# Identifying suitable settlement Areas in Minjar Shenkora Woreda, Ethiopia

Mekuanint Anberbir Bekele

A Thesis Submitted to

Department of Architecture and urban planning and design

School of Civil Engineering and Architecture

Presented in partial fulfilment of the requirements for the degree of Masters of Science in Environmental Architecture

Office of Graduate Studies

Adama Science and Technology University

**Adama, Ethiopia**

**January, 2021**

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Advisor: Tibebu Assefa (Ph.D.)

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## Approval of Board of examiners

We, the undersigned, members of the board of examiners of the final open defense by Mekuanint Anberbir have read and evaluated his thesis entitled **“Identifying suitable settlement areas in Minjar Shenkora Woreda, Ethiopia ”** and examined the candidate. This therefore, to certify that the thesis has been accepted in partial fulfilment of the requirement of the degree of masters of Science in Environmental Architecture.

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**Declaration**

I hereby declare that this MSC Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Therefore, I recommend that the student has fulfilled the requirement and hence hereby he can submit the thesis to the department.

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| DEM | Digital Elevation Model |
| EATA | Ethiopian Agricultural Transformation Agency |
| FAO | Food and Agriculture Organization |
| GIS | Geographic Information System |
| GPS | Geographic positioning System |
| IDW | Inverse Distance Weighted |
| KML | Keyhole Markup Language |
| LULC | Land Use Land Cover |
| MCA | Multi-Criteria Analysis |
| MCDMA | Multi-Criteria Decision Making Analysis |
| MSDARDB | Minjar-Shenkora District Agriculture and Rural Development Bureau |
| MWUD | Ministry of Works and Urban Development |
| NaLUA | National Land Use Act |
| NSZARDB | North Showa Zone Agriculture and Rural Development Bureau |
| WOA | Weighted Overlay Analysis |

## ABSTRACT

*Due to the increase in the number of population, immigration of people from the rural areas to towns are increasing year to year in Minjar Shenkora Woreda. This makes the increasing of a house demands in the urban settlement. Consequently, Arerty and Balchi towns including the newly emerged towns are expanding in every direction rapidly with the deterioration of prime agricultural land and causes different conflicts with government such as social, economic and political instability. Besides, poor dispersed settlements in rural areas is difficult to expand infrastructure with minimum cost. Therefore, the purpose of this study is to identify suitable settlement areas in Minjar Shenkora Wereda in terms of 10 criteria such as prime agricultural land, slope, soil types, soil depth, underground water, geology, land use land cover, distance from roads, distances from towns and distance from rivers/drainage so as to identify sustainable settlement areas. Two approaches: the combination of geographic information systems (GIS) and the analytic hierarchy process (AHP) which is one of the multi-criteria decision-making methods to identify the settlement areas have been used. As a result, of all 1587 square kilometers of the Woreda,234km$^2$(14.6%) of the area is found to be most suitable, 1303km$^2$(82%) is moderately suitable, 43km$^2$ (3%) is less suitable and 7 km$^2$ (0.4%) is not suitable for settlement at all. Lastly, 166.88 km$^2$ are prime agricultural land that had to be conserved & used wisely. Finally the study recommended that before planning new settlement, land suitability analysis should be done to develop sustainable settlement environment.*



***Key words.*** *Settlement suitability analysis, GIS, multi-criteria decision-making analysis, AHP, Ethiopia, Minjar shenkora*

# CHAPTER ONE

# INTRODUCTION

This chapter deals with the background study, statement of the problem, the objectives, research question, scope, significance, limitation and organization of the paper. The motivation for this title of the study is that most towns in Ethiopia are expanding rapidly with the deterioration of prime agricultural land which can yields a maximum production crops in the country. There are a lot of agricultural land, fertile land that can sustain food availability for the peoples of Minjar shenkora woreda. But from time to time this land is changed to urban development. This makes the farmers  loses their land with the reduction of production of crops specially White Magna Teff.

## 1.1. Background of study

A human settlement derives from the structured landscape of a territory. It takes into consideration spatial allocation of functions while maintaining equilibrium between the needs of the population, the availability and allocation of resources, economic dynamics, the improvement of living conditions, the provision of services and enhancing transportation networks, as well as recreational spaces (UNCHR, 2019).

Urbanization is a global phenomenon that is transforming human settlements. It refers to the demographic process of shifting the balance of national population from rural to urban areas. In most recent years, over half of the world's people now reside in cities. The increase in the absolute number of people now living in cities is the more dramatic statistic. In 1950 only 18 % of people in developing countries lived in cities. In 2000, the proportion was 40 %, and by 2030 the developing world is predicted to be 56 % urban. And also two thirds of the world's population will be living in metropolitan cities by 2050 (Mifh, 2014).

Accelerated urbanization has been viewed as an important instrument for promoting economic development and reducing regional wealth disparities in some developing countries. Nevertheless, it has a wide range of negative effects pertaining to the human-environment system in sprawled urban areas. It caused for the emergence of new kinds of slums, the growth of squatter and informal housing all around the rapidly expanding cities of the developing world. A frequent conflict exists between urban expansion and farmland protection, because urban expansion is unavoidably at the expense of clearing surrounding fertile farmlands, the fundamental city's agricultural market (Du & Shi, 2014).

Rapid urbanization in rural and urban areas affects especially prime agricultural land in the way that for the direct conversion of farm land to urban land and indirectly reduces the agricultural potential of the remaining farms (William, 2019) . This caused for unprecedented challenges in terms of hunger, food insecurity and malnutrition in developing countries particularly in Africa and Asia since urban expansion will be occurring on some of the world's most productive agricultural land (Hatab et al., 2019).

The low density residential development and commercial strip development along arterial roads scattered out of villages, suburbs and smaller cities in rural sprawl makes a challenge for fulfilling infrastructures like sewer and water. And also the farmer more likely to sell their land for house lot because the land price is increased. This in turn, result for a greater reduction of agricultural land (Theobald, 2003).

Farmland preservation is a longstanding challenge on the urban fringe. In the last two decades, farmland loss has increasingly become a worldwide matter of concern, both for environmental and food security reasons. Settlement should be planned to adapt to the specific urban context, addressing a variety of environmental, socio-cultural and economic factors (Countries, 2020).

### 1.2. Statement of the Problem

Improper settlement and unplanned development have been increased significantly due to the industrialization and fast population growth in the world. As a result, the relationship between the urban areas and rural areas has been ruptured; the life in the city became monotonous; the biodiversity has been damaged and the cities became environments that are insufficient regarding social, cultural and biological opportunities (UNCHR, 2019).

The migration of peoples from different rural areas to the towns of the Minjar Shenkora Woreda was reported yearly. It has caused for the alteration of spatial distribution of human settlements. It was because in rural areas the lack of infrastructures like water, electricity, roads and the issue unemployment was occurred. This makes for the increment of house demands and informal settlement in urban and suburb areas in the Woreda. And also the scattered settlements outside the villages in rural areas and along the roads in the Woreda is difficult to expand infrastructures with the minimum cost and has a tendency to change to the urban sprawl.

In recent years, Arerty town and the newly emerged towns (Bolo, Balchi, Eranbuti, Yohanis, Dire, Adama and Melkajilo) increases in size from time to time by four sides and have witnessed unprecedented prime agricultural land conversion due to urban sprawl. This causes many farmers displaced from their land and loss of their farming land. As a result, the farmers was exposed to the problems of livelihood base as the economic base of woreda is agriculture. According to Woreda municipality report 2011 EC, an average of 70-80 hectares of prime agricultural land was changed to the urban land particularly in Arerty and its environs starting from 2007 EC (2015GC) due to high house demands in the Woreda.

The reginal administration office planned to organize peoples for getting house land within their kebele center to reduce the migration of peoples and deterioration of prime agricultural land. But there is no any study concerning settlement suitability rather the political decision is prevalent. Hence, this study aimed at filling decision gap by identifying suitable human settlement areas in Minjar Shenkora Woreda using multi criteria analysis and GIS tools while keeping the prime agricultural land intact.

### 1.3. Research objective

**General objective:**

To identify and map potentially suitable settlement areas in Minjar Shenkora Woreda.

**Specific objectives:**

1. To assess the existing settlement condition of the study area;
2. To identify the main determinant factors for the selection of suitable settlement areas;

### 1.4. Research questions

1. What is the existing settlement condition in Minjar Shenkora Woreda?
2. What are the main factors for the selection of suitable settlement areas in study area?
3. Which areas are suitable for settlement?

### 1.5. Significance of study

The purpose of this study is creating sustainable rural and urban settlement in case of social, economic, political and environmental aspects. It is also useful for keeping environmental deterioration particularly prime agricultural land which produces especially white Magna Teff which is the base for economic development of Minjar and also for Ethiopia. It helps as input for policymakers in formulating policies and strategies along with the issue. And also helps for urban and regional planning institute to plan new emerging towns & villages. It was also used as a benchmark information to those scholars, who want to conduct future studies on land suitability analysis using GIS and RS by integrating multi criteria decision analysis approach.

### 1.6. Scope of study

This study focused on the whole Minjar Shenkora Woreda jurisdictional boundary which covers 1,587 square kilometers. Thematically, it only focused on identifying suitable areas for settlement while keeping aside the prime agricultural land.

### 1.7. Limitation of study

This study certainly has some limitations that could be solved through future projects in the area. The major limitations was getting the relevant data sources in the form of map even at the regional level. It was also difficult to collect related data from different offices due to COVID 19 pandemic to complete settlement suitability analysis perfectly. And also the difficulties of getting some contextual standards of the criteria suitability class. But, most of the standards were through different literature in this research.

### 1.8. Organization of the paper

This paper consists of five chapters. Chapter one presents background of the study, statement of the problem, objectives, research questions, significance, scope and limitations of the study. Chapter two reviews the theoretical and contextual literature. Chapter three gives description of the study area and details of materials and methods. Chapter four presents results of the study and chapter five presents discussion. The final chapter presents the conclusions and recommendations.

## CHAPTER TWO

## LITRATURE REVIEW

### 2.1. Theoretical Review

#### 2.1.1. Definition of human settlement

The study of human settlements is basic to human geography because the form of settlement in any particular region reflects human relationship with the environment. It may be a village, a town or a city. Settlement also refers to the physical spaces and environments in which households are sheltered, and how one shelter relates to others (Bigio & Blanco, 2014).

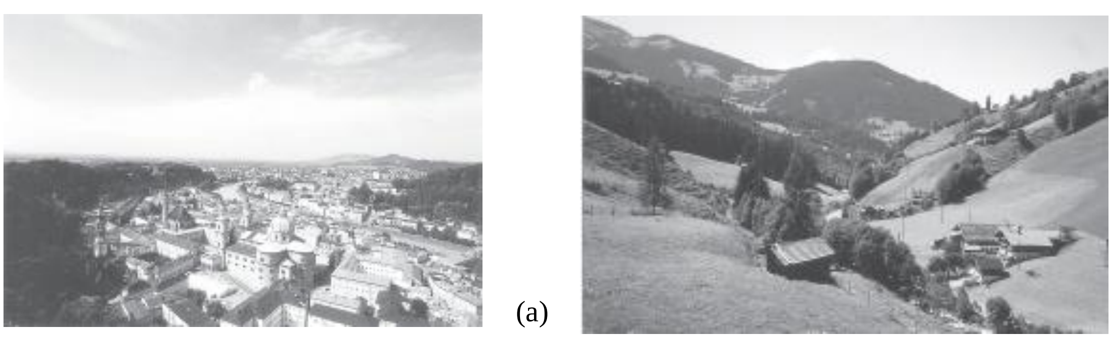
Human settlements is a very complex system of five elements - nature, man, society, shells (buildings), and networks. It is a system of natural, social, and man-made elements which can be seen in many ways economic, social, political, technological, and cultural (Doxiadis, 1970).

#### 2.1.2. Types, patterns and classification of settlements

Settlements may also be classified by their shape, patterns types. The major types classified by shape are:

**(i) Compact or Nucleated settlements:** These settlements are those in which large number of houses are built very close to each other. Such settlements develop along river valleys and in fertile plains. Communities are closely knit and share common occupations.

**(ii) Dispersed Settlements:** in these settlements, houses are spaced far apart and often interspersed with fields. A cultural feature such as a place of worship or a market, binds the settlement together (See Fig.2.1).



(a) (b)

Figure 2.1. Classification of settlements by shape (a) compact Settlement (b) dispersed Settlement (Source: Vasudevan, 2007)

It is widely accepted that settlements can be differentiated in terms of rural and urban, but there is no consensus on what exactly defines a village or a town. Although population size is an important criterion, it is not a universal criterion since there are many villages in densely populated countries.

At one time, people living in villages pursued agriculture or other primary activities, but presently in developed countries, large sections of urban populations prefer to live in villages even though they work in the city. The basic difference between towns and villages is that in towns the main occupation of the peoples related to secondary and tertiary sectors, while in the villages most of the people are engaged in primary occupations such as agriculture, fishing, lumbering, mining, animal husbandry, etc. Differentiations between rural and urban on the basis of functions are more meaningful even though there is no uniformity in the hierarchy of the functions provided by rural and urban settlements (Vasudevan, 2007).

The major classification of settlements by types are as follows.

**(i). Rural Settlements:** rural settlements are most closely and directly related to land. They are dominated by primary activities such as agriculture, animal husbandry, fishing etc. The settlements size is relatively small. Some factors affecting the location of rural settlements are: water Supply, land upland, building material, and defense planned settlements etc.

The settlers often looked for certain features in an area to make life easier: flat land, to make building easier and safer; local raw materials, e.g. wood and stone, to build homes; a local water supply for drinking, washing, cooking and transport; dry land, so that people could build on areas that don't flood; defendable site, e.g. a hilltop or river bend to protect from attackers; good farm land with fertile soils, so people could grow crops; shelter, e.g. to protect from bad weather; transport links, e.g. a ford or low crossing point of a river.

Rural settlements in the developing countries are large in number and poorly equipped with infrastructure. They represent a great challenge and opportunity for planners. Supply of water to rural settlements in developing countries is not adequate. People in villages, particularly in mountainous and arid areas have to walk long distances to fetch drinking water. Water borne diseases such as cholera and jaundice tend to be a common problem. The design and use of building materials of houses vary from one ecological region to another. The houses made up of mud, wood and thatch, remain susceptible to damage during heavy rains and floods, and require proper maintenance every year (Vasudevan, 2007).

**(ii). Urban Settlements:** Rapid urban growth is a recent phenomenon. Until recent times, few settlements reached the population size of more than a few thousand inhabitants. Location of urban centers is examined with reference to their function. For example, the sitting requirements of a holiday resort are quite different from that of an industrial town, a military center or a seaport. Strategic towns require sites offering natural defense; mining towns require the presence of economically valuable minerals; industrial towns generally need local energy supplies or raw materials; tourist centers require attractive scenery, or a marine beach, a spring with medicinal water or historical relics, ports require a harbor etc.

Locations of the earliest urban settlements were based on the availability of water, building materials and fertile land. Today, while these considerations still remain valid, modern technology plays a significant role in locating urban settlements far away from the source of these materials. Piped water can be supplied to a distant settlement, building material can be transported from long distances. People migrate to cities to search employment opportunities and civic amenities. Since most cities in developing countries are unplanned, it creates severe congestion. Shortage of housing, vertical expansion and growth of slums are characteristic features of modern cities of developing countries. In many cities an increasing proportion of the population lives in substandard housing, e.g. slums and squatter settlements.

**Types of urban settlements**: Depending on the size and the services available and functions rendered, urban centers are designated as town, city, million city, conurbation, and megalopolis as shown in Table 2.1.

Table 2.1. Types of urban settlements

| Classification | Description |
|---|---|
| Towns | Several thousands of people, larger than rural towns |
| City | A few million people |
| Megacity | At least ten million people |
| Conurbation | Formed by the merging of a few cities |
| Megalopolis | Formed by the merging of a few conurbation |

(Source: Vasudevan, 2007).

### 2.1.3. The effect of urban and rural sprawl on prime agricultural land

**Urban sprawl** is unrestricted growth in many urban areas of housing, commercial development and roads ever large expenses of land, with little concern of urban planning.

Urban sprawl on agricultural lands has become a global phenomenon plaguing all countries of the world, rich or poor. This phenomenon formed a challenge to most countries of the world, especially developing ones, because of the increasing of population at high rates, consequent the depletion of resources, especially agricultural lands around cities. Urban sprawl is a problem affecting urban communities and suburban and rural areas, resulting from loss of agricultural land to decay of old urban centers. In his way, sprawl consumes thousands of acres of agricultural land (Madallah & Tarawneh, 2014).

Many studies found that the land policies only reduced the net loss of farmland through reclaiming farmlands in peripheral areas. Moreover, it is still unclear how the conflict between increasing urbanization for economic development and protecting farmland against urban sprawl is addressed. It is therefore necessary to compare the land use changes before and after the enacting of the main policies (Du & Shi, 2014).

**Rural sprawl** is defined as low-density residential development scattered outside of suburbs and cities, and as commercial strip development along roads outside cites. In some states, rural areas have >20 acres per housing unit or >40 acres (T. Daniels, 1999). The farmer more likely to sell their land for house lot because the land priced increased due to sprawling.

This in turn causes a greater fragmenting of the land base, making it more difficult for remaining farmers to assemble land to rent. This in turns, a greater reduction of agricultural land and the reduction of agricultural production. Rural sprawl mostly caused by weak local planning and zoning and some state subdivision control acts (Theobald, 2003).

### 2.1.4. Land Use Policy for Protecting Prime Agricultural Lands

Prime agricultural lands basically refer to the best agricultural lands which is highly productive farm lands, very fertile and highly suitable for growing the country's major food crops and various agricultural products. Many countries have actually tried to preserve agricultural lands from being converted to others use.

America's experience with farmland preservation is a combination of modest success and inconsistent farm policies. Farmland preservation in the United States is relatively new. The first farmland preservation program arose in Suffolk County, New York (the eastern end of Long Island) in the mid-1970s. The goals of farmland preservation vary somewhat from place to place. Yet, common goals are: 1) a desire to curb sprawling development in the countryside which drives up the price of farmland beyond what farmers can afford; 2) a desire to protect high quality agricultural soils and maintain agriculture as part of the local economy; 3) a desire to manage growth, both in terms of location and cost; 4) a desire to maintain the open space and scenic vistas that farming provides; and a desire for locally-grown produce (T. L. Daniels, 2004).

With only less than 10 million hectares of agricultural land that is threatened by a rapidly urbanizing economy in Philippines. To protect irreplaceable prime agricultural lands from conversion, a national land use policy or NaLUA should be able to promoted to address issues on urban expansion, efficiency, and capacity. The national land use policy of Philippines for protecting agricultural lands in general, and prime agricultural lands in particular focus on the protection of agriculture as a very important local industry, and enhance the potential of agriculture and agriculture-based industries to generate more jobs and further reduce poverty; promote food self-sufficiency and maintain local food supplies (Neil & Navata, 2019).

### 2.1.5. Factors affecting location of settlements

**Physical Factors:** There are many factors that can influence where settlements locate within a region. The site of a settlement is the actual land that the settlements is built upon. The situation is the location of a settlement in relation to the things that are around it.

According to Mhenyu (2013), Physical environment determine the site of a settlement depend on:

i. Water supply – water is essential for human survival and agricultural activities.
ii. Relief – the availability of broad flat land such as floodplains promote agricultural activities.
iii. Soils- fertility of soils also another considerations for agricultural activities
iv. Shelter-which are sheltered from natural elements. Windswept highland with harsh cold climate are conducive for settlement.
v. Defense– Threat from enemies and predatory animals drove people to live together for protection
vi. Aspect and shelter- In the northern hemisphere south facing slopes receive more sunlight and are protected from cold northerly winds. More settlements and agricultural land is therefore located on South facing slopes.

**Economic Factors**

i. Communications – settlements often located next to rivers that could be easily crossed. These are called bridging points. Other favorable places included where at the junctions of valleys or in gaps through hills. These locations allowed maximum communication between different settlements and increased trade.
ii. Resources - Early settlers relied upon wood for fuel and building. A site close to wood land was therefore an advantage. Later, resources such as Iron ore, coal and bauxite encouraged the growth of settlements.

### 2.1.6. Settlement planning principles for development

A series of planning principles which implemented through local planning policies, will provide for efficient and sustainable development of land. Analysis should be undertaken during the preparedness of planning phase, in which settlement options are identified in collaboration with stakeholders. Responses should take account of the capacity of communities, and resources offered by the city and its communities (UNHCR, 2019).

According to Mid et al., (2007), the local growth management strategy will need to address the following planning principles and demonstrate, where relevant, how they will be applied to assist in achieving the outcomes and actions of the regional strategies.

**Location:** The future urban settlement should be located predominantly within the agreed growth areas and it is permitted by the regional strategies and outside the agreed growth areas, must be located to minimize environmental impacts and be sustainable.

**Land suitability (environment, natural resources, and hazard):** The Future development should be located on land that is suitable for the development and capable of supporting the proposed uses. Additionally, the planning on the land already zoned for settlement but not yet developed should identify the constraints and opportunities of the land. The future development should also avoid areas of environmental significance, significant natural and economic resource, potential hazard, high landscape or cultural heritage value.

**Settlement form and hierarchy:** The hierarchy of settlement identified in the regional strategies, support and maintain strong multi-functional business centers which minimize urban sprawl, and maximize infrastructure and service efficiencies. So planning to create communities is very important within the hierarchy of settlement. It should be considered that the form and hierarchy of settlement depends on the ultimate geographical extent and population target. For example, in the case of residential development, provide for a variety of dwelling types and a choice in location, form and affordability enables mixed uses and home-based employment in residential or village zonings where appropriate.

**Urban design and heritage:** The settlement should reflect high quality design that is compatible with the local and regional attributes which make up the region's character, such as climate, landscape, history, topography, and existing built environment and reflects the drainage and water quality maintenance, and nature conservation and biodiversity protection. The urban also be designed to ensure there is public access to an adequate supply of appropriately located public open space and recreation areas.

**Infrastructure provision:** The future settlement development should only be permitted where it can be provided with adequate, cost effective physical and social infrastructure to match the expected population for each settlement. It should be designed and located to minimize the need to travel; to maximize opportunity for efficient public transport and pedestrian access options; well-connected and accessible urban areas for residents and visitors and to encourage energy and resource efficiency.

**Employment lands:** The Industrial land should be made available in a variety of locations in the settlement to encourage new opportunities as they arise in all major regional centers.

**Tourism opportunities:** The future tourism development should not negatively impact on the natural, economic or social fabric of the area it is to be located in. The investment and the growth of tourism products or services should not occur at the expense of local environmental and social values (Mid et al., 2007).

### 2.1.7. Application of Geographic information system in suitability analysis

Geographic Information System (GIS) is used as a tool for input, storage and retrieval, manipulation and analysis, and output of spatial data. GIS has been applied in many disciplines including geography, forestry, urban planning, and environmental studies. Particularly, in suitability analysis, GIS has a great role in multi criteria decision making process . Multi-criteria decision making (MCDM) techniques involve the evaluation of several criteria or datasets to meet a specific objective (Eastman, 2001).

In MCDM process, criteria or datasets are examined for assigning relative ranks and individual feature weights based on the land use type for which suitability being examined. Weighted summation is sufficiently straight forward to use GIS data. It will be incorporated into the land-use suitability analysis. The suitability analysis process requires the identification of the appropriate locations for a particular land use activity by considering physical resources (elevation, slope, aspect, climate), natural resources (soils, geology, hydrology, vegetation and wildlife habitat and environmentally sensitive areas), and existing land use and development of man-made facilities such as transportation systems, existing urban areas, and utility networks (Pareta, 2013).

Weighted Overlay analysis (WOA) is a technique for applying a common measurement scale of values to diverse and different inputs to create an integrated analysis in GIS environment. The next step before running the model using weighted overly method; weight is estimated to the input raster's. Accordingly each model parameters is weighted as a percentage influence, based on its importance to the model objective. Multi criteria Decision Making problems typically involve criteria of varying importance to decision makers. The derivation of weights is a critical step in eliciting the decision maker's performance preferences. A weight is a critical step in eliciting to an evaluation criterion that indicates its importance relative to other criteria under consideration. The larger the weight shows the more important criterion in the overall analysis process.

### 2.1.8. Analytic Hierarchy Process in Suitability Analysis

AHP offers some advantages over the classical site suitability analysis techniques. First, it provides a structured approach to measuring suitability by "decomposing" the suitability analysis problem into hierarchical units and levels. This allows a systematic in depth analysis of the factors which may be better understood to their lower and more specific forms or indicators. Second, AHP relies less on the completeness of the data set, and more on "expert" opinions or observations about the different factors and their perceived effects on land suitability. Third, the approach is more transparent and hence more likely to be accepted especially when the suitability analysis will ultimately serve as a basis for land allocation. Fourth, AHP allows for the participation of both experts and stakeholders in providing the suitability measure of a land relative to a proposed land use. Land suitability analysis deals with large amount of data on different dimensions. AHP is a classical land use approach in making decisions for best site selection and site allocation of lands for different uses with the integration of GIS (Erkut & Tarimcilar, 1991).

### 2.1.9. Land suitability classification

According to FAO (2013) land suitability classification is divided into order, class, sub-class and unit.  Land suitability orders indicate whether the land is assessed as suitable or not suitable for the use under consideration. There are two orders represented in maps, tables, etc. by the symbols S and N respectively. Order S suitable land on which sustained use of the kind under consideration is expected to benefits, without unacceptable risk of damage to land resources. Order N not suitable land which has qualities that appear to preclude sustained use of the kind under consideration.

Land suitability classes reflect degrees of suitability. The classes are numbered consecutively, in sequence of decreasing degrees of suitability within the order. Within the order suitable the number of classes is not specified. Land suitability units are subdivisions of a subclass. All the units within a subclass have the same degree of suitability at the class level and similar kinds of limitations at the subclass level .The orders with symbols S and N respectively used in land suitability classification shown in the Table 2.2 below.

Table 2.2. Structure of land suitability classification based on FAO (2013)

| Classification | Degree of suitability | Description |
|---|---|---|
| Class S | Suitable | Land that can support the land use type without degrading its productive capacity and yielding benefits that justify the inputs |
| Class S1 | Most suitable | Land without limitations or with only minor limitations that will not significantly reduce productivity nor require extra inputs. |
| Class S2 | Moderately suitable | Land having limitations that will reduce productivity or increase the inputs required to maintain productivity compared to S1 but still clearly suitable and offering attractive benefits for use. |
| Class S3 | Marginally suitable | Land having limitations so severe those benefits are reduced and/ or require inputs increased so that this expenditure is only marginally justified. |
| Class N | Not Suitable | Land that cannot support a specified land use type on a sustained basis. Either the Land use is technically impractical or cannot be sustained |
| Class N1 | Currently not suitable | land having limitations which may be manageable in time, but which cannot be corrected with existing knowledge of current acceptable cost; |
| Class N2 | permanently not suitable | Land having limitations which appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner. |

(Source: FAO, 2013)

### 2.1.10. Criteria for settlement suitability analysis

Criteria are very significant in the site selection of the identified land use and used as key drivers in the selection of the geographic location. The criteria was classified according to the degree of suitability and each of will assigned a weight value. Then map was consolidated after weights based on preference made by decision makers are assigned. Each criterion will be ranked from the most suitable to unsuitable while identifying the areas of suitable settlements. Digital raster maps will be then created by assigning susceptibility values after classification of the data (Mifh, 2014).

Different researchers mentioned different criteria and sub-criteria for settlement suitability analysis such as LULC, proximity to the river/streams , proximity to the roads, elevation, slope, aspect, drainage , hydrology, soil type and soil depth , vegetation etc ( Making et al., 2019).

Table 2.3 shows that 9 criteria with the degree of suitability in number and weight percentage preference made by the decision makers /experts within the criteria for settlement suitability analysis. And also shows that for the selection of suitable settlement areas geological structure and drainage have high weight percentage of influence which is 30% and 22% respectively.

Table 2.3: The evaluation criteria used to identify suitable settlement area

| Main criteria | Sub criteria | Score | Weight | Percent |
|---|---|---|---|---|
| Land Use Capability Class | VII. and VIII. Class | 4 | 0.113 | 11.3 |
| | VI. Class | 3 | | |
| | V. Class | 2 | | |
| | I., II. III. IV. Class | 1 | | |
| Slope (%) | 0-2 | 4 | 0.151 | 15.1 |
| | 5-10 | 3 | | |
| | 10-15 | 2 | | |
| | 15-20 | 1 | | |
| | 20 < | 1 | | |

Continued

Table 2.3: Continued

| Main criteria | Sub criteria | Score | Weight | Percent |
|---|---|---|---|---|
| Aspect | S, SE, SW | 4 | 0.026 | 2.6 |
| | E, W | 3 | | |
| | NE, NW | 2 | | |
| | N | 1 | | |
| Elevation (m) | 1000-1200 | 4 | 0.021 | 2.1 |
| | 1201-1400 | 3 | | |
| | 1401-1600 | 3 | | |
| | 1601-1800 | 2 | | |
| | 1801-2000 | 2 | | |
| | 2001≤ | 1 | | |
| Geological Structure | Other geological formations | 4 | 0.303 | 30.3 |
| | Alluvial areas | 1 | | |
| Soil depth (cm) | Shallow and very shallow | 4 | 0.036 | 3.6 |
| | Medium deep and deep | 1 | | |
| Drainage | Sufficient | 4 | 0.224 | 22.4 |
| | Insufficient or Damaged | 1 | | |
| Vegetation | Outside the forest regime | 4 | 0.071 | 7.1 |
| | Inside the forest regime | 1 | | |
| Hydrology/proximity to the water (m) | 2000≤ | 4 | 0.055 | 5.5 |
| | 1000-2000 | 3 | | |
| | 300-1000 | 2 | | |
| | 0-300 | 1 | | |

(Source: Making et al., 2019)

### 2.1.11. Conceptual framework

Theory comes from one of the different fields that deal with the interaction of humans with their environment (e.g., economy, sociology, political, ecology, and social psychology). Theory, observation, and models are crucial components of land use research. There are three main traditions of theorizing land use such as urban and regional economics and regional science, sociology and political economy and nature society theories (Hersperger et al., 2010).

The driving forces are forces which interact with actors to shape the land change like climate change, human activities, urbanization and population growth, etc. Government policy influences the actors through making decisions (e.g., land use policy, urban utilities planning, resettlement, etc.)

Suitable site selection process considers three parameters such as location, physiographic feature and planning aspects. Locational analysis encompasses any spatial analysis of the area like proximity to the different services; dangerousness of the location and natural feature. Physiographic features deal with features and attributes of the land surface.

Land suitability analysis for selection of suitable land is shown in the figure 2.2 which depicts the conceptual frame work of land suitability analysis.

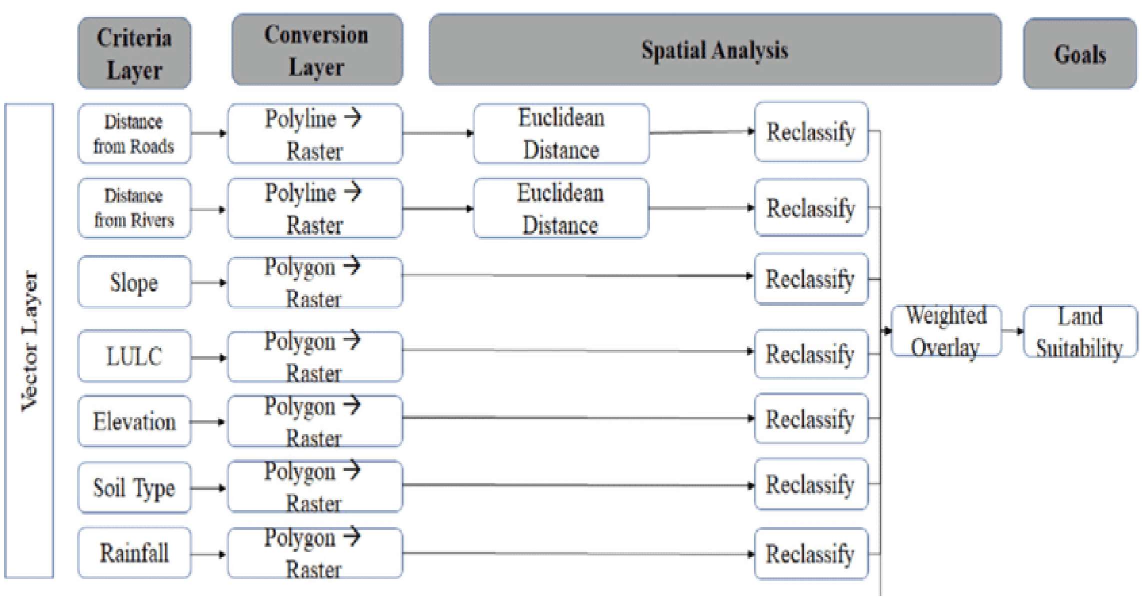



Figure 2.2: Conceptual frame work for land suitability analysis (source: Habibie et al., 2019)

## 2.2. Contextual review

### 2.2.1. Rural and urban settlement condition in Ethiopia

Urbanization in Ethiopia is a recent phenomenon because of the historical factors of the country. Many of the middle sized towns in Ethiopia were founded during the nineteenth century for political-military reasons. According to Donald Crummey, three major institutions shaped Ethiopian towns during the 19$^{th}$ and 20$^{th}$ centuries: palace, market and church. These institutions played three roles: political, economic and cultural (Bahiru, 2008: 486). The establishment of the current capital, Addis Ababa, in 1886 is the third in line following Axum and Gonder from the early and middle age Ethiopian history, respectively.

Throughout most of its history, Ethiopia remained a land of small villages and isolated homesteads. The reason for the absence of large settlement of urban areas in Ethiopia for long time is given by Richard Pankhurst as the continuous move of the royal camp (Markakis, J. 2006). Middle age royal court was composed of immense agglomerations of population which consisted not only courtiers and warriors, but also of numerous non-combatants, among them wives, servants, and slaves, armourers, tent-carriers, muleteers, priests, traders, prostitutes, beggars, and even not a few children . On the other hand, Molla Mengistu argued that there was a little need for urbanization, since it contradicts the existing self-sufficient peasantry life style. Urbanization by its nature needs to transfer more land away from agricultural production to urban settlement. And yet, it can be concluded that modern Ethiopian urbanization has been flourished during the 20$^{th}$ century because of political stability (especial during the reign of Emperor Hailesselasi I), and the modernization of the country. Most cities in the country, including Bahir Dar, were flourished around some economic center such as railway, factory, or trade route-(Molla, 2009:150).

Ethiopia is one of the least urbanized countries in the world today, and only18% of its population lives in urban areas. In common with many other developing countries, however, this patterns changing. Ethiopia's urban growth rate is more than 4.0% per year, which places it among the highest in Africa and the world-(MWUD, 2007).

The fig.2.3 below shows the percentage change of rural and urban population with in the year. While the year increases, the rate of urbanization increases as the same time rural decreases. This shows urbanization increases rapidly in Ethiopia.

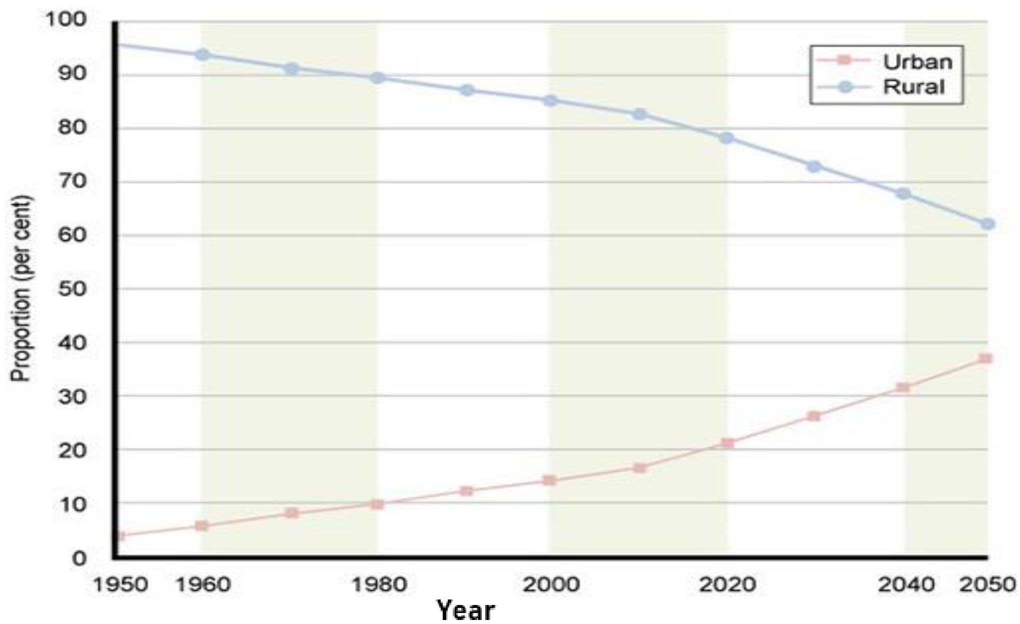



Figure 2.3: Changing proportion of urban and rural population in Ethiopia from 1950 to 2050 (source: MWUD, 2007).

The rapid increase in urban populations has meant that peri-urban areas are growing. Much more quickly than formal urban centers. Peri-urban areas are those areas immediately around town or city. They are areas in transition from country side to city (rural to urban), often with undeveloped infrastructure, where health and sanitation services are under pressure and where the natural environments at risk of degradation. They do not neatly separate themselves by lines on a map. On the contrary, the sprawling nature of urban development means that the areas merge into each other. The lack of a clear boundary can make it difficult to assess the size of towns by their population or geographical area. However, judgements have to be made for planning and administrative purposes, data on population size are collected (Works, 2016).

### 2.2.2. Urban Development Policy of Ethiopia

According to Ministry of Urban Development And Construction ,the main theme of the National Urban Development policy is founded on ADLI (Agricultural Development Led Industrialization), Industrial Development Strategy, federalism, democratization and civil service reform. The focus of urban development is dependent on rural development and vice versa. According to the policy, the main challenges that facing urban areas in the country are poorly developed social and physical infrastructure; shortage and deterioration of housing; lack of recreation areas, inadequate municipal waste management; absence of well integrated urban-rural linkage; unbalanced urban growth and weakly developed national and regional urban systems. The policy gives key emphasis to urban-rural and urban-urban linkages. The overall vision of the policy is to ensure the growth and development of Ethiopian urban centers is guided by plans and to make the cities and towns competitive centers of integrated and sustainable development that are sufficiently responsive to the needs of their inhabitants. The proclamation, i.e. "A Proclamation to Provide for Urban Plans (Proclamation No. 574/ 2008)" is declared in response to the need to regulate and guide urban centers by sound and visionary urban plans to bring about balanced and integrated national, regional and local development.

### 2.2.3. Historical background of settlement in Minjar Shenkora Woreda

According to the Woreda communication report 2012 EC, it is told that the name Minjar is taken from the name of Meneijara which means "Make House". The people of Minjar wrere displaced to Menz,Yifat,Tegulet and around Bulga due the reign of Gragn Mohammod Algazi conquer in the 15$^{th}$ century. But, the displaced people came back to their former place,Minjar by the order of Emperor Sahile Sillasie in 1802 EC. Starting from 1802 EC, Minjar and its capital Arerty was established formally. The concept of settlement in the woreda was derived during the Durg Regime for sake of defensive mechanism. The people was living dispersedly on their land until the Durg Regime. Different robberies emerged with in that year. It was difficult to protect people from such robberies by the government. Therefore the Durg government planned to settle people to new settlement area.

## CHAPTER THREE

## MATERIALS AND METHODS

### 3.1. Description of the study area

This study mainly focused and conducted in the Minjar Shenkora district, which is one of the 24 woredas located in the North Shewa Zone, Amhara Region, Ethiopia. The study area is astronomically found from 8°42'46" N to 9°7'37" N latitude and from 39°12'57" E to 39°46'53"E longitude as shown in the fig 3.1.

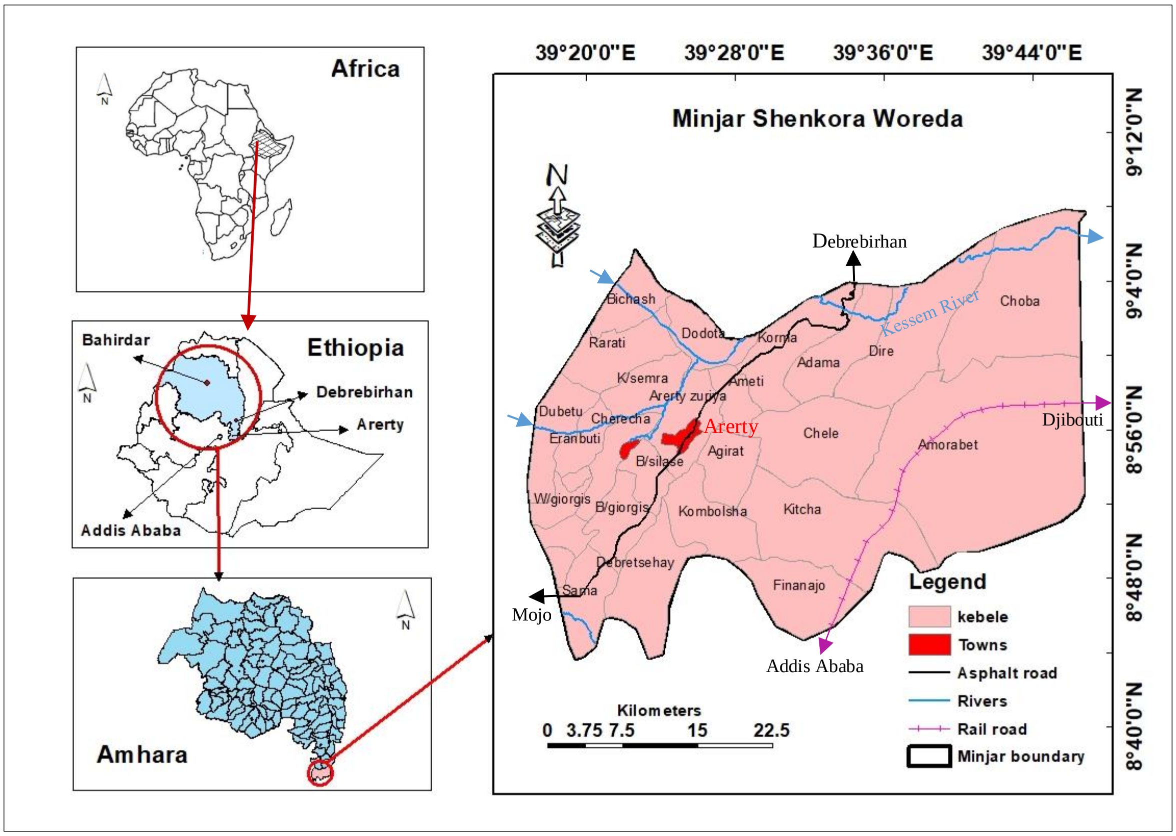



Figure 3.1: Location map of study area

Its capital, Arerty Town found 130 km away from the national capital city, Addis Ababa and 260 km from its zonal administration capital, Debrebirhan. The district is divided in to 29 kebele, of which 2 are towns and the rest 27 kebele are rural. According to 2010 E.C Statistical journal of woreda administration office, its total population was 167156, of which 36,468 were urban dwellers and 130,688 were rural dwellers. Its population density was 85.35. And also had 28,221 housing units and a total of 29,359 households, resulting average of 4.39 persons to a household. It has a total area of 1587 square kilometers, out of this total area 34.98% or 55,860.38 hectare is cultivated agricultural land. The number of household which accounts 88% of the total households are depend on agricultural activities

### 2.2. Sampling techniques

The sampling techniques that the researcher used non probability sampling which is purposive sampling. This means that data was gathered from the most important group of the related field of study, (12) experts or professionals in municipality of minjar shenkora woreda on multi criteria analysis.

### 3.3. Materials

The following materials or software have been used in the present study for data acquisition, design, analysis and presentation of the final research results were shown in Table 3.1.

Table 3.1. Types of software's used to execute the research

| No | Types of Software used | Used for |
|---|---|---|
| 1 | ArcGIS10.4 | For data editing, digitizing ,creating, analyzing and mapping |
| 2 | Google Earth | For preparation land use land cover & generating GPS data in the form of GPX file which has been converted DEM data. |
| 3 | Micro soft office word | For word processing |
| 4 | Micro soft office Excel | For preparation of graphs ,charts for illustration |

### 3.4. Data types and Source

To achieve the purpose of this research, the data have been collected from both primary and secondary sources. The primary data sources are data from field survey and also interview or questionnaire of related field experts (Architects, engineers, environmentalist) in the municipality the woreda. The secondary data sources are relevant literature and the data taken from different organization as shown in the Table 3.2.

Table 3.2. Summary of data types and source used

| No | Data types | Description | Data sources |
|---|---|---|---|
| 1 | Spatial | Slope | IDW generated in GIS from the GPX/KML data format in Google Earth |
| 2 | Spatial | Prime agricultural land Map | From soil fertility status map of the Minjar shenkora agricultural office |
| 3 | Spatial | LULC & underground water map | Researcher |
| 4 | Spatial | Roads, River and Town network map | Shape file from Amhara rural and regional development bureau |
| 5 | Spatial | Soil types and soil depth map | Ethiopian Agricultural Transformation Agency(ATA) |
| 6 | Spatial | Geology map | Data base of Hydrogeology of Ethiopia(2018) |
| 7 | Non spatial | Population data | Minjar shenkora worda administration office (2012) |

## 3.5. Data collection techniques

The techniques that used to collect the necessary data regarding the identification of suitable settlement areas in Minjar Shenkora Woreda are literature survey, observation (field survey), interview and questionnaire with field experts /stakeholders. From the literature survey, it was collected that the selection of criteria and some standards of the suitability classes of each criteria. Through interview and questionnaire, the relative importance of each criteria with one another or the weight influence of criteria was collected. Finally the data on the existing settlement condition was collected by field survey (Table 3.3).

Table 3.3. Data collection instruments and the data collected

| No | Instruments | Data collected |
|---|---|---|
| 1 | literature survey | the selection of criteria and the standards of the suitability classes of each criteria |
| 2 | Interview and questionnaire | the relative importance of each criteria with one another or the weight influence of each criteria |
| 3 | field survey | Existing settlement condition of the study area |

### 3.6. Methods of data Analysis

#### 3.6.1. Existing settlement condition of the study area

The raw data, which was both qualitative and quantitative data was collected through interview & questionnaire, observation/field survey. The data was carefully tabulated, graphed and mapped. The qualitative data used to describe the findings qualitatively whereas quantitative data were analyzed by using MS Excel 2013, Google Earth and GIS.

#### 3.6.2. Settlement suitability analysis and suitable areas

Multi criteria decision making analysis with analytic hierarchy process (AHP), geographic information systems (GIS) was used as a methods to identify the suitable settlement areas. Multi-criteria analysis (MCA) is a technique used to consider many different criteria when making a decision. MCA gives a logical, well-structured process to follow so different factors can be clearly identified and prioritized. It allows the alternative solutions being considered to be ranked in order of suitability (Omar & Raheem, 2016).

In order to select suitable settlement areas, 3 main steps were used. Namely calculation of criteria weights with AHP, creation of data infrastructure structure with GIS and weighted overlay analysis. These are elaborated further below.

**(i) Calculating the criteria weights with AHP**

It has four different steps. The 1st step is determine factor, sub factor and conformity values. The factors used for site selection process for a suitable settlement were selected based on field experts and prior knowledge of that particular area. Based on the different literature and previous related studies conducted by different researchers (e.g.Mifh, 2014; Making et al., 2019; Omar & Raheem, 2016), 10 factors were selected for selection of suitable settlement areas in Minjar Shenkora Woreda such as slope, soil types, soil depth (cm), distance from road, drainage (distance from rivers), town network, land use land cover (LULC), prime agricultural land, geology and underground water. And also the conformity values of sub-factors were determined with the 4-point Likert scale from the most suitable to the lowest as 4- most suitable, 3- moderately suitable, and 2- less suitable, 1- not suitable.

The 2nd step is creating the paired comparison matrix. The paired comparison questions among the criteria which were filled by the experts in the Woreda municipality such as urban planner and design (3), Architects (2), civil engineer (5), and environmental science (2) on the voluntary basis. According to the comparisons made by experts, paired comparison matrices were created. In this context, in order to assign a value to the paired comparison matrices, the level of significance varied from 1 to 9 developed by Saaty was used as shown in Table 3.4 (Saaty, 1980).

Table 3.4: The Saaty comparison scale in AHP

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance of i and j | Two activities contribute equally to the objective |
| 3 | Weak importance of i over j | Experience and judgment slightly favor one activity over another |
| 5 | Strong importance of i over j | Experience and judgment strongly favor one activity over another |
| 7 | Very strong importance of i over j | An activity is strongly favored and its dominance is demonstrated in practice |
| 9 | Absolute importance of i over j | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values the two adjacent judgments | When compromise is needed |
| Reciprocals of above nonzero | If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with Where i and j are criteria to be evaluated | |

(Source: Yalew et al., 2016)

This pair wise comparison matrix shows how important is one criteria with respect to other criteria based on the Saaty comparison scale to know the influence in final suitability map as shown in the Table 3.5.

Table 3.5: Pairwise comparison matrix for multi-criteria decision layers

| criteria | Prime agricultural land | Underground water | Slope | LULC | Geology | Soil depth | Soil type | Road network | River network | Town network |
|---|---|---|---|---|---|---|---|---|---|---|
| Prime agricultural land | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 7 | 8 | 8 |
| Underground water | 0.5 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 |
| Slope | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 6 |
| LULC | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 | 6 |
| Geology | 0.25 | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 | 5 |
| Soil depth | 0.2 | 0.25 | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 | 4 | 5 |
| Soil type | 0.2 | 0.2 | 0.2 | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 | 4 |
| Road network | 0.14 | 0.17 | 0.2 | 0.2 | 0.25 | 0.33 | 0.5 | 1 | 2 | 3 |
| River network | 0.13 | 0.14 | 0.17 | 0.17 | 0.2 | 0.25 | 0.33 | 0.5 | 1 | 2 |
| Town network | 0.13 | 0.13 | 0.17 | 0.17 | 0.2 | 0.2 | 0.25 | 0.33 | 0.5 | 1 |

(Source: field survey, 2020)

The 3rd step is calculating the priority vector matrix and eigenvalue ($\lambda$max). After preparing the paired comparison matrix, the matrix must be normalized as shown the Table 3.6. In order to normalize the matrix, the sum of each column in the matrix is calculated and the matrix elements are divided by the sum of the related columns.

Table 3.6: Normalized Pairwise comparison matrix /priority vector matrix

| criteria | Prime agricultural land | Underground water | Slope | LULC | Geology | Soil depth | Soil type | Road network | River network | Town network | criteria weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Prime agricultural land | 0.32 | 0.40 | 0.38 | 0.34 | 0.26 | 0.25 | 0.19 | 0.21 | 0.19 | 0.17 | 0.27 |
| Underground water | 0.16 | 0.20 | 0.26 | 0.26 | 0.26 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 | 0.20 |
| Slope | 0.11 | 0.10 | 0.13 | 0.17 | 0.19 | 0.20 | 0.19 | 0.15 | 0.14 | 0.13 | 0.15 |
| LULC | 0.08 | 0.07 | 0.06 | 0.09 | 0.13 | 0.15 | 0.15 | 0.15 | 0.14 | 0.12 | 0.11 |

Continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Geology | 0.08 | 0.05 | 0.04 | 0.04 | 0.07 | 0.20 | 0.12 | 0.19 | 0.19 | 0.10 | 0.08 |
| Soil depth | 0.06 | 0.05 | 0.03 | 0.09 | 0.03 | 0.05 | 0.08 | 0.09 | 0.09 | 0.10 | 0.06 |
| Soil type | 0.06 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.04 | 0.06 | 0.07 | 0.08 | 0.05 |
| Road network | 0.05 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.06 | 0.04 |
| River network | 0.04 | 0.03 | 0.02 | 0.02 | 0.013 | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 | 0.02 |
| Town network | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |

The values of the sum in the weighted total matrix were divided into priority vector matrix column values and the value of eigenvalue (λmax) was calculated by taking the arithmetic average of the values in the last matrix that was created as shown in the Table3.7.

Table 3.7: Eigenvalue (λmax) calculation

| | Prime agricultural land | Underground water | Slope | LULC | Geology | Soil depth | Soil type | Road network | River network | Town network |
|---|---|---|---|---|---|---|---|---|---|---|
| Weighted sum value | 2.993 | 2.27 | 1.69 | 1.254 | 0.89 | 0.65 | 0.46 | 0.42 | 0.23 | 0.19 |
| Criteria weight | 0.27 | 0.2 | 0.15 | 0.11 | 0.08 | 0.06 | 0.05 | 0.03 | 0.02 | 0.02 |
| WSV /CW | 11.08 | 11.4 | 11.3 | 11.4 | 11.17 | 10.77 | 9.16 | 14.03 | 11.47 | 9.31 |
| Eigenvalue (λmax)=(11.08+11.4+11.3+11.4+11.17+10.77+9.16+14.3+11.47+9.31)/10<br>λmax =11.10174 | | | | | | | | | | |

Where WSV-weighted sum value, CW-criteria weight

The 4th step calculating consistency index and consistency ratio using formula below.

CI= (λmax-n)/ (n-1) = 0.122, RI=1.49 (Table 3.8) (1)

CR=consistency index (CI)/Random inconsistency (RI) = 0.08 (2)

Where CR- consistency ratio, RI is random consistency index and CI the consistency index, λmax is the maximum eigenvalue of the matrix and n is the number of compared elements. Consistency ratio index values CR>0.10 indicate an inadequate evaluation of criteria whereas CR index < 0.10 denotes the consistent judgment of a matrix acceptable results. Therefore in this research the consistency ratio (CR) =0.08< 0.1 which is acceptable result of consistent judgment of decision makers

Table 3.8: Random consistency indices (RI) for n = 10

| **n** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.46 | 1.49 |

( Source : Pramanik, 2016)

### (ii) Creation of data structure or standardization with GIS

All of the selected 10 criteria are in different units. They had to be converted in same units to have a standardized value in order to execute weighted overlay analysis. The resulted score lose their dimension along with their measurement unit of all criteria (Effat & Hassan, 2013). The vector layer of all criteria maps was converted to raster layer. After that, all raster layers were reclassified using the Spatial Analyst tool in ArcMap into four comparative categories as: most suitable (4), moderately suitable (3), less suitable (2) and not suitable (1). The weights of each criteria map can be calculated using AHP. Then WOA method was applied to produce the final suitability map.

### (iii) Weighted overlay analysis (WOA)

Weighted overlay analysis is applied to determine the influential factors in the hierarchy of selected dissimilar inputs of all criteria. Moreover, all created thematic layer were combined with each other in GIS to apply the weighted overlay techniques. Land suitability has been found using weighted overlay techniques based on analytic hierarchy process and multi-criterion decision making process. Selected raster layers were overlaid by recognizing their cell values to the same scale, giving a weight value to individual criterion and integrating the weight cell values together (Eq.3). The cell values of each raster layer are also multiplied by their weight value (Akbulak, 2009).

$$\mathrm{Ls} = \sum_{i=0}^{n} \mathrm{WiXi} \qquad (3)$$

Where, LS indicates the total land suitability score, $W_i$ denotes the weight of the selected criteria, $X_i$ indicates the assigned sub-criteria score of i land suitability criteria, and n denotes the total number of criteria to the study.

### 3.7. Methodology

Methodology of suitability map illustrates the procedures that are undertaken while running suitability analysis for identification of settlement areas in Minjar Shenkora Woreda as shown in the Figure 3.2.

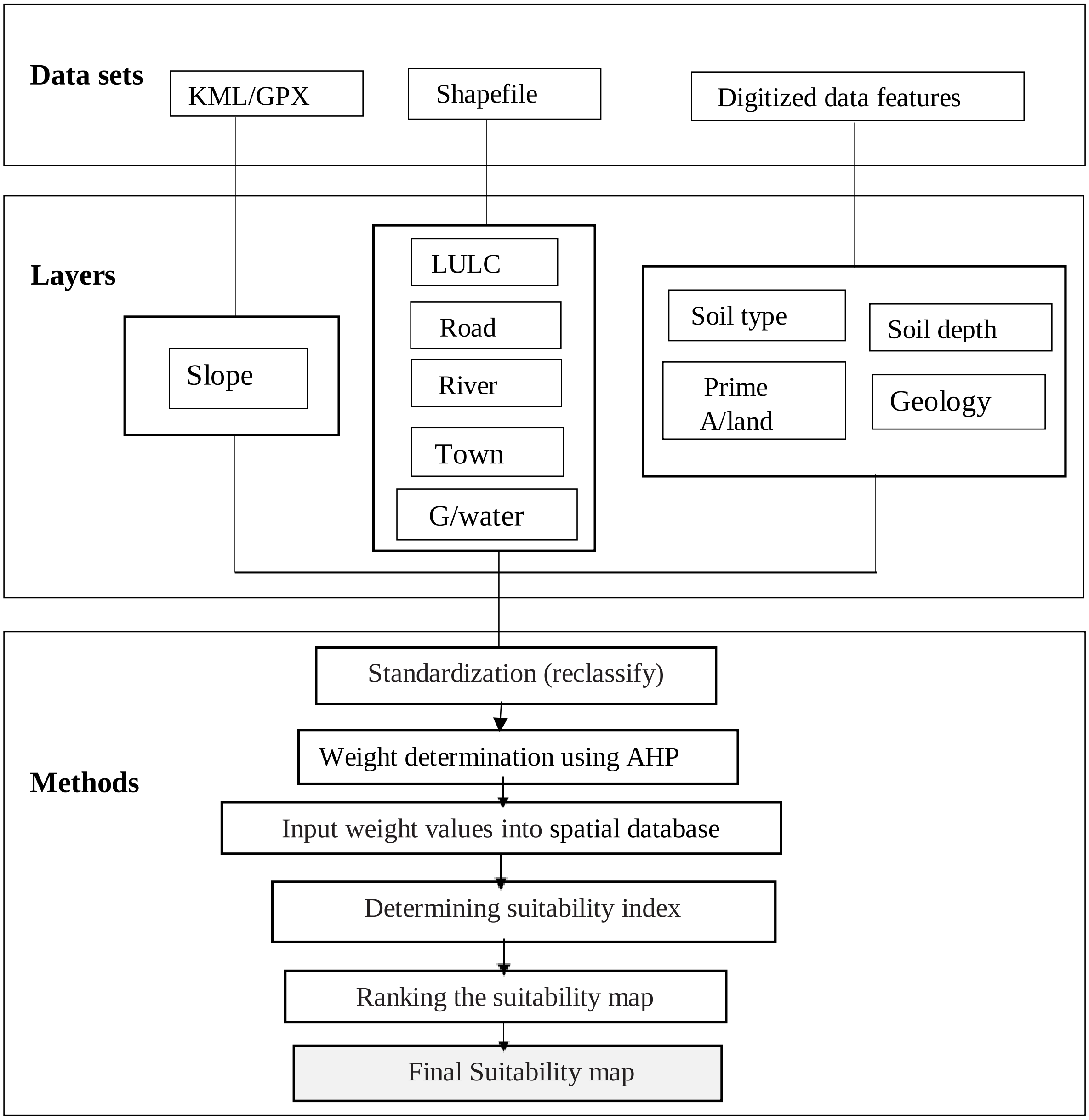



Figure 3.2: Methodology to complete the research

# CHAPTER FOUR

# RESULT

## 4.1. Existing settlement condition of the study area

### (i) Size of settlements

The settlement covers a total area of 58.78 $km^2$ (3.8%**)** from the total study area, of which 48.80 $km^2$is rural settlement and 11.98 $km^2$ is urban settlement. The figure 4.1 shows the existing urban and rural settlement at each kebele in Minjar Shenkora Woreda.

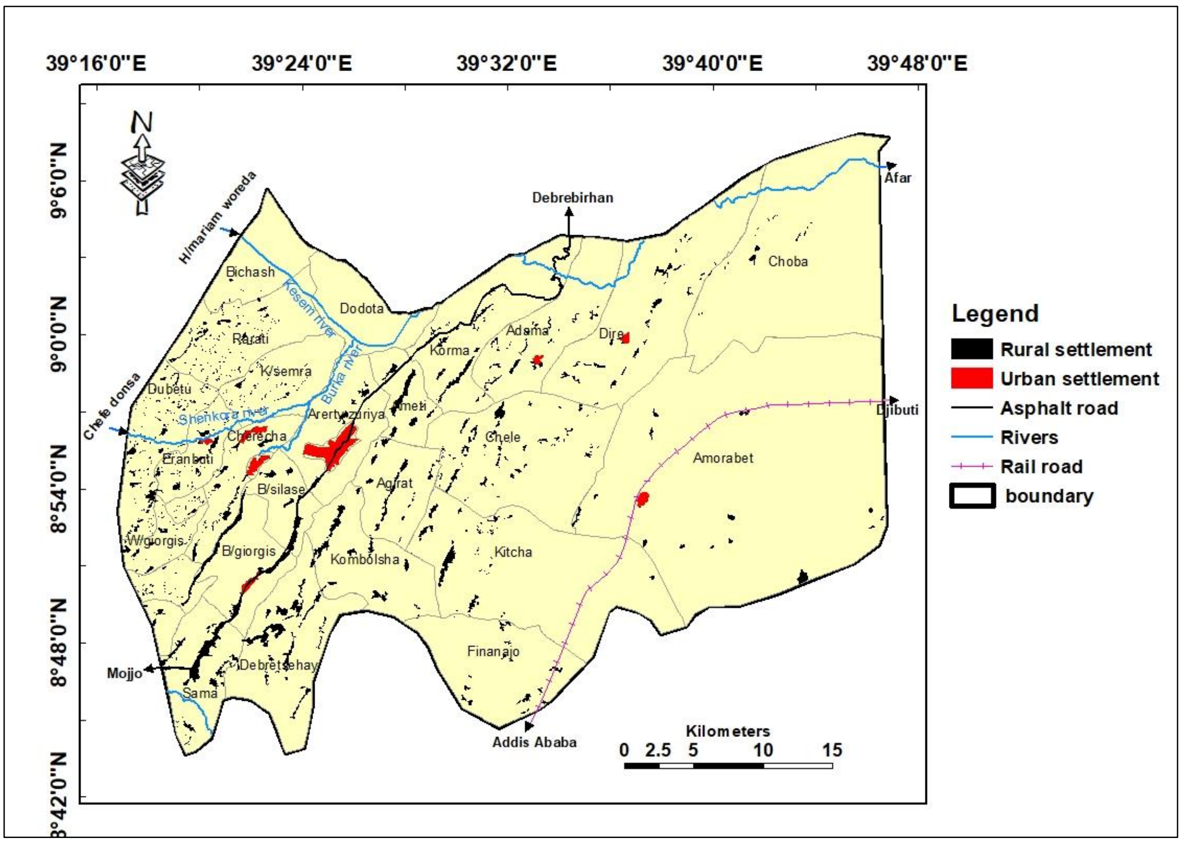



Figure 4.1.Existing settlement map of the study area

There are 8 emerging towns in the study area including the two admistrataive towns. These are Aerty (capital town), Balchi, Bolo, Yohanis, Eranbuti, Adama, Dire and Melkajilo. The two towns Arerty and Bolo are located along the asphalt road which passes from Mojjo to Debrebirihan Town. Melkajilo town is located near to the rail way which passes from Addis Ababa to Djibouti but the rest are along the rural gravel road. The three towns namely Balchi, Eranbuit and Yohanis are located near to Shenkora River and Burka River (Figure 4.2).

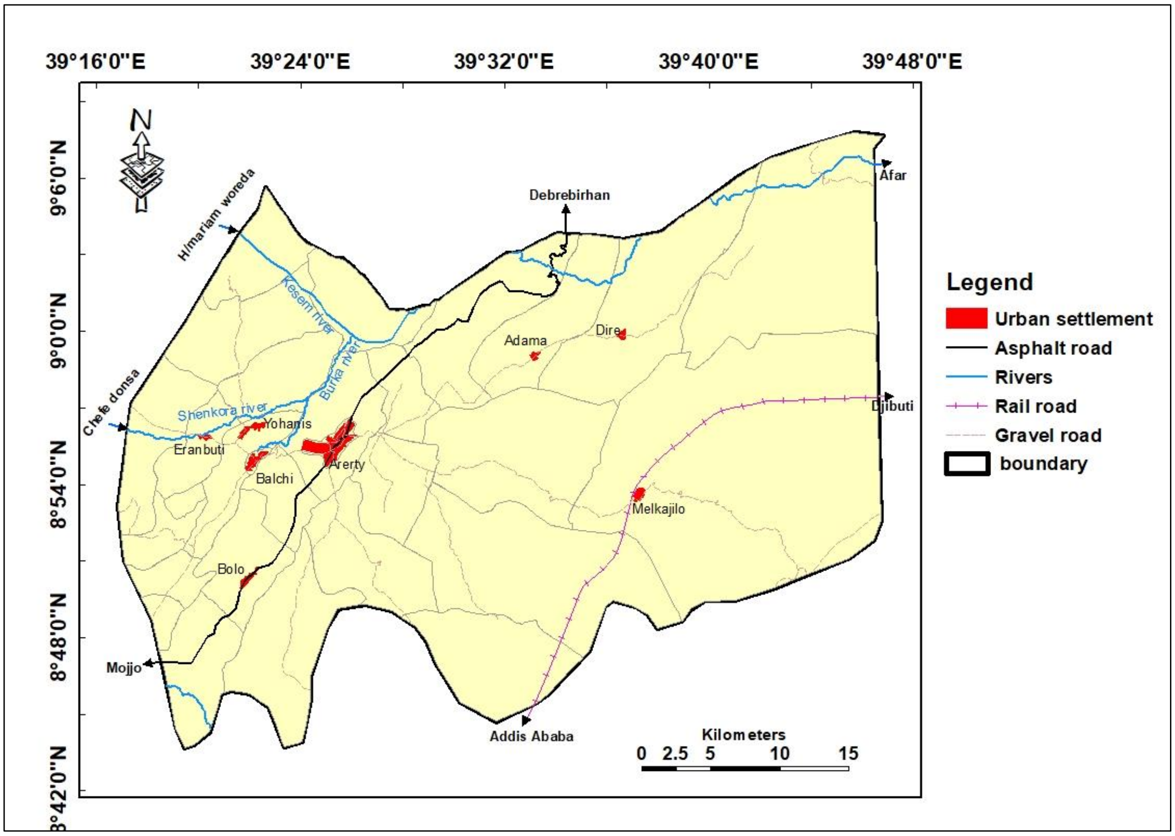



Figure 4.2: Existing town settlement map of the study area

The figure 4.3 shows the two main urban settlement which is larger than the other towns in the study area. Arerty Town is more exposed to expand in four direction but Balchi Town is expanding in the two direction because there is mountain in the north and east direction.


Figure 4.3: Example of urban settlements

### (ii) Types and pattern of settlements

Settlements may also be classified by their shape, patterns types. The major types classified by shape are compacted and dispersed settlements. Patterns of settlements reflect the way the houses are sited in relation to each other. The patterns of settlements are described in terms of population density. This map shows the population density of the Woreda by census as the number of population in each kebele per unit area (hectare). High density is the darkest tone whereas low density is the lightest. The two towns (Arerty,Balchi) are densely populated or compacted settlements. The rural kebeles specially the western and central part (Woldegiorgis, Eranbuti and Bologiorgis) are moderately compacted settlements. But, the eastern part (Kitcha,Finanajo,Amorabet and Choba) are less dense populated that means dispersed settlement (see fig.4.4).

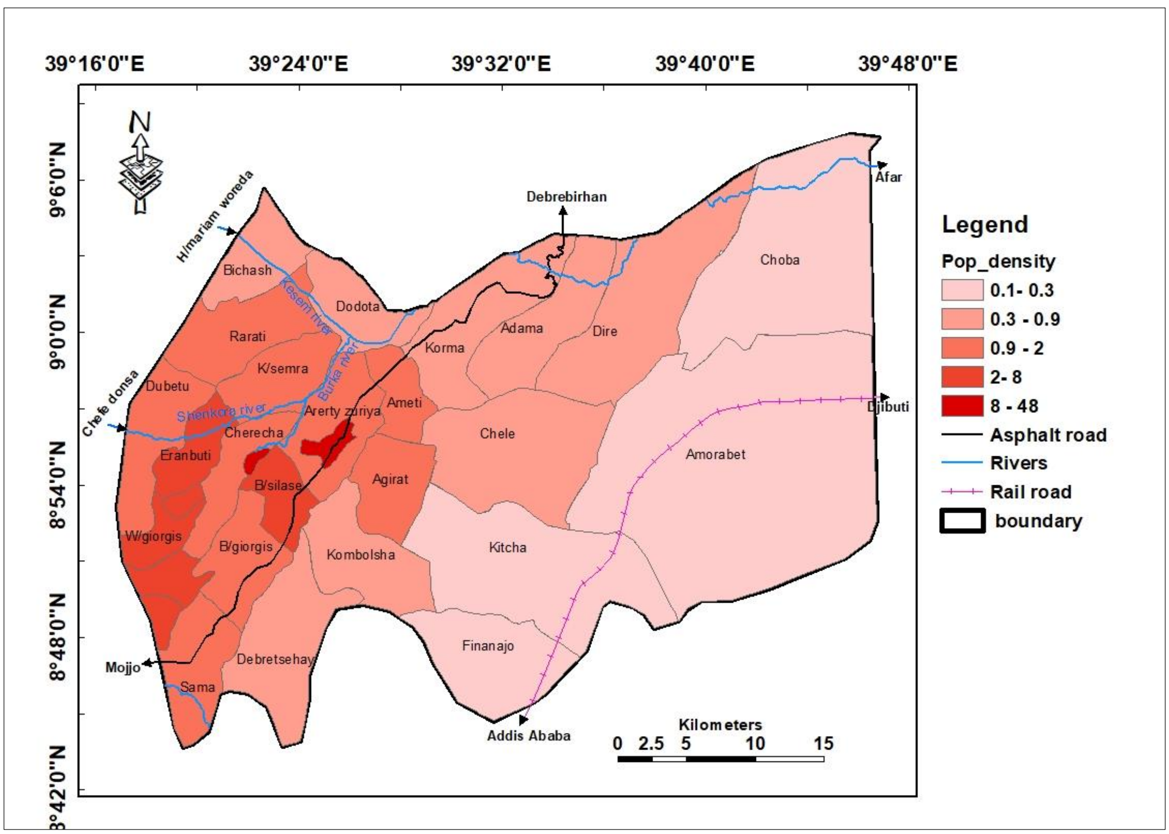



Figure 4.4. Population density of the study area (source: census, 2012)

The settlements can be classified as plain and plateau villages based on the setting. In this study, most peoples of the shenkora are settle on the plain areas especially on the flat agricultural land which near to their houses. The settlements are not well arranged which is pointed arrangements as shown figure 4.5a & 4.6.

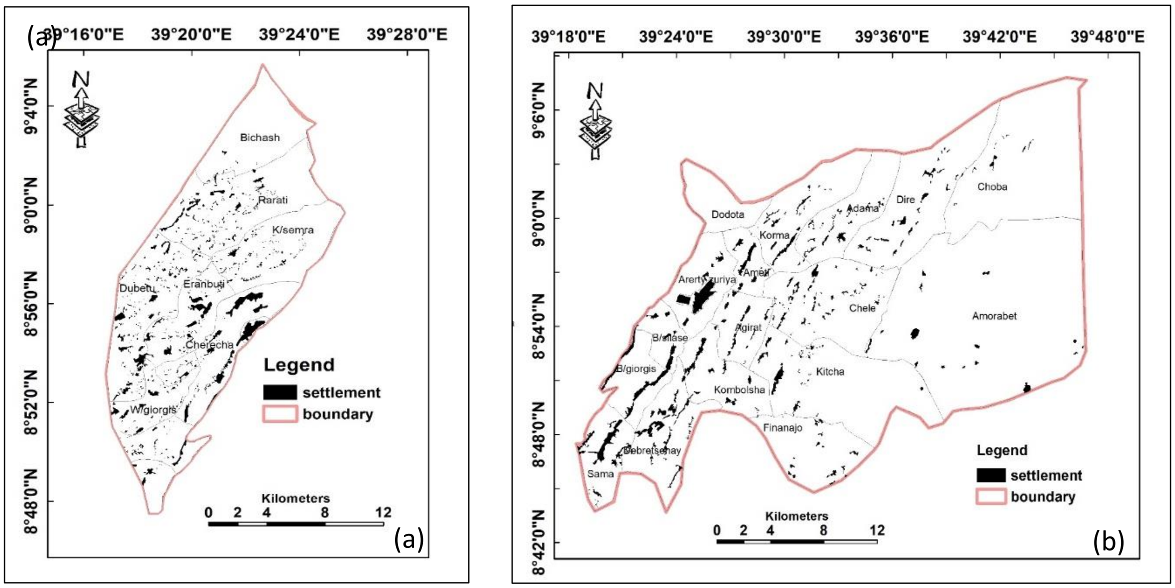


Figure 4.5: Settlements on (a) plain areas in shenkora part (b) plateau areas in minjar part

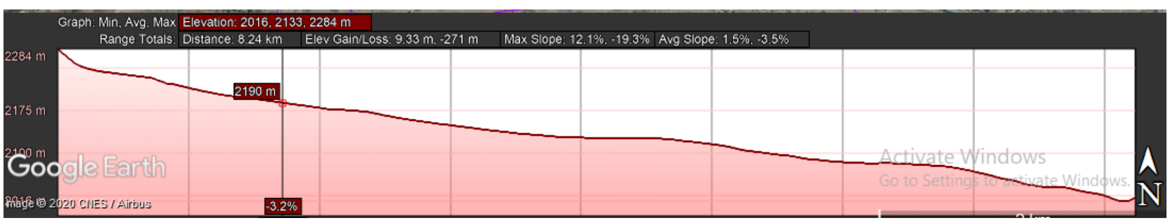


Figure 4.6: Sectional view of plain areas in shenkora part

Most peoples of Minjar are settle on the plateau areas which is not good for agriculture. The settlements are located appropriate distance from their houses. The settlements are almost well arranged which is a linear arrangements especially around Arerty town as shown figure 4.5 b & 4.7.

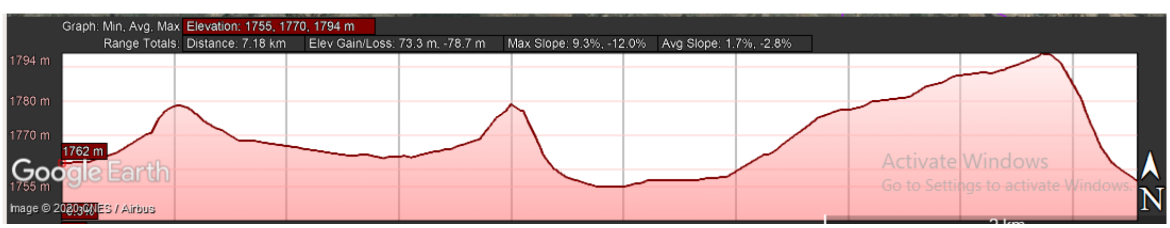


Figure 4.7: Sectional view of plateau areas in minjar part

### (iii) Water availability

Water is essential for the environment, for ensuring agriculture growth and food security.

**Surface water:** The rivers/stream and the wetlands are located in the study area. There are one main river which is called Kessem and three streams in the Woreda namely Burka, Shenkora &Tebo. Kessem River runs through the northern part the woreda starts from Hageremariam Woreda that flows to Afar region and finally gets in to Awash River. The two streams Buraka and Shenkora are tributary to Kessem River where as Tebo River is flow to Oromia region. The Rivers are mainly used for irrigation rather than for drinking because they are far away from most existing settlements (Figure 4.8).

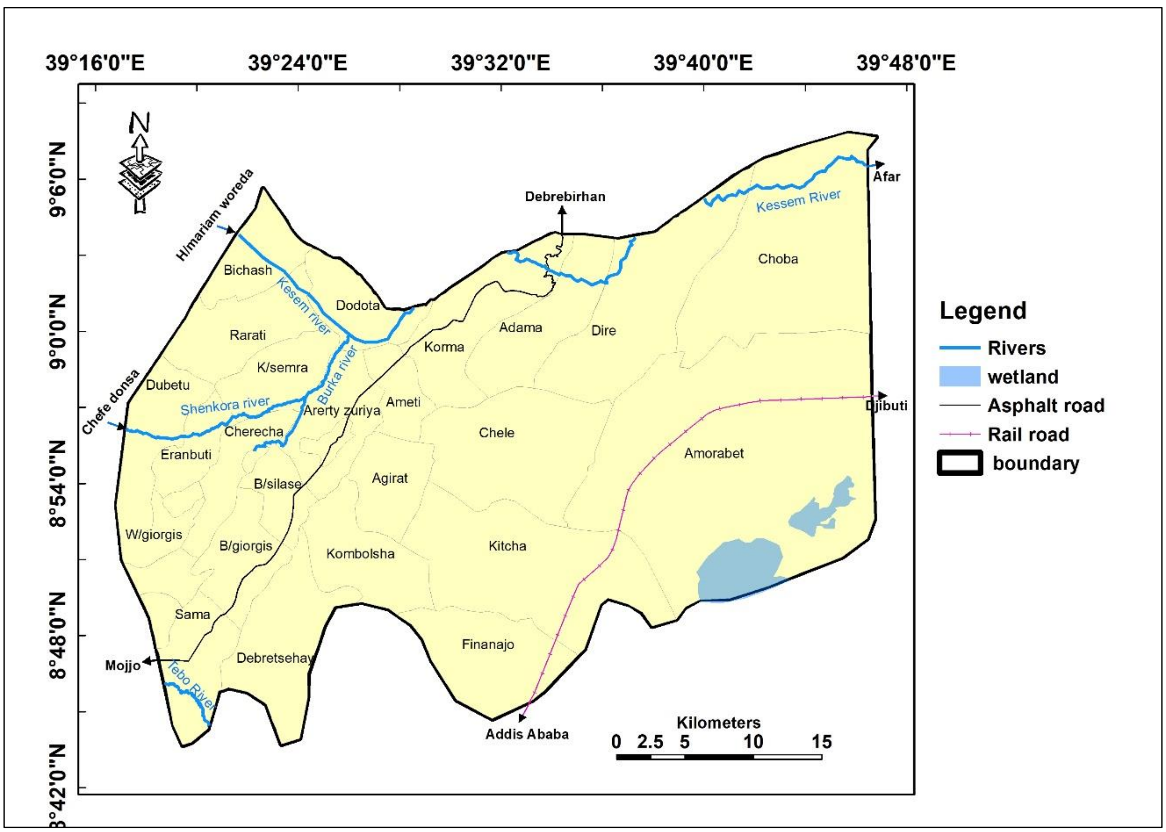



Figure 4.8: Surface water map of the study area

**Rain water:** Rain water is one the source of water if it is harvested. Rainwater harvesting is a technique to utilize and store precious water that otherwise would go waste. The amount of rainfall is collected in Arerty meteorology station, which is located in the administrative town of the study area. According to National Meteorological Agency

(NMA), Minjar Shenkora district receives the highest annual rainfall (770-818mm) in the summer and also in the spring season or locally known as Belge, it covers 236-277mm. It can get 761,760,000$m^3$ of water from rain water harvesting (Annex 2).

**Local water wells:** A well is an excavation or structure created in the ground by digging, driving, or drilling to access liquid resources, usually water. A water well used to access groundwater in underground aquifers. All wells are deep water wells which have a depth from 100-250 m with different yields 1.5 - 40 L/S. The wells provide a reliable supply of potable water for almost 85% of the peoples in this worada. It can get 7,711,200 liter of potable water from a total of water well yields (178.5l/s) if they work 12 hours in a day. Most water wells is located in Arerty zuriya, Ameti and Bolo gioris kebele. Most kebele get water through the pipes from wells and distributed in the bono (Figure 4.9 & Table 4.1).

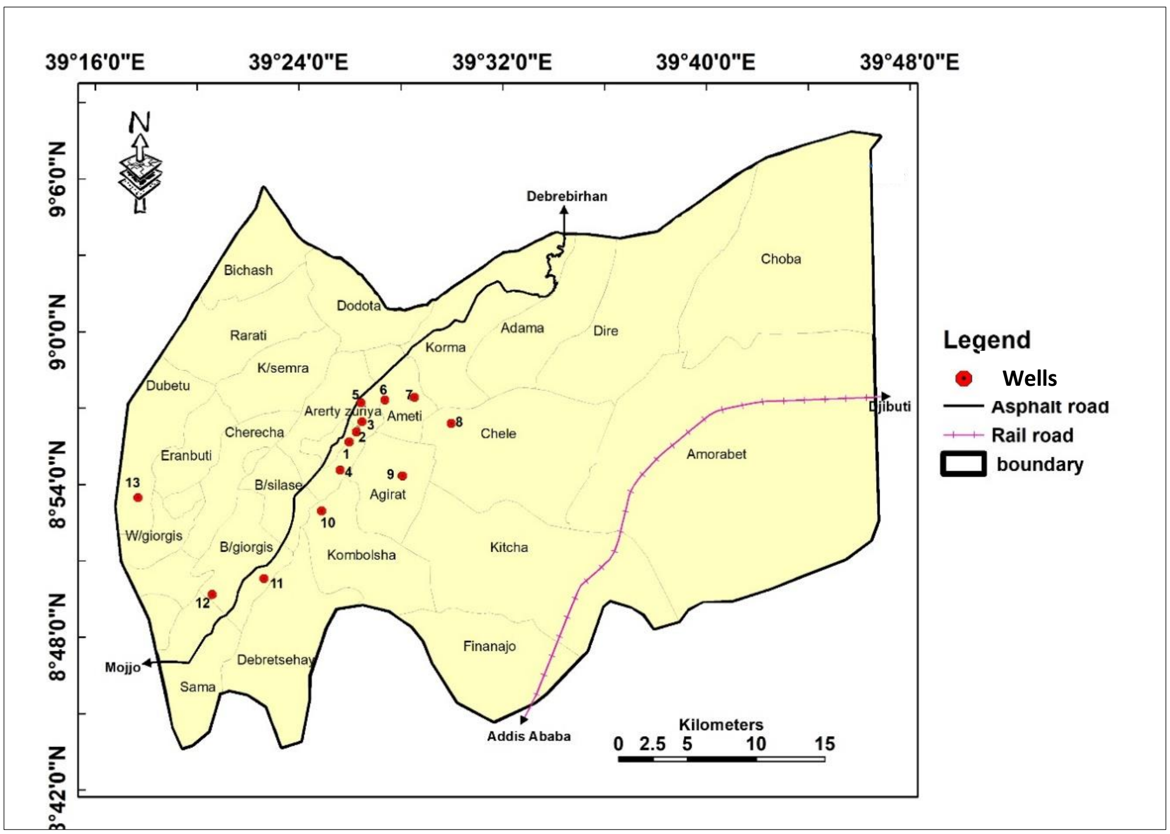



Figure 4.9: Local water wells map of the study area

Table 4.1: The distribution and water yields (L/S) of local deep water wells in the study area

| Wells | Location of wells kebele | Occupied kebele | Qty bono | No Pop. used | Well yields(L/S) | Coverage (%) |
|---|---|---|---|---|---|---|
| 1,2, 3&4 | Arerty zurya | Arerty | - | 30432 | 1.5,5,12 & 15 | 100 |
| | | Zemuna mehiri | 2 | 1200 | | 100 |
| 5 | Welnso | Welenso | 2 | 1300 | 1.5 | |
| 6 | Ameti | Ameti | 10 | 4635 | 5 | 100 |
| | | Korma | 11 | 4385 | | 1000 |
| 7 | Ameti | Adama | 14 | 4887 | 26 | 100 |
| | | Dire | 15 | 6205 | | 100 |
| | | Choba | 8 | 1797 | | 100 |
| 8 | Alemneh dire | Chele | 13 | 6392 | 19 | 85.01 |
| 9 | Agirat | Agirat | 11 | 4700 | 40 | 100 |
| | | Kitcha | 11 | 2500 | | 100 |
| | | Finanajo | 9 | 2437 | | 100 |
| | | Amorabet | 9 | 4167 | | 66.57 |
| 10 | Kombolsha | Kombolsha | 5 | 1728 | 1.5 | 38.47 |
| 11 | Hageregenet | Bolo giorgis | 7 | 1692 | 5 | 100 |
| 12 | Bolo giorgis | B/silase | 14 | 6163 | 15 | 93.82 |
| | | B/giorgis | 18 | 7751 | | 100 |
| | | Sama | 13 | 5147 | | 100 |
| | | D/tsehay | 11 | 4814 | | 100 |
| | | M/hager | 8 | 3420 | | 100 |
| | | Zewolde | 3 | 280 | | 19.57 |
| 13 | Dubetu | W/giorgis | 9 | 3059 | | 50.15 |
| | | Zewolde | 5 | 280 | | 19.15 |
| | | Cherecha | 15 | 5101 | | 87.16 |
| | | Dubetu | 7 | 980 | | 75.98 |
| | | Akilal | 4 | 1029 | | 82.70 |
| | | Eranbuti | 15 | 1700 | | 95.20 |
| | | Balchi | 4 | 2833 | 32 | 100 |

## (iv) Land availability

People choose to settle near fertile lands suitable for agriculture. According to the soil fertility status of minjar shenkora and field survey, 166.88 $km^2$ prime agricultural land is identified from the total of 1212 $km^{2.}$ These lands are very fertile soil which is brownish color, high moisture content, deep soil, productive lands. And also has a soil with acceptable acidity or alkalinity, salt and sodium contents, and few or no rocks. It can produce high yields of different crops especially White Magna Teff, wheat in the woreda. Prime agricultural lands are located in many kebele such as Arerty Zurya, Agirat, Sama, Bologiorgis, Bolosilase, Ameti and Korma where the settlements are compacted as shown in the fig.4.10.

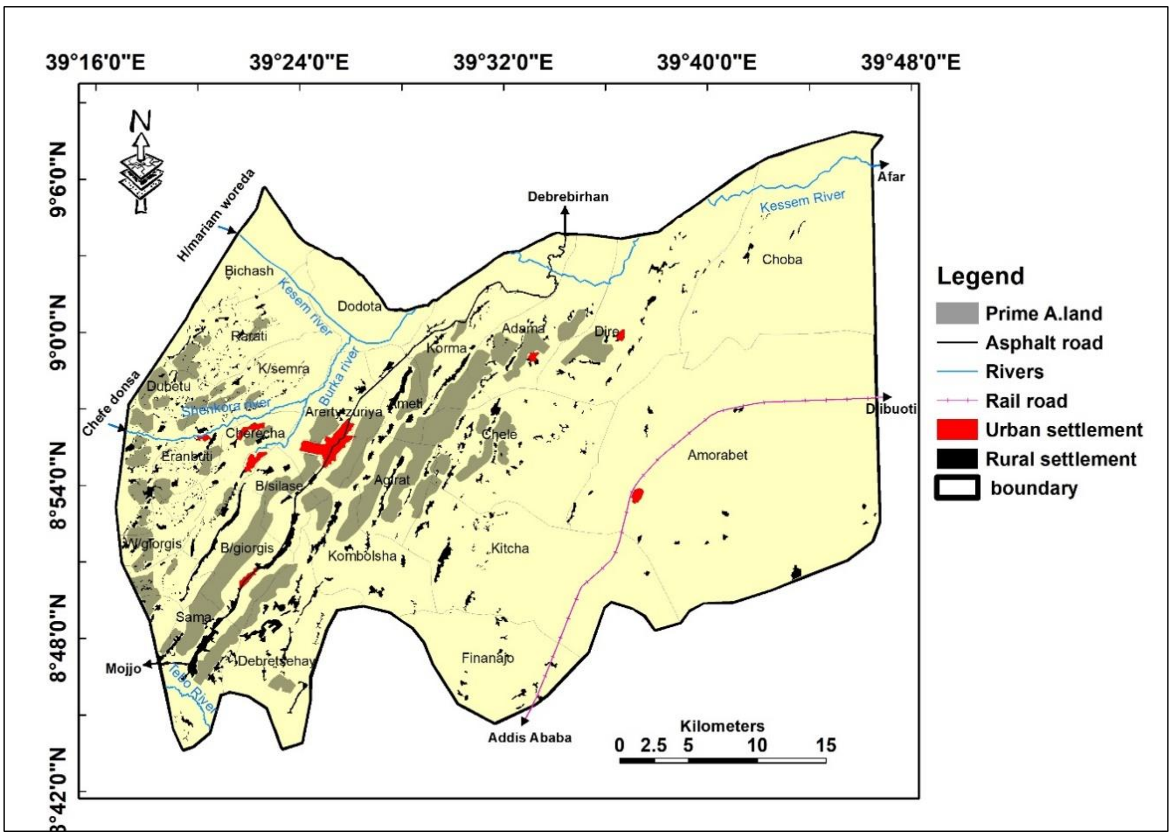



Figure 4.10: Availability of agricultural lands in the study area

### (v) Material availability

In this study, 23.72km$^2$ of mineral site is identified in the study area. There are different kinds of mineral namely pumice, ceramic mineral, quarry stone, selected materials, sand in Minjar shenkora Woreda that are used as a materials for building and road constriction as shown in the fig 4.11.

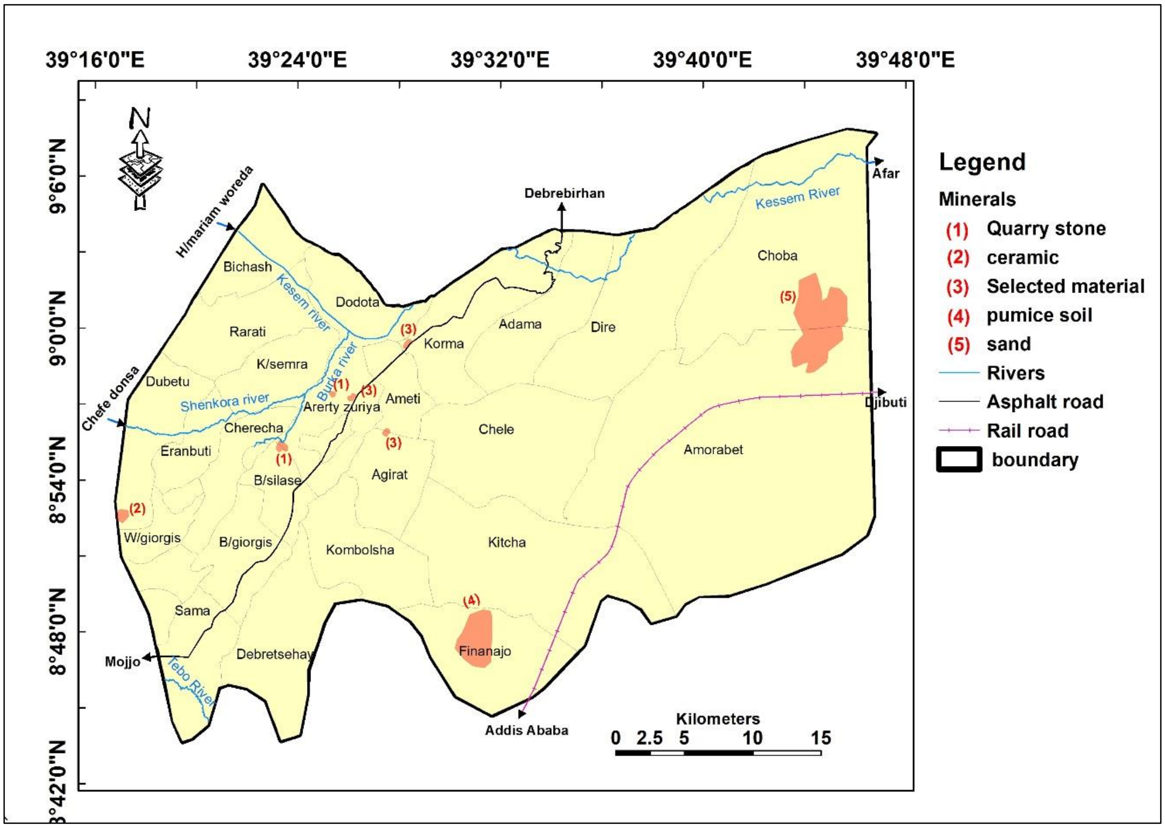


Figure 4.11: Mineral materials map in the study area

### (vi) Energy availability

The availability of renewable energy (hydropower, solar and wind) is very important to create sustainable settlement environment. Ethiopia can produce 1350 GW from wind and 2.199 million TWH/annum is from solar energy (Debebe & Shibesi, 2017). In the study area has not a potential to generate hydropower because there is no large river in the study area. But it can generate electricity from solar and wind energy.

**Solar energy:** According to solar and wind master plan (1994-2018) of Ethiopia, the study area has high photovoltaic power potential which can produces 5.2 and 4.8 KWH/day solar energy.

The area in the western and eastern part of the woreda has high solar energy potential and middle part especially around Arerty has also optimum solar energy as shown in the figure 4.12.

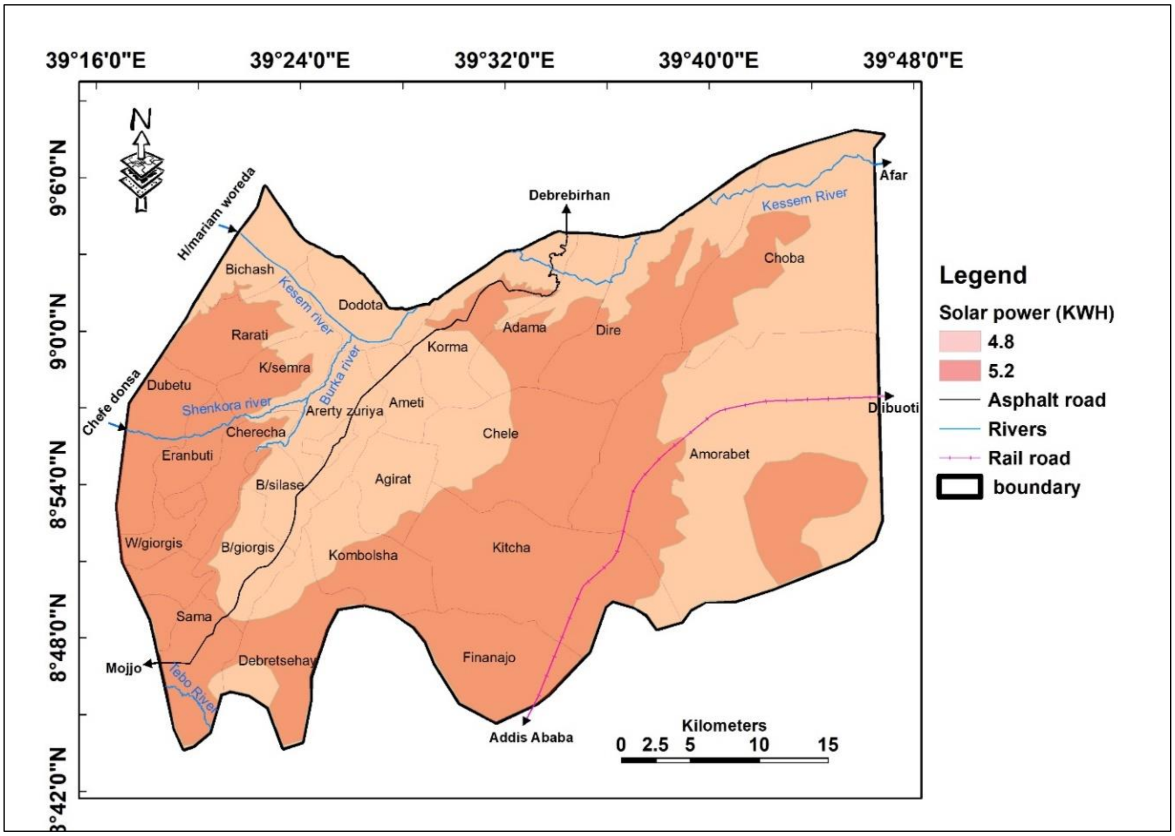



Figure 4.12: Solar energy potential map of the study area

**Wind energy:** The wind turbines is sited in the optimal locations with the exposure to the longest winds. Any site has an average wind speed of 7m/s or more would be considered excellent for wind turbines (Wu et al., 2014). According to solar and wind master plan (1994-2018) of Ethiopia, the study area has high wind energy potential which can produces an average of 591 W/m$^2$ @ 50m height in the western tip (shenkora part) which has a wind speed of 7.5- 9.5 m/s which is adjacent to Adama wind farm as shown in the figure 4.13.

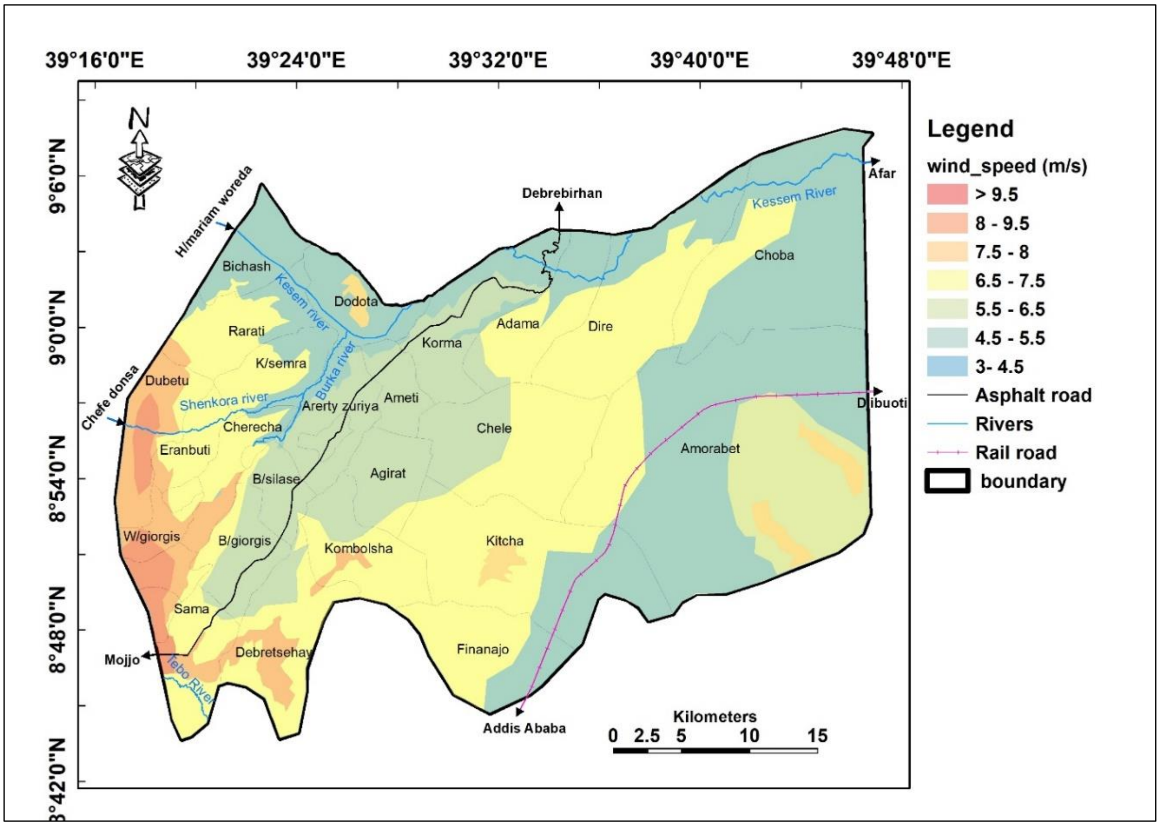



Figure 4.13: Wind energy potential map of the study area

## 4.2. Settlement Suitability Analysis

### (i) Prime agricultural land

The prime agricultural land is one of the major criteria for the selection of suitable and sustainable settlement areas in this study area. From this study, 166.88km$^2$ of prime agricultural lands are identified as shown in the fig 4.14.

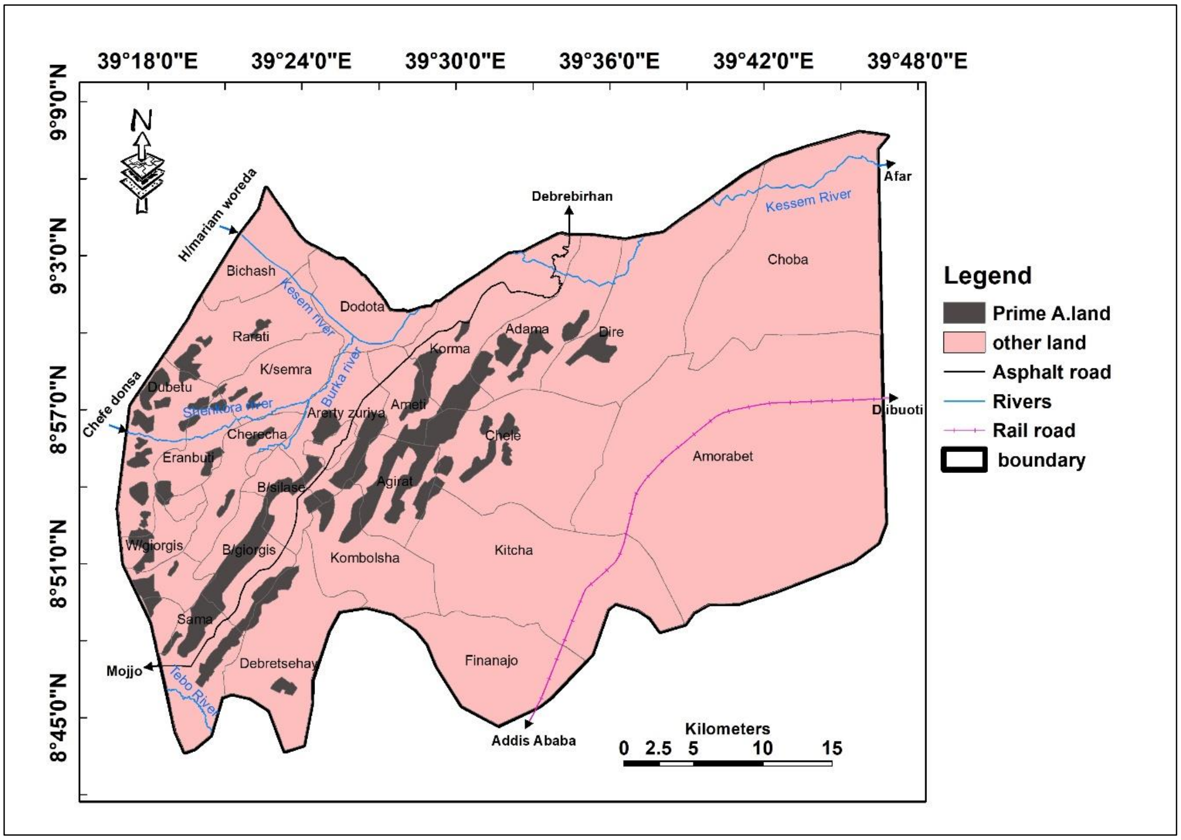



Figure 4.14: Prime agricultural land map of the study area

Different researcher (e.g. T. L. Daniels, 2004; Neil & Navata, 2019) tells that the prime agricultural land should be protected for agriculture not for settlement development. Therefore, it is not suitable for settlement at all. Based on this argument, 89.5 % of the study area is highly suitable where as 10.5 % is no suitable as shown in the Table 4.2.

Table 4.2: Reclassified prime agricultural map and area coverage of suitability levels

| Prime agricultural land | Level of suitability | Value | Area (km$^2$) | Percentage (%) |
|---|---|---|---|---|
| Other land | Most suitable | 4 | 1,420.12 | 89.5 |
| Prime land | Not suitable | 1 | 166.88 | 10.5 |
| | | Total | 1587 | 100 |

**(ii) Slope**

Slope can be expressed as the amount of rise of a surface change in elevation divided by the distance over which the rise is computed by the run. Slope was derived from IDW data in a GIS platform by using surface analysis in ArcGIS®10.4.The result is shown in Figure 4.15 derived from elevation of the study area which comprise slope steepness ranging 0 to 75 %.

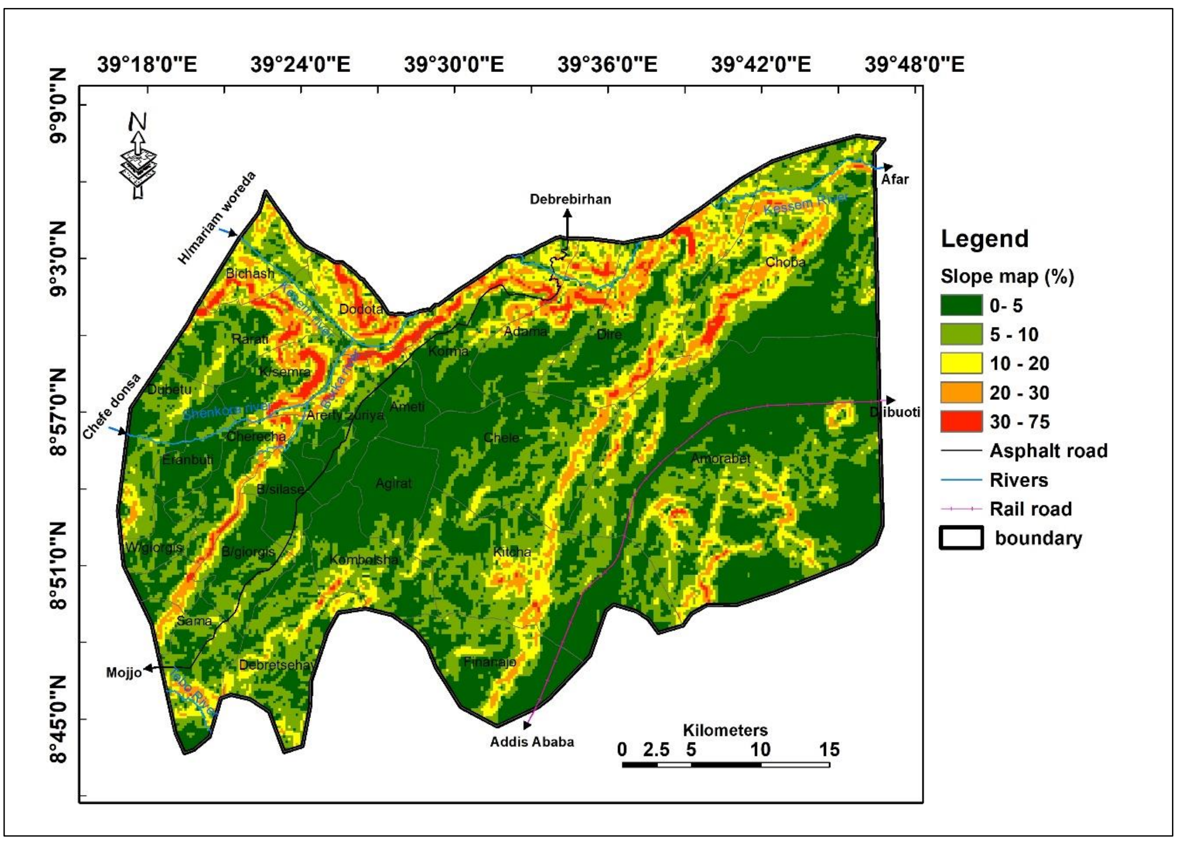



Figure 4.15. Slope map of the study area

Different literature (Vasudevan, 2007; Mhenyu, 2013;Making et al., 2019; Puntsag, 2014) suggest that the least slope is highly suitable for settlement development to make building easier and safer. Based on this argument, the majority of the study area falls under the slope class of less than 5% is highly suitable which covers 45% of the total study area. The slope value of 5-10% is moderately suitable which covers 29 % of the total study area and slope value greater than 15%, which has less coverage (12.5%) is not suitable (Table 4.3 & Figure 4.16).

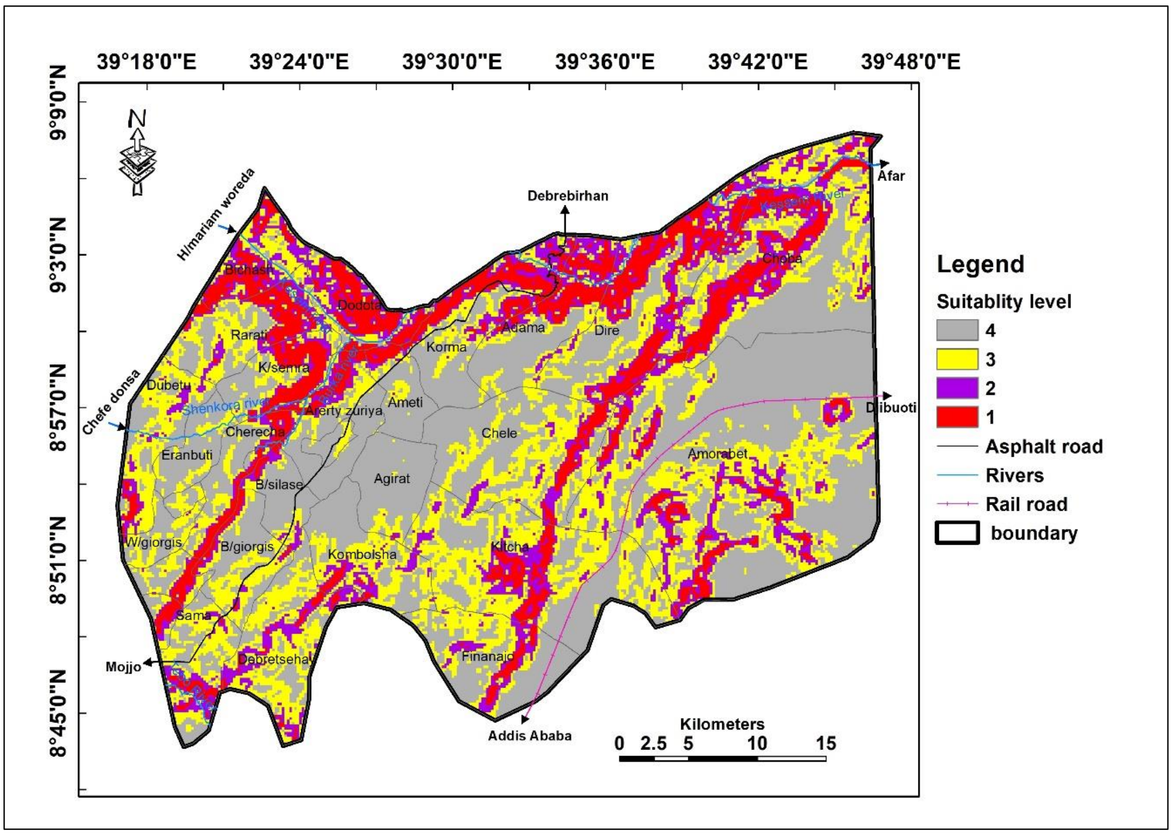



Figure 4.16: Reclassified slope map of the study area

Table 4.3: Reclassified slope map and area coverage of suitability levels

| Slope (%) | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| 0-5 | Most suitable | 4 | 714 | 45 |
| 5-10 | Moderately suitable | 3 | 466 | 29 |
| 10-15 | Less suitable | 2 | 209 | 13.5 |
| >15 | Not suitable | 1 | 198 | 12.5 |
| | | Total | 1587 | 100 |

### (iii) Land use land cover (LULC)

The land use land cover map of the study area is shown in Figure 4.17. The major LULC classes are agricultural land which covers almost the whole area (72.7%), forest and swampy (18.1%), bare land (5.5. %), the settlement which has least coverage (3.7%).

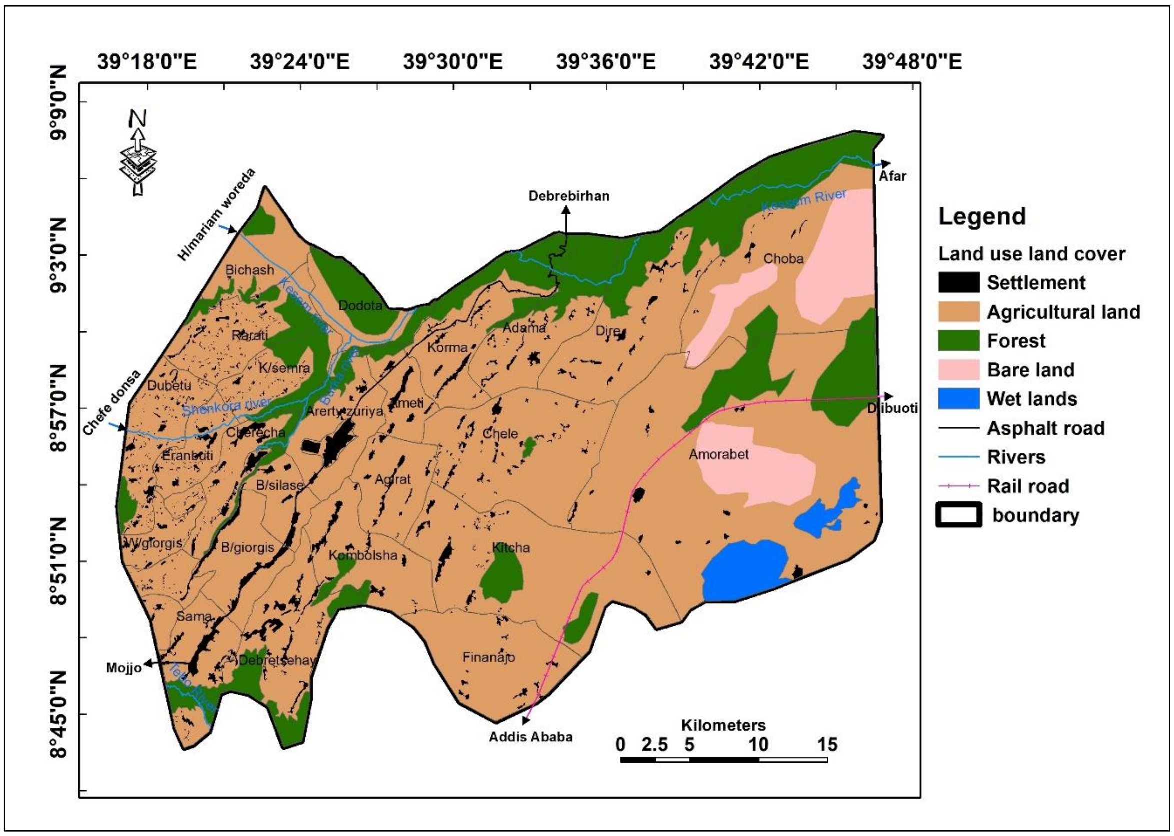



Figure 4.17. Land use land cover map of the study area

In most literatures, existing land use land cover map was used as criteria for land suitability analysis. According to Puntsag (2014), Omar & Raheem (2016) & Ullah (2014), it is preferable to keep settlement areas for future sustainability because it expensive to build a new towns or villages. Therefore, settlement area is suitable for settlement development. Based on this argument, 3.5 % is highly suitable, 82.2% is less suitable and 18.1% is not suitable (Table 4.4 & Figure 4.18).

Table 4.4: Reclassified LULC map and area coverage of suitability levels

| LULC | Level of suitability | Value | Area (km$^2$) | Percentage (%) |
|---|---|---|---|---|
| Settlement | Most suitable | 4 | 59 | 3.7 |
| Agriculture & Bare land | Less suitable | 2 | 1241 | 82.2 |
| Forest and swampy | Not suitable | 1 | 287 | 18.1 |
| | | Total | 1587 | 100 |

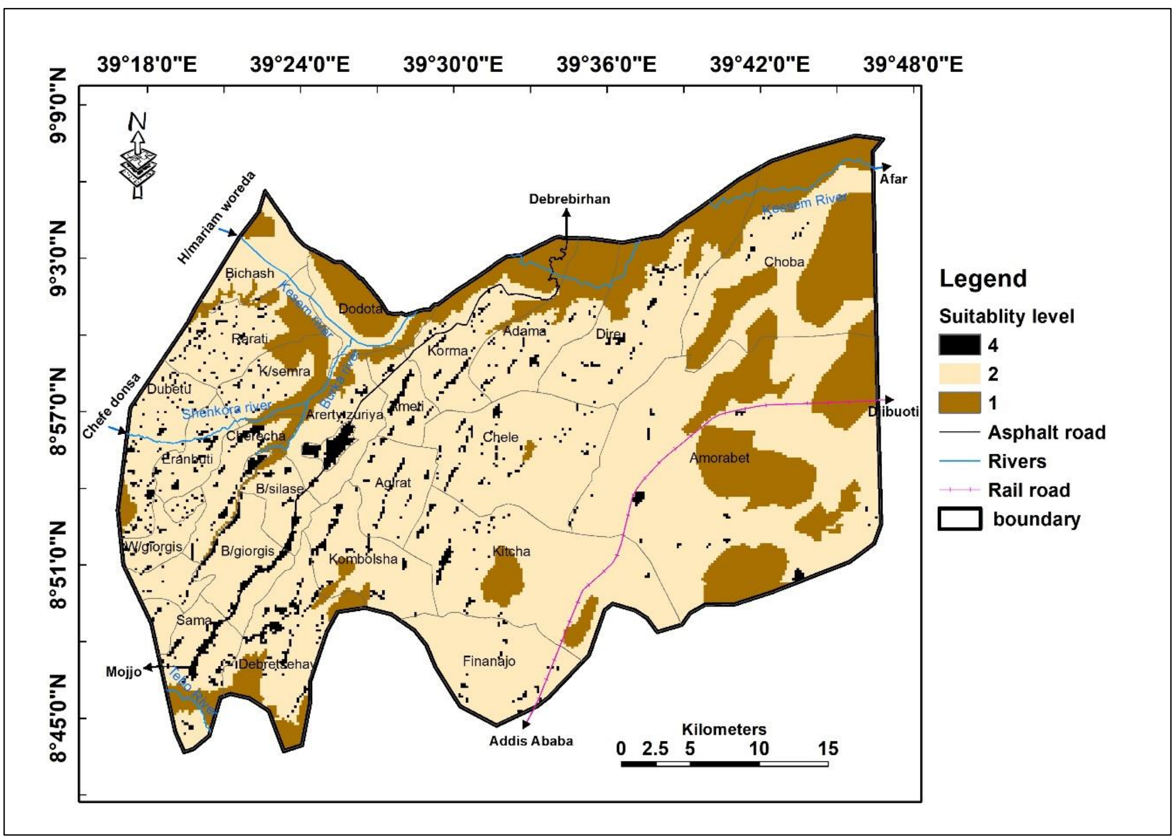



Figure 4.18: Reclassified land use land cover map of the study area

### (iv) Soil types

Soil is the most important criterion for determining an area of suitability for urban construction or for agriculture. Joshua et al. (2013) identified that soil types which have high fertility, nutrient deficiency and high water holding capacity and can be used for agriculture. According to FAO soil classification map of Ethiopia conducted in the mid to late eighties in Amhara Region, there are three types of soil types which are vertisols, cambisols and lithosols in Minjar Shenkora Woreda as shown in the Figure 4.19.

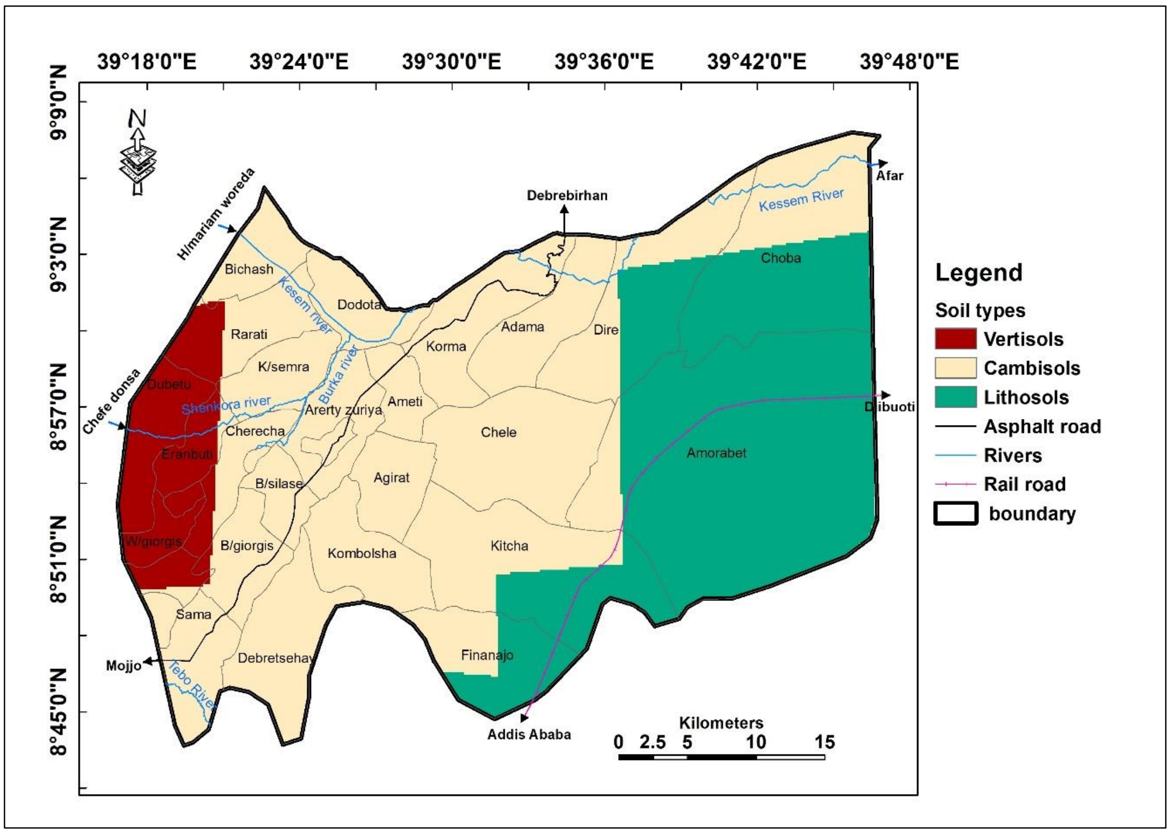



Figure 4.19: Soil type map of the study area

The soil map was reclassified in to three for the sake of compatibility to the weighted overlay analysis in ArcGIS environment. According to *Puntsag (2014*), leptosols /lithosols which is shallow soil is highly suitable for settlement or urban area, where as cambic virtisols-erenic, cambic virtisol has moderate suitability for urban area. Brown Andosol has only low suitability for urban land.

Based on these criteria, 32.9 % is most suitable for 59.5% of the study area is found to be moderately suitable and 7.6% is less suitable settlement (Table 4.5. & Figure 4.20).

Table 4.5: Reclassified soil types and area coverage of suitability levels

| Soil type | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| Lithosols | Most suitable | 4 | 522 | 32.9 |
| cambisols | Moderately suitable | 3 | 946 | 59.5 |
| Vertisols | Less suitable | 2 | 119 | 7.6 |
| | | Total | 1587 | 100 |

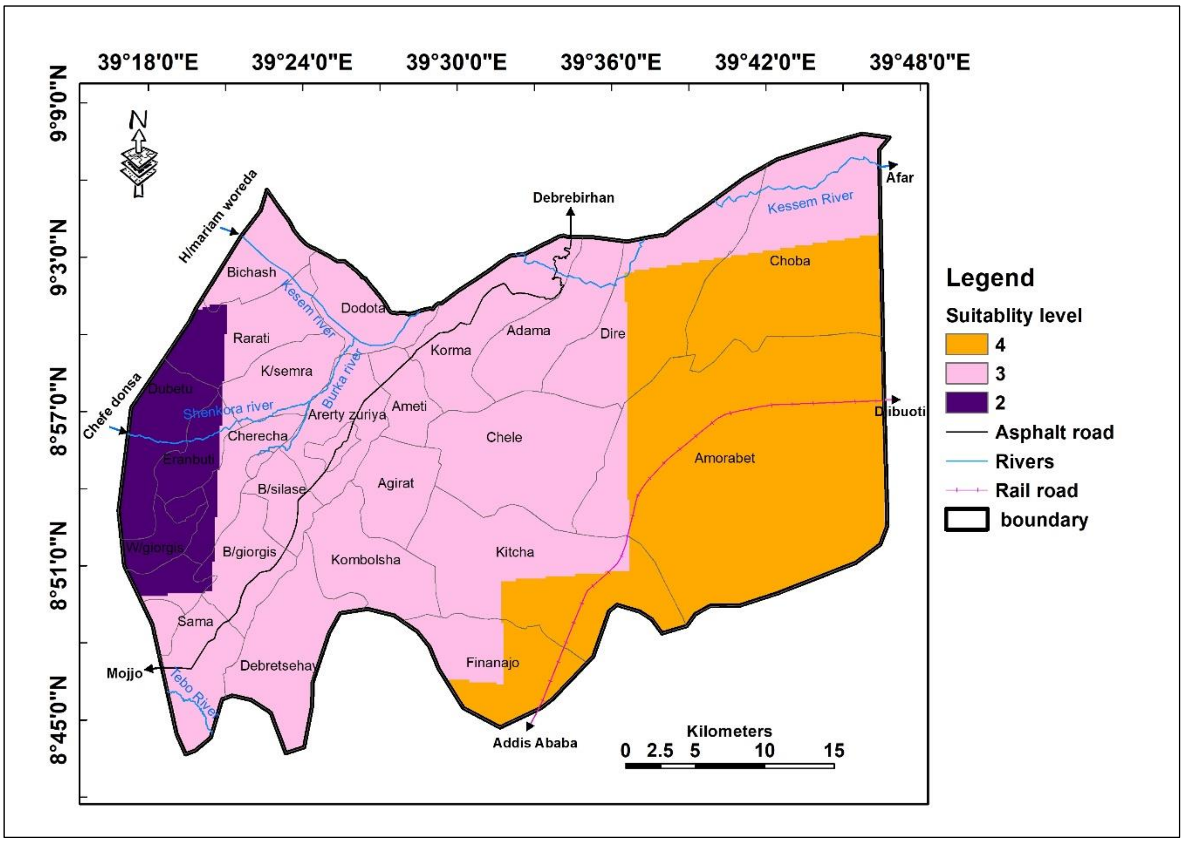


Figure 4.20: Reclassified soil type map of the study area

### (v) Soil depth

The effective soil depth is one of the most important factors for construction of buildings /houses in rural and urban development. According to FAO (2014), the effective soil depth map of the study area each 5' by 5' grid cell is categorized in three depth namely 14 cm, 46cm and 54 cm in the study area as shown in the Figure 4.21. The soil depth of the study area is dominated by 54cm which covers 59.5 % of the total study area.

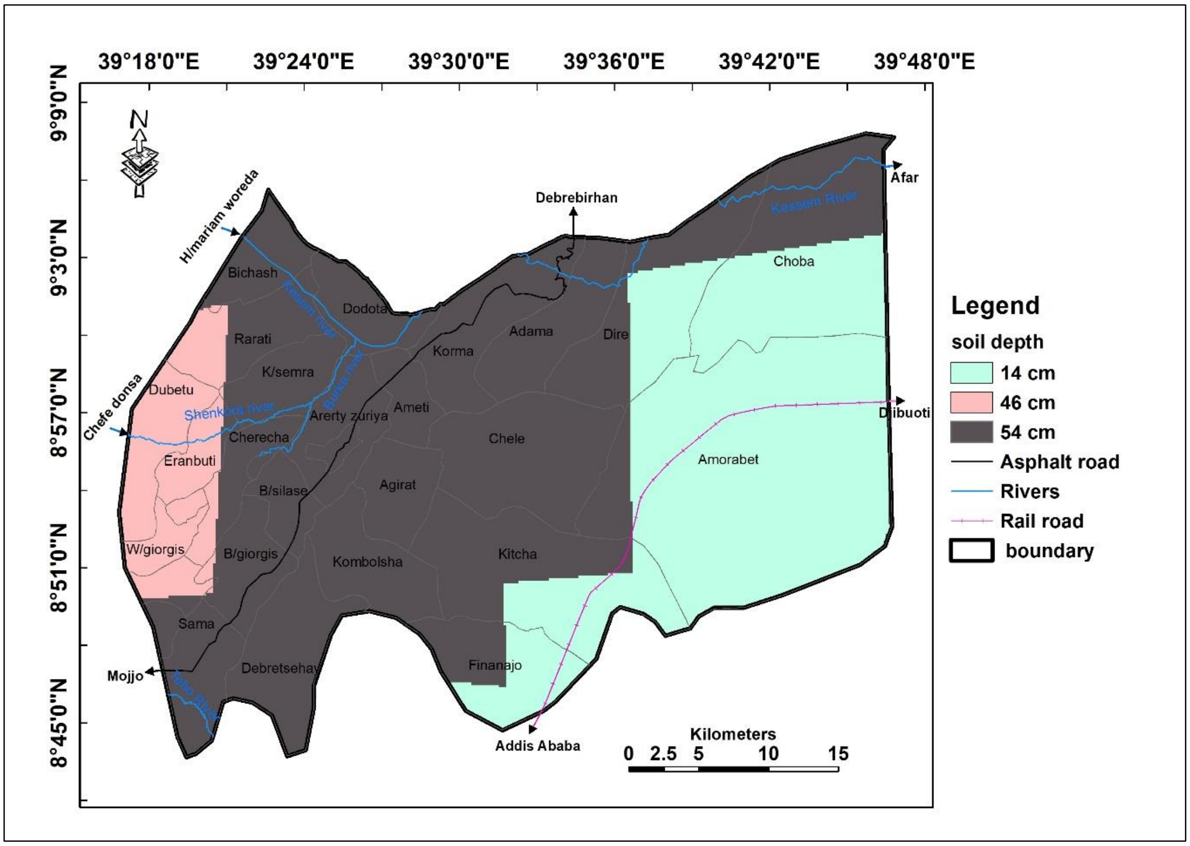



Figure 4.21: Soil depth map of the study area.

Making et al., (2019) & Berhe (2015) suggests that it suitable for rural and urban settlement when the soil is becoming shallow and not suitable if it gets deeper & deeper but the deepest is good for agriculture. The soil map of the world classifies the soil depth each 5' by 5' grid cell in to five classes: less than 10 cm (very shallow), 10-50 cm (shallow), 50-100cm (moderately deep), 100-150(deep) and 150-300cm (very deep). Therefore based on this classes, 40 % total study area is highly suitable where as 60% is less suitable (Figure 4.22 & Table 4.6).

Table 4.6: Reclassified soil depth and area coverage of suitability levels

| Soil depth | Level of suitability | Value | Area (km$^2$) | Percentage (%) |
|---|---|---|---|---|
| 10-50cm | Most suitable | 4 | 641 | 40 |
| 50-100cm | Not suitable | 2 | 946 | 60 |
| | | | | |
| | | Total | 1587 | 100 |

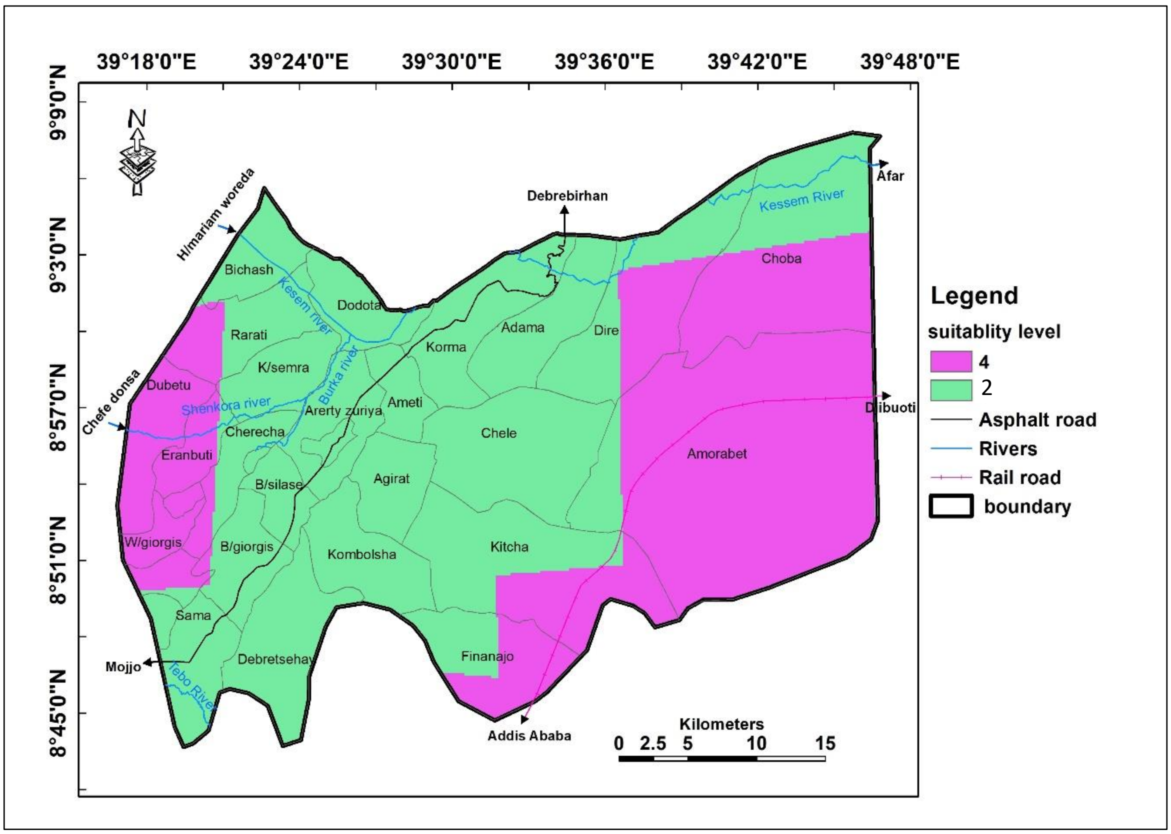



Figure 4.22: Reclassified soil depth map of the study area

### (vi) Geology

Geology is one of the most important criteria that should be considered in settlement suitability analysis. According to hydrogeology map of Ethiopia (2018), there are three types of geology in the study area namely igneous volcanic, alluvial sediments and quaternary sediments The geology map of the study area is dominated by igneous volcanic as shown in the Figure 4.23.

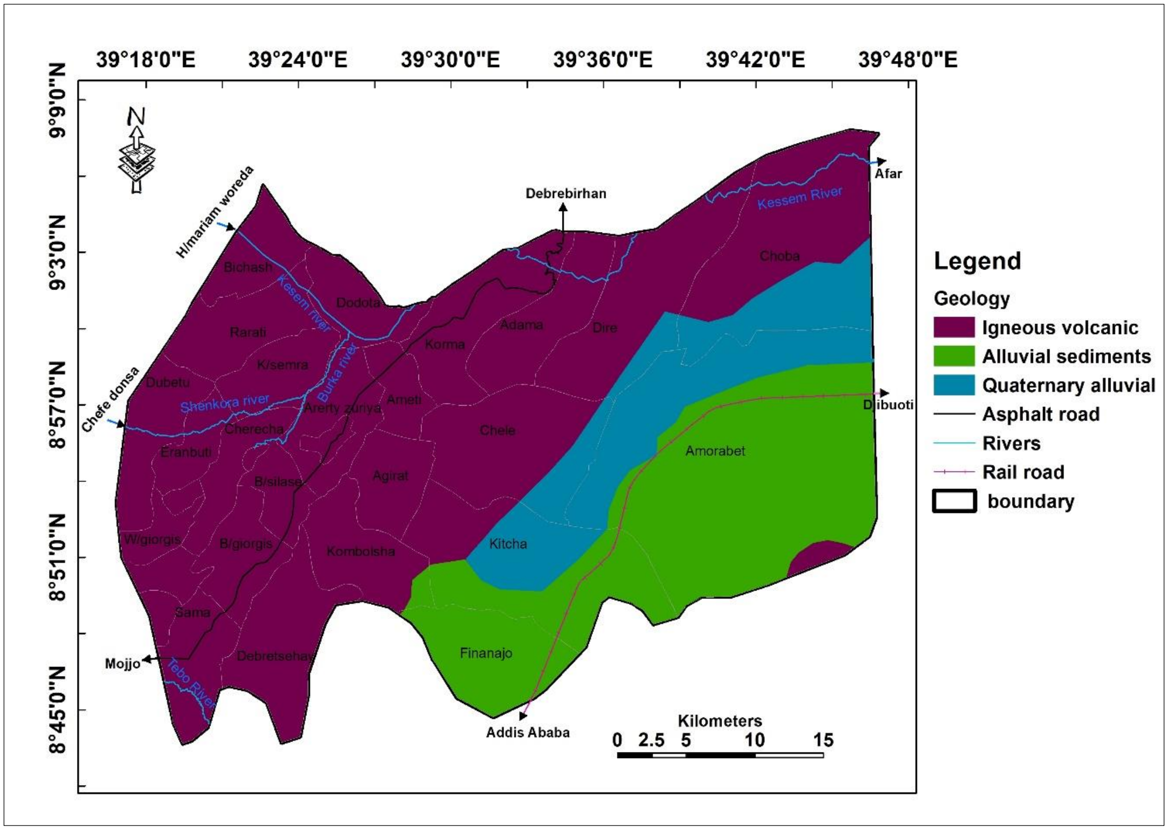



Figure 4.23: Geology map of the study area.

Making et al., (2019) says that geological structures away from alluvial sediment is highly suitable for settlement because alluvial sediment is prone to earth slide. And also quaternary basalts are permeable which marginally suitable due to high degree of weathering and fractures whereas quaternary and tertiary alluvial unsuitable for urban development (Tamiru et al., 2003). Therefore, based on this argument 64% are most suitable and 36% are not suitable (Table 4.7&Figure 4.24).

Table 4.7: Reclassified geology map and area coverage of suitability levels

| Geology | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| IV | Most suitable | 4 | 1016 | 64 |
| AS&QA | Not suitable | 1 | 571 | 36 |
| | | Total | 1587 | 100 |

Where IV- Igneous Volcanic, AS -alluvial sediments and QA- quaternary alluvial

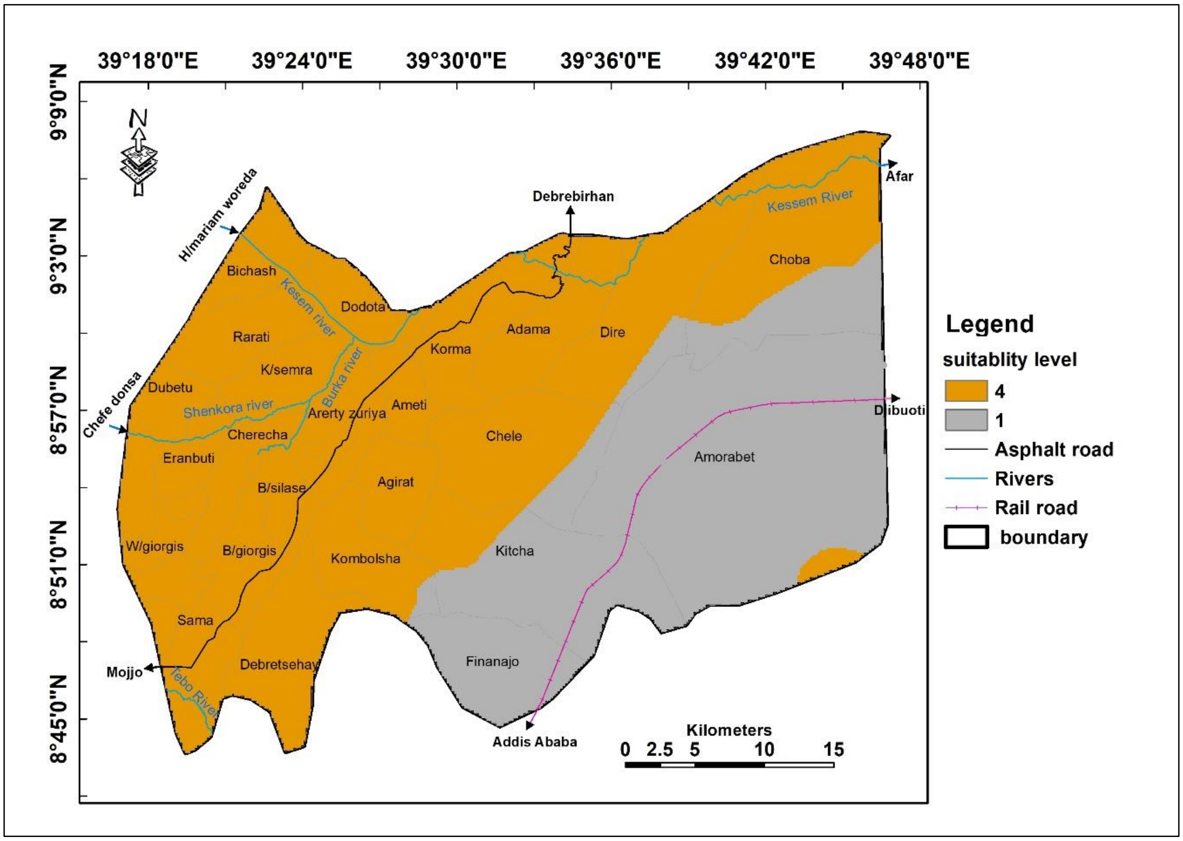



Figure 4.24: Reclassified geology map of the study area.

### (vii) Underground water

Ground water is also important criteria for settlement suitability analysis as it gives pure potable water for the people of Minjar shenkora Woreda. It is the water found under ground in soil pore spaces and aquifers or fractures of rock formation. The ground water in the study area is accessed from deep local water wells. According to Amhara Water Works Construction Enterprise strategies, the buffer zone of water wells is up to 1km from settlement/urban development as a water source is very important for the sustainability of settlement environment as whole. This zone has high ground water potential that gets high yields of water from the wells. Therefore, based on this argument 95% of the study area are most suitable and 5% are not suitable for settlement development (Figure 4.25 &Table 4.8).

Table 4.8: Reclassified underground water potential map and area coverage of suitability levels

| Underground water | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| Low | Most suitable | 4 | 1508 | 95 |
| High | Not suitable | 1 | 89 | 5 |
| | | Total | 1587 | 100 |

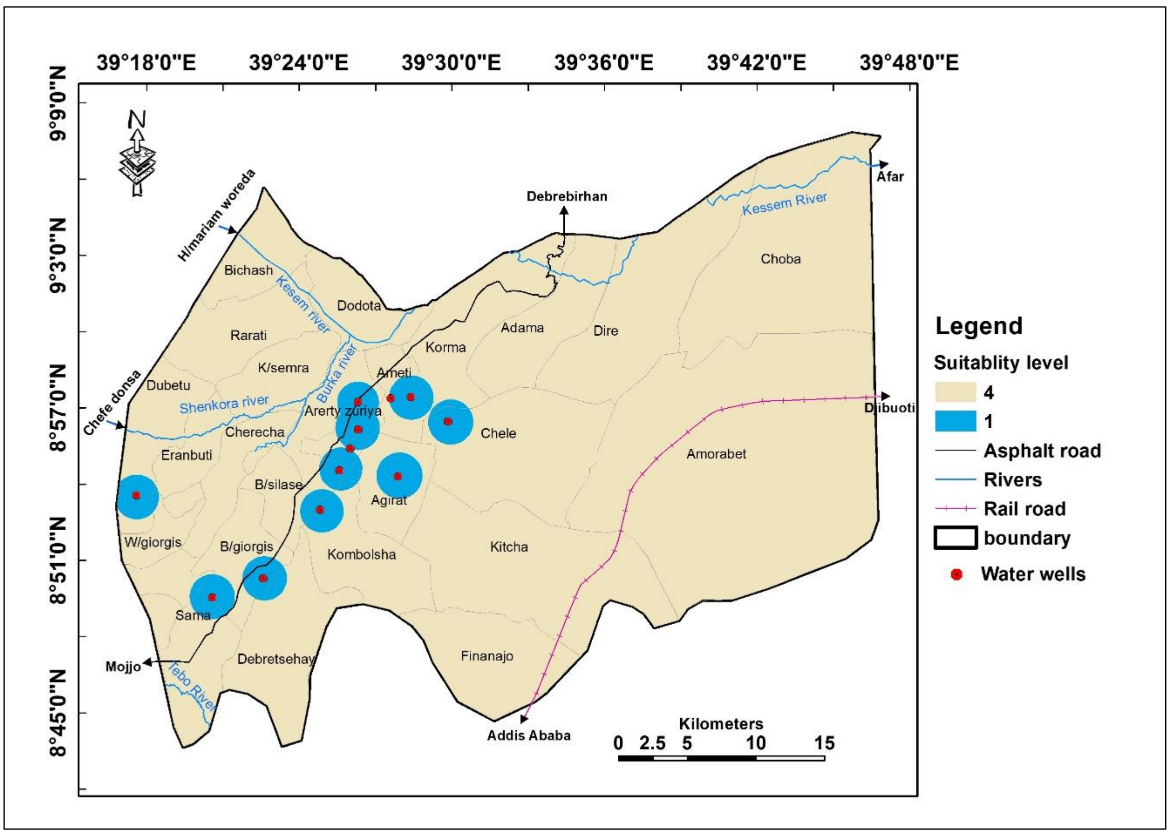



Figure 4.25: Reclassified underground water potential map of study area.

### (viii) Distance from road network

Road network is also an important factor used to identify areas for settlement as it provides a linkage between rural and urban settlement. It also should be considered from economic and social points of view during urban and agricultural site selection processes (Puntsag, 2014).

There is one main asphalt road (61 km) from Mojjo to Debrebirhan which passes through Arerty and Bolo Town and also 7 main rural gravel roads which are totally 198km length in Minjar Shenkora Woreda. Some of the rural roads connects from town to town and others are from kebele to kebele. The existing road network vector data converted to raster data in order to be compatible for GIS analysis. The distance from the roads were calculated by Euclidian Distance tool in ArchGIS®10.4 as shown in the Figure 4.26.

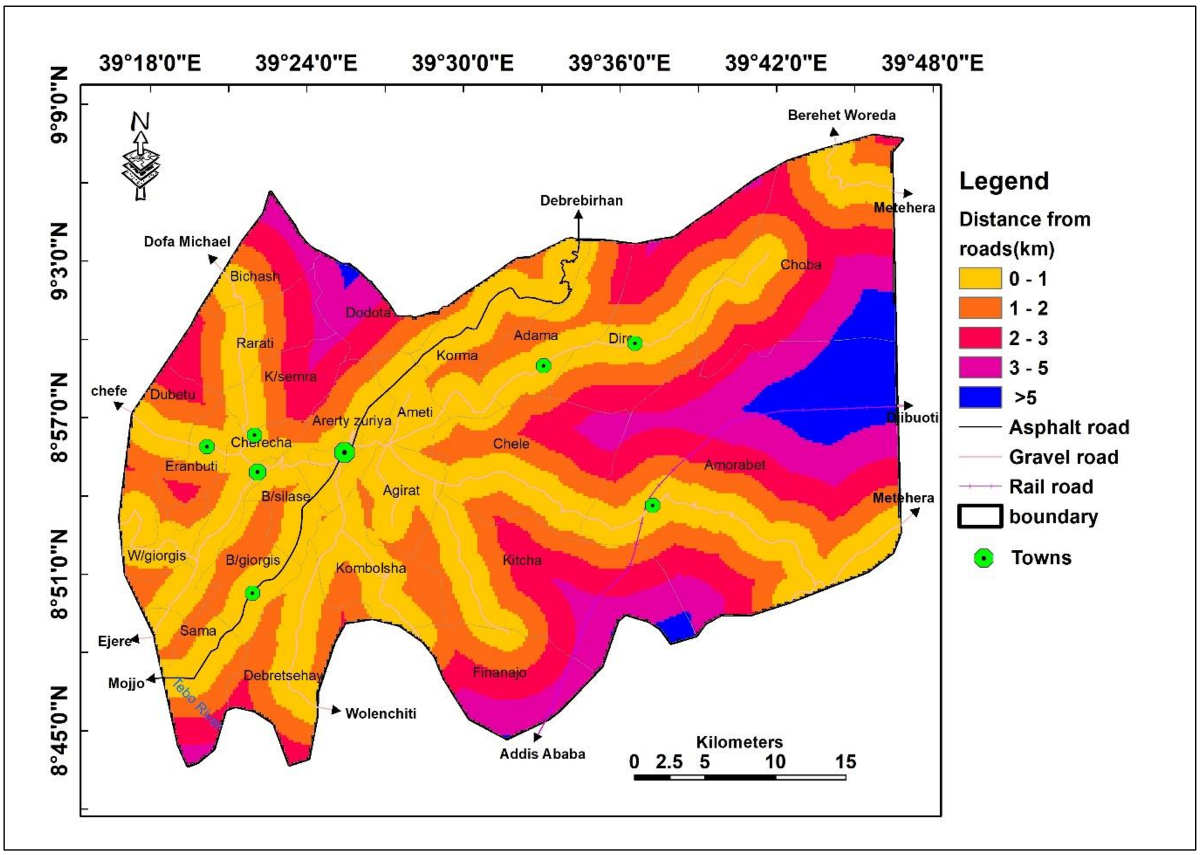



Figure 4.26: Distance from roads map of the study area

Most literature ( Omar & Raheem, 2016; Puntsag, 2014; Ullah, 2014) said that proximity to the roads network is suitable for settlement and agricultural suitability in case of transportation costs and ease of accessibility.

Therefore, an area within 1000m is considered highly suitable whereas area greater than 5000m is not suitable. Based on this argument, 34% of the study area is found to be highly suitable; 43% moderately suitable, and 11% is not suitable for settlement development (Table 4.9 &Figure 4.27).

Table 4.9: Reclassified distance from roads map and area coverage of suitability levels

| Distance from roads (km) | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| 0-1 | Most suitable | 4 | 535 | 34 |
| 1-3 | Moderately suitable | 3 | 683 | 43 |
| 3-5 | Less suitable | 2 | 198 | 12 |
| >5 | Not suitable | 1 | 171 | 11 |
| | | Total | 1587 | 100 |

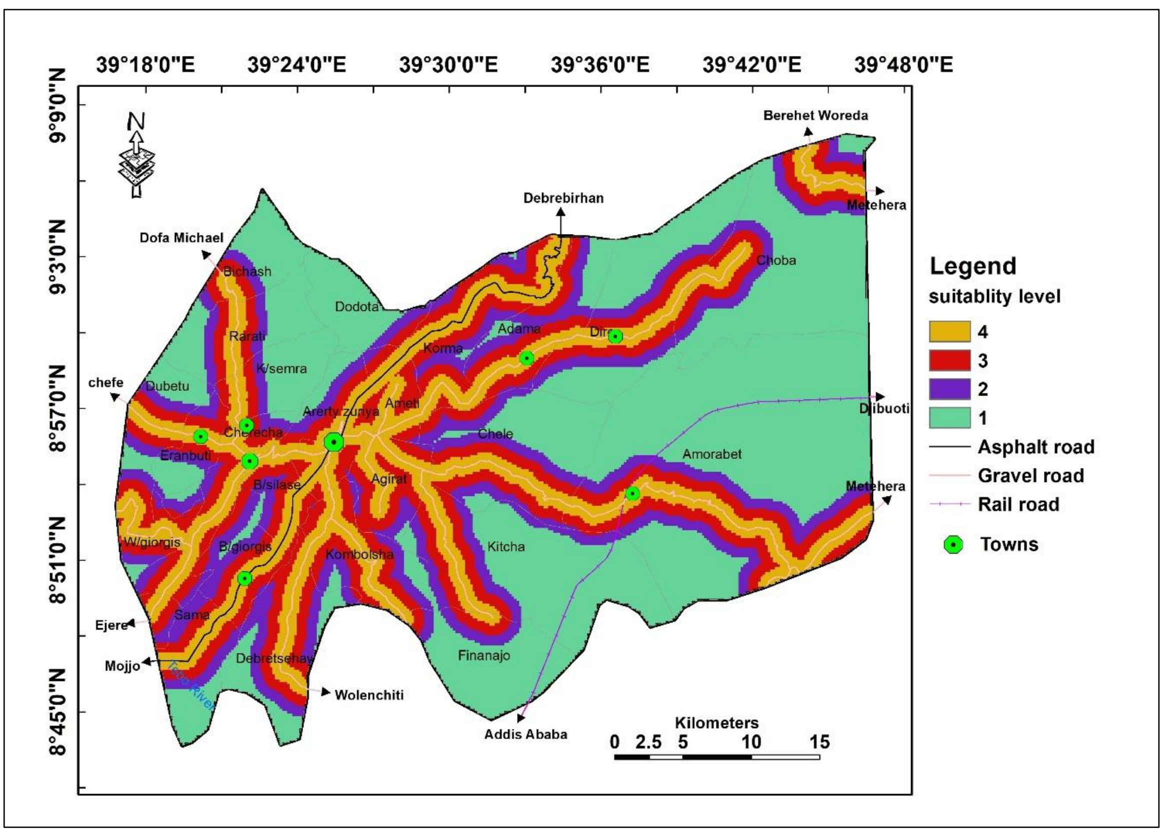



Figure 4.27: Reclassified distance from roads map of the study area

### (ix) Distance from drainage/river network

Drainage network is an important factor used to identify areas for settlement as it provides a way for surface runoff in the reduction of localized flood. As part of drainage system, watershed is the area of land that drains or sheds water in to the specific water body. There are three watershed area in the study area. The one is Kessem river watershed and second Tobo river watershed and the third is the different stream watershed in the eastern part. Each sub watershed has its own watershed outlet. From kessem river basin there is kessem dam & irrigation project in the Afar region (Figure 4.28).

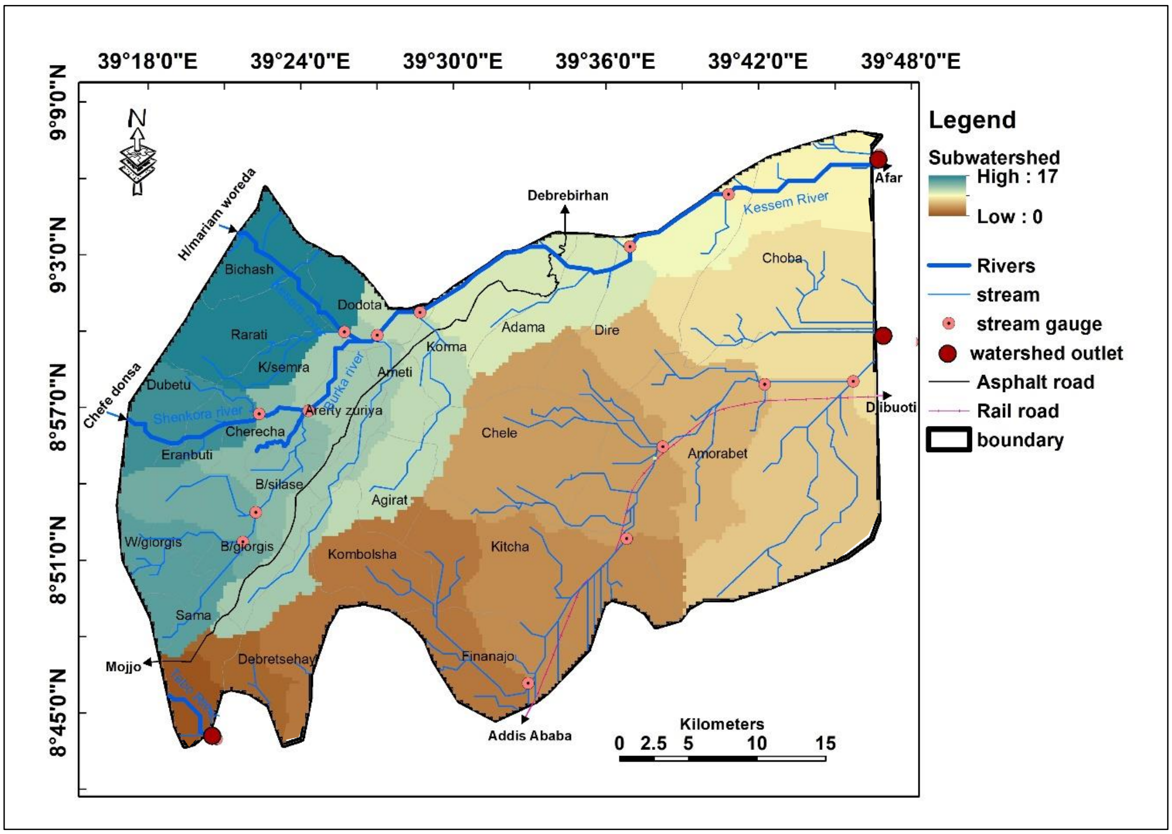



Figure 4.28: Watershed map of the study area

In this study, it is cosidered that the distance from rivers is taken as a criteria for minmizing flooding because most source of drinking water is underground water from wells.

Making et al ( 2019) and Omar & Raheem (2016) noted that the area closer to the stream is not suitable which is prone to flooding but far away from the stream is highly suitable for sustainable settlement environment. Based on this arguiment, the distance greater than 800m

(31%) is considered as the most suitable and in between 400 and 800m (20%) is moderately suitable. Whereas 0 – 200 (30 %) of the area is not suitable (Table 4.10 &Figure 4.29).

Table 4.10: Reclassified distance from rivers map and area coverage of suitability levels

| Distance from river network (m) | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| >800 | Most suitable | 4 | 485 | 31 |
| 400-800 | Moderately suitable | 3 | 324 | 20 |
| 200-400 | Less suitable | 2 | 300 | 19 |
| 0-200 | Not suitable | 1 | 478 | 30 |
| | | Total | 1587 | 100 |

(Source: MUDW, 2007)

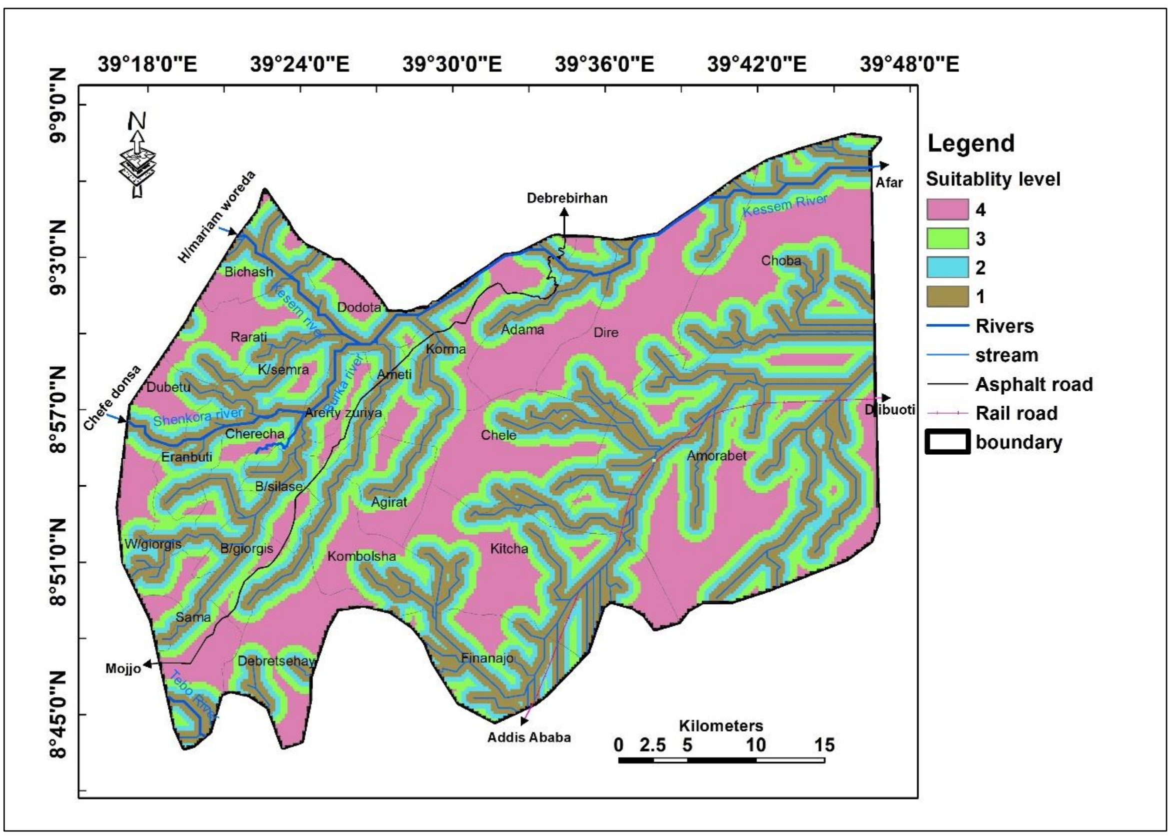



Figure 4.29: Reclassified distance from river network map of the study area

### (x) Distance from Town network

Distance from town center is very important criteria for settlement and agricultural suitability analysis. Different activities were held on the town like administrative issues, market facilities and recreational activities. The distance of area which is 0 to 22 km to the town's center is shown in the Figure 4.30.

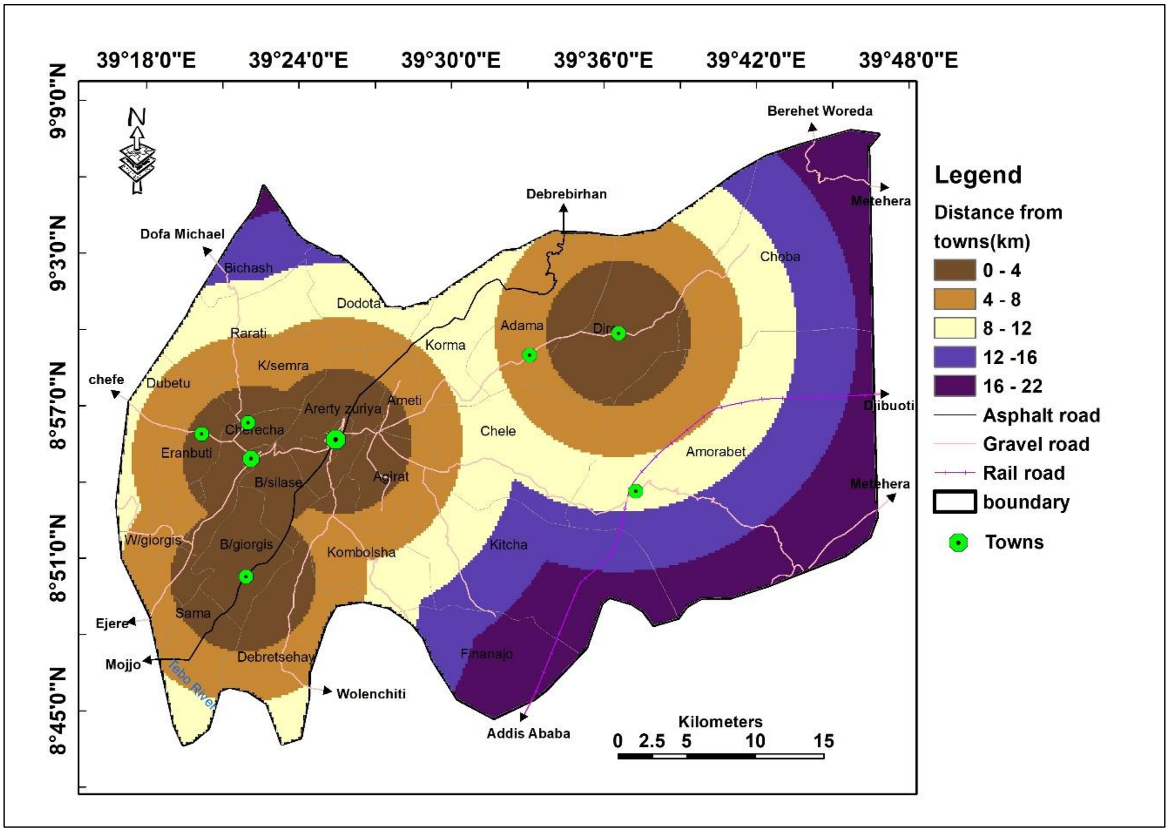



Figure 4.30: Distance from town network map of the study area

Most literature (Omar & Raheem, 2016; Yalew et al., 2016) noted that the settlement near the town is more suitable than the area far away from the town center and also the land close to the town is highly suitable for agricultural activities as it reduce food mile distance of agricultural product. Therefore, an area is suitable for agriculture, it is also suitable for settlement because most people's livelihood bases are agriculture in the study area.

Based on this argument, the distance less than 5km (31%) is highly suitable and between 5km and 10 km (36%) is moderately suitable whereas the distance greater than 15km (20.5 %) of the area is not suitable (Table 4.11&Figure 4.31).

Table 4.11: Reclassified distance from town center and area coverage of suitability levels

| Distance from town center (km) | Level of suitability | Value | Area ($km^2$) | Percentage (%) |
|---|---|---|---|---|
| 0-5 | Most suitable | 4 | 489 | 31 |
| 5-10 | Moderately suitable | 3 | 570 | 36 |
| 10-15 | Less suitable | 2 | 201 | 12.5 |
| > 15 | Not suitable | 1 | 326 | 20.5 |
| | | Total | 1587 | 100 |

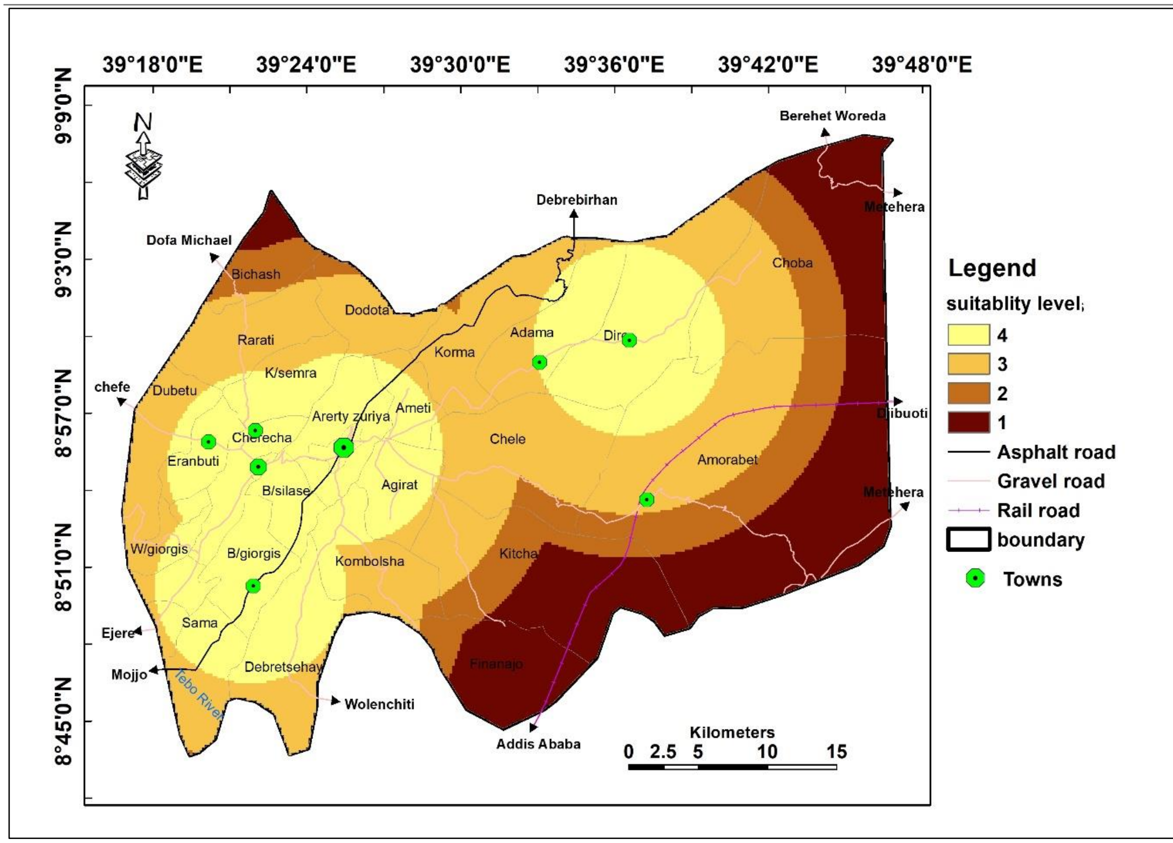



Figure 4.31: Reclassified distance from town network map of the study area

## 4.3. Overlaying and Suitable Areas

AHP pair wise comparison matrix was created and criteria weights were calculated for each factor by comparing factors using a scale with values 9 to 1/9. The reclassified input data sets were assigned a weight value to express the importance of each criterion to the other criteria for the selection of suitable settlement areas. In order to select suitable settlement areas, all the reclassified input datasets were overlaid using the weighted overlay tool or a raster calculator in ArcGIS (Table 4.12&Figure 4.32).

Table 4.12: Suitability levels and weight (%) of criteria for the selection of suitable settlement areas

| **Criteria** | **Unit** | **Suitability level** | | | | **Wt. (%)** |
|---|---|---|---|---|---|---|
| | | 4 | 3 | 2 | 1 | |
| Prime agricultural land | Type | Other land | - | - | P.A land | 27 |
| Underground water | Type | low | - | - | High | 20 |
| Slope | % | 0-5 | 5-10 | 10-15 | >15 | 15 |
| LULC | Type | S | - | Ag& BL | F ,Sw | 11 |
| Geology | Type | IV | - | - | AS, QA | 8 |
| Soil depth | Cm | 0-50 | - | 50-100 | - | 6 |
| Soil type | Type | Litho-sols | Cambi-sols | Verti-sols | - | 5 |
| Distance from Road | km | 0-1 | 1-3 | 3-5 | >5 | 4 |
| Distance from river | M | >800 | 400-800 | 200-400 | 0 - 200 | 2 |
| Distance from Town | Km | 0-5 | 5-10 | 10-15 | > 15 | 2 |

Where P.A land – Prime Agricultural Land, IV- Igneous Volcanic, AS-alluvial sediments, QA-quaternary alluvial, S-Settlement, Ag-Agriculture, and BR- Bare land, F-Forest and Sw. - swampy, Wt.-weight

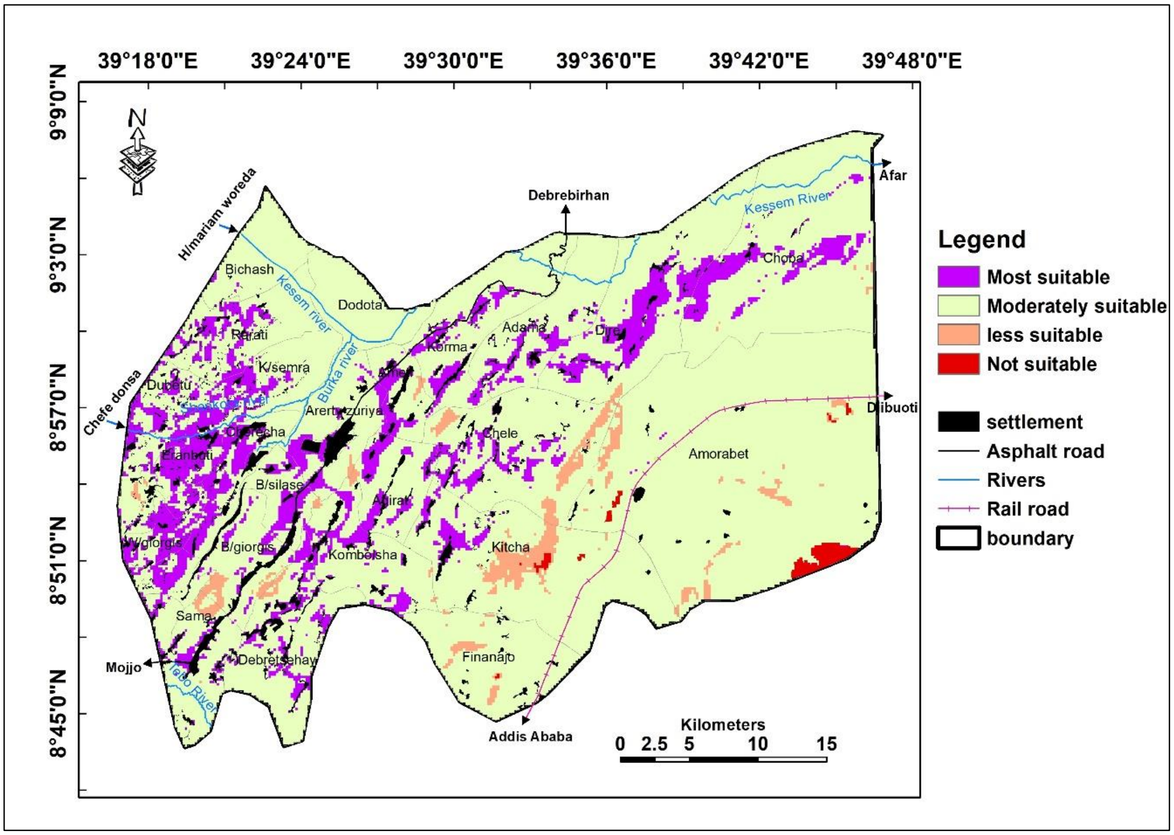



Figure 4.32: Final suitability map of the study area including constraints layer

According to the map generated by weighted overly method in ArcGIS, it was determined that 14.6% (234km$^2$) of the study area is most suitable, 82% (1303km$^2$) is moderately suitable, 3% (43km$^2$) is less suitable and 0.4% (7km$^2$) is not suitable for settlement (Table 4.13).

Table 4.13: Area and percentage coverages of final suitability map

| Level of suitability | Value | Area (km$^2$) | Percentage (%) |
|---|---|---|---|
| Most suitable | 4 | 234 | 14.6 |
| Moderately suitable | 3 | 1303 | 82 |
| Less suitable | 2 | 43 | 3 |
| Not suitable | 1 | 7 | 0.4 |
| | Total | 1587 | 100 |

The two towns, Arerty and Balchi including the newly emerged towns such as Bolo, Dire, Adama, Eranbuti and Yohanis are most suitable town and Melkajilo is moderately suitable town. The peoples who are living in the center of Woreda (around Arerty town), west (shenkora) and north east direction are most suitable. But, peoples who settle in the North & East (Bichash, Dodota, Finanjo Kitcha& Amorabet) are moderately suitable and also some parts of Finanjo, chele &Amorabet are less suitable and not suitable in the above Figure 4.32.

It is identified that constraints like forest, mineral site, swampy (wetland) that no settlement should be in the study area. The constraints were not included in the suitability categorization but instead superimposed on the computed suitability map (Table 4.14 &Figure 4.33).

Table 4.14: Area and percentage coverages of final suitability map excluding constraints layer

| **Suitability level** | **Most suitable** | **Moderately suitable** | **Less suitable** | **Not suitable** | **Forest** | **Swampy** | **Mineral site** | **Total** |
|---|---|---|---|---|---|---|---|---|
| Value | 4 | 3 | 2 | 1 | - | - | - | - |
| Area ( $Km^2$) | 234 | 1017 | 38.5 | 7 | 238.3 | 28.67 | 23.72 | 1587 |
| Percentage (%) | 14.6 | 64 | 2.4 | 0.4 | 15 | 2 | 1.6 | 100 |

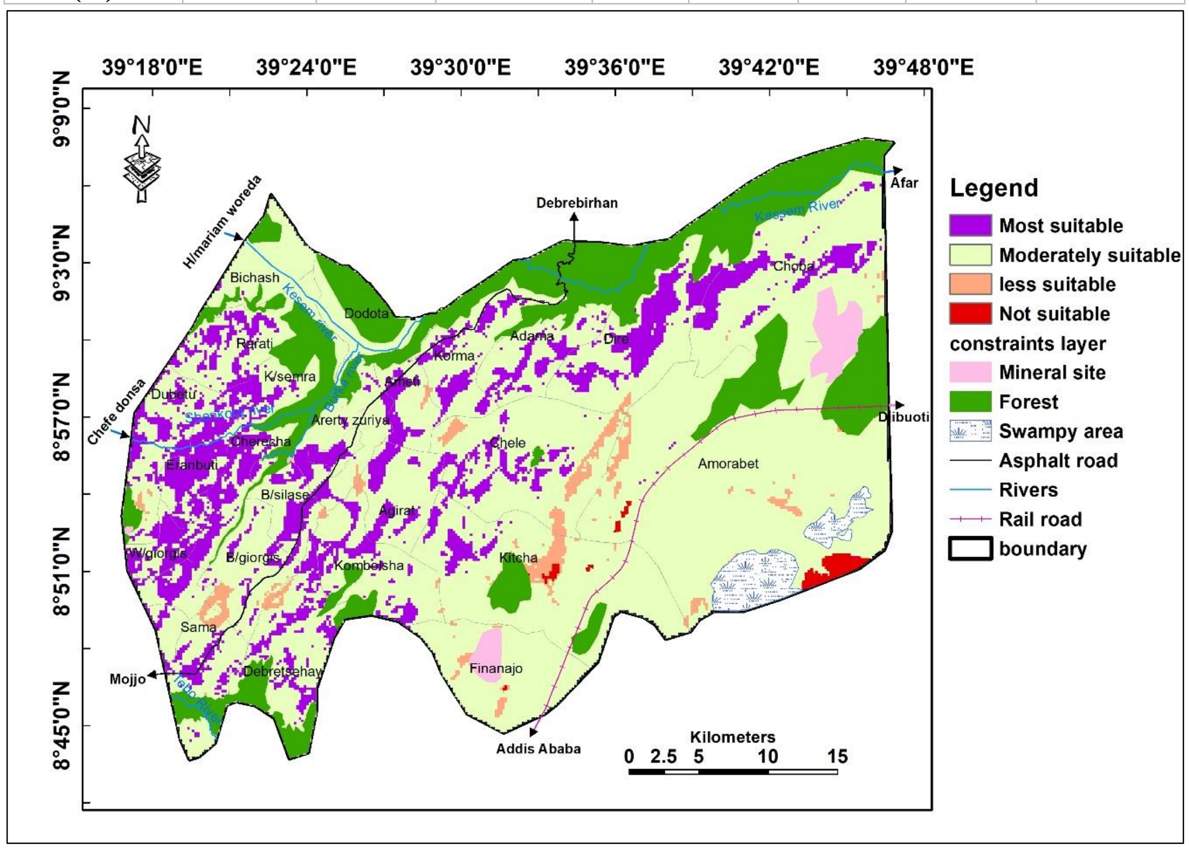


Figure 4.33: Final suitability map of the study area excluding constraints layer

# CHAPTER FIVE

# DISCUSSION

## 5.1. Existing settlement condition of the study area

The global population is increasing and continue to grow rapidly. According to the 2003 UN-Habitat global report on human settlements, urban populations have increased explosively in the past 50 years, and will continue to do so for at least the next 30 years as the number of people born in cities increase and as people continue to be displaced from rural areas that are almost at capacity. The process of urbanization affects all sizes of settlements, so villages gradually grow to become small towns, smaller towns become larger towns, and large towns become cities (Works, 2016). In this study, the settlement is affected with increasing of the newly emerging towns including Arerty and Balchi in the study area. The size is also affected as indicated that 48.80 $km^2$ and 11.98 $km^2$ is rural & urban respectively. The settlements including urban settlement are most closely and directly related to land. Most of rural settlement is dominated by agriculture which dispersed on their land in study area.

A settlement is established in one area based when there is  a water supply, fertile soil, dry land, defendable site, energy supply (Mhenyu, 2013). The most of the land are fertile land which is prime agricultural land that can supply crops for food. As a water is very essential for life of sustainability of human being, most settlements (80%) use underground water for drinking and surface water like Kessem Rivers for agricultural purposes &other activities.

A people in the settlement need a local raw materials like wood and stone is to build homes (Vasudevan, 2007). The area is enriched with different mineral material like pumice, ceramic ingredient, natural stone and wood from forest that enables material supply in and attract the investors to the woreda.

As the settlement to be sustained in energy supply, renewable energy (hydropower, solar and wind) is very important. Ethiopia can produce 1350 GW from wind and 2.199 million TWH/annum is from solar energy (Debebe & Shibesi, 2017). From this amount, the study area can generate electricity of 5.2 KWH/day from solar energy in the western and eastern part and 591W/$m^2$ from wind especially in the western part of the study area.

### 5.2. Settlement suitability analysis and suitable areas

Land use suitability analysis is useful tool for land managers and urban or regional planner as it can be used to develop a master plan or land use plan of settlement area. It is important to use the AHP method with the geographic information systems in the sustainable ecological urban planning stage in order to obtain accurate results (Making et al., 2019). In this study to exclude subjective evaluation of the research the weight value of the criteria were determined at the end of survey with 12 experts of municipality.

In most literature (Making et al., 2019;Omar & Raheem, 2016 ;Mifh, 2014) the criteria used for the determination of suitable settlement area are mostly the same with some difference because the nature of study area is different. The study area is dominated by fertile land, so prime agricultural land is used in addition to the criteria used in the above scholars.

In this study, existing settlements are kept as most suitable area for settlements. Some most suitable area for settlements which are located around Arerty town are located on the prime agricultural land which should be preserved. The most flat lands in Minjar Shenkora are suitable for agricultural purposes. And also the existing settlements are most suitable in the western, shenkora part but practically the settlements are dispersed in case of rural sprawl. Most parts forest lands are marked as moderately suitable settlement area as forest land should not include as a criteria even it is within land use land cover layer.

# CHAPTER SIX

# CONCLUSION AND RECOMMENDATION

## 6.1. Conclusion

This research was carried out to find the suitable areas for settlement in Minjar shenkora woreda using a multi criteria analysis integrated with GIS and AHP. The results of this study indicate that the settlement covers a total area of 58.78 km$^2$ (3.8%**)** from the total study area, of which 48.80 km$^2$ is rural settlement and 11.98 km$^2$ is urban settlement. It is identified that most rural settlement are farmer villages which are dispersed in the eastern part and compacted pattern of settlements in the center and western part of the woreda.

The source of potable water for most peoples of woreda is underground water from the 13 deep water wells. But some people of shenkora use the rivers as source of water. The rivers like kessem, burka, shenkora & tebo are used mainly for irrigation. The most common local materials in the woreda are pumice, ceramic, quarry stone and wood from Dubetu forest which are very important to build a house and others activities. The study area also has a potential of generating electricity from solar and wind energy especially in the western tips and the eastern part.

Based on the suitability analysis, 14.6% of the area (234km$^2$) is highly suitable, 82% (1303km$^2$) is moderately suitable, 3% (43km$^2$) is less suitable and 0.4% (7km$^2$) is not suitable for settlement at all. The most suitable land is located around the towns in the study area. It also identified that different constraints like mineral site, forest, and swampy area that are unsuitable for the settlement. The most suitable land can hold 526,500 people which very greater than the current number of people, 167,156 in the study area (Annex 1). And also the available water from rain water harvesting and the deep water wells in the study area can hold 69,251,610 people (Annex 3). Land suitability analysis is a critical element in determining suitable areas for some specific purposes. As demonstrated in this study, GIS technologies can play a crucial role in urban and environmental research.

## 6.2. Recommendation

- Land suitability analysis should be done based on the current study before urban planning and design implementation rather than using previous standards and guidelines.
- The government should decentralize investments or infrastructures from urban to rural areas. At this time, the Ethiopian government distribute infrastructures in urban areas. This causes immigration of people from rural to urban in case of employment issue. As a result rapid urban expansion with the deterioration of environment is happened.
- Prime agricultural land should be identified and defined based on the integrated study. Because prime lands are very fertile lands that can yield high amount of crops that is needed to keep food security.
- The rural settlement should be planned and urbanized to decrease rural sprawl.
- The carrying capacity of the study area in terms of house land, available water, materials and energy should be done to create sustainable settlement environment
- For further study, study should be on multiple criteria with the local standards of suitability classes per different criteria.

## References


Akbulak, C. (2009). Application of analytical hierarchy process and geographic information systems in land-use suitability evaluation : a case study of Du ¨ mrek village ( C. 16(4), 286–294. https://doi.org/10.1080/13504500903106634

Anthony Bigio & Hilda Blanco. (2014). Human Settlements , Infrastructure and Spatial Planning. Mitigation of Climate Change, 125.

Bahiru, Z., The City Center: A Shifting Concept in the History of Addis Ababa, in Bahiru Zewde (ed.2008), Society, State and History: Selected Essays, Addis Ababa University press.

Berhe, T. (2015). Remote Senesing And Gis Based Urban Land Suitablity Modeling At Parcel Level Using Multicritria Decision Analysis; A Case Study Of Bole Sub City, Addis Abeba, Ethiopia (Issue 1397).

Countries, D. (2020). Preserving Farmland on the Urban Fringe : A Literature Review on Land Policies in Developed Countries.

Daniels, T. (1999). what to Do about Rural SPrawl?

Daniels, T. L. (2004). Farmland Preservation Policies in the United States : Successes and Shortcomings Farmland Preservation Policies in the United States : Successes and. June.

Debebe & Tefera Shibesi, S. (2017). Federal Democratic Republic of Ethiopia report.

Doxiadis, C. A. (1970). Articles Ekistics, the Science of Human Settlements.

Du, S., & Shi, P. (2014). The Relationship between Urban Sprawl and Farmland Displacement in the Pearl River Delta, China. March. https://doi.org/10.3390/land3010034

Eastman, J. R. (2001). Release 2 Guide to GIS and Image Processing Volume 2. 2(May).

Effat, H. A., & Hassan, O. A. (2013). Designing and evaluation of three alternatives highway routes using the Analytical Hierarchy Process and the least-cost path analysis , application in Sinai. The Egyptian Journal of Remote Sensing and Space Sciences, 16(2), 141–151. https://doi.org/10.1016/j.ejrs.2013.08.001

Erkut, E., & Tarimcilar, M. (1991). On sensitivity analysis in the analytic hierarchy process. IMA Journalof Management Mathematics,3(1),61–83. https://doi.org/10.1093/imaman/3.1.61

FAO. (2013). Lada Land Degradation Assessment In Drylands.

Habibie, M. I., Noguchi, R., Shusuke, M., & Ahamed, T. (2019). Land suitability analysis for maize production in Indonesia using satellite remote sensing and GIS-based multicriteria decision support system. In GeoJournal (Issue October). Springer Netherlands. https://doi.org/10.1007/s10708-019-10091-5

Hatab, A. A., Eduarda, M., Cavinato, R., Lindemer, A., & Lagerkvist, C. (2019). Urban sprawl , food security and agricultural systems in developing countries : A systematic review of the literature. Cities, 94(July 2018), 129–142. https://doi.org/10.1016/j.cities.2019.06.001

Hersperger, A. M., Gennaio, M., & Verburg, P. H. (2010). Linking Land Change with Driving Forces and Actors : Four Conceptual. 15(4).

Jeba, N. (2017). Monitoring Urban Expansion and Suitability Analysis for Residential Housing by Using Geographic Information System and Remote Sensing; the Case of Sululta Town; Oromia Regional State of Ethiopia By.

Madallah, W., & Tarawneh, A. (2014). Urban Sprawl on Agricultural Land (Literature Survey of Causes, Effects, Relationship with Land Use Planning and Environment) A Case Study from Jordan (Shihan Municipality Areas). Journal of Environment and Earth Science, 4(20), 97–125.

Making, M. D., The, A., & Province, N. (2019). Determination of Ecologically Suitable Settlement Areas by Using Gis Based. September.

Markakis, J. (2006), Ethiopia, Anatomy of the Traditional Polity, Shama Books, Addis Ababa.

Mhenyu,V.(2013). Urban & Rural Settlement Geography. Golearn Geography,49(1), 10–24.

Mid, A., North, F., & Regional, C. (2007). Settlement planning guidelines. August.

Mifh, A. H. (2014). settlement suitablity analysis for local ground characterstics of Iskurederun:A case study. 120, 637–644. https://doi.org/10.1016/j.sbspro.2014.02.144

Ministry of Works and Urban Development (MWUD). (2007). Plan for accelerated and sustained development to end poverty (PASDEP): Plan for Urban Development and Urban Good Governance 2005/06-2009/10

Molla, M, (2009) . The Ethiopian Urban Landholding System: An Assessment of the Governing Legal Regime, in Muradu Abdo (Ed.) Land Law and Policy in Ethiopia since 1991: Continuities and Changes, Ethiopian Business Law Series, Addis Ababa University, Faculty of Law, Vol. III

Neil, P., & Navata, S. (2019). National Land Use Policy: Protecting Prime Agricultural Lands. July, 0–15.

Omar, N. Q., & Raheem, A. M. (2016). Determining the suitability trends for settlement based on multi criteria in. 1–9. https://doi.org/10.1186/s40965-016-0011-2

Pareta, D. K. (2013). Remote Sensing And Gis Based Site Suitability Analysis For Tourism Issn : 2278-6252. International Journal of Advanced Research in Engineering and Applied Sciences, 2(5), 43–58.

Pramanik, M. K. (2016). Site suitability analysis for agricultural land use of Darjeeling district using AHP and GIS techniques. Modeling Earth Systems and Environment, 2(2), 1–22. https://doi.org/10.1007/s40808-016-0116-8

Puntsag, G. (2014). Land Suitability Analysis For Urban And Agricultural Land Using Gis : Case Study In Hvita To Hvita , Iceland.

Saaty, T. L. (1980). The Analytic Hierarchy Process. New York: McGraw Hill.

Theobald, D. M. (2003). Defining and Mapping Urban Sprawl. Geographical Review, 1–6.

UNHCR. (2019). Settlement in urban areas. 1–10.

Vasudevan, H. (2007). Fundamentals of human geography. In National Council of Educational Research and Training.

Works, L. (2016). Open Learn Works Study Session 5 Urbanisation : Trends , Causes and Effects.

Wu, Y., Lee, T., Hsieh, T., & Lin, W. (2014). A Review of Technical Requirements for High Penetration of Wind Power Systems. December, 11–17.

Yalew, S. G., van Griensven, A., Mul, M. L., & van der Zaag, P. (2016). Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. Modeling Earth Systems and Environment, 2(2), 1–14. https://doi.org/10.1007/s40808-016-0167-x

## APPENDIX

### Pairwise comparison questionnaire

Compare the relative importance of the following 10 criteria with respect to the identification of suitable settlement area in Minjar Shenkora Woreda for the professionals of municipality in the woreda.

Circle one number per row below using saaty comparison scale.

1=Equal 3=Weak 5= Strong 7=Very strong 9=Absolute (2, 4, 6, 8) = Intermediate

(½, 1/3, 1/4……1/9) =the reciprocal value for vice versa comparison

| criteria | Prime agricultural land | Underground water | Slope | LULC | Geology | Soil depth | Soil type | Road network | River network | Town network |
|---|---|---|---|---|---|---|---|---|---|---|
| Prime agricultural land | | | | | | | | | | |
| Underground water | | | | | | | | | | |
| Slope | | | | | | | | | | |
| LULC | | | | | | | | | | |
| Geology | | | | | | | | | | |
| Soil depth | | | | | | | | | | |
| Soil type | | | | | | | | | | |
| Road network | | | | | | | | | | |
| River network | | | | | | | | | | |
| Town network | | | | | | | | | | |

## ANNEX

### Calculation of carrying capacity of most suitable settlement areas (234km$^2$)

To calculate how many people can hold in this area of land, first it must be known that the structural plan of Ethiopian town planning standards for 1$^{st}$ level -4$^{th}$ level urban center.

Proposed percentage of the respective land use standards for 3$^{rd}$ level urban center, population size (10000-45000) of most suitable land.

| No | Structural plan components | Proposed percentage | Area (km$^2$) |
|---|---|---|---|
| 1 | Residences | 45 | 105.3 |
| 2 | Business and commercial | 10 | 23.4 |
| 3 | Services | 10 | 23.4 |
| 4 | Manufacturing &storage | 10 | 23.4 |
| 5 | Roads | 15 | 35.1 |
| 6 | Open space & environmental sensitive area | 10 | 23.4 |

To calculate the number of people lived with in the suitable residence area, 105.3km2

No of people to be hold = 105,300,000 m$^2$/200m$^2$

= 526,500 people

Given = 200 m2 per individual, according to municipality of Minjar Shenkora Woreda

### Calculation of the volume of rain water in the study area

Mean rain water supply in (m$^3$) = mean annual rain fall in m/year*catchment area in m$^2$*runoff coefficient

=0.8m*1587*10$^6$ m$^2$ *0.6

=761,760,000 m$^3$ volume of water

Where annual rain fall=800mm, Area=1587 km$^2$, runoff coefficient=0.6 for soil

**Calculation of carrying capacity of available water supply**

Total volume of water ($m^3$) =761,760,000 $m^3$ rain water +7,711.2 $m^3$ ground water

=761,767,711.2 $m^3$

According to GTP 2, 25 l/capita/day for rural and 50 l/capita/day for urban (population 20,000-50,000) , by taking an average of 30 l/capita/day or 11$m^3$,

Number of population used =761,767,711$m^3$/11$m^3$

=69,251,610 people