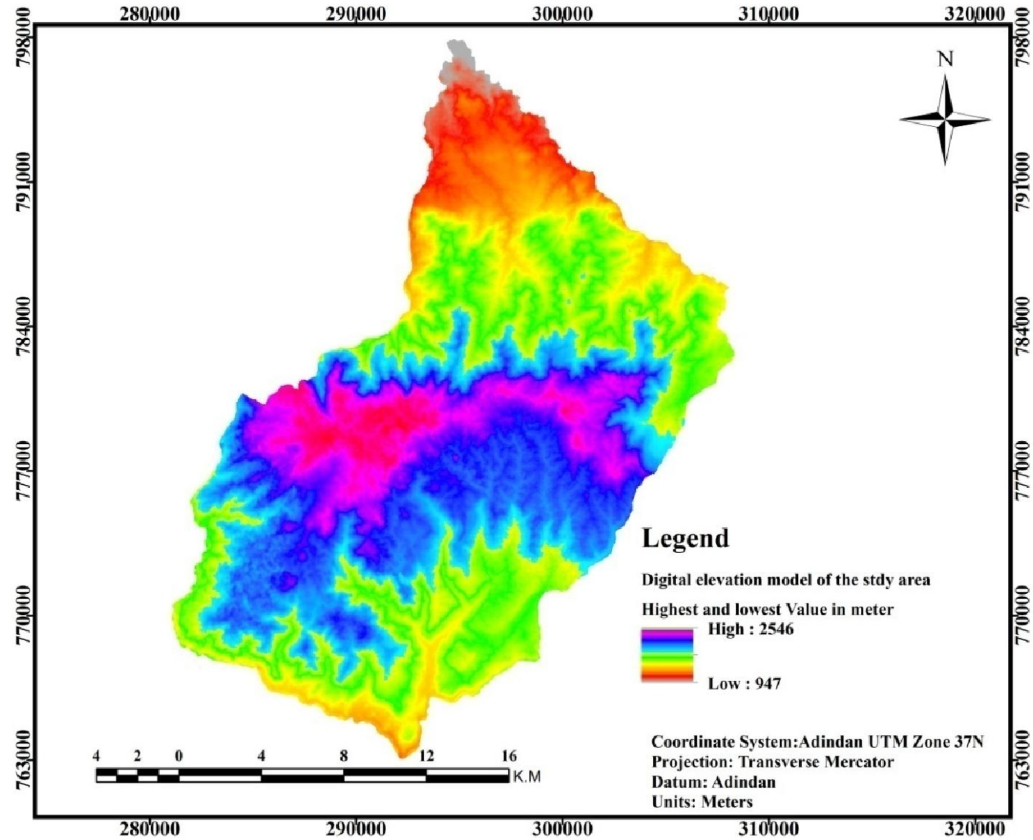

Figure 10: Spatial variation of digital elevation of the study area

Area with higher elevation is considered to be suitable for *enset* cultivation whereas places with lower elevation due to deficiency of rainfall and high average temperature, is not suitable for *enset* cultivation.

4.3.1 Elevation suitability evaluation

The altitude of the study area further classified into four *enset* suitability sub classes based on experts' knowledge as elaborated in the following.

Table 7: Altitude suitability classes (based on experts knowledge)

Elevation ranges (m.a.s.l)	Area in (ha)	Area in (%)	Suitability class
> 2,175	6,480	13.9	Highly suitable
1,859-2175	16,604.4	35.5	Moderately suitable
1,484-1,859	13,542.2	29	Marginally suitable
< 1,484	10,097.4	21.6	Not suitable

The central parts of the study area with altitude ranging from 2,174 up to 2,546 m.a.s.l covering about 6,480 hectare or 14% is classified as highly or potentially suitable for *enset* agriculture. While south east and northwest most tips containing about 10,097.4 hac or 21.6% of total area is classified as not suitable. The remaining area that cover large share of the District 13,542.2 and 16,604.4 hectares or 29 and 35.5 % classified as moderately and marginally suitable for *enset* cultivation.

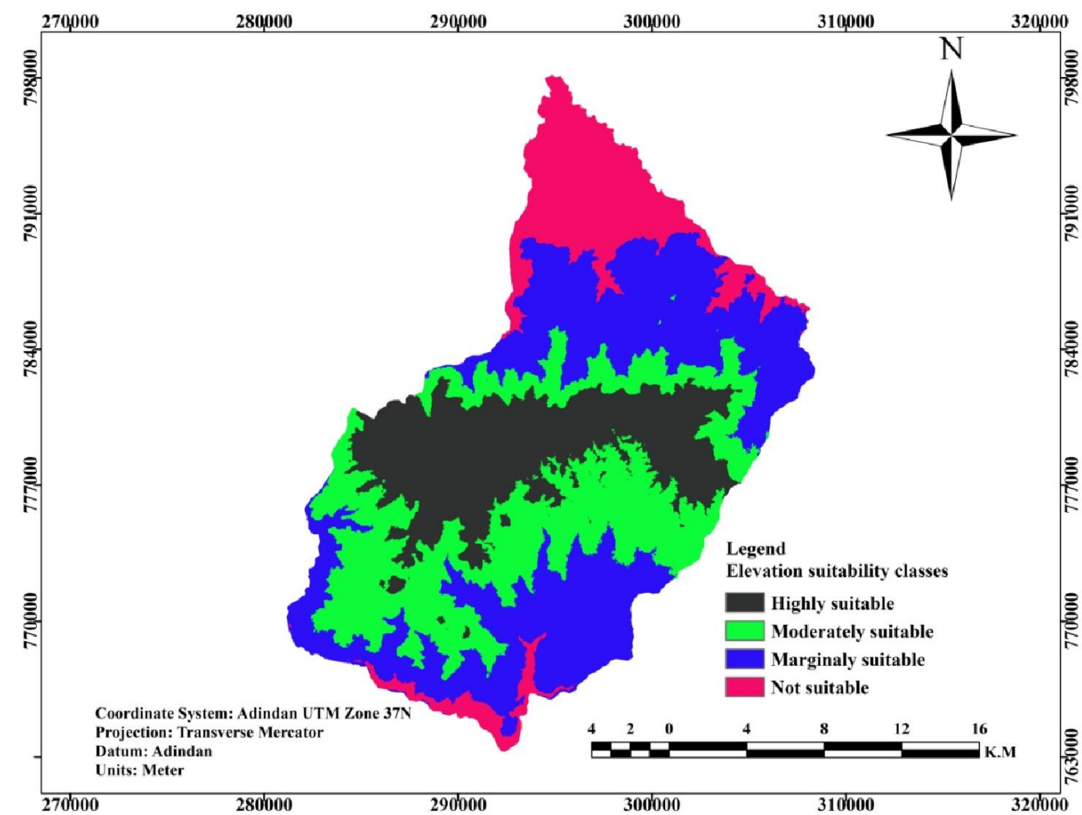

Figure 11: Altitude suitability map of the study area

Altitude as environmental factor strongly influences climate of a given place. It also determines the amount of temperature and rainfall that an area receives. This in turn determines suitability of land for *enset* crop (Smith et al, 2008).

According to Birmeta, Nybom & Bekele (2004), altitude range >2,000masl is considered to be highly suitable for *enset* cultivation this is also justified with this study, whereas areas having altitude greater than 2,800 m and lesser than 1,100masl not suitable.

4.4 Soil Types

Difference in types of soil play significant role in the cultivation of *enset.* Due to this there are cultivation variations in different parts of the study area.

According to FAO, among them dystric nitosols is dominant in the study area which accounts about 52% of total soil types. This nitosoil were basically associated with high rainfall and were probably formed originally on forest cover areas. They were mostly suitable and used in cultivation due to its high agricultural productivity. Dystric fluvisols formed through erosion from elevated area to lower place and deposited in lower place. As classified by FAO (1977), fluvisols were categorized under moderately suitable for cultivation of different crops. Whereas cambisols and acrisols were marginally suitable for agricultural practice if and only if factors like climate conditions allows for cultivation process. The remaining gleysols and histosols are not potentially suitable for agricultural development. This classification of soil was based on soil quality for crops.

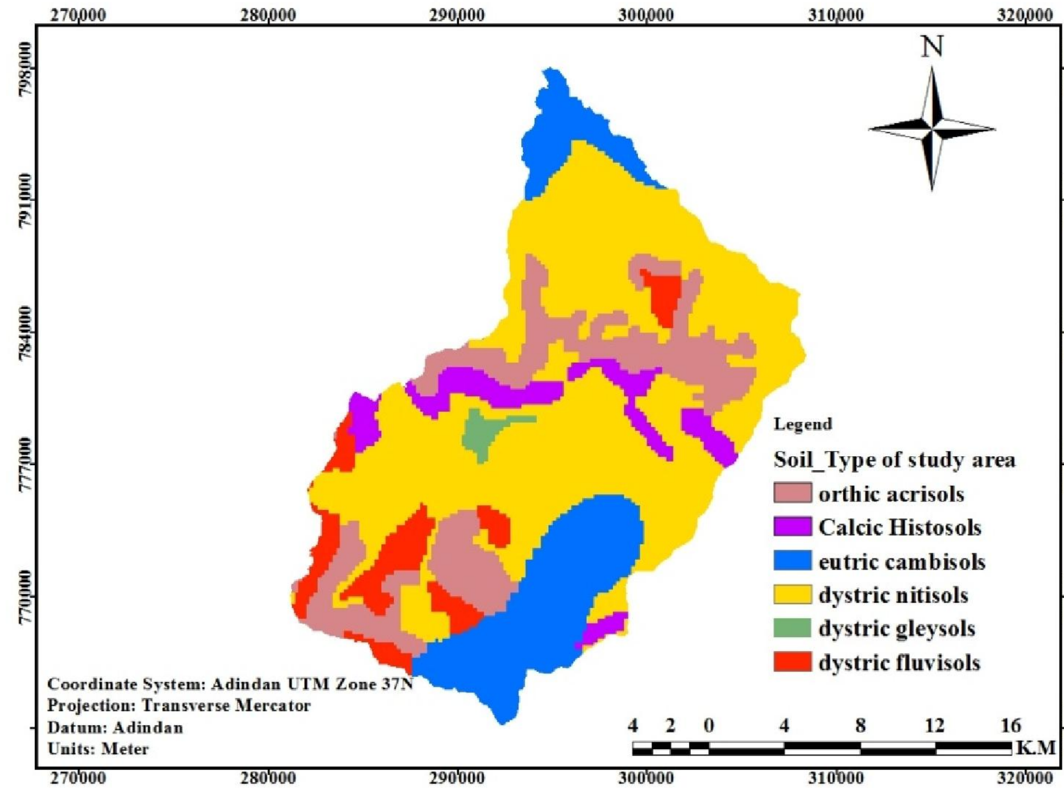

Figure 12: Soil types map of the study area

As classified and shown on the above figure, the area covered with nitosols coincides with places receiving high average annual amount of rainfall, low average temperature and having higher altitude. This in turn considered being good opportunity for *enset* cultivation.

Table 8: Soil type Proportion of the study area

Soil type	Area in hectare	Area in percent
Orthic Acrisols	8,054.55	17.2
Calcic Histosols	2,883.08	6.155
Eutric Cambisols	7,912.75	16.89
Dystric Nitosols	24,234.76	51.74
Dystric Gleysols	448.06	0.095
Dystric Fluvisols	3240.45	6.92

The dominant soil type of the study area is dystric nitosols covering more than half of an area. According to local experts, nitosols are the most suitable soil type for any agricultural activities. Following dystric nitosols orthic, eutric cambisols, dystric fluvisols and calcic histosols share large size in decreasing size of an area respectively. Very small size of area is covered with dystric gleysols.

4.4.1 Soi1 type suitability evaluation

Soil types that exist in study area are evaluated in their potential classes of suitability for agricultural production. The suitable particular soil type for *enset* cultivation identified and classified based on experts and FAO guidelines. Accordingly, among the soil type identified, dystric nitosol which cover the largest portion of the study area was classified as highly suitable to the *enset* cultivation. Dystric fluvisols was classified as moderately, orthic acrisols and eutric cambisols are classified as marginally suitable and calcic histosols and gleysols are classified as not suitable for *enset* agriculture.

Table 9: soil type suitability classification (based on literatures and experts knowledge)

Soil types	Area in ha	Area in %	Suitability class
Drystic Nitosols	24,209.1	51.74	Highly suitable
Dystric Fluvisols	3,237.1	6.92	Moderately suitable
Orthic Acrisols and Eutric Cambisols	15,950.5	34.09	Marginally suitable
Dystric Gleysols and calcic Histosols	3,327.3	7.50	Not suitable

Enset can potentially cultivated in most soil types if other factors like rainfall, temperature, land use and altitude are suitable, but nitosols are most preferable/highly suitable/ than any another soil types. The study result is in line with the idea of (Brandt et al. 1997). Accordingly, nitosol with area extent of 24,209.1ha classified as highly suitable for *enset* cultivation, fluvisols with 3,237.1ha area coverage is moderately suitable. Whereas acrisols and cambisols with area of 15,950.5ha as marginally, and gleysols and histosols that cover about 3,327.3ha area classified as and not suitable for *enset.*

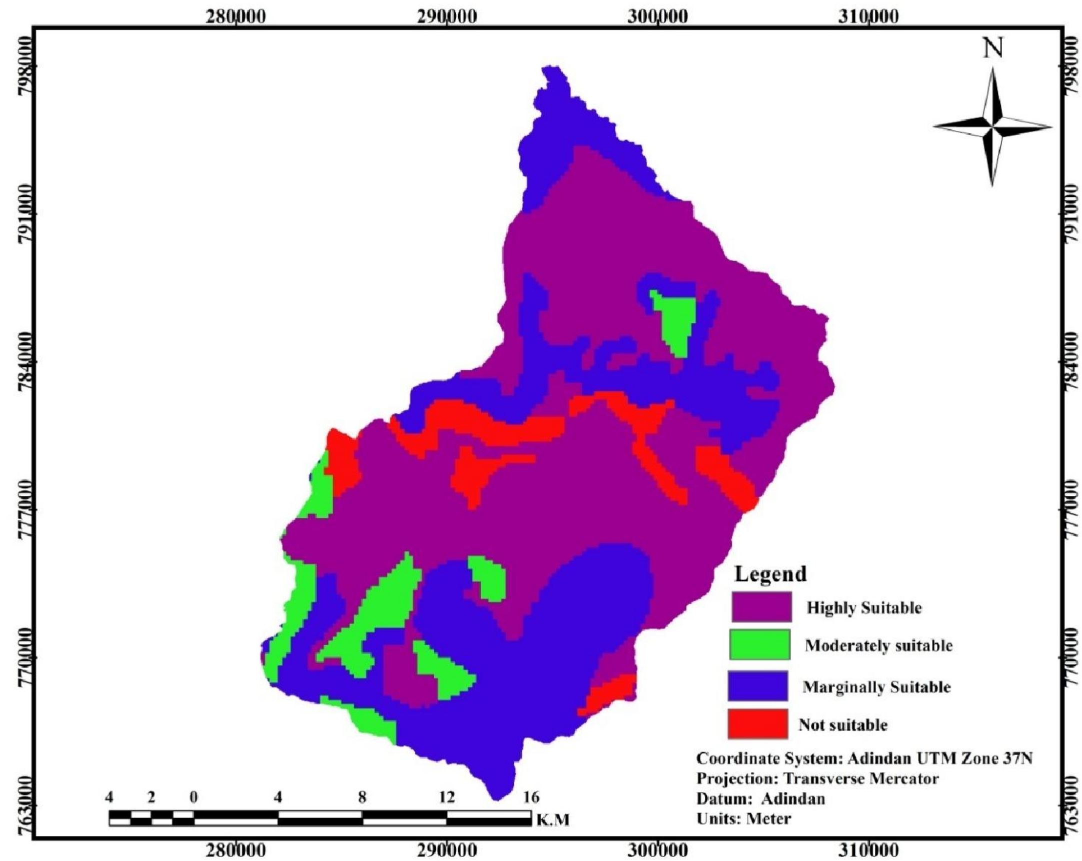

Figure 13: Soil type suitability classes

Dystric nitosols itself covers the significant amount of the area classified as highly suitable based experts' opinion and literature. From the total area, nitosols cover about 51.74 % which is classified as highly suitable for *enset* crop cultivation when compared with remaining soil types in the study area.

4.5 Discussion of Key Informants Interview (KII)

LU/LC type of the study area was classified with different names but similar expression. This all class expressions were organized in four general categories. These are; crop land, open area, settlement and forest.

KII have replied that there are different environmental factors that determine the physical suitability for *enset* cultivation. The dominant environmental factors that influence *enset* cultivation includes precipitation, elevation, temperature, soil types and land use of the area.

Most of the key informant i.e. 14 (90%) responded that rainfall is dominant of all factors in determining the land suitability for *enset* crop cultivation and production, and then rainfall is followed by altitude, temperature, soil type and lastly land use. This rank was established in descending order of the influence of environmental factors on land suitability for *enset* agriculture.

The responses of KII on ordering, weighting and rating the influence of the considered factors were analyzed inform of table under criteria standardization table below in table 12.

4.6 Multi Criteria Decision Making (MCDM) and Weighted Overlay Analysis

4.6.1 Criteria standardization

Following the processing and preparation of data, the factors were organized in an order of fit to their weight of importance. In AHP approach, the criteria are standardized, by using pair wise comparison methods. The standardization of factors or criteria brought about in ratings.

Table 10: Criteria considered for *enset* suitability analysis (experts knowledge)

No.	Criteria considered	Ratings	Suitability order	weight	Source
1	LU/LC	1	S1	5.42	Experts
		2	S2		
		3	S3		
		Restricted	S4		
2	Average annual temperature	1	S1	11.28	Experts
		2	S2		
		3	S3		
		4	S4		
3	Average annual rainfall	1	S1	51.80	Experts
		2	S2		
		3	S3		
		4	S4		
4	Altitude	1	S1	23.96	Experts
		2	S2		
		3	S3		
		4	S4		
5	Soil type	1	S1	7.54	Experts
		2	S2		
		3	S3		
		4	S4		
	Total			100	

In order to make comparison of one criterion with other, all values transformed into the same unit of measurement scale 1 to 4, while the different in put factor maps have dissimilar measurement units. The value of 1represents highly suitable, 2 stands for moderately suitable, 3 represents marginally suitable and 4 are not suitable based on sub suitability classification of the factors.

4.6.2 Analytical Hierarchy process (AHP)

In Saaty method, weights of this nature can be derived by taking the principal eigen vector of a square reciprocal matrix of Pair-wise comparisons between the criteria. The reason of weighting is to express the significance or preference of factors in relation to other factor affect on *enset* cultivation and growth. Pair-wise comparisons are relays on making judgments between two given factors rather than trying to prioritize an entire list of elements. A matrix is built, where each factor is compared with the other factors, comparative to its importance, on a scale from 1 to 9.

Table 11: AHP derivation

Criteria	Altitude	Land use	Rainfall	Soil type	Temperature
Altitude	**1**	3	1/3	3	4
Land use	1/3	**1**	1/7	½	1/3
Rainfall	3	7	**1**	7	5
Soil type	1/3	2	1/7	**1**	1/2
Temperature	½	3	1/5	2	**1**

The weights generated by this module are produced by means of the principal eigenvector of the pair wise comparison matrix. The information gained from experts standardized again by AHP eigenvector weight. Then, a weight calculated approximately and used to derive a consistency ratio (CR) of the Pair-wise comparisons. If the CR > 0.10, then some Pair-wise values required to be reconsidered and the process is repeated till the desired value of CR < 0.10 is reached.

All factors, which were selected for the evaluation of Land suitability in the study area, were weighted using pair-wise comparison. After the Pair-wise comparison matrices were filled, the weight module was used to identify consistency ratio and develop the best-fit weights. The consistency ratio (CR) was 0.05, which was acceptable for weighting of the factors to evaluate the physical land suitability of the area.

The finding reached with this study is in line with different research works done with in different time. Meaning that most of factors analyzed give the result that support the previous research done on *enset* with regards of physical environmental requirements for *enset* cultivation.

Table 12: Eigen vector weight

Criteria	Weight	% influence	Rating
Altitude	0.2396	23.96	2
LU/LC	0.0542	5.42	5
Rainfall	0.5180	51.80	1
Temperature	0.1128	11.28	3
Soil type	0.0754	7.54	4

Consistency ratio= 0.05

This is acceptable

Rainfall is a dominant factor that determines the suitability of *enset* cultivation in the District composing the largest share of the influence which is about 55.8%. The factors including altitude, land use, temperature and soil type has the percentage influence of 21.01%, 4.86%, 6.94% and 11.36% respectively. The ratings value 1,2,3,4 and 5 are given as result of the corresponding weight influences of each and individual factors.

The eventual suitable land decision for *enset* crop capability surface was done by multiplying the pixel value of each provided factors reclassification raster by weight of influence and summing the result of pixel value to get the suitable surface for *enset* cultivation.

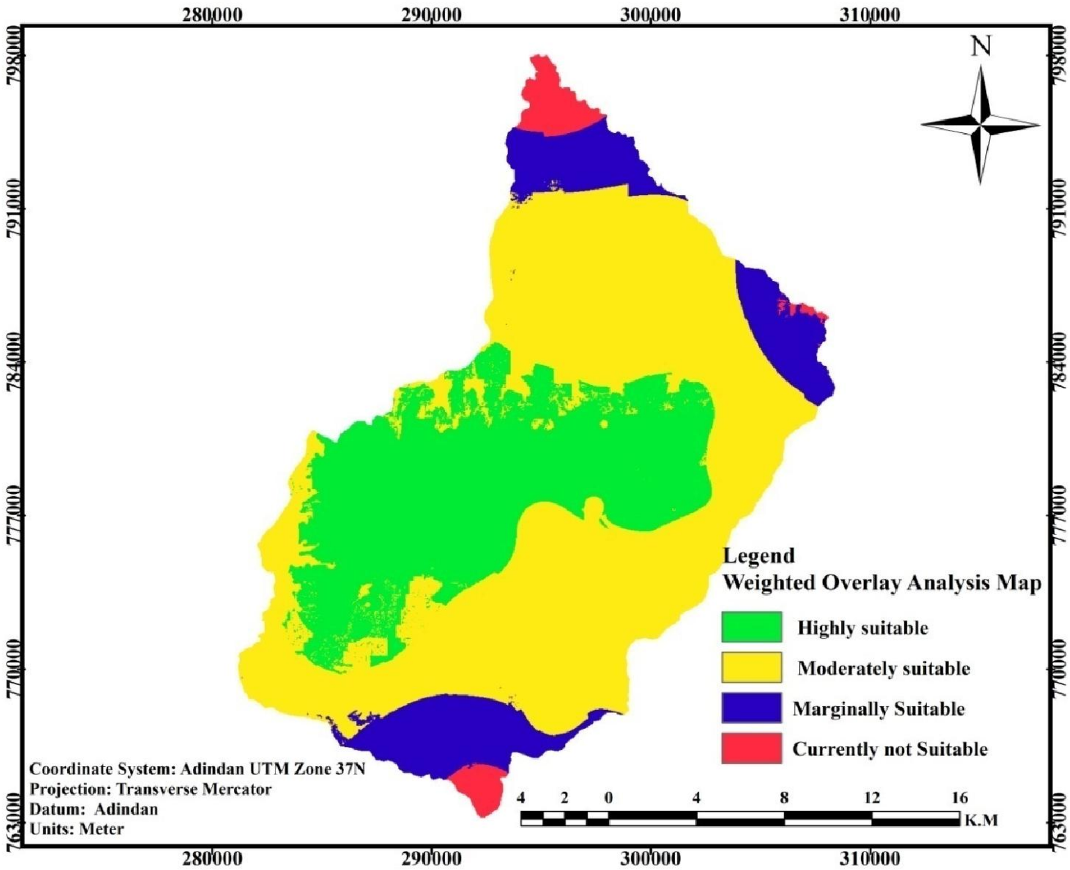

Figure 14: *Enset* cultivation suitability map of the study area

4.6.3 Suitability Evaluation

The findings map the Mareka District tells that the District has the suitable potential for *enset* agriculture. The highly and moderately suitable portion of area sums to 39,282.1ha or about 84.1% of the total land surface area. The others marginally and not suitable classes 5,657.12 and 1,844.65 hectare or 12.1 and 3.8 % for *enset* cultivation.

Table 13: Over all *enset* suitability analysis

Suitability class	Area (ha)	Area in %
Highly suitable	14,185	30.4
Moderately suitable	25,097.17	53.7
Marginally suitable	56,57.12	12.1
Not suitable	18,44.65	3.8

Among the whole area of 46,724 hectares of Mareka District, 14,185ha is highly suitable to the *enset* cultivation. This suitable area is distributed to the central part of the District laying from east to west in widening pattern. This is due to the existence of favorable physical environmental conditions like optimum rain fall, temperature, suitable soil type so on.

Suitability of an area for *enset* cultivation is not based on the influence of a given factor. Suitability is function of different factors combined together. That means both suitability and unsuitability of a given plot of an area for *enset* cultivation is result of the combined effects of physical environmental factors. The final suitable area gained in the analysis is still cannot be used to carry out *enset* cultivation without limitation. Due to parcels of land covered with different types of LU/LC. This area is in fact predominated existing cover of *enset* cultivation.

In addition to the above, the study has also come across with open area which is located within potentially cultivated area that can be cultivated *enset* without any limitation identified and displayed on map.

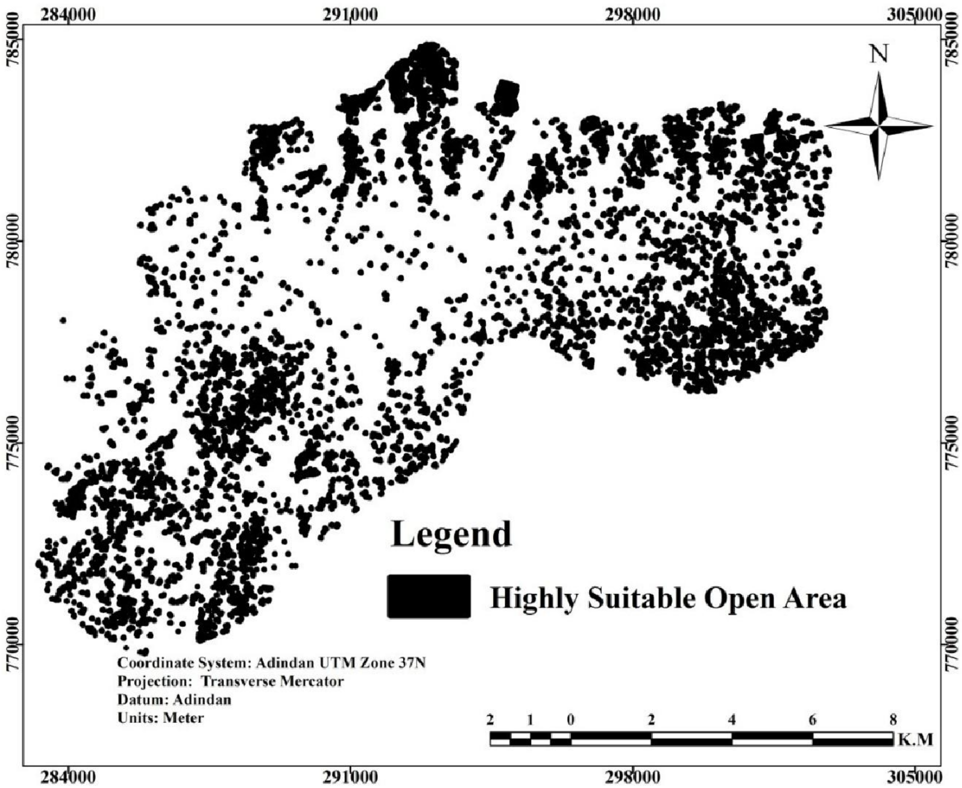

Figure 15: Suitability Model Map

Total highly suitable area is 14,185ha; this is about 30.4% of total study area. Potentially highly suitable open area is 635.3ha. This is about 1.4 % of total study area coverage and 4.5 of area highly suitable for *enset* cultivation. This open area can be utilized for *enset* cultivation without limitation and little economic cost.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research was intended to identify the suitable land for *enset* cultivation. Thus a methodology of GIS and AHP based land suitability analysis has been used to determine the suitability of *enset* crop cultivation in Mareka District by using factors such as LU/LC, climate, altitude and soil type characteristics of the area.

The research results evidence that the comparison of current land use highly and moderately suitable land surface for *enset* cultivation are already being used in the area for *enset* and other agriculture cultivation. The result of the study indicated that about 39,282.2 hectares or 85% of the total area 46,724 is analyzed as potentially from highly to moderately suitable for *enset* agriculture in the study area.

The final suitability weighted overlay analysis surface map shows that the suitable area for *enset* crop cultivation is situated to the central parts laying from east to west in widening pattern of the study area. This area characterized by higher elevation, receiving higher average annual rainfall, lower temperature, existence of nitosols and fluvisols. While areas having lower altitude, characterized by lower average annual rainfall , higher temperature and cambisols type which situated to the most tips of southeast and north are marginally to currently not potentially suitable for *enset* agricultural practice. These are because of the total biophysical conditions of the surface in the central parts of the study area is favorable for cultivation, but the aforementioned places have harsh agro ecological condition for agricultural practices. This can be understood from the displayed suitability weighted overlay analysis map.

The result of this study can help policy makers in *enset* agricultural development project in Mareka District. The data produced in the course of this study like land use land cover, altitude, climate and soil type can be used by planners and decision makers to organize suitability analysis for *enset* agriculture investment. This work can also help government to raise awareness concerning *enset* cultivation suitability.

Generally, as a finding the existing highly suitable *enset* growing area in Mareka District lies in the central parts from east to west. There is more suitable land for *enset* cultivation and production capacity than current utilization of area. Defining the suitability for factors to be considered requires expert knowledge in the subject of interest and consults expert in the specific field. Suitability analysis is a wide area of concern. There are different ways in which analysis could be carried out depending on required results and data available. It was clear that GIS provides the ability to analyze features and attribute data which are in the heart of spatial MCDM. Maps give well-organized representation and analysis of geographical phenomena.

5.2 Recommendations

As the land suitability has been analyzed, Mareka District has much very great potential for *enset* crop cultivation. The study involved *enset* crop and the same process can be applied to other crops.

The study limited the major factors in consideration to five. The study can be carried out considering all possible factors influencing the *enset* crop cultivation.

The study was carried out in Mareka District and it is possible to apply the exercise to the whole Dawuro zone and even possibly on the whole *enset* growing area out of Dawuro Zone too.

The results of this research could be applied by Mareka District office of agriculture to remark their *enset* growing area as there are areas that are suitable for *enset* cultivation potential beyond the present capacity in terms of areal extent.

The suitability weighted overlay analysis map was produced which can be good planning guide to Mareka District Agricultural and Natural Resource offices.

The study indicated that very slight amount of land surface is considered to be unsuitable for the *enset* crop cultivation and production. This Mean that the largest portion of land surface is potentially suitable for *enset* crop. It is highly recommended to any concerned body to invest on *enset* cultivation in open suitable land area by evaluating general advantages of the *enset* crop compared with other crop type cultivation with regards of physical environment conservation, human and animal population values at any time.

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Appendix I

Rainfall data of the study area for thirty years from (1970-2000)

					Precipitation												
No.	Kebeles	Latitude	Long	Elev.	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	APPT
1	T/zuriya	797789	295263	980	32	39	90	129	151	171	200	180	144	93	57	28	1314
2	Mari Ediget	778389	290265	2476	42	56	134	158	184	179	196	182	175	124	62	22	1514
3	Mayla	771422	292581	1879	39	52	111	141	165	168	189	175	173	114	67	25	1419
4	Yamala Meso	779509	304018	1872	38	50	109	139	162	165	205	194	170	105	59	23	1419
5	Arusi Mogis	778246	301692	2328	35	46	104	158	190	182	202	186	170	116	57	21	1467
6	Gozo Bamushi	780355	300577	2435	33	59	125	157	188	172	203	190	178	118	67	21	1511
7	Gozo Shasho	787044	300233	1691	36	48	106	125	170	181	210	196	164	100	59	24	1419
8	Shaba Yoyo	786252	295168	1651	36	49	107	128	169	175	209	195	166	100	60	25	1419
9	Daka Yali	779971	292921	2531	34	45	103	155	191	183	210	198	178	129	68	22	1516
10	Bala Yoyo	776582	295037	2204	37	50	108	158	172	160	201	188	164	115	64	23	1440
11	Maydi	777493	297426	2155	37	49	108	156	183	162	202	189	170	113	62	23	1454
12	Gendo Bacho	772332	298846	1801	40	52	107	162	169	165	201	178	152	102	66	25	1419
13	Bato Kalbo	773609	296147	1889	40	53	102	154	165	177	202	180	152	101	68	25	1419

14	Ocha Dorori	779845	290065	2436	33	45	120	156	190	158	209	196	178	121	69	22	1497
15	Iyesus	780807	296214	2377	34	46	120	151	192	164	204	194	189	120	61	22	1497
16	Waka 01	781158	297883	2369	34	45	117	155	189	161	195	186	178	117	56	21	1454
17	Waka02	780719	299199	2420	34	45	123	148	189	172	203	195	187	121	59	21	1497
18	Kawuka	773355	287034	2205	37	51	124	161	188	169	199	185	172	116	70	25	1497
19	Dashi	773244	285828	2135	38	51	110	162	187	182	199	184	172	117	70	25	1497
20	Womba Boro	777147	290620	2398	35	54	112	165	184	178	206	189	172	116	63	23	1497
21	Koysha	784475	297915	1759	37	49	108	150	174	174	210	176	154	103	60	24	1419
23	Madakuyli	775999	302521	2213	36	47	110	153	181	168	200	188	169	108	58	22	1440
26	Semu	775701	282087	1860	39	54	110	151	167	176	203	167	152	101	75	29	1424
27	Nekiri	780465	284302	2074	36	50	108	155	184	175	201	189	163	102	66	25	1454
29	Yamala	786234	308190	1452	35	44	101	120	160	162	199	178	142	95	57	23	1316
22	Shama Tongi	767979	295473	1831	35	46	104	151	184	159	192	182	166	112	65	23	1419
24	Chelisho	765931	290140	1434	39	51	108	161	153	156	198	181	145	101	54	29	1376
25	Aseli	769600	281304	1601	39	54	111	170	182	162	192	175	150	102	51	31	1419
28	Gidicho	763372	292190	1300	37	47	93	137	152	164	187	162	149	105	52	29	1314
30	Mendida	769075	294951	1884	39	51	101	154	168	177	204	171	152	112	69	26	1424

Appendix II

Temperature data thirty years from (1970 to 2000)

					Temperature												
No.	Kebeles	Lati	Long	Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	A.A.T
1	T/zuriya	797789	295263	980	24.7	23.8	23.2	23.0	22.8	22.8	22.6	23.0	23.0	22.6	23.9	24.3	23.3
2	Mari Ediget	778389	290265	2476	17.1	16.8	16.3	15.3	14.7	14.2	15.3	16.5	16.6	16.6	16.6	16.8	16.1
3	Mayla	771422	292581	1879	20.9	20.1	18.9	17.9	17.2	17.1	18.5	18.7	18.8	18.9	20.2	20.9	19.0
4	Yamala Meso	779509	304018	1872	20.3	19.6	18.4	17.1	15.9	15.9	17.2	18.0	18.2	17.6	18.4	20.1	18.0
5	Arusi Mogis	778246	301692	2328	18.3	17.7	17.4	16.0	15.1	14.7	16.0	16.7	16.9	16.5	16.8	18.2	16.7
6	Gozo Bamushi	780355	300577	2435	18.2	17.7	17.3	15.8	14.8	14.6	15.9	16.5	16.8	16.3	16.6	18.0	16.6
7	Gozo Shasho	787044	300233	1691	22.1	21.3	20.6	19.6	18.8	18.8	19.7	20.3	20.8	21.1	21.6	22.2	20.6
8	Shaba Yoyo	786252	295168	1651	21.9	21.4	20.1	19.4	18.3	18.3	19.1	19.7	19.2	19.7	20.8	21.7	20.0
9	Daka Yali	779971	292921	2531	17.5	17.1	16.7	15.4	14.8	14.3	15.4	16.6	16.7	16.6	16.8	17.2	16.3

10	Bala Yoyo	776582	295037	2204	18.7	18.1	17.8	16.5	15.4	15.2	16.5	17.2	17.4	17.0	17.4	19.0	17.2
11	Maydi	777493	297426	2155	18.8	18.2	17.8	16.5	15.5	15.3	16.5	17.2	17.4	16.9	17.4	18.9	17.2
12	Gendo Bacho	772332	298846	1801	21.6	20.5	19.4	18.5	17.7	17.9	18.6	19.2	18.9	19.7	21.2	21.9	19.6
13	Bato Kalbo	773609	296147	1889	21.4	20.4	19.4	18.5	17.6	17.8	18.5	19.1	18.9	19.5	20.9	21.6	19.5
14	Ocha Dorori	779845	290065	2436	17.1	16.8	16.4	15.2	14.6	14.2	15.2	16.4	16.6	16.5	16.5	16.7	16.0
15	Iyesus	780807	296214	2377	18.1	17.6	17.3	16.0	15.1	14.8	15.9	16.8	17.0	16.9	17.2	18.3	16.8
16	Waka 01	781158	297883	2369	18.2	17.7	17.4	16.1	15.1	14.8	16.0	16.8	17.0	16.7	17.0	18.4	16.8
17	Waka02	780719	299199	2420	18.3	17.8	17.4	16.0	15.0	14.7	16.0	16.7	16.9	16.5	16.8	18.2	16.7
18	Kawuka	773355	287034	2205	18.6	18.0	17.7	16.4	15.5	15.2	16.7	17.2	17.4	16.9	17.5	19.0	17.2
19	Dashi	773244	285828	2135	18.7	18.1	17.8	16.6	15.8	15.7	17.0	17.3	17.5	17.0	17.6	19.1	17.3
20	Womba Boro	777147	290620	2398	17.7	17.3	16.8	15.7	14.9	14.5	15.6	16.8	16.9	16.9	17.0	17.6	16.5
21	Koysha	784475	297915	1759	20.5	20.3	18.9	17.7	16.6	16.2	17.6	18.7	18.6	18.0	18.6	20.2	18.5
23	Madakuyli	775999	302521	2213	18.9	18.2	17.7	16.4	15.4	15.2	16.5	17.1	17.3	16.8	17.3	18.9	17.2
26	Semu	775701	282087	1860	19.4	18.7	18.1	17.5	17.0	16.8	17.7	17.8	18.0	17.6	18.4	20.1	18.1
27	Nekiri	780465	284302	2074	18.1	17.9	17.2	16.2	15.4	15.2	16.2	17.4	17.4	17.4	17.4	17.8	17.0

29	Yamala	786234	308190	1452	23.1	22.3	21.7	20.9	20.2	20.2	20.6	21.3	21.9	21.7	22.1	22.8	21.6
22	Shama Tongi	767979	295473	1831	22.3	21.5	20.5	19.8	18.9	18.9	19.8	19.9	19.7	20.2	21.8	22.2	20.5
24	Chelisho	765931	290140	1434	23.0	22.0	20.7	20.1	19.5	19.5	20.5	20.3	20.2	20.3	22.1	22.4	20.9
25	Aseli	769600	281304	1601	19.6	19.3	18.4	17.7	17.2	16.9	17.9	18.2	18.5	17.7	18.7	20.4	18.4
28	Gidicho	763372	292190	1300	23.4	22.7	21.3	20.7	20.0	20.0	20.9	20.8	20.7	21.2	22.9	23.3	21.5
30	Mendida	769075	294951	1884	22.0	21.1	20.2	19.5	18.6	18.7	19.5	19.7	19.5	20.1	21.6	22.0	20.2

Appendix III

Key informants Interview

Dear respondents I am students of Jimma university undertaking research entitled GIS based suitability analysis of of *enset* crop cultivation in Mareka District, Dawuro zone south west Ethiopia. This interview is prepared to assess the factors that determine suitable physical environmental condition for *enset* crop cultivation in the study area. Therefore the intention of this interview is to gather necessary information on an aforementioned topic so as to contribute solution for *enset* crop dependant community. We are grateful for your participation and time devoted with us. According to fact mentioned above, you are politely requested give dependable and reliable responses to interviews presented below. The information gathered during this interview remains confidential and cannot be transferred to third party. We are not interested to know your name or any things related to your personality rather than information you provide us.

Directions don't write your name on the paper. Please give as much as possible accurate responses to the following questions and provide your response on the space allowed for each.

General information questions

Education back ground. Below grade 8 ☐ below grade l0 ☐

Below grade 12 ☐ Certificate ☐ levels ☐

College diploma ☐ Degree ☐

2nd degree ☐ rd degree ☐

Other if any………………………………………………………………………………………

Field of study………………………..specialization…………………………………...………..

Current position……………………………………………………………….……………

Interviews asked to get specific information concerning the study topic

1. What are the land use land cover types of the Mareka District? Please list down them

   ……………………………………………………………………………………………………
   …………………………………………………………………………

2. What are the dominant environmental factors that determine suitability land for *enset* cultivation? Explain briefly below
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………

3. Classify sub classes for each of the dominate factors you listed during interview in the above.

1st……………………………………………2d…………………3rd……………………4rth……
………………………………..5th……………………………………………6th…………………
…………………

4. Rate each of sub factor classes' value by assigning weight for each from number 1up to 4.
…………………………………………………………………………………………………
………………………………………………………………………………

5. Rate each of main factor classes with value assigning weight for each from numbers 1 up to 4
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………

Interviewee **Interviewer**

Name…………………………………………….Name…………………………………

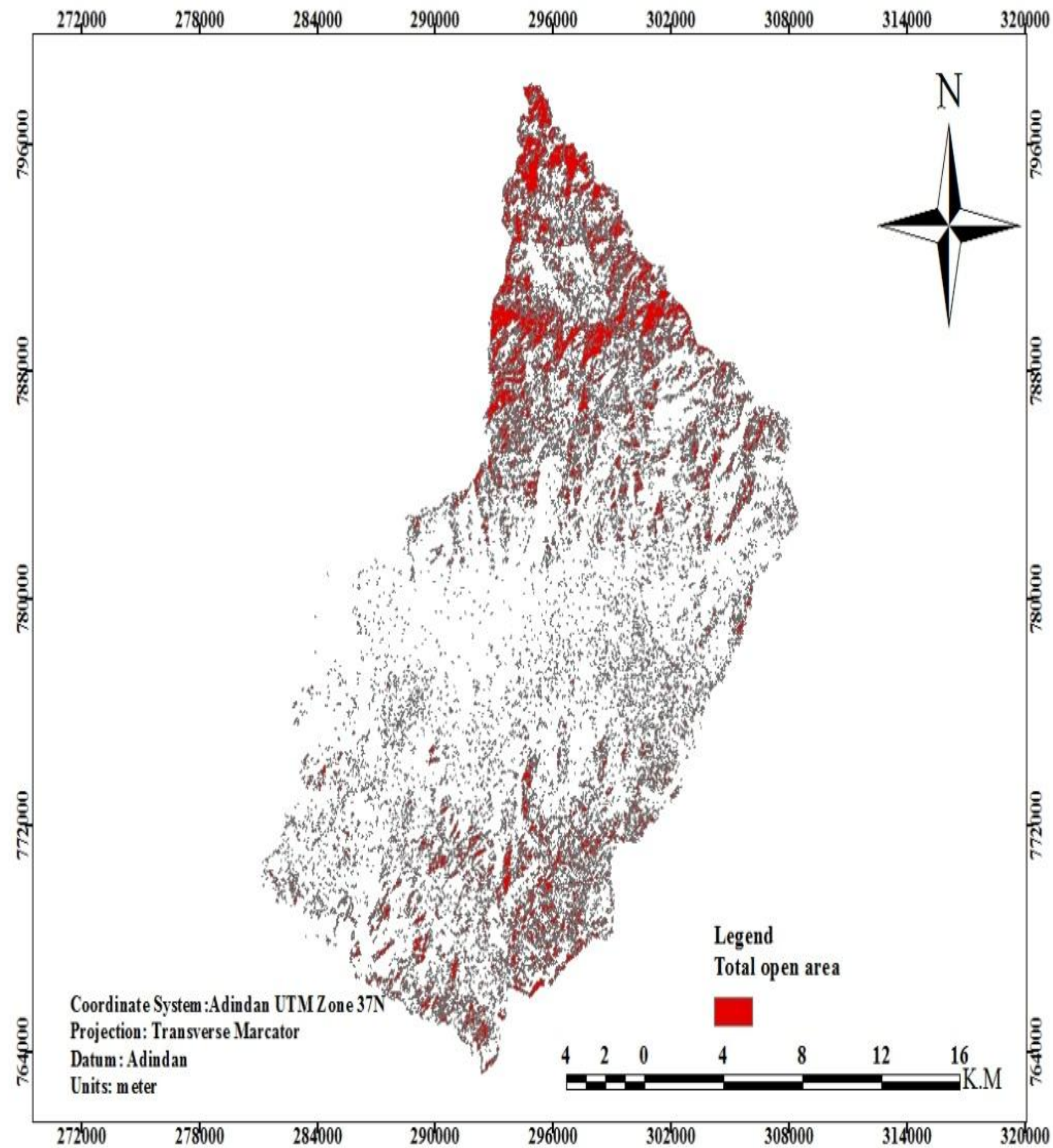
Signature…………………………………….….Signature…………………………….

Date………………………………………….. Date…………………………………

With great regards!

Appendix IV

Total open area map of the study area



Appendix V

***Enset* pictures taken where it is dominantly grown (plate 1-4)**