# Urban Land Suitability Analysis for Residential Areas using Geospatial techniques: A Case Study of Dire Dawa city, Ethiopia

Katama Gilo Ararso

A Thesis Submitted to

The department of Geomatics Engineering,

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geoinformatics

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

**Urban Land Suitability Analysis for Residential Areas using Geospatial techniques: A Case Study of Dire Dawa city, Ethiopia**

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# Approval Page of M.Sc. Thesis

We, the advisors of the thesis entitled "Urban Land Suitability Analysis for Residential Areas using Geospatial techniques: A Case Study of Dire Dawa city, Ethiopia" and developed by Katama Gilo, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the board of Examiners of the thesis by Katama Gilo have read and evaluated the thesis entitled "Urban Land Suitability Analysis for Residential Areas using Geospatial techniques: A Case Study of Dire Dawa city, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics

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# Declaration

I hereby declare that this Master Thesis entitled "Urban Land Suitability Analysis for Residential Areas using Geospatial Techniques: A case study of Dire Dawa City, Ethiopia" is my original work. That is, it has not been submitted for the award of a degree, diploma or certificate in any other universities. All sources of material used for this thesis have been duly acknowledged through citation.

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# Recommendation

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "Urban Land Suitability Analysis for Residential Areas using Geospatial techniques: A case study of Dire Dawa City, Ethiopia" prepared under our guidance by Katama Gilo Ararso submitted in partial fulfillment of the requirements for the degree of Master's of Science in Geoinformatics. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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| | |
|---|---|
| AHP | Analytical Hierarchy Process |
| AMPR | Adama Master plan Revision Project |
| CI | consistency index |
| CR | Consistence ratio |
| CSA | Central Statistical Agency |
| DEM | Digital Elevation Model |
| EEP | Ethiopian electric power |
| ESRI | Environmental system research institute |
| FAO | Food and Agriculture Organization |
| GIS | Geographic Information System |
| GNSS | Global navigation satellite system |
| GPS | Global Positioning System |
| IDP | Integrated Development Plan |
| masl | Meter Above Sea Level |
| MCDA | Multi-criteria decision analysis |
| MCE | Multi-criteria Evaluation |
| MUDC | Ministry of Urban Development and Construction |
| RMSE | Route mean square error |
| UTM | Universal Transverse Mercator |
| WGS | World Geodetic System |
| WLC | Weighted Linear Combination |
| WWDSE | Water Works Design and Supervision Enterprise |

# Abstract

*Urban land suitability analysis for particular land use is the preliminary task in the context of urban land use planning and development. However, land suitability analysis, by its nature is a complex process and involves considerations of multi-criteria evaluation which considers not only physical conditions but also environmental, social, and economic factors. Hence, this study aimed to analyze urban land suitability for residential areas in Dire Dawa city, using geospatial techniques and multi-criteria evaluation. Eleven factors namely: land-use land-covers, built-up, slope, aspect, flood plains, road, water supply, electric transmission, healthcare service, soil, and recreational area and ten constraints including built up, heavy industries, airport, railway station, military camp, cemeteries, waterbody, fault lines, high voltage electric stations, and high-tension electric lines were evaluated and prioritized as per judgment of urban planning experts. Factors were weighted in a hierarchical order using the analytical hierarchy process approach in IDRISI selva software to produce their weights of importance to the land suitability for a residential area. Boolean overlay tool of ArcGIS 10.7 software was used to incorporate all layers of constraints to produce a composite constraint map. Weighted overlay analysis of ArcGIS 10.7 software was adopted to integrate all weighted factors and multiplied with constraint map to produce the final suitability map. The final suitability map classified the whole Dire Dawa city area into five suitability classes. Accordingly,55.78% area covers unsuitable,1.22% area covers less suitable, 4.56% area covers moderate suitable, 34.63% area covers high suitable and 3.81% area covers very high suitable. To validate the suitability of the proposed residential land use plan of the city, the plan was compared with the final suitability map. The validated result of the study reveals 8.156% and 33.376% of proposed residential land use plan which are still undeveloped exist under very high suitable and high suitable respectively whereas 42.57% (287 $km^{2)}$ areas of proposed land uses are already developed while 15.57% (1.05$km^2$) area of proposed residential land use is undeveloped but categorized under restriction areas. Therefore, the final suitability map provides a useful guide for the proposed residential land use. Thus, the study implies the effectiveness of geospatial techniques and MCE to handle land suitability analysis aimed at identifying environmentally safe and economically feasible sites for residential areas. The study would support the planning efforts being made to improve residential land provision, and also supports the government in formulating effective policies to the context.*



**Keywords:** *Analytic Hierarchy Process, Multi-criteria Evaluation, Residential Land suitability, Planning*

# CHAPTER ONE

# 1. INTRODUCTION

## 1.1 Background of the study

Urbanization is one of the most dynamic processes of geographic phenomena in the history of humankind and is represented by two contradictory and conflict perspectives (Gezahegn & Anteneh, 2016). It also acts as an engine and indicator of transformation from traditional rural economy, both physically and functionally, is widely recognized for enormous socio-economic improvements of the resident. Urban dwellers have the opportunity to access better dwelling infrastructure and facilities, social-wellbeing, and improved living standards as compared to their rural counterparts (Wondimu,2011). However, urbanization in the case of developing countries is overshadowed due to the absence of proper planning domains that are accompanied by acute socioeconomic and ecological impacts (Brinkerhoff, 2000; Bela & Moghanm, 2011).

Urbanization is a continuous process and it results in attracting people to urban areas for better living conditions. The migration of rural people to urban areas are also with the hope for better job opportunities and better standards of living that the level of education will not stop the phenomenon (Shukla et *al.,* 2017). So, the need to live in an urban area is eventually increasing from time to time in both developed and developing countries (Wondimu, 2011). Planning regulations are not strong enough to avoid the negative consequences of informal settlement, urban sprawl, and undesired urban expansion. That is why most of the residential areas are unable to meet better living conditions. Therefore, analysis of urban land and identification of optimal areas for future residential development is the most important task in planning and it is observed that present land use planning and zoning regulations cannot fulfill this requirement. As a result, demands for residential land in the cities are prominent. Urban sprawl, informal settlement, and misuse of lands are also common phenomena in most developed and developing countries. Therefore, cities face the most challenging task of providing land with better infrastructure to fulfill this demand (Ekanayaka, 2014). Similarly, the situation of developing countries like Ethiopia is more aggravated due to the lack of proper planning regulations and economic inefficiency (Ekanayaka, 2014).

Hence, ensuring land suitability for residential areas is one of the main purposes of land-use planning through spatial analysis of a particular location. Planning of residential area is one of the most components in the urban planning tools in any country including Ethiopia (Raghunath, 2006). As indicated in the urban planning and implementation manual of Ethiopia (MUDC, 2012) the location of the residential area should be in terms of certain predetermined factors such as physical, economic, and environmental conditions which influence the suitability of the site. A residential area is a place classified under land use categories in which housing predominates as opposed to industrial and commercial areas. However, due to lack of proper planning and limitation of the effectiveness of plan regulation and implementation, urban development in Ethiopia urban centers rarely meets the standards. According to Dejene (2015), the urbanization rate is growing annually and generating high demand for residential land. Hence, planners and policymakers need to prepare proper guidelines for a suitable location for residential development.

Suitable site selection has become more complex with an increasing desire to integrate goals related to sustainable development. Hence the modern site selection process has evolved into a path of conflicting and contradicting interests among spatial, environmental, economic, and social issues (Wandimu,2011). Planners are facing new challenges in assessing land suitability to identify the optimal site for a particular project as they attempt to plan and design projects which maintain safe and quality places, ecological system sustainability, and contribute to economic development. Access to safe and healthy shelter and basic services is essential to a person's physical, psychological, social, and economic well-being (Seid,2007)

Urban land suitability analysis for residential purposes is a complex process that involves considerations of multi-criteria evaluation which considers not only physical conditions but also environmental, social, and economic factors in the multifunctional pattern of urban areas and a scientific approach should be used for that (Ekanayaka,2014). Geospatial technologies and techniques are powerful tools and methods that can be used to analyze spatial data and its sophisticated analysis functionalities with multi-criteria evaluation provide a better approach for suitability analysis. The process of land suitability analysis involved the evaluation and grouping of specific areas of land in terms of their suitability for a defined use (Ekanayaka,2014). Integrated geospatial techniques and the MCE process add some valuable insight to a strong analysis platform for finding suitable residential locations.

The rapid progress made in geospatial sciences and technologies like GIS, remote sensing, and GPS augmented with multicriteria evaluation and analytical hierarchy process nowadays have been put forward with a series of functional capabilities and applications to solve conflicts and complexities in any geospatial decision making. Hence this study aims at analyzing urban land suitability to identify possible suitable locations for future residential development in Dire Dawa city, Ethiopia using geospatial techniques with Multicriteria Evaluation (MCE) and analytical hierarchy process (AHP) approach.

Providing urban land which is clean, environmentally healthy and economically feasible for residential housing purpose has been and will be one of the most imperative efforts of the national government as it has been identified and determined as among the key urban problems of the country which needs good governance. To mitigate the adverse impact of ongoing unplanned settlement developments in the urban area, analyzing urban land suitability and identifying suitable areas for future residential housing development is a useful approach for government in urban land provision which is economically safe, environmentally healthy, and socially acceptable.

### 1.2 Statements of the Problem

The growth of the city is a rapid continuous process and attracting people from different parts of the lands of the country to its urban centers due to its strategic location. Therefore, analyzing urban lands and identifying optimal areas for future residential housing development is the most important task in planning and it is observed that the present proposed land use plan cannot fulfill this requirement. Therefore, the urban residential land suitability analysis is designed to determine and locate the best potential sites for residential land planning. It is also aimed to identify the most suitable settlements for residential development after the land use planning is done (Huang et al., 2019).

Dire Dawa is among the fast-growing and principal cities in the country. The city has attractive potential that contributed to its accelerated growth due to its location along with the principal export corridor that links the country to the Djibouti port (Cities Alliance, 2016). The city has been spurred by rapid population growth and industrialization, which brought unprecedented urbanization process over the past few decades. As per the national population and housing census of 1994, the city was the home of about 173,188 and about 233,224 during the census period of 2007 and estimated to reach 660000 by 2030 (CSA,2015). As a result, in previous decades, the city has experienced an increased demand for residential land following the footstep of population growth of the city (Ananwa, 2006).

This resulted in the high demand for housing and become a challenge for the city administration to accommodate all the urban dwellers. In addition, the housing problems and the housing needs are manifested in overcrowding, poor and inadequate social amenities, unsatisfactory and unwholesome environmental conditions and urban squalor, the absence of open space, the development of land area leading to overcrowding of buildings, inaccessibility within residential areas and in scarcity and high cost of building materials (Wondimu,2011).

The present problem of residential houses in the city is putting pressure on the unplanned growth of the city and poor quality of life. Moreover, high population growth, municipal ineffectiveness, high cost of construction materials, low level of income and saving, shortage of infrastructure, and shortage of financial sources, contributed a lot to the current gap between demand and supply of residential houses (IDP,2006). The rising demand for residential housing land tends to push urban dwellers to expand into different corridors of the city, even ignoring topographic factors such as steeper slopes and flood-prone areas (Wondimu,2011).

In addition, the most challenging problem is meeting the demand for urban infrastructure facilities and lack of access to good quality, affordable and reliable services. The current demand for infrastructure and services far outstrips supply in most areas (Ekanayaka,2014). Therefore, Dire Dawa city faces the most challenging task of providing land with better infrastructure to fulfill this demand.

A range of case study has been conducted to analyze the level of urban land suitability for residential housing development (Raghunath,2006; Al-shalabi et al., 2006; Seid,2007; Murseli & Isuf, 2014; Ullah and Mansourian,2015; Rahim, et. al, 2014; Ekanayaka, 2014; Huang et al., 2019). From the literature reviews, it was found that there are no uniform criteria for urban residential land-use suitability analysis. Researchers selected their criteria for urban land-use suitability analysis according to their objectives, subjective judgment, and theoretical knowledge, as well as their local knowledge. However, many of the studies relied on a small number of evaluation criteria, which reduces the ability to incorporate enough evaluation criteria to represent a wide range of human decision-making and reasoning.

Moreover, analyzing urban land suitability for a particular use such as residential areas using advanced technologies in Ethiopian urban centers is uncommon. Particularly, in Dire Dawa city despite preparing proposed land use plans at different time intervals, the level of suitability for future residential areas has remained unclear. However, Urban residential land use planning by its nature is not a one-time activity. It is an ongoing process and should be updated regularly. Since we are operating in an extremely dynamic environment, the plan should be periodically evaluated and adjusted as the situation on the ground dictates (IDP,2006).

Dire Dawa city is taken as the study area because it is suffering adverse human life, economic and ecological damage resulting from rapid, relatively uncontrolled urban expansion. Importantly, no comprehensive urban land suitability analysis for residential areas has previously been undertaken for the Dire Dawa city other than some brief restrictive zone analyses presented in the Dire Dawa City Master Plan (2004-2020) and proposed land use plan (2015-2021).

Using the geospatial technique augmented with MCE and AHP approach, a complete residential land-use suitability map for future urban residential housing development covering the whole of Dire Dawa city, is generated, and the resultant maps used to re-evaluate the proposed land use plan. Suggestions are then offered to support long-term urban land for future residential development planning in Dire Dawa city.

Hence, this study attempts to analyze urban land suitability for future residential areas in Dire Dawa using Geospatial techniques augmented with Multi-Criteria Evaluation (MCE) approach and analytical hierarchy process (AHP).

### 1.3 Objectives

#### 1.3.1 General Objective

The general objective of this study is to analyze urban land suitability for future residential land use by applying geospatial techniques augmented with multicriteria evaluation and analytical hierarchy process approach in Dire Dawa City, Eastern Ethiopia.

#### 1.3.2 Specific objectives

The specific objectives of this research are:

- to determine criteria that influence the suitability of urban land for residential areas,
- to evaluate the suitability of urban land of the study area for future residential land use,
- to locate urban land suitability index for new residential development in Dire Dawa
- to validate the suitability of existing proposed residential land use of the city.

### 1.4 Research questions

- What are the underlying parameters that influence the suitability of urban land for residential use in dire Dawa city?
- What looks like the suitability of the future of the urban residential land of the study area?
- Where is the suitable site for future residential areas of Dire Dawa city?
- How is the suitability of the proposed residential land use plan of the city?

### 1.5 Significance of the research

The findings of this research identified the suitability indexes of the entire urban land of Dire Dawa city for future use of residential areas. Moreover, the study focused on mapping suitable sites for future housing development. These can create awareness of residential land use sustainable development.

The study also evaluated the suitability of the proposed residential land use plan comparing with the final suitability map and the result showed that the proposed residential areas were classified into different suitability levels. This scientific classification in line with the final suitability map can be used as a guide map to the proposed residential land use plan of the study area. In line with the above, the result drawn from the study may support spatial decision-making to satisfy the housing demand of the highly increased population of the city. Additionally, the adaptive approach and techniques used in this research will provide a basis for urban land suitability analysis for residential areas to identify the optimal site in other urban centers of the country as well. Hence, the paper is useful for planners, policy-makers, developers, and land managers. Moreover, it helps Dire Dawa city planners and developers to recognize that where is optimal land for future housing development to keep urban sustainable development while utilizing the land properly

### 1.6 Scope of the study

This study focused on analyzing urban land suitability for future residential use in Dire Dawa city. Hence, Dire Dawa city boundary of administration as of 2021 was considered as spatial restriction of the study. While thematically, relevant related kinds of literature, reports, and urban land policies have been reviewed to acquire background information, strong theoretical bases, selection of appropriate methodology, identification of gaps in the literature, and to compare the findings in the existing body of knowledge. Based on this, the review was focused on the following themes; definition and concept of a residential area, land-use zoning, controls and regulations, compatibility of land uses, land-use suitability analysis, Suitability of urban residential land and influencing factors, Suitability of urban land and urban residential development, Urban residential land suitability index system, determination of criteria for land-use suitability analysis, geospatial technologies in land-use suitability analysis, multicriteria evaluation, analytical hierarchy process, weighted overlay analysis, and Boolean overlay analysis.

### 1.7 Limitations

This study aimed at analyzing urban land suitability for residential areas. However, due to the existing limitation of availability of data, time, and intended depth of analysis, land uses other than residential are not considered in this study. Furthermore, the study was confronted with a range of challenges such as the scarcity of the relevant data in expected expertise offices, the occurrence of the virus, ‘COVID-19’ situations followed by the unwillingness of important groups for the sack of the physical contact, and other constraints. However, this limitation did not affect the result of the study.

### 1.8 Organization of the Paper

This thesis includes four chapters and the conclusions and recommendations section. The first chapter presents the introductory part, which describes the background of the study, statement of the problem, the objectives of this research, research question, the significance of the study, the scope of the study, limitation of the study, and organization of the paper.

The second chapter discusses the literature related to the study, reviews related papers to find the scientific support and the theories behind the methodology. The third chapter includes a description of the study area, data sources, and data collection methods, software, and facilities used to analyze the data. The fourth chapter presents results and discussions that focus on developing spatial data analysis using geospatial techniques with MCE and AHP methods. In this chapter, the determination of criteria (factors and constraints), weight computation are key parts of the study. At the last, conclusions are drawn from the findings, and recommendations are provided to improve the analysis of urban land suitability for a residential area for future decisions.

# CHAPTER TWO

# 2. LITERATURE REVIEW

## 2.1 Definition and concepts of residential areas

A residential area can be defined as a land-use type in which a living house predominates when compared with commercial and industrial areas. But there are different housings throughout residential areas. These may include single-family housing and multifamily housing. Residential use zoning may allow some services or activities or may restrict industries and businesses from residential areas (Dejene, 2015).

### 2.1.1 Land use zoning regulation and control for residential areas

Zoning regulation is part of the development guide to establish a compatible land use pattern that will help to secure optimum, economic, and environmental advantages. The decision for allocating different activities on different sites should at least be examined based on the area and location of the proposed sites concerning the different parts of the city, neighboring activities, alternative activities and sites for allocation, land value, and future development (IDP, 2006). On the other hand, land-use zoning regulation is an implementation tool for planning and plan implementation to control the nature of development in line with the neighboring activities and the natural environment (IDP, 2006).

Land use regulations are used to restrict the rights of private landholders while they use the land. Land use controls and regulations are also used to protect the public interest when they need to use private land. These regulations are also used to ensure the availability of land to all groups, and to ensure that the benefits of development go to the community as a whole (Dejene, 2015). Land use controls and regulations are common urban land policies in almost all cities of the world. Kono & Joshi (2018) mentioned common regulations. These are Zoning by which urban land uses are restricted zone by zone; lot size regulations that limit the size of each housing area; urban growth boundary control which separates urban development areas from urbanization control areas; and floor area ratio regulations which directly limits building sizes both in horizontal and vertical dimensions. However, the methods and implementations of these regulations may vary from country to country or city.

### 2.1.2 Compatibility of Land Uses

Compatible is defined as development, building and/or land use that is designed to be able to exist or occur without conflict with its surroundings in terms of its uses, scale, height, massing, and location on its site (Austin,2019). Land use compatibility is a recognized factor and principle of good land use planning, whereby land uses which are known or expected to cause environmental problems for one another when in proximity, are deemed incompatible and are protected from one another by separation and/or other means (Ontario,2019). Land uses in a structured plan ought to be proposed taking into account compatibility of adjacent land uses or compatibility of different land uses which would be proposed close to each other. Table 1 shows the compatibility matrix produced based on major land use functions.

Table 1: Compatibility of land use

| Land Use | Residence | Commerce | large-scale Industries | Small-scale Industries | Social Service | Cultural Center | Adminis tration |
|---|---|---|---|---|---|---|---|
| Mixed | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| Center | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| Manufact uring & Storage | X | ✓ | ✓ | ✓ | x | X | X |
| Green Frame | X | ✓ | X | X | x | ✓ | X |
| Services | ? | X | X | X | | | X |
| Transport Centers | X | ✓ | X | ✓ | x | X | ? |

Source: MUDC (2012)

N.B

✓ Denotes compatibility

? Represents for partly compatible but to be decided depending on the specific situation.

X denotes the incompatibility of functions.

### 2.2 Suitability of urban residential land and influencing factors

#### 2.2.1 Influencing factors for suitability of residential areas

According to Al-shalabi et al (2006), suitability analysis and site selection require consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for defined land use. Multicriteria evaluation is a technical procedure that typically multiplies conflicting and corresponding criteria that are essential to be assessed in decision-making (Wu, 2012). In general, the basic advantage of using the MCE method is the possibility to evaluate complex and multiple factors at different scales and aggregated to produce a composite map that portrays suitable land for a particular project.

Murseli & Isufi (2014) revealed that "During the planning process two steps are very important, the first step is to know and locate which area important resources to preserve or restrict for future development in an area and the second step is what is left from a preserve or restrict resources to plane than to develop for future development. Defining the criteria is made based on the restrictions of spatial developments arising as part of the national legislation, planning documents, analyzing the most appropriate distance for land functions dedicated for housing, as well as documents and different practices"

Therefore, "site suitability is the process of understanding existing site qualities and factors which will determine the location of particular activity" (Haymanot, 2011). So, it requires analysis of wide-ranging and consistent datasets to achieve the objective. Hence, to ensure the maximum society's benefits and sustainable environmental health, this study considered the real urban situations of the study area with factors such as economic, environmental, and physical conditions and support in the analysis of urban land sites for future residential areas.

Therefore, based on different countries' experience, local expert's opinion, Ethiopia's Ministry of Urban Development and Construction manual on Revised Standards for Structure Plan Preparation and Implementation, and availability of data different parameters for future residential areas can be considered in the context of study area. Accordingly, from these literature reviews the following criteria are identified:

- ❖ The settlement site should be on a slope range of 2-8%
- ❖ Residential be placed on vacant (open area)

- ❖ For accessibility of transportation, the new residential areas should not be far from major roads.
- ❖ For safety, the residential site should be away from the river (flooding during the summer season). it should be no residential areas within 30m of the river.
- ❖ The presence of physical hazards reduces the suitability of a site. For Selecting safe housing sites and avoid the risks. i.e., it should not be located in risk areas (susceptible to natural hazards.
- ❖ For safety and noise, it should be away from railway lineside. 200m away from it.
- ❖ Some protection areas should be masked like parks, Industries, etc.

urban planning and implementation manual (MUDC,2012) suggests that the following activities should be considered during residential area identification. Residential areas should be: -

- ➢ free from black cotton soil as much as possible.
- ➢ located in all corners of the town unless there is a constraint
- ➢ Have gentle slope i.e., 2%-15% (a slope between 2% and 8% is highly recommendable) due to its gentleness it reduces cost of construction, landslide risk, and flood;
- ➢ free from exposure to natural disasters such as geological hazards (land and mudslides and rockfall), flood, malaria-affected areas (unless both are protected (treated) properly), etc.
- ➢ Avoid unplanned settlements on hazard-prone lands that contribute both environmental degradation and vulnerability to catastrophic events;
- ➢ Delineate all hazard-prone lands and identify those to be allocated for preservation to protect them from the coincidence of potential hazards and those to be used for settlement or another purpose by taking the necessary environmental impact assessment;
- ➢ Allocate those areas subject to landslides, slope falls, mudslides, avalanches, rock falls as closure areas or preservation until the soil gets stabilized and take the necessary engineering measures to mitigate the situation;
- ➢ Allocate certain hazard-prone lands such as those wetland areas for recreation so long as these particular areas and the adjacent land uses are not affected by human and animal interferences;
- ➢ Provide the necessary management controls to prevent incompatible land use and environmentally destructive activities; and,

- Provide a proper drainage network system for avoiding floods and stormwater, which in all cases aggravate environmental degradation thereby causing catastrophic events.

When land is zoned in a development plan designation, the development plan should identify where practicable the sequential and coordinated manner in which zoned lands will be developed, to avoid a haphazard and costly approach to the provision of social and physical infrastructure. The development plan specifies that zoning shall extend outwards from the Centre of an urban area, with undeveloped lands closest to the core and public transport routes being given preference, encouraging infill opportunities, and that areas to be zoned shall be contiguous to existing zoned development lands((MEHLG), 2009).

The provision of utility investment programs by planning authorities must also be related to the sequencing of residential lands and must also be integrated with the provision of public transport, schools, community, and facilities, etc. This will involve keeping up the close contact with other agencies, which would have occurred during the plan-making period((MEHLG), 2009).

As stated in Minister for the Environment, Heritage and Local Government (MEHLG). (2009). ((MEHLG), 2009) for sustainable residential development the range of relevant national policies were established to share a common goal to create high-quality places which:

- Prioritize walking, cycling, and public transport, and minimize the need to use cars
- Deliver quality of life which residents and visitors are entitled to expect, in terms of amenity, safety, and convenience;
- Provide a good range of community and support facilities, where and when they are needed and that are easily accessible;
- Present an attractive, well-maintained appearance, with a distinct sense of place and a quality public realm that is easily maintained;
- Are easy to access for all and to find one's way around;
- Promote the efficient use of land and energy, and minimize greenhouse gas emissions;
- Provide a mix of land uses to minimize transport demand;

- ❖ Promote social integration and provide accommodation for a diverse range of household types and age groups;
- ❖ Enhance and protect the green infrastructure and biodiversity; and
- ❖ Enhance and protect the built and natural heritage

**2.2.2 Land suitability analysis**

Land-use suitability is the capacity or level of land suitable for prescribed uses (Steiner et al., 2000; Collins et al.,2001; Marull et al., 2007), and involves collective physical, socioeconomic, environmental, and ecological perspectives which are quantified through set criteria (Collins et al.,2001). Malczewski, (2004) stated that suitability analysis or assessment should be made according to specific requirements, preferences, or predictors of certain activities. Accordingly, local expert knowledge, the preferences of decision-makers, and community participation are represented in land suitability analysis by scientific integration of existing real-world criteria.

According to McSherry et al. (2000) land-use suitability analysis is the process of determining the fitness of a given tract of land for a defined specific use. It is also process to evaluates the advantages of possible locations in which a predetermined use can be developed (Opadeyi, & Nizeyimana, 2005). It helps to locate the most desirable direction for future urban growth, the suitability of various land uses should be carefully analyzed and interpreted as appropriately as possible. Hence, land suitability analysis aimed to identify the suitable spatial patterns of land for future uses as predetermined specific requirements, preferences (Collins et al.,2001). Generally, the main purposes of land suitability analysis are also to identify and locate the suitable areas for a possible land use development activity, such as residential, industrial, tourism development, agricultural land use, potential areas for forestry, and other such land-use activities.

The process of site suitability requires the identification of the appropriate locations for a particular land use activity by considering physical resources (Laurin & Ongaro, 2006).There are various criteria to be considered in land suitability analysis some of the relevant parameters include: topographic factors (elevation, slope, aspect), natural resources (soils, geology, hydrology, flora and fauna habitat, and environmentally sensitive areas), and existing land use and development (manmade facilities such as transportation systems, existing urban areas, and utility networks) (Pareta, 2013). These different types of information constitute the “criteria” based on which the area under consideration (Keeney

& Raiffa, 1993). These criteria are individually considered to identify areas of opportunity for areas suitable to the land use under consideration and constraints than (areas not suitable to the land use under consideration (Pareta, 2013).

In the land-use planning process, land suitability analysis is a mandatory component of the local land-use plan. It is a process for determining a planning area's supply of land that is suitable for development (Division et al., 2005). The analysis includes consideration of several factors such as natural system constraints, compatibility with existing land uses and development patterns, existing land-use policies, and the availability of community facilities. A key output of the analysis is a land suitability map that shows vacant or under-utilized land that is suited for the development (Division et al., 2005). In general, different factors considered in a land suitability analysis fall into one of three categories: (1) physical constraints, such as slope, soil, groundwater aquifers, and flood plains; (2) access, such as distance to roads, surface waters, sewer lines, or water lines; and (3) costs and benefits of the development. New developments could impact the physical environment or human society, such as an aquifer, a wildlife habitat, or historical sites.

Land suitability analysis is a systematic procedure for examining combined effects of a related set of factors that an analyst assumes to be the important determinants of locational suitability (Kaiser et al., 1995). Specifically, a land suitability analysis examines selected land characteristics to determine the level of suitability and ranks available land accordingly. The optimal land will be used for intended purpose first. The selection of land characteristics is normally a judgment of the person in charge of the study. Those characteristics are represented by a set of factors. According to (Wang & Hofe, 2007) the process follows the following eight steps:

(1) Select a land-use type for analysis;
(2) Select factors to be considered and attribute values of each factor;
(3) Determine a score for each factor attribute;
(4) Weigh the factors;
(5) Calculate a composite score from the attribute values and weight it for each factor;
(6) Rank the combined scores to establish suitability levels;
(7) Identify available land-based on existing land uses;
(8) Compare with comprehensive plan, zoning, or other land use controls that further remove unavailable land

### 2.2.3 Multi-criteria evaluation in the land suitability analysis

Analyzing urban land suitability for residential areas is a complex decision-making problem, involving several, sometimes conflicting, criteria and multiple objectives. Ezzat &Hamoud, (2016) demonstrated the Analytic Hierarchy Process (AHP) is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales.
AHP measures rely on the judgments of experts to drive the priority of parameters under consideration. The comparisons are made using a scale of absolute judgments that represents how much more one element dominates another concerning a given attribute. The judgments may be inconsistent, and measuring inconsistency and improving the judgments, when possible, to obtain better consistency is a concern of the AHP (Saaty, 1980). The Analytic Hierarchy Process (AHP) was introduced by (Saaty,1980) and is a very popular means to calculate the needed weighting factors with the help of a preference matrix where all identified relevant criteria are compared against each other with reproducible preference factors (Malczewski 1999).

GIS and Multi-criteria evaluation (MCE) have been globally recognized for their outstanding capacities in spatial decision support systems in suitability analysis (Carver, S.J.1991 & Malczewski. J, 1999) frequently applied to solve complex decisions to boost proper land-use planning (Malczewski.1999). MCE is a procedure that typically multiplies conflicting, contradicting, and corresponding criteria that are essential to be evaluated in decision-making (Malczewski,1999).According to (Yassine & Adel,2011), "The principal of the MCE is to condense complex problems with multiple criteria into the finest ranking of the best scenarios from which an option is selected". The selected criteria are weighted based on their importance on the site, and their weight has more or less impact on the final suitability site decision than another (Diakoulaki & Karangelis 2007). Hence, attention should be given to the selection of criteria and weight assigning for them.

Previously, various methods of spatial analysis for land use are commonly used in suitability assessment studies. The problem of land-use suitability assessment has often been tackled using multi-criteria decision analysis (MCDA) since the 1980s (Collins et al. 2001, Kiker et al. 2005, Sharifi et al. 2006, Kunwar et al. 2010). Integrated MCDA and GIS have been widely promoted and recognized for solving geospatial problems by creating visualized suitability maps in urban suitability analysis and planning for users and decision-makers (Phua and Minowa 2005).

The integration of MCDA techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis (Malczewski, 1999). GIS-based MCDA can be thought of as a process that combines and transforms spatial data into a resultant decision (output). (Malczewski,2004) revealed that MCDA can incorporate both geographical data and stakeholders' preferences into quantified values for assessment and further decisions.

AHP, which was proposed by Saaty (1980), is a structured technique for decision-making based on a hierarchical framework constructed through mathematical pairwise comparisons. The weights for the decision-making criteria are derived from the pairwise comparisons of the relative importance between every two criteria (the sum of the weights equals 1). (Saaty, 1980). In general, the basic advantage of using the MCE method is the possibility to evaluate complex and multiple factors at different scales and aggregate them to produce a composite map that portrays suitable land for a particular project.

### 2.2.4 Determination of criteria weights in land suitability analysis

AHP method is a powerful and popular technique that can be applied in a GIS environment and provides a means for analyzing multiple complicated problems that allow subjective as well as objective factors to be considered in a multicriteria decision-making process (Haile and Suryabhagavan 2019; Kou et al. 2016; Jablonsky 2015; Vaidya and Kumar 2006).

For valuation of the criteria features, various methods such as logistic regression, the AHP method, the weight of evidence, ratio estimation, and the Delphi process could be chosen (Adewumi et al. 2019). Several researchers have used the AHP method of pair-wise comparison matrix, to assign the weights to each of the considered factors (Haile and Suryabhagavan 2019; Rajasekhar et al. 2019; Ramík 2017; Mandal and Mondal 2016; Ataei et al. 2008; Vaidya and Kumar 2006).

Mayunga (2018) showed that the essence of pair-wise comparison is that two criteria are evaluated at a time to determine their relative importance. In this research, the AHP method was adopted to give value to the criteria and select the best appropriate site. After the hierarchy has been established, a pair-wise comparison matrix of each element within each level is constructed. This pair-wise comparison permits for an independent rating of each factor's contribution, which therefore simplifies the decision-making process (Adewumi et al. 2019).

Local expertise can weigh each element against each other within each level by adapting a comparison scale (Table 2), which is related to the levels above and below it, and mathematically tie the entire scheme together. The consistency of the weight for various factors was checked through, a single numerical value, the consistency ratio (CR), which measures the level of the inconsistency of the pair-wise comparison matrix (i.e., the likelihood of whether factor weights were randomly assigned). The consistency ratio (CR) can be defined by the mathematical relation equation (Vaidya 2006). The weight of each factor is computed using the Principal Eigen Value of squire reciprocal matrix using Analytical AHP in IDRISI software (Eastman,1999). The Eigenvalue in AHP lies between 1 and 9; Where, class 1 = represents equal preference between two factors and class 9 stands for a factor extremely preferred over the other (Eastman,2012.).

Table 2: Example scale for comparisons

| Intensity of importance | Description |
|---|---|
| 1 | Equal to Moderate importance |
| 3 | Strong or essential importance |
| 5 | Strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2,4,6,8 | Intermediate values Reciprocals Values for inverse comparison |

Source: Adapted from (Saaty, 1980)

This can be done based on the relative importance of each criterion mentioned in the literature related to the study and judgment of planning experts familiar with the urban environment of the study area (Eastman,2012), (Ebistu & Minale, 2016). This requires the determination of factor weights in the following three steps:

1) Filling the eigenvector value of the reciprocal matrix by comparing the priority importance of every two factors with respect to the problem. Either the upper or the lower triangle filling is sufficient

2) Adding every value of the column.

3) Dividing values corresponding to every factor by the column total to determine the relative weight of the factors.

Computation of consistency ratios (CR) was done after calculating consistency index (CI) and obtaining random index (RI), corresponding to the number of parameters considered, from the table. The general formula of Consistency ratio is given below (Equation 1). Based on the above techniques, the criteria weights for the seven parameters are determined using the ArcGIS software after they get prioritized and the consistency ratio is found to be acceptable.

Moreover, the Consistency Ratio (CR) has been estimated to check the degree of consistency in the aggregate group judgments made by experts (Forman & Selly,2001). and CI which is the consistency index; RI is the random index - the average result of consistency index depending on the order of the matrix. Moreover, the Consistency Index (CI) is simplified as Where, $\lambda$ max, is the largest or Principal Eigenvalue of the matrix; and n stands for the order of the matrix. Accordingly, the CR does not exceed1. i.e., CR of $\leq$0. 1 is considered as reasonable to accept (Saaty,1997). However, is an indicator of inconsistent judgments and needs to revise the matrix

$$CR=CI/RI \qquad \text{Equation 1}$$

Where CI is the consistency index and RI is the random consistency index of a comparison matrix. CI was computed as:

$$CI= (\lambda\ max-n)/(n-1) \qquad \text{Equation 2}$$

Where '$\lambda$ max' is the largest eigenvalue of the comparison matrix and 'n' is the number of criteria or factors.

### 2.2.5 Proximity analysis in land suitability

The Proximity toolset of the arc toolbox contains tools that are used to calculate the proximity of features within either one or multiple feature classes. These tools can identify features that are closest to one another or calculate the distances between or around them((ESRI),2015). This proximity tool is further classified into two classes based on the types of input data the tool accepts: vector or raster data. The vector-based tools vary in the space of output they create. For instance, the Buffer tool outputs polygon features, which can then be used as input to overlay or spatial selection tools such as Select Layer by Location.

Buffers are created by proximity tools to delineate preserved zones around real-world features or to specify areas of influence. For instance, you might buffer a hospital by two kilometers and use this buffer to select all the people that live within two kilometers and those who live more than two kilometers from the hospital to plan for their transportation to and from the hospital.

In the GIS function, buffers can be used to select features from another feature class, or they can be integrated with other features using an overlay tool and find parts of features that fall within the buffer areas ((ESRI),2020). It is possible to use the multiring buffer tools to reclassify the areas around a feature into near, moderate far, and very far distance classes for analysis. Buffers are also used to clip data to a given study area or to exclude features within a critical distance of something from further consideration in an analysis.

### 2.2.6 Overlay computation in land suitability analysis

In raster overlay, the grid or pixel cell values of each raster data are combined using arithmetic and Boolean operators to drive a new value in a composite map. This method is often expressed as map algebra. The raster GIS provides the functional ability to perform map layers mathematically. This is particularly important for the multi-criteria overlay analysis in which various maps are combined using various mathematical functions. In this case Conditional operators such as: “and”, “or” and “if” are the base of mathematical functions that are supported in GIS.

Overlay analysis is one of the most methodologies applied in suitability analysis and optimum site selection. ESRI (2020) demonstrates Overlay analysis as a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated analysis. Suitability analysis identifies the best or most preferred locations for a specific phenomenon. Types of problems addressed by suitability analysis include:

- Where to site a new housing development?
- Which sites are better for deer habitat?
- Where economic growth is most likely to occur?
- Where the locations are that are most susceptible to landslides?

Overlay analysis always requires many different criteria of a common reference system for analysis. For example, selecting a suitable site for a new residential housing development needs analyzing of such parameters as land value, proximity to existing utilities, proximity to existing social services slope, and flood frequency.

It is impossible to add a raster of land value (dollars) to a raster of proximity to utilities (Kilometers) and obtain a meaningful value. In addition, the parameters under investigation may not be equally important. It may be that the cost of land is more important in choosing a site than the distance to utility lines((ESRI),2020). Some values in a particular raster may be ideal for your purposes (for example, slopes of 0 to 5 degrees), while others may be good, others bad, and still others unacceptable. According to ESRI (2005), The following lists are the general steps to perform overlay analysis:

1. Define the problem.
2. Break the problem into sub-models.
3. Determine significant layers.
4. Reclassify the data within a layer.
5. Weight the input layers.
6. Add or combine the layers.
7. Analyze.

The three main overlay approaches available are Fuzzy Overlay, Weighted Overlay, and Weighted Sum, and each approach has different basic premises and assumptions((ESRI), 2015).

### 2.2.7 Weighted overlay in land suitability analysis

In Weighted Overlay analysis, a series of tools can complement the Weighted Overlay tool to follow the general overlay analysis steps described above ((ESRI), 2015). The Weighted Overlay tool scales the input data on a defined scale (the default being 1 to 9), weights the input roasters, and adds them together. The more favorable locations for each input criterion will be re-classed to the higher values such as 9.

In the Weighted Overlay tool, the weights assigned to the input raster must equal 100 percent. The layers are multiplied by the appropriate multiplier, and for each cell, the resulting values are added together and weighted Overlay assumes that more favorable factors result in higher values in the output raster, therefore identifying these locations as being the best(Baidya et al., 2014).

The weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Weighted overlay only accepts integer raster as input, such as a raster of land use or soil types. Continuous (floating point) raster must be reclassified to integer before they can be used. Generally, the values of the continuous raster are grouped into ranges, such as for slope, or Euclidean distance outputs. Each range must be assigned a single value before it can be used in the weighted overlay tool. One can either not worry about the value assigned to each range (but note the range of values the new value corresponds to), and assign weights to the cell values in the weighted overlay dialog box later, or we can assign weights at the time of reclassifying, then with the correct evaluation scale chosen, simply add the raster to the weighted overlay dialog box. The cells in the raster will already be set according to suitability (or preference, or risk, or some similarly unifying scale). The output raster can be weighed by importance and added to produce an output raster((ESRI), 2015).

### 2.2.8 Boolean overlay in land suitability analysis

Boolean logic which was introduced by the English mathematician and logician, George Boole, generally applies a binary condition to the inputs and evaluates to a binary condition for the output. The Boolean tools evaluate the inputs only as True or False conditions and return the result of the particular tool as a 1 or 0 (True or False) Boolean value((ESRI), 2020). The Combination tools identify unique combinations of input values based on the logic of the particular tool and return a different value for each unique combination. The Relational tools compare the values of one input relative to another and return the result of the particular tool as 1 or 0 Boolean value ((ESRI), 2015). The Logical tools have different ways to apply Boolean logic, such as identifying only the input cells that are No Data or using a logical expression that you define to determine which cells are evaluated as true.

## 2.3 Urban residential land suitability index system

The following general principles need to be considered for the Urban residential suitability analysis index system (Dongdong, et. al, 2010): 1) The evaluation indexes should be a concise and scientific approach. The number of indexes needs to be scientifically set as excessive indexes may result in index overlapping and conflict whereas insufficient indexes may lead to missing of information and thereby wrong decision making; 2) systematical integrity principle. The indexes should stand independently as well as interrelated to each other and they should be united into an organic evaluative system with the hierarchical order of importance; 3) comparability, quantification, and feasibility principle. To create a good comparison condition, the indexes must include common features of the evaluative objects under consideration. For a good calculation, qualitative indexes are supposed to be assigned values based on their importance and quantitative indexes can be directly quantified and get their importance score which can be integrated with the former. The feasibility principle needs convenience in the availability and analysis of index data to drive new information for decision support; 4) the principle of objective. The indexes are considered as the fundamental guarantee for an objective under investigation and accurate evaluation.

The FAO classification model for land suitability index is widely used in the studies of land suitability analysis (Qiang and Ping, 2000; Zhang, 2003; Aburas et al.,2017). It classifies land suitability levels into five different classes as permanently unsuitable, least suitable, moderately suitable, suitable, and highly suitable. According to each selection, the element is evaluated according to established criteria and ranked on a simple five-point scale from 0 to 4. Criteria Ranking Scores 0 = unacceptable (undesirable/least cost-effective), 1= poor, 2 = fair,3 = good,4 = excellent (most desirable/most cost-effective) (ICEFP, 2004). For each criterion, a suitability score was applied using a five-point scale to determine the qualitative rankings of the suitability on each criterion under consideration. The ranking ranges from 0 (restriction) to 4 (very high suitable). The scores understandable well since the higher the score, the more suitable the site is. Suitability classes are given below:

Unsuitable (0): This is attributed to areas with characteristics imposing certain constraints or restrictions, which cannot be overcome or legally excluded for the development of residential areas.

Low suitable (1): areas that are not good for residential development. A level of sites with characteristics imposing constraints which can be overcome but massive investment

Moderately suitable (2): areas moderately appropriate for residential housing development. It represents sites with good conditions in relation to a low suitable site, but it needs some improvements to make it better conditions**.**

High suitable (3): it denotes sites with good characteristics but may be slight challenges to develop residential areas which can be overcome by least investment.

Very high suitable (4): This is attributed to areas with characteristics imposing no significant constraints for future residential housing development. Optimal lands for the development of areas for residential housing activities.

## 2.4 Proposed residential land use suitability validation

Huang et al., (2019) demonstrated that the urban residential land suitability analysis is designed to determine and locate the best potential sites for residential land planning and it is also aimed to identify the most suitable settlements for residential development after the land use planning is done. Lwasa, (2005) and Ekanayaka, (2014) used land suitability analysis for residential areas to validate the suitability level of proposed residential land use by superimposing the final suitability map with the proposed residential layer. Analysis of urban land and identification of optimal areas for future residential development is the most important task in planning zoning regulations that can be done either before land use planning to prepare land use plan or after the proposed land use is prepared at different time interval to understand the nature and level of proposed land suitability. (IDP, (2006)) clearly stated that Urban residential land use planning by its nature is not a one-time activity. However, it is an ongoing process and should be updated regularly. So proposed land use plan should be timely analyzed and since we are operating in an extremely dynamic environment, the plan should be periodically evaluated and adjusted as the situation on the ground dictates (IDP, 2006)

## 2.5 Geospatial Technologies in the land suitability analysis

Geospatial technology is a multidisciplinary field that includes disciplines such as surveying, photogrammetry, remote sensing, mapping, geographic information systems (GIS), geodesy, and global navigation satellite system (GNSS) (PunCheng, 2001). As the U.S. Department of labor defined, the geospatial industry can be considered as "an information technology of practical fieldwork that acquires, manages, interprets, integrates, displays analyzes, or otherwise use data focusing on the geographic, temporal, and spatial context" (Klinkenberg,2007). Ethnological progress relates to geospatial software and analyzes of geospatial data are some of them. The integrated approach of geospatial technologies such as GPS data, remote sensing imagery, aerial photographs, Google Earth and GIS are valuable in the development of modern Geoinformation.

### 2.5.1 Role of GIS and Remote Sensing in land suitability analysis

Geographic information systems (GIS) have emerged as useful computer-based tools for Spatial analysis, description, and manipulation. it is now accepted widely as a valuable tool for managing, manipulating, measuring and analyzing, and displaying large volumes of diverse data pertinent to many local and regional planning activities and its use in environmental planning is rapidly increasing (Bualhamam, 2009).

A geographic information system (GIS) is a computer-based system that is designed as an efficient tool for organizing, storing, manipulating, analyzing, displaying, and reporting geographic information and its capabilities for spatial analysis overcome the drawbacks of the hand-drawn overlay techniques approach while the integrations of all means used for the measurement, analysis, and visualization of features or phenomena that are location based on the Earth surface including the Earth itself referred as geospatial technologies.

Geospatial technologies refer to all the means used for the measurement, analysis, and visualization of features or phenomena that occur on Earth and They include three different technologies that are all related to mapping features on the surface of Earth: Global Positioning Systems (GPS). Geographical Information Systems (GIS).Remote Sensing (RS), Google earth pro(Nonguierma, 2007).

Kennedy (2009) defined GIS as “an organized collection of computer hardware and software, people, money, and organizational infrastructure that makes possible the acquisition and storage of geographic and related attribute data, for retrieval, analysis, and display to promote understanding and assist decision making. “The ability of GIS to store, manage and manipulate large amounts of spatial data provides urban managers with a powerful tool. GIS's ability to link tabular, non-spatial data to locational information is likewise a powerful analytic capability. Many different facets of government use GIS technology. It also provides means of visualizing and analyzing data that was previously impractical. With the aid of a GIS, a local planning and community development office can track zoning and site design plans that help form and shape a city (Zeng, 1999).

The use of Remote Sensing technology has become increasingly important in describing a variety of satellite-driven data sets and their applications to understand the situation of the land and its surrounding environment. Remote sensing technology enables us to collect a huge amount of inaccessible spatial data.

## 2.6 Research Gap

There are several studies performed recently about land use suitability analysis, settlement site selection and Locational suitability analysis for residential housing development using the application of GIS and remote sensing across the world. Some of them are reviewed well to guide and shape this.

On the other hand, Gezahegn & Anteneh (2016) conducted a study entitled “Identification of Potential Sites for Housing Development Using GIS-Based Multi-Criteria Evaluation in Dire Dawa” The main weaknesses of this study are the omission of certain relevant criteria such as Electric transmission line, accessibility of water supply line, healthcare services, and recreational areas. Besides, they did not consider constraints that should have to be considered in suitability analysis as they restrict the use of land for intended purposes due to environmental sensitivity, natural hazards, and legally limited from future development. Lastly, they did not evaluate the suitability of proposed residential land use to validate its suitability and status. Analyzing urban land suitability for residential areas should be considered in a broad context, encompassing specific physical, environmental and economic factors of the study area.

From the literature reviews it was found that there is no uniform criteria for urban residential land-use suitability analysis. Researchers selected their own criteria for urban land-use suitability analysis according to their objectives, subjective judgment, and theoretical knowledge, as well as their local knowledge. however, many of the studies relied on a small amount of evaluation criteria, which reduces the ability to incorporate enough evaluation criteria to represent a wide range of human decision-making and reasoning.

In criteria determination, most of previous study did not incorporate Constraints in their analysis for residential suitability site identification. But constraints should have to be considered in suitability analysis as they are a restriction set up by legal framework. hence this study uses the multi-criteria methods integrated a larger amount of evaluation criteria (eleven factors and ten constraints) than in previous studies to determine the suitability index of urban land for future residential land use.

KGPK Weerakoon, conducted research entitled “Analysis of Locational Suitability for Residential Development in Colombo Sub Urban Area: Application of Analytic Hierarchy Process.” He has used some data set such as population density, proximity to roads, proximity to town Centre, proximity to primary & secondary schools, land value and land use factor to analyze location for residential development of the study area using GIS integrated Multi Criteria Evaluation. In his study, he used multi-criteria evaluation augmented with GIS techniques. He was able to incorporate experts' opinion from various institutes of different professionals like town planners, architects, engineers, quantity surveyors, environmentalist, scientists and administrators to develop criteria weights and then he used AHP method to drive weights for each criterion. The main weaknesses of the study reviewed the omission of certain relevant criteria such as: soil condition, slope, aspects and geological characteristics, the unsupported categorization of all the criterion as constraint and factors (Weerakoon 2007).

Almost all of the previous studies did not validate the suitability index of their analysis by comparing with proposed land use plan of their study areas which would have prepared by authorized body for city's spatial development and regulation. From principles of land use suitability analysis, the final results of suitability analysis for land use should be compared with proposed land use plans, comprehensive plan, zoning or other land use controls that further gives detail pictures of land use control tools and remove unavailable land. This research tried to fill this gap of knowledge by comparing the final suitability map with existing proposed land use plan to validate its suitability. this is not experienced well before in suitability analysis of urban land uses for some particular purpose.

# CHAPTER THREE

# 3. MATERIALS AND METHODS

## 3.1 Description of the study area

### 3.1.1 Location

The study is conducted in Dire Dawa Administration Council where it is located in the eastern part of Ethiopia. The Administration is surrounded by East Hararge Administrative Zone of Oromia National Regional State to the South and Southeast, while the Shinele Zone of Somali National Regional State bounded the Administration to North and Northeast. It is also located on the border of Afar plain and on the Eastern highland just at foot slope of the Dengego mountain between $9^0$ 27' and $9^0$ 49' N Latitude and $41^0$ 38' and $42^0$ 19' E Longitude. Dire Dawa city is found at 515 kilometers by road east of Addis Ababa and 311 kilometers to the west of Djibouti port. It covers an altitude from 950 to1250m above sea level. Figure 1 shows the location map of Dire Dawa city in reference to Ethiopia regional map.

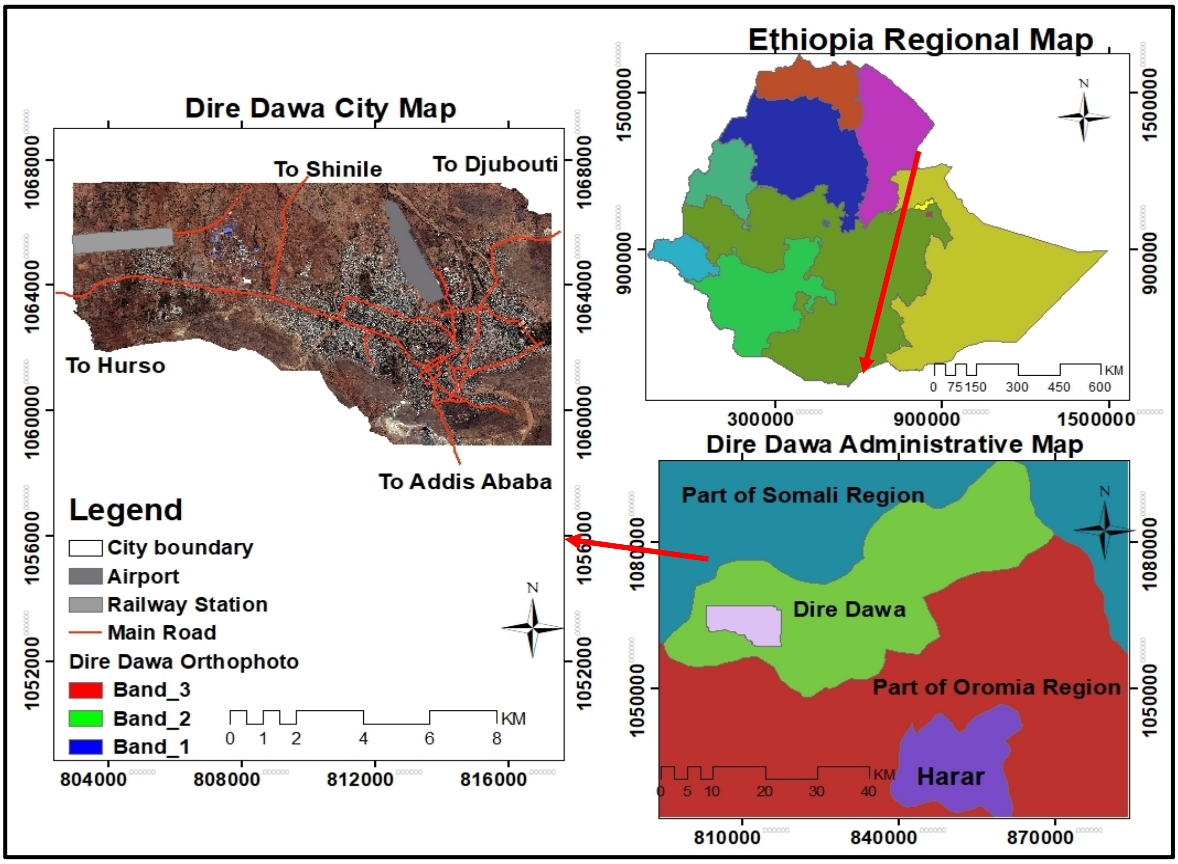



Figure 1. Location map of Dire Dawa city, background aerial photo as of 2020

### 3.1.2 Population

Although urbanization has been a slow process in Ethiopia, recent growth rates have been high. This is also true for Dire Dawa city where the population is highly increasing from time to time. The total population of the city was estimated to 99,980 as per the national population and housing census of Ethiopia in 1984. Whereas, in the second and third national census periods of 1994 and 2007 the total population of the city was about 173,188 and 233,224 respectively (CSA, 2015). According to 2019 population projections, the total population of the city is 313,000 people (63 percent) live in the City of Dire Dawa and 180,000 people (37 percent) live in rural areas.

### 3.1.3 Climate

The climate of Dire Dawa and its environs is characterized by a tropical climate and exhibits warm and dry weather with less rainfall due to its equatorial location and high-altitude factors. As Figure 2 demonstrates, Dire Dawa has an annual average temperature of $25^0$ C with an average maximum temperature of $31.2^0$ C and an average minimum temperature of $18.7^0$C. The month of June records the highest temperature of $34.2^0$C while December has the lowest temperature ($14.8^0$ C). According to Dire Dawa Meteorological Agency, Dire Dawa enjoys annual daily sunshine of 8 hours; it also exhibits a dry climate defined by an average relative humidity of 41.6%. Regarding precipitation falling annually, the local meteorological center recorded an average of 670 mm of rainfall.

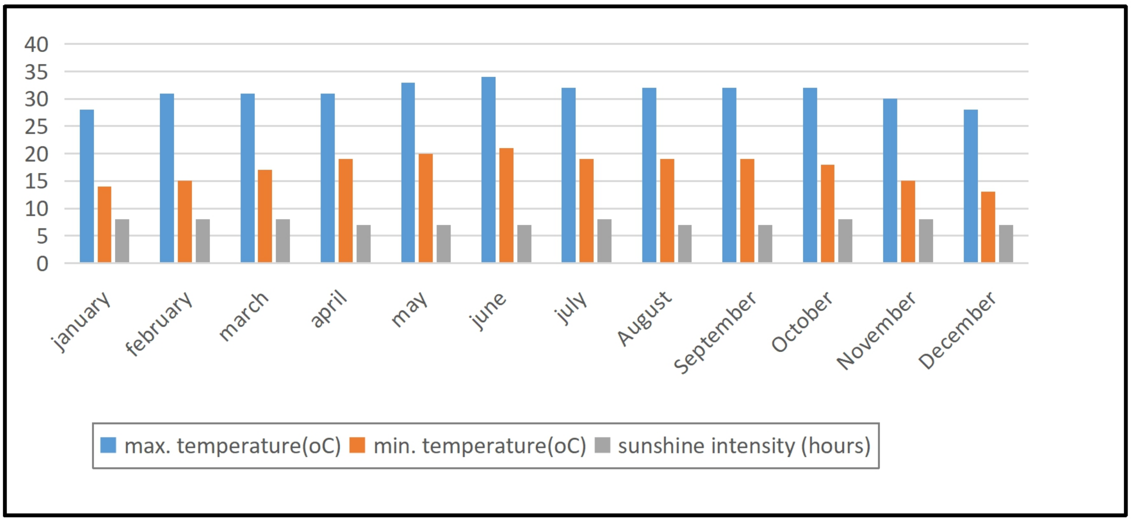



Figure 2. Seasonal distribution of temperature and sunshine of Dire Dawa city

(Source: Dire Dawa meteorological agency, 2021).

Two rainy seasons, known as March-April and July-September, account for approximately 70% of the overall average annual rainfall. Wind blows dominantly in the north-south direction, with a slight northerly direction during December-February and southerly during June-August. Its average annual speed is 4.5m/sec the following Figure 3 gives a seasonal distribution of rainfall and humidity of the city

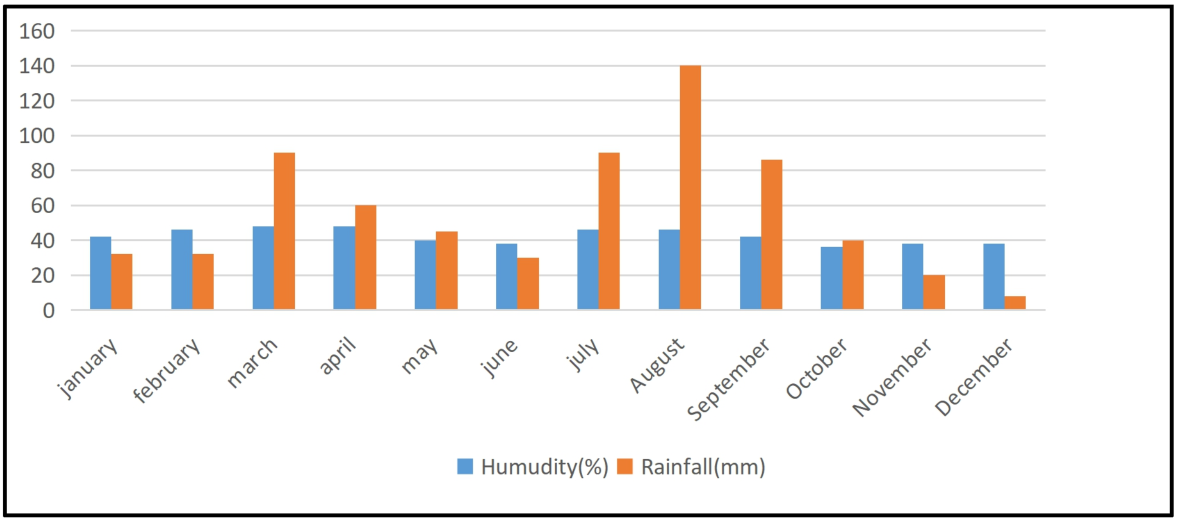



Figure 3. Seasonal distribution of rainfall and humidity of Dire Dawa city

(Source: Dire Dawa meteorological agency, 2021).

The natural environment of the Dire Dawa administration is under extreme threat due to the interaction of several factors (natural and human-made), land degradation aggravated by soil erosion and loss of soil fertility, deforestation and overgrazing with their concomitant impact on the loss of biodiversity and water resource degradation are the challenging problems of the Administration (EEP, 2017).

### 3.1.4 Soil conditions

The nature of the soil resources depends upon the type of landforms, parent material, altitude, climate, geology, and topography of the area. In this regard, shallow and infertile soils are the characteristics of the mountain and hills while deep and fertile soils are the major features of the valley bottoms, river terraces, and flat plains of DDA. A recent soil survey study of DDA by Water Works Design and Supervision Enterprise has identified several soil units. Among the identified soil units, the most important ones are Cambisols, Eutric Cambisols, Calcaric Cambisols, Eutric Vertisols, Fluvisols, Calcaric Fluvisols, Regosols, Leptosols and Arenesols (EEP, 2017).

The interaction of several factors accelerates the process of soil erosion, which in turn accelerates the process of land degradation(Gebremedhin, 2019). The following are among the major causes for accelerated soil erosion in Dire Dawa Administration: Heavy Rainfall, subsurface flow, overgrazing, erodible nature of the soil, deforestation, cultivation of steep lands and Poor farming Practice, steep slopes, undulating and rugged terrain, improperly laid out and constructed roads, and improper exploration of construction materials (EEP, 2017).

### 3.1.5 Economic conditions and livelihood activities

Dire Dawa's strategic geographic location between Addis Ababa and the port of Djibouti has accorded it various economic and commercial advantages. It serves as a transit and terminal for the import and export of commodities and services. Import-export trade thus characterizes the town's economic structure (EEP, 2017).

In Dire Dawa city, trade and industry are the predominant of its economy and the city is acknowledged well to be a center of trade and industry in East of Ethiopia. The majority of the people who live in the city center directly or indirectly derive their livelihood from trade, industry, and related activities. According to earlier studies, the trade and service giving sectors employ 30% of the economically active population of the town, followed by manufacturing with 16% and transport with 9%. The study further mentions that among the economically active population of the city, over 55% were employed in the private sector. It also indicated that 55.24% of the adult population was economically active and 35% were unemployed (EEP, 2017).

But when it comes to the areas where the proposed well fields are to be implemented which, of course, are the subject of this Resettlement Action Plan (RAP), they are inhabited by farming households whereas Boren is mostly pastoralist. The proposed Tome well field is occupied by urban dwellers that directly or indirectly derive their livelihood from petty trade and related activities.

### 3.1.6 Housing

Although shelter is the basic necessity and right of human beings, it is one of the major challenges Dire Dawa city faces in its endeavor to bring about sustainable development. The housing problem in Dire Dawa is not only of quantity but the quality of many housing units is also a prime concern. It is observed that out of the total housing stock, about 30.5

percent are built-up of wood and mud. Stone and cement houses constitute about 26.4 percent and about 17 percent of the houses are made up of stone and mud. The percentage share of houses built by hollow blocks and bricks is insignificant and constitutes about only 12.6 percent.

The present problem of residential houses in the city is putting pressure on unplanned growth of the city and poor quality of life. Moreover, high population growth, municipal ineffectiveness, high cost of construction materials, low level of income and saving, shortage of infrastructure, and shortage of financial sources, contributed a lot to the current gap between demand and supply of residential houses IDP (2006).

### 3.1.7 Infrastructure

In terms of the road network, Dire Dawa is connected with Addis Ababa by a recently upgraded asphalted road, which is about 510 km long. There are also several roads radiating from Dire Dawa and linking all the districts of the Dire Dawa City Administration. In addition, Dire Dawa is connected to all the major towns of Somali, Oromia, and Harar region and administrative regions in the west, southwest, and southern parts of Ethiopia through major link roads (EEP, 2017).

Transportation and communication facilities have a significant role in the development of the Administration as they facilitate efficient production, exchange, and distribution of goods and services as well as information and people to and from the Administration. The DDA is served by all modes of transportation and communication except for water transport. Ethiopian Electric Power Corporation is the sole electric power supplier in Dire Dawa. Power is distributed to the town from three substations, namely; the Sabian, the Legahare, and the Hnaz substation (EEP, 2017).

## 3.2 Method of Data collection

In this research, multiple data collection methods had been used to maximize the research benefits as shown in Figure 4. Both qualitative and quantitative data were collected using primary and secondary data collection methods. Primary data collection emphasis had been placed on field surveys using handheld GPS, open-ended questionnaires, and interviews with local expertise. Whereas secondary data collections included reviewed literature and policy analysis on urban land suitability analysis for residential areas and gathered spatial data from different institutes which were existed in a different format.

Questionnaires were formulated and used as a guide to collect data from experts, a form is attached in appendix I. The formulated questionnaires were distributed to five experts to answers the raised questions. Their inputs were used to understand the causes of the identified problem, parameters to be considered, data required and their availability to solve the problem, their suggestions on how to deal with the problem. While the interview focused on ordering and assigning weight to each criterion under investigation.

Field survey data were collected by the researcher using handheld (GPS) appendix II and III. The northing and easting coordinate data for Accuracy assessment of land use land cover and environmentally sensitive areas such as heavy industries, cemeteries, high voltage electric station, military camp playing ground, open space, recreational areas and health care services were collected and distributed over orthophoto of the city which was acquired in 2020. From the aerial photo the plot of each spatial data was extracted for further analysis. Secondary data which include: literature, urban land policies, reports, and different spatial data were obtained from various governments and non-government departments in various digital formats as shown in the Figure 4.

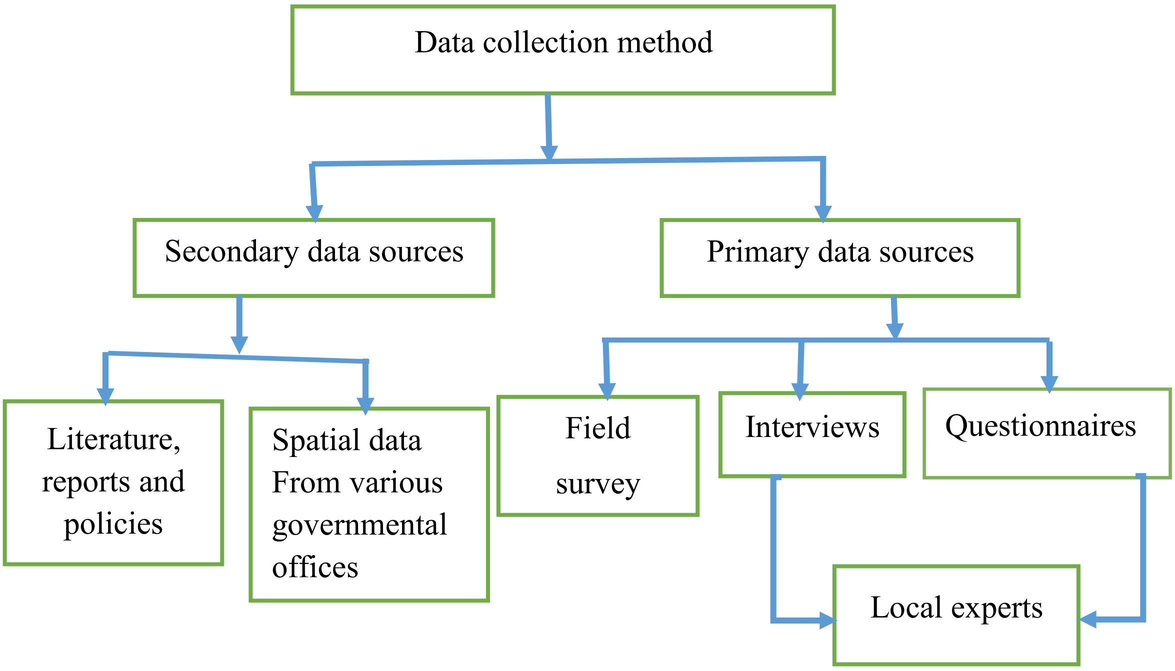



Figure 4. Methods of data collection

In this study, for each criterion, a suitability score was applied using a five-point scale to determine the qualitative rankings of the suitability on each criterion under consideration. The ranking ranges from 0 (restriction) to 4 (very high suitable). The scores understandable well since the higher the score, the more suitable the site is. Suitability classes are given below:

Unsuitable (0): This is attributed to areas with characteristics imposing certain constraints or restrictions, which cannot be overcome or legally excluded for the development of residential areas.

Low suitable (1): areas that are not good for residential development. A level of sites with characteristics imposing constraints which can be overcome but massive investment

Moderately suitable (2): areas moderately appropriate for residential housing development. It represents sites with good conditions in relation to a low suitable site, but it needs some improvements to make it better conditions**.**

High suitable (3): it denotes sites with good characteristics but may be slight challenges to develop residential areas which can be overcome by least investment.

Very high suitable (4): This is attributed to areas with characteristics imposing no significant constraints for future residential housing development. It represents optimal lands for the development of areas for residential housing activities.

### 3.2.1 Data types and sources

Table 3 shows the list of data and their sources along with their resolution and year of acquisition and the format of the data in detail.

Table 3: List of Data sets and data source

| Data type | Format | Source | Resolution | Year |
|---|---|---|---|---|
| Point data | Text | Field survey | | 2021 |
| Landuse plan | Shapefile | Dire Dawa Municipal, Land management office | 1:24000 | 2015 |
| Structural plan map | . dwg | Dire Dawa Municipal, Land management office | 1:24000 | 2004 |
| Topographic map | Shapefile | Dire Dawa Municipal, Land management office | 1:24000 | 2015 |
| Geological map | .jpg | Geological Survey of Ethiopia | 1:250000 | 1994 |
| Orthophoto | .jpg | Dire Dawa city urban land management office | 15 cm | 2020 |
| Population data | Text | Statistical Agency (CSA) Dire Dawa branch | | |
| Contour | Shapefile | Dire Dawa Municipal | 30 | 2015 |
| Soil class-map | Shapefile | Dire Dawa city Ministry of Energy and Water resources | | 2004 |
| Climate data | Text | National Metrology Agency Dire Dawa branch | | 2021 |

### 3.2.2 Instruments and Software

ArcGIS desktop is widely used software for this study. The three components of ArcGIS desktop like Arc Map, Arc Catalog, and Arc Toolbox have been used to create the geodatabase, editing, data management and storage, geo referencing data from different sources, performing spatial multi criteria analysis, generating criteria maps and assigning weightage for each criterion, overlaying, analysis and visualization of output data (Asefa & Mindahun, 2020).

In this study, ERDAS imagine 2015 was also another software used to process aerial photo and prepare land use land cover of study area which was then became input for analysis in GIS environment. Furthermore, IDRISI is a comprehensive geographic analysis and image processing system that has been developed by Clark Labs for Cartographic Technology and Geographic Analysis at Clark University, South Carolina, USA. This software has been used to perform multi criteria decision analysis using the built-in decision support module. Garmin handheld GPS was utilized in this study for collection of spatial data and identification environmental sensitive area during field survey (Table 4)

Table 4: Lists of software and instrument used

| No. | Facility and software | Purpose |
|---|---|---|
| 1 | ArcGIS 10.7 | Spatial data processing, analysis, and output generation |
| 2 | ERIDAS imagine 2015 | Aerial photo processing and land use land cover preparation |
| 3 | Idris32 | To drive the eigenvector weights of each factor |
| 4 | GERMIN handheld GPS | To collect coordinate data from field |
| 5 | Google Earth Pro. | To verify and validate the result with the existing situation |
| 6 | Microsoft Word and Excel | Integrate attribute data and composite final thesis |

### 3.3 Data preparation for analysis

#### 3.3.1 Spatial location of environmentally sensitive areas

The spatial location of environmentally sensitive areas as a result of a field survey conducted using handheld GPS including existing health care services, landmarks, cemeteries, heavy industries was identified on digital orthophoto. Next, each plot of these features was digitized in ArcGIS and incorporated with other constraints to preserve them from the analysis as they are legally restricted to build residential houses on them.

### 3.3.2 Geo-referencing

Raster datasets which are obtained by scanning maps usually do not contain the locational information on the surface of the earth and need to be geo-referenced. Geo referencing is the process of assigning a coordinate system that associates the data with a specific location on the earth in real-world coordinate system.

In this study, the initial data format of geological data was in the form Jpg and it was not georeferenced. Hence, control points were selected in the input raster dataset and the output location was specified by typing in the known output coordinates. First, eight grid line intersections as control points with uniform distribution were selected on the input raster data and their ground coordinates of grid are recorded. Next, in ArcGIS software, using geo-referencing function coordinates of all control points were registered to their respective grid intersection point.

Root Mean Square Error (RMSE) for all control points was computed using geo-referencing function to estimate their positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and known ground coordinate values entered. Since positions will be determined with millimeter accuracy, the RMSEs standard was set to 0.5millimeters. Finally, the map was rectified with acceptable root mean square error (RMSE) of each point. The root mean square (RMSE) for geological map was computed as 0.047mm.

### 3.3.3 Geodatabase development

A geodatabase is the physical storage of geographic information (spatial, aspatial, metadata, and relationship) inside a relational database management system. It contains layers vector data representing features and raster data representing images and grid surfaces. Each layer represents particular types of features that have been used for spatial analysis. In this study, a common personal geodatabase was built using Universal Transverse Mercator projection system world geodetic system 1984 to store, query, and manage both spatial and non-spatial data that could be used for the final analysis to achieve the proposed objectives.

Feature datasets were created for the area and line feature geometry in single personal geodatabase. Using ArcGIS functions, city boundary, road network, and rivers lines, and fault lines were digitized from Georeferenced maps and orthophoto and then stored in a common personal Geodatabase which is shown in Figure 5. Next, topology was created and applied for all datasets and digitization errors were corrected.

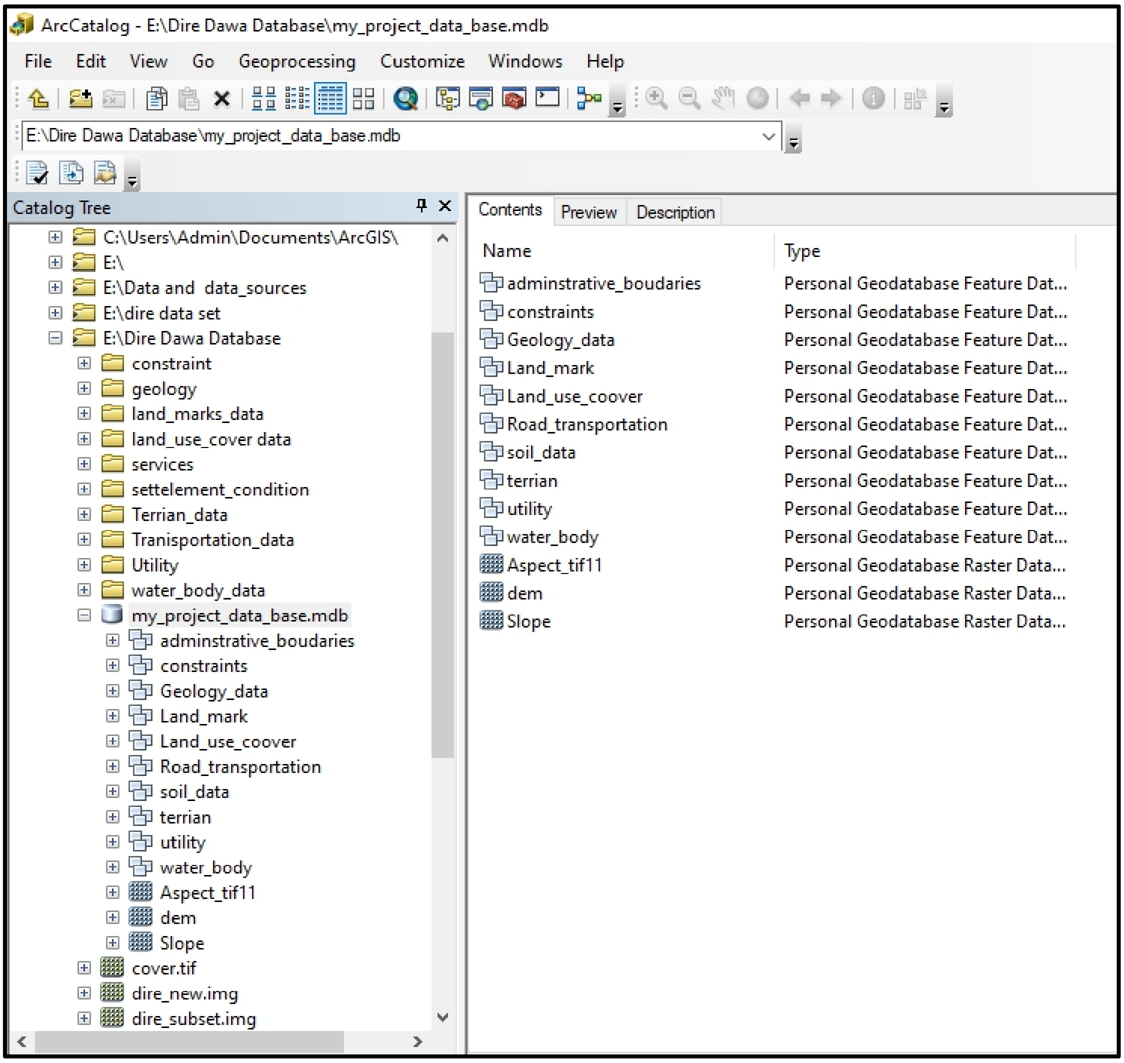



Figure 5. Developed geo-database for the study

### 3.3.4 Layer extraction (Digitization)

Digitization is the process where features on a map or image are converted into digital format for use by a GIS. This can be done by either manual or automation technique. In this study, on-screen digitization was performed to extract layers that represent criteria for decision making.

Using ArcGIS functions, flood paths, fault lines, and road networks were digitized from Georeferenced map and orthophoto and entered into a common personal Geodatabase. Then, topology was created and applied for all datasets, and digitization errors were corrected.

### 3.4 Methods of data analysis

The data analysis process of urban land suitability analysis for residential areas involves numerous factors with complicated correlations. Therefore, the Geospatial technique with multi-criteria spatial analysis techniques and The Analytic Hierarchy Process (AHP) approach has been used to address the proposed study. The methodological procedure of urban land suitability analysis for identification of optimal residential areas is presented well the following in Figure 6.

#### 3.4.1 Reclassifying or rescaling values of a set of rasters

The Reclass tools are used to allow the researcher to reclassify or change input cell values to alternative values. In this study, all thematic layers were converted to raster, and then raster reclassification using reclass tool of ArcGIS 10.7 was adopted to reclassify the old value to the new one. The reason behind reclassifying raster data was to:

- Replace new values with the old ones based on new information;
- Group certain values and
- Reclassify values to a common scale of measurement.

#### 3.4.2 Spatial multi-criteria decision making (MCDM)

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and was introduced by Saaty (1980). AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub-criteria, and alternatives uses the fundamental scale of absolute numbers to express individual preferences or judgment below this scale consists of nine points (Table 5).

In general, nine objects are the most, which an individual can simultaneously compare and consistently rank. The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion. To ensure the credibility of the relative significance used, AHP also provides measures to determine the inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR< 0.1indicates that level of consistency in the pair-wise comparison is acceptable. Saaty (1980) Suggested that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable (Table 5). But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and the AHP method may not yield meaningful results (Chu & Liu, 2002).

Table 5: The preference scale for pairwise comparison

| Intensity of importance | Definition |
|---|---|
| 1 | Equal importance- two activities contribute equally to the objective. |
| 3 | Moderate importance- Experience and judgment slightly favoring one activity over another. |
| 5 | Essential or strong importance- Experience and judgments strongly favor one activity over another |
| 7 | Very strong / demonstrated importance-An activity is strongly favored and its dominance is demonstrated in practice |
| 9 | Extreme importance- The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | intermediate values between the two adjacent judgments when the above numbers compromise is needed |
| 1/3,1/5,1/7,1/9 | Reciprocal values of the previous appreciation |

Source: Adopted from Saaty (1980)

### 3.4.3 Boolean Overlaying

In this study, Boolean overlay analysis was computed to prepare a composite constraint map which was later on multiplied with a weighted overlay map to further restrict areas of unsuitable from suitability result. A Boolean raster contains two possible values, ones or zeros. One corresponds to a true result where the area of study is suitable for analysis, whereas zero corresponds to a false result where the area of study is unsuitable and excluded from the analysis.

Ten constraints were identified in this study namely built-up area, waterbody, fault lines, high voltage electric lines, high voltage electric station, cemeteries, heavy industries, military camp, railway, and airport. These were integrated and composite constraint maps were produced. The produced constraint maps have two values, value one represents for true which means the possibility of areas of interest to do suitability analysis whereas zero value represents for false which means the impossibility of the areas for suitability analysis, was multiplied with a weighted overlay map to restrict unsuitable areas from suitability index.

### 3.4.4 Weighted overlay analysis

The Weighted overlay approach is the most commonly used GIS-based decision rules technique ((ESRI), 2015). One of its most common applications is to solve land-use suitability analysis and site selection, the decision-maker determines and assigns the weights of relative importance directly to each attribute map layer (Tesfaye,2017). The total score for each alternative under consideration is the product of the importance weight assigned to each attribute multiplied by the scaled value given for that attribute to the alternative and then summing the product's overall attributes. The scores are calculated for all of the alternatives. The one chosen is that with the highest overall score. The method can be executed using any GIS system with overlay capabilities.

The use of this method allows the evaluation criterion map layers to be combined to determine the resulting composite map layer. Using the weighted linear combination, factors are combined by first applying a weight to each factor, followed by a summation of the results to yield a suitability map. The GIS overlay process can be used to combine the factors and constraints in the form of a Weighting Overlay process and the result is then summed up producing a suitability map (Al-shalabi et al., 2006). Equation 3 represents the general formula Suitability Map = Σ [ factor map (cn) * weight (wn) * constraint(b0/1)] Equation 3 Where, c n = standardized raster cell, wn = weight derived from AHP pairwise comparison, and b0/1 = Boolean map with values 0 or 1

### 3.5 Conceptual framework and flowchart of the analysis

In this study, there were five important steps to analyze urban land suitability maps for residential areas. These are: (1) determining influencing parameters to be used in the analysis for decision making, (2) assigning factor priority, weight, and class weight (ranking) to the parameters involved, (3) Delineating constraints by developing a Boolean constraint map to exclude from the analysis (4) Developing weighted overlay analysis and determine overall suitability of the entire study area and (5) Validate the suitability by comparing with the proposed land use plan of the study to further restrict the suitability. The details of the conceptual framework and each processing step are shown in Figure6.

MCDA technique is applied to incorporate decision maker’s judgment and preferences using the AHP method. This method includes the selection of the criteria for the spatial Multi-Criteria Evaluation (MCE) technique for the suitability analysis for residential areas.

The final step involved in AHP is the aggregation of the relative weights obtained at each level of the hierarchy to calculate the suitability index. ArcGIS is used to combine the spatial data with the suitability index so that a continuous land suitability map is generated. The output is an urban land suitability map for residential areas.

In general, Figure 6 summarizes the overall methods, techniques, and approaches used to carry out this study, to analyze urban land and identify suitable areas for future residential housing development in Dire Daw City.

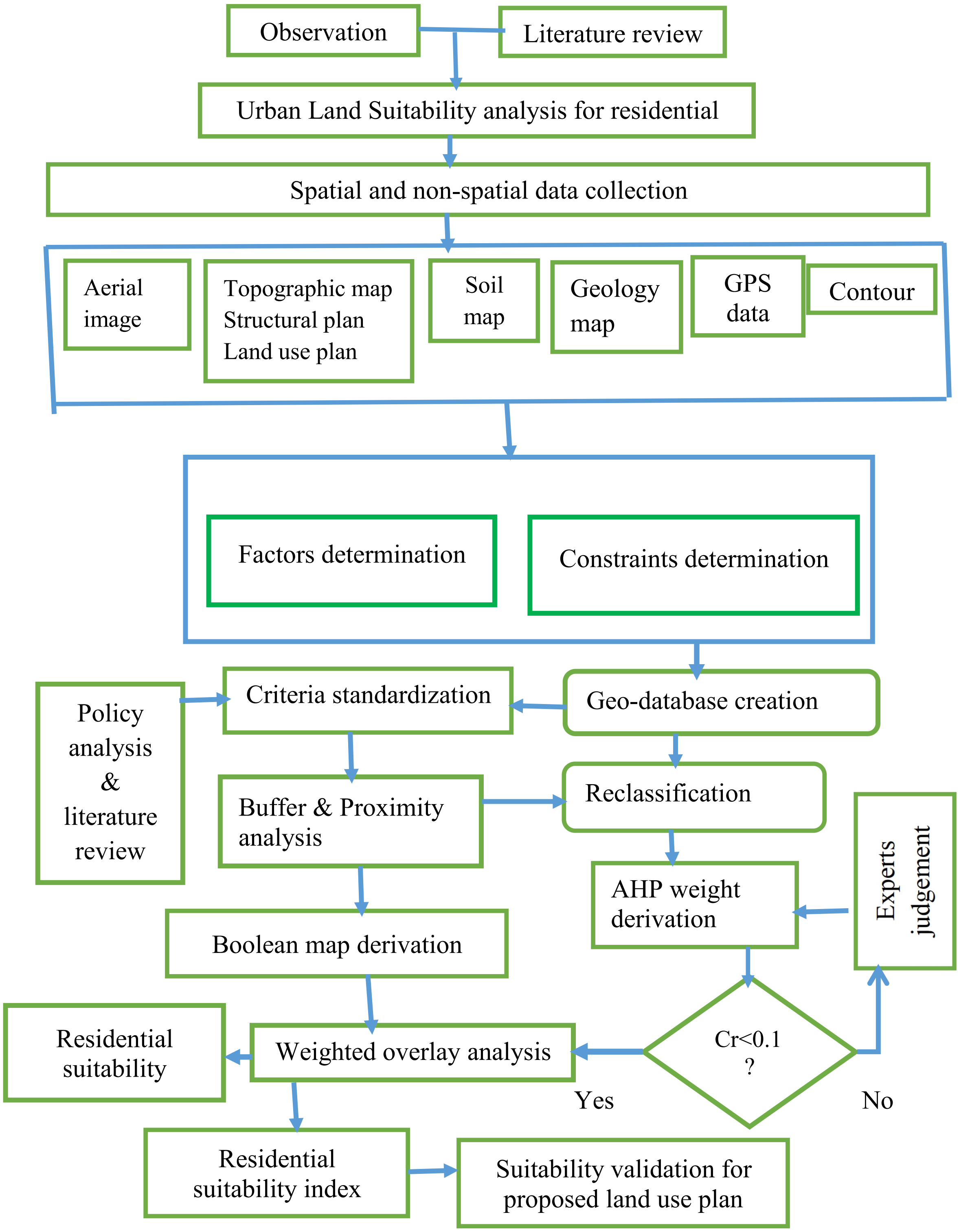



Figure 6. General workflow of the study

# CHAPTER FOUR

# 4. RESULTS AND DISCUSSIONS

## 4.1 Influencing Criteria for residential suitability analysis

By synthesizing literature reviews, expert opinions, and available data, a wide variety of criteria (factors and constraints) have been selected to achieve the objectives of this study. Accordingly, the reviewed literature to determine criteria that influence the suitability of urban land of study area include: Rahim et al., (2014); (NBC, (2016); (MUDC, (2012); Murseli & Isufi (2014); Al-Shalabi et al., (2006); Ullah and Mansourian (2015); Raghunath (2006); Ekanayaka (2014) and Huang et al., (2019). Five experts were also selected from the Dire Dawa city municipality office. Accordingly, Urban planners (Mr. Tilahun and Chala) from Dire Dawa city, recommended to consider accessibility of transportation, distance from floodplain, availability utilities, terrain conditions, Soil conditions, legal conditions on urban land development and proximity to recreational area) while Mr. Dereje and Efrem, who are experts from urban land managements were also recommended me to focus on the land use land cover, legal aspects, Proximity to developed areas and compatibility with land uses),whereas Mr. Gebeyo also recommended me the same criteria mentioned above.

Accordingly, four major criteria which include: Legal, economic, environmental, and natural parameters were identified. These criteria further classified into the following:
A) Naturally hazards areas like flooding sheet and water body, fault lines
B) Environmentally sensitive areas including heavy industry, airport, railway, high voltage electric stations and electric lines, military camp.
C) Proximity to developed areas and compatibility with land uses;
D) Proximity to main roads of the city;
E) Land use land cover conditions and development requirements of local development regulations, use standards and other applicable state regulations, and applicable federal regulations;
F) Availability of utility, including water, electric transmission;
G) Proximity to neighbors' amenities like recreational areas and health care services and
H) Soil and topographic conditions such as slope and aspects.

In parallel to the identified factors, eleven criteria including slope conditions, aspect conditions, soil conditions, land use land cover conditions, proximity to main roads, built-up areas, proximity to natural hazardous areas (flood plain), proximity to amenities (health care and recreational areas accessibility) and proximity to utilities (accessibility to water supply line and electric transmission line and Ten constraints namely: airport, railway station, built-up areas, cemeteries, waterbody, heavy industries, military comp, fault lines, high voltage stations and high-tension electric lines were also identified (Al-Shalabi et al., 2006; MUDC, (2012); Murseli & Isufi 2014; Rahim et al., 2014 Ullah and Mansourian ,2015; NBC, 2016). These criteria (factors and constraints) were considered highly specific and relevant for the study area. The factors were selected to evaluate and identify the most suitable areas for future residential housing development to satisfy the demand for land for housing purposes while utilizing it.

### 4.1.1 Determined weight values for influencing criteria in AHP

The prioritization of the suitability criteria and the computation of influencing weights were the necessary steps in site suitability analysis. therefore, the influencing weight of all criteria was generated using 9 class values applied in each factor based on their relative importance (Satty,1980). The attributes of all factors were standardized by transforming the original values to a suitability value using a suitability scale from 1 - 9 (Saaty T., 1997). The eigenvector weights of eleven factors are computed using decision support wizard IDRISI 32 software (Eastman,1995) with the supports of expert judgments (Chandio et al, 2014). figure 7 and Table 7 show the in-put value of pair-wise comparison using nine points continuous rating scale and the derived eigenvector of all criteria.

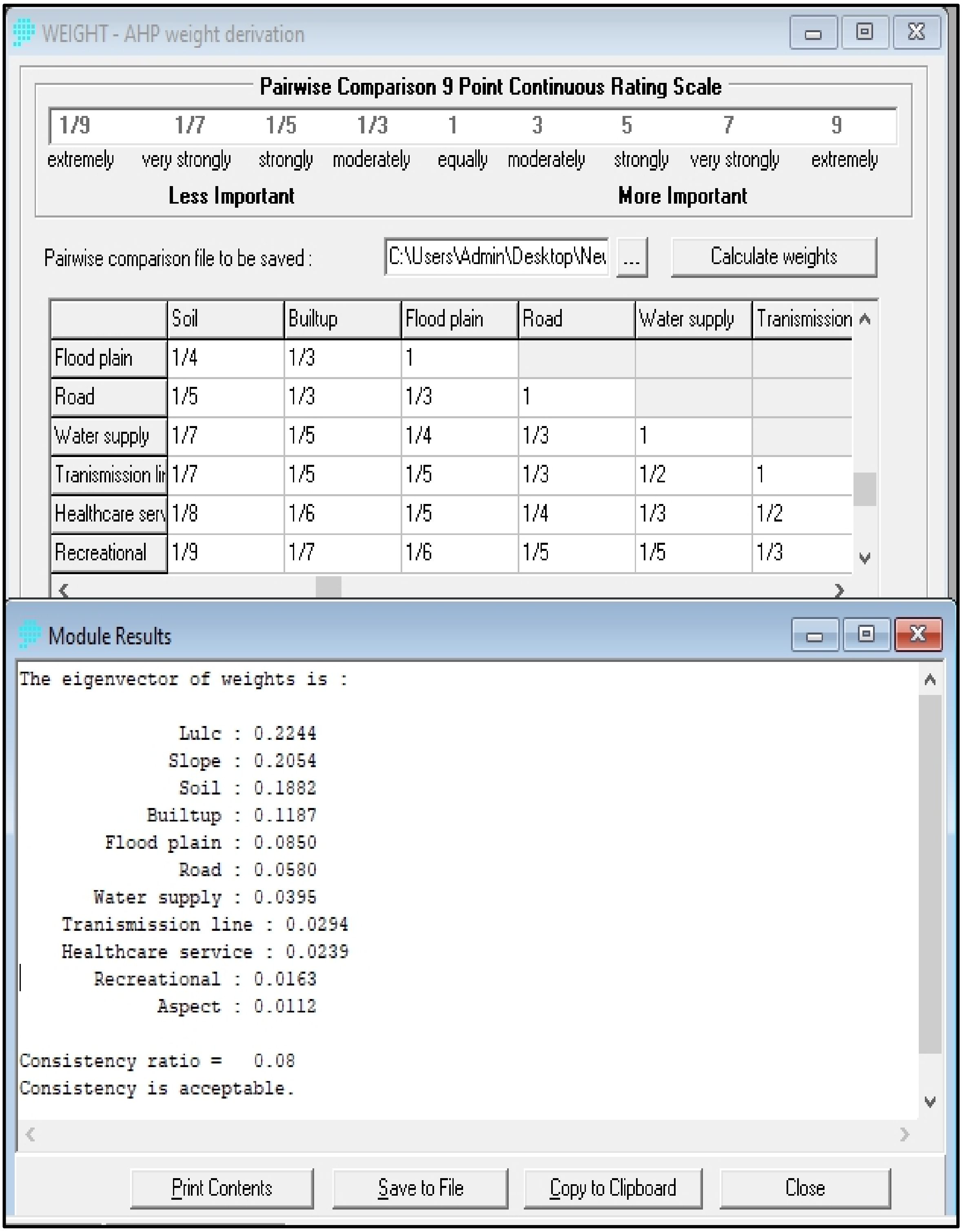



Figure 7. Weight derived by AHP methods

Table 6: Pairwise comparison and weight derived by AHP method

| Factor | Lu/ Lc | Sl | So | BU | FP | Rd | WS | ET | HC | R | A | Weight | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lu/Lc | 1 | | | | | | | | | | | 0.2244 | 22.44 |
| Slope | 1/2 | 1 | | | | | | | | | | 0.2054 | 20.54 |
| So | 1/2 | ½ | 1 | | | | | | | | | 0.1882 | 18.82 |
| BU | 1/3 | 1/3 | 1/3 | 1 | | | | | | | | 0.1187 | 11.87 |
| FP | 1/4 | 1/5 | 1/4 | 1/3 | 1 | | | | | | | 0.0850 | 8.50 |
| Rd | 1/5 | 1/5 | 1/5 | 1/3 | 1/3 | 1 | | | | | | 0.0580 | 5.80 |
| WS | 1/5 | 1/5 | 1/7 | 1/5 | 1/4 | 1/3 | 1 | | | | | 0.0395 | 3.95 |
| ETL | 1/6 | 1/6 | 1/7 | 1/5 | 1/5 | 1/3 | ½ | 1 | | | | 0.0294 | 2.94 |
| Hcs | 1/7 | 1/7 | 1/8 | 1/6 | 1/5 | 1/4 | 1/3 | 1/2 | 1 | | | 0.0239 | 2.39 |
| R | 1/7 | 1/7 | 1/7 | 1/7 | 1/6 | 1/5 | 1/5 | 1/3 | 1/3 | 1 | | 0.0163 | 1.63 |
| A | 1/9 | 1/9 | 1/7 | 1/9 | 1/7 | 1/7 | 1/5 | 1/5 | 1/5 | 1/3 | 1 | 0.0112 | 1.12 |

Consistency ratio (Cr)= 0.08<0.1 so consistency is acceptable ∑ weights= 1; ∑% = 100 Lulc= land use land cover, Sl= slope, so = soil, BU =built up, FP = flood plain, Rd = road, A= aspect, WS = water supply, ET= electric transmission line, Hcs = Healthcare services, R= Recreational

### 4.1.2 Ranking the Suitability of influencing criteria

The FAO classification model for suitability is widely used in the studies of land suitability analysis (Qiang and Ping, 2000; Zhang, 2003; Aburas et al.,2017). So, this study classifies suitability levels into five classes as unsuitable, low suitable, moderately suitable, high suitable, and very high suitable. According to established criteria and ranked on a simple five-point scale from 0 to 4. Criteria Ranking Scores 0 = unacceptable (undesirable/least cost-effective), 1= poor, 2 = fair,3 = good,4 = excellent (most desirable/most cost-effective) (ICEFP, 2004)

## 4.2 Suitability of urban land for future residential land use in Dire Dawa city

### 4.2.1 Slope suitability conditions

In this study, a maximum slope of 25% is assumed. Accordingly, the area was classified in to five slope classes:<2%, 2-8%, 8-15%, 15-25%, and >25% (Table 7; Figure 8). Slope can be described as the ratio of rising/fall divided by the run between two points. It indicates the steepness, incline, or grade. The sites on or near cliffs are not suitable for facilities like roads, water supply, electricity, and so on, are much more costly in comparison with the flat areas (Seid,2007). NBC, (2016) suggested that no construction should be ordinarily undertaken in areas with slopes above 30% or in areas that fall in landslide hazard zones. Whereas, MUDC (2012) suggests that priority should be given for a comparatively gentle slope not more than 20% and a slope between 2 and 8% highly recommendable.

Table 7: Slope conditions suitability

| s/no | Slope (%) | Score | Suitability index | Area (Sq km) | Area (%) |
|---|---|---|---|---|---|
| 1 | <2 | 1 | Low suitable | 4.62 | 4.88 |
| 2 | 2-8 | 4 | Very high suitable | 63.20 | 66.8 |
| 3 | 8-15 | 3 | High suitable | 12.46 | 13.17 |
| 4 | 15-25 | 2 | Moderate suitable | 3.88 | 4.101 |
| 5 | >25 | 1 | Low suitable | 10.45 | 11.04 |
| Total | | | | 94.61 | 100 |

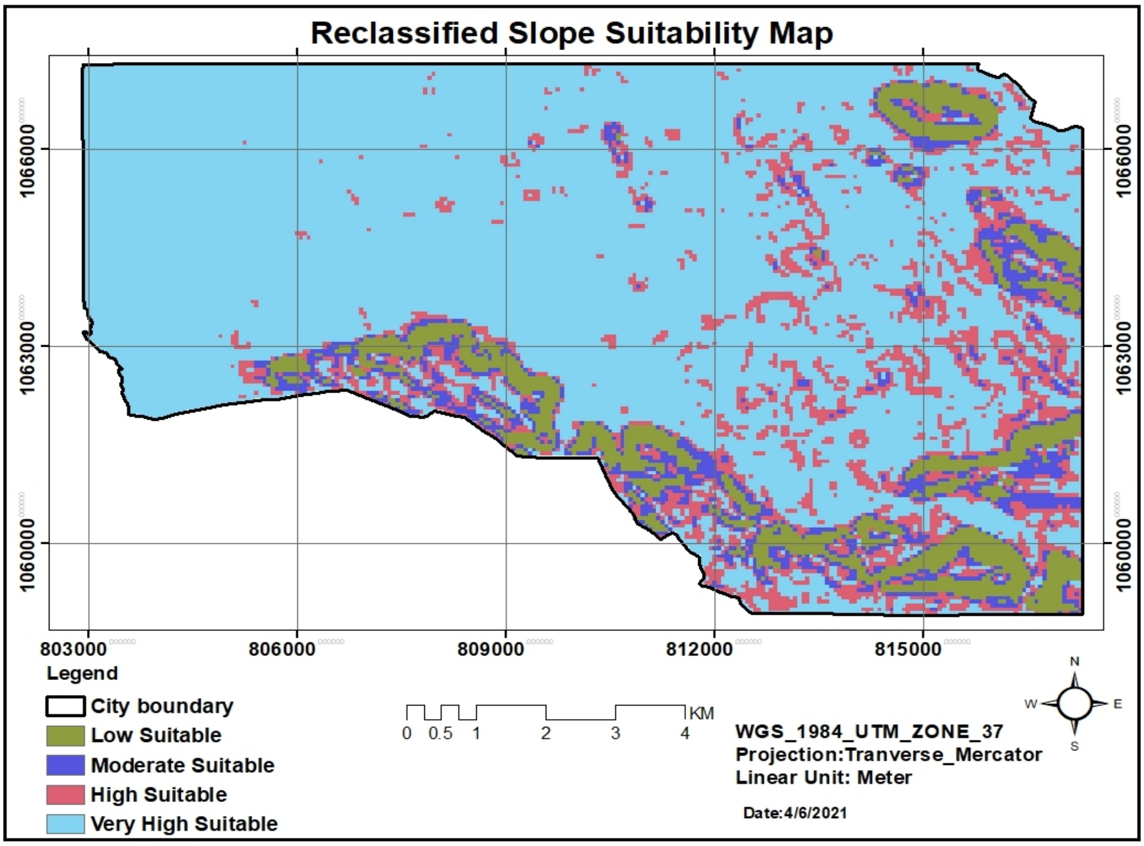



Figure 8. Reclassified slope condition factor

### 4.2.2 Aspect suitability conditions

In this study, aspect was computed from contour data and reclassified into suitability classes by considering experiences of the previous study (Figure 9). Hence, the eastern and western direction was considered to be more suitable. (Al-shalabi et al., 2006), (Murseli & Issue, 2014) used aspect conditions in their studies to find out suitable residential areas (Table 7).

Table 8: Aspect suitability analysis

| s/no | Aspect category | Score | Suitability index | Area (km$^2$) | Area (%) |
|---|---|---|---|---|---|
| 1 | N-NE-NW | 1 | Low suitable | 14.3 | 15.2 |
| 2 | E-W | 2 | Moderate suitable | 23.52 | 24.8 |
| 3 | SE-SW | 3 | High suitable | 30.51 | 32.22 |
| 4 | S | 4 | Very high suitable | 26.3 | 27.79 |
| Total | | | | 94.61 | 100 |

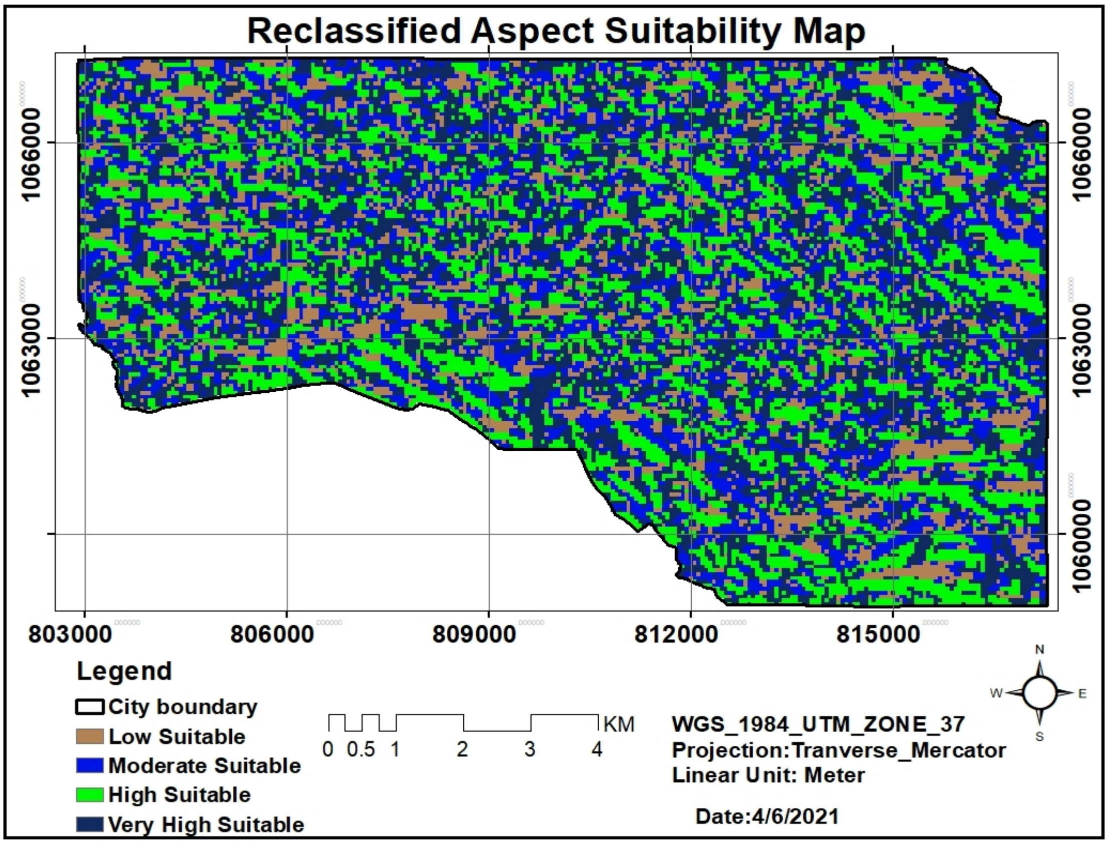



Figure 9. Reclassified aspect conditions suitability

### 4.2.3 Proximity to the main road suitability

In this research, main roads of the study area were extracted from aerial photo with reference to structural plan (Figure 10). Table 9 reveals more than 79.47% (75.67 km$^2$) of the land of the study area exist under very high suitable whereas only 0.67% (0.64 km$^2$) of the land of the study area fall under low suitable. Road accessibility is one of the important parameters for urban land suitability analysis as it provides linkage between the settlements. The distance to existing urban areas is important because the significantly impact moving costs and time, so the roads are an important factor in housing development because their presence indicates human activity (Seid, 2007). In the most residential area site assessments, the area further away from roads are considered less suitable than those closer to roads (Babban, Parry., 2001). Based on the fact, area with longer distance from the roads get the lower value score and the value scores increase with decreasing distance to main roads (Table 9). analysis Therefore, areas less than 1000-meter from the road are more suitable for urban development. Whereas area greater than 3000 meters from main road are least suitable.

Table 9: Proximity to main road suitability analysi

| s/no | buffer(m) | Score | suitability index | Area (sq. km) | Area (%) |
|---|---|---|---|---|---|
| 1 | <1000 | 4 | Very high suitable | 75.67 | 79.47 |
| 2 | 1000-2000 | 3 | High suitable | 13.77 | 14.46 |
| 3 | 2000-3000 | 2 | Moderate suitable | 5.13 | 5.40 |
| 4 | >3000 | 1 | Low suitable | 0.64 | 0.6722 |
| Total | | | | 94.61 | 100 |

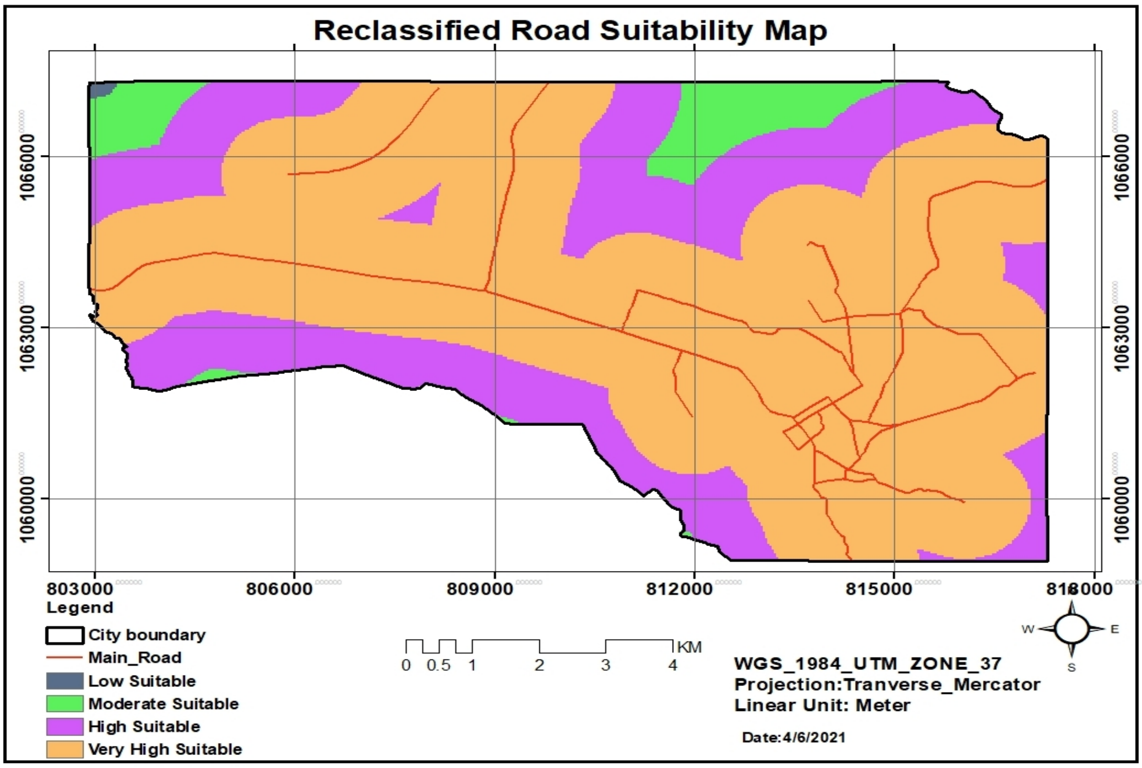



Figure 10. Reclassified road suitability map

### 4.2.4 Proximity to Urban built-up area suitability

A buffer of 500 M is normally considered in urban development studies. Table 10 shows that more than 65% of the land of the study area fall under low suitable. It is only 3% of the land is very high suitable (Figure 11). Therefore, areas within 500-meter buffer radius are more suitable for urban development than areas outside 500 M buffer limit. Built up area is considered due to the reason that the cost of future urban development depends on proximity to the built-up area (Raghunath, 2006).

Table 10: Proximity to Urban built-up area suitability analysis

| s/no | Buffer(m) | Score | Suitability index | Area (Sq km) | Area (%) |
|---|---|---|---|---|---|
| 1 | <500 | 4 | Very high suitable | 3.03 | 3.20 |
| 2 | 500-1000 | 3 | High suitable | 11.15 | 11.78 |
| 3 | 1000-1500 | 2 | Moderate suitable | 18.49 | 19.54 |
| 4 | >1500 | 1 | Low suitable | 61.94 | 65.46 |
| Total | | | | 94.61 | 100 |

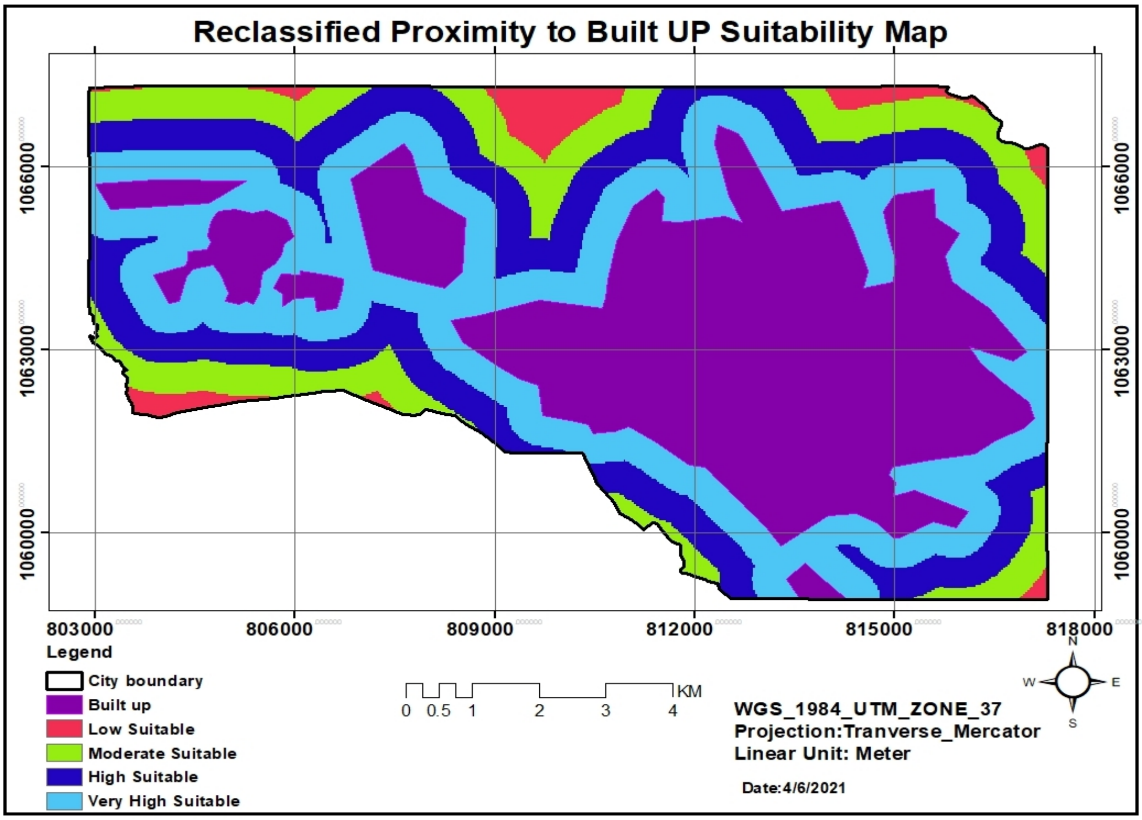


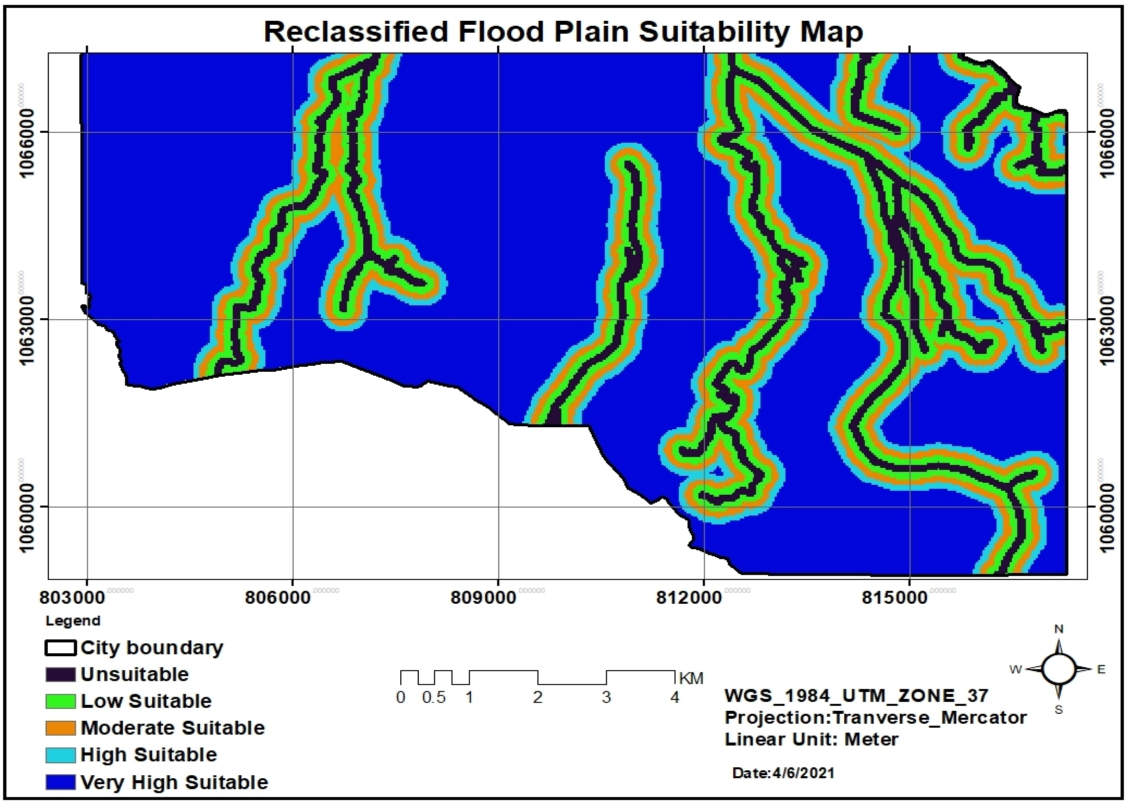

Figure 11. Reclassified built-up suitability map

### 4.2.5 Proximity to Flood plain suitability

A buffer of 30 meters radius to existing flood sheet areas were created to restrict from future residential housing development. Table 10 shows 62.25 % of total lands are falls under very high suitable. It is only 7.54% of land is unsuitable (Table 11; Figure 12). Murseli & Isufi, 2014) also suggested that no residential housing development is permitted within 30 meters on both sides of flood sheets areas. Therefore, areas greater than 500-meter from the river are more suitable for urban development than areas within 500 M buffer limit.

Table 11: Proximity to floodplain area suitability analysis

| s/no | Buffer(m) | score | suitability index | Area (km$^2$) | Area (%) |
|---|---|---|---|---|---|
| 1 | <30 | 0 | Unsuitable | 7.13 | 7.54 |
| 2 | 30-130 | 1 | Low suitable | 10.60 | 11.20 |
| 3 | 130 -230 | 2 | Moderate suitable | 9.44 | 9.98 |
| 4 | 230-500 | 3 | High suitable | 8.55 | 9.07 |
| 5 | >500 | 4 | Very high suitable | 58.89 | 62.25 |
| Total | | | | 94.61 | 100 |




F

igure 12. Reclassified flood hazard suitability map

### 4.2.6 Proximity to transmission line suitability

Table 12 shows that more than 36% of the land of the study area falls under low suitable. It is only 19.38% (18.34 km$^2$) of the land is very high suitable (Table 12; Figure. Murseli & Isufi,( 2014) suggests that areas that are less than 200 meters to electric transmission are the most suitable site, whereas areas greater than 2500 meters are the least suitable for residential areas development. Therefore, areas greater than 1000-meter from the electric transmission lines are less suitable than areas within the 1000 Meter buffer limit whereas, areas within a 200-meter buffer radius are the most suitable.

Table 12: Proximity to electric transmission line suitability

| S/no | Buffer(m) | Score | Suitability index | Area ($km^2$) | Area (%) |
|---|---|---|---|---|---|
| 1 | <200 | 4 | Very high suitable | 18.34 | 19.38 |
| 2 | 200-500 | 3 | High suitable | 16.72 | 17.67 |
| 3 | 500-1000 | 2 | Moderate suitable | 25.23 | 26.67 |
| 4 | >1000 | 1 | Low suitable | 34.31 | 36.26 |
| Total | | | | 94.61 | 100 |

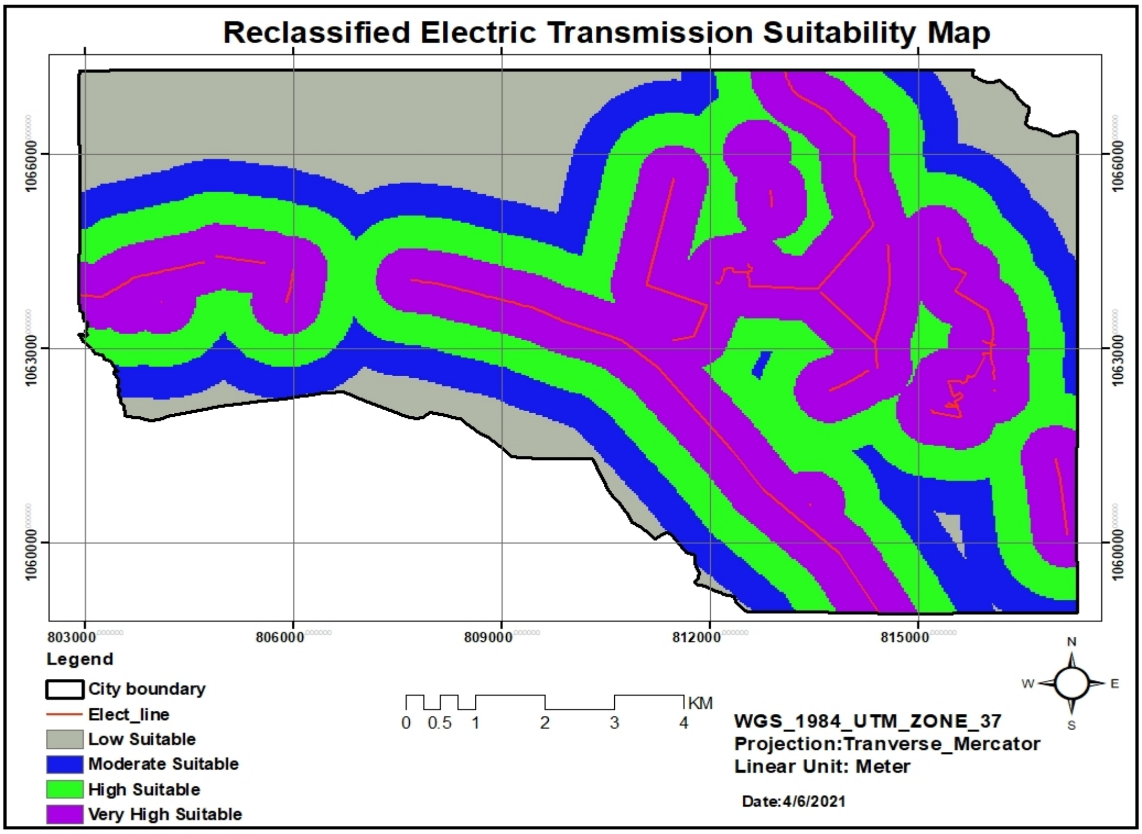



Figure 13. Reclassified transmission line suitability map

### 4.2.7 Soil suitability conditions

The result of this analysis show (Table 13) that loamy sand which is Very high suitable for future residential housing has the highest percentage of area coverage of the land of the study area while more than 23% of the land of the study area fall under low suitable. Figure 14 shows most of the lands of the study area in the central part and to the west are very high suitable. The texture is one of the most soil conditions that influence building construction stability. Clayey soils increase in volume due to absorption of water and may result in differential settlement of foundations resulting in their failure. Therefore, highly clayey soils are less suitable and sandy soils are more suitable for foundations of future residential housing development (Raghunath 2006).

The major soil types of Dire Dawa Administrative Council exhibit a general relationship with altitude and slopes. Fluvisols and Vertosols are generally dominating the region and particularly lowland flat plains, valley bottoms, and river terraces. Texturally these soils are sandy loam and sandy clay respectively. Shallow Leptisols are the dominant type of soil found in the mountain and hills of the region (WWDSE 2004).

Table 13: Soil conditions suitability analysis

| S/no | Soil class | Texture | score | suitability index | Area (km$^2$) | Area (%) |
|---|---|---|---|---|---|---|
| 1 | Flubisols | loamy sand | 4 | Very high suitable | 59.40 | 62.78 |
| 2 | Cambisols | Loamy | 3 | High suitable | 2.89 | 3.05 |
| 3 | Leptosols | Loamy clay | 2 | Moderate suitable | 9.83 | 10.40 |
| 4 | Vertosols | sandy clay | 1 | Low suitable | 22.49 | 23.77 |
| Total | | | | | 94.61 | 100 |

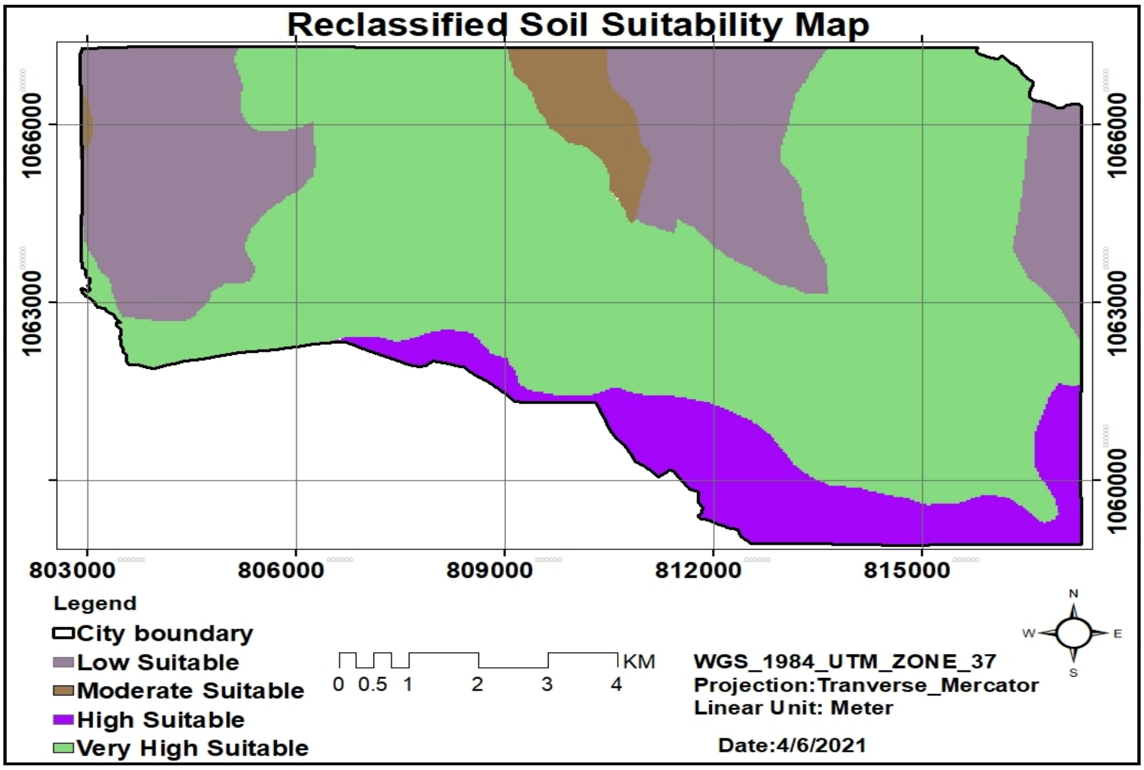



Figure 14. Reclassified soil suitability map

### 4.2.8 Land-uses land-cover suitability

According to national urban planning institute experiences, vacant (bare) lands are more preferable for future urban development. Therefore, baren lands are ranked as very high suitable followed by shrublands whereas built-up lands are already developed; thus, it was ranked as unsuitable for future urban development (Table 13; Figure 15).

Table 14: LU/LC classification and suitability analysis, 2021

| s/no | Category | score | suitability index | Area (sq km) | Area (%) |
|---|---|---|---|---|---|
| 1 | Built up area | 0 | Unsuitable | 33.0515 | 34.94 |
| 2 | Plantation | 1 | Low suitable | 9.8766 | 10.44 |
| 3 | Urban agricultural | 2 | Moderate suitable | 15.6231 | 16.51 |
| 4 | Shrub land | 3 | High suitable | 11.3364 | 11.98 |
| 5 | Bare land | 4 | Very high suitable | 24.7167 | 26.13 |
| Total | | | | 94.61 | 100 |

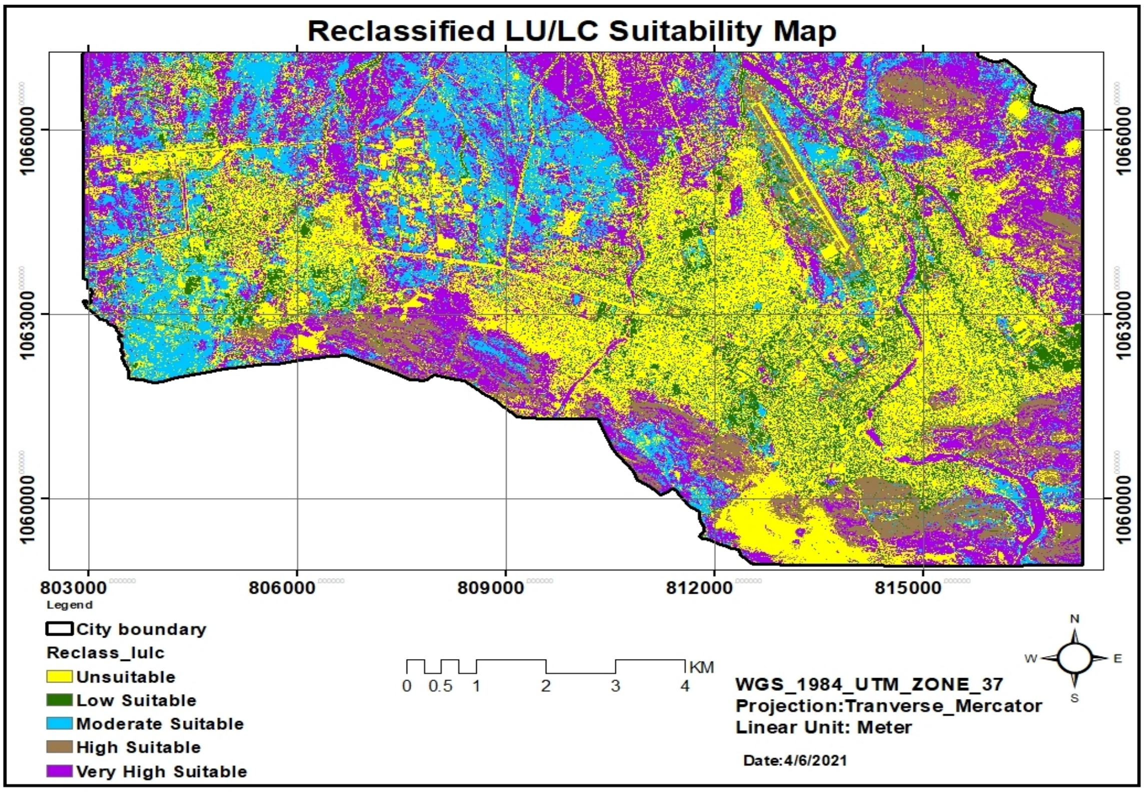



Figure 15. Reclassified land use land cover suitability map,2021

**Accuracy assessment**

The aerial photo of the city as of 2020 was classified using a supervised classification with an overall accuracy of 93.5% and its kappa coefficient (K) of 0.918. In this study, the producer's accuracy measures how well a certain area has been classified. Meanwhile, the user's accuracy is computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (Chauhan et al., 2016). Overall accuracy is calculated by dividing the total number of correctly classified pixels by the total number of reference pixels (Mishra et al., 2014). It shows an overall result of the tabular error matrix. The overall accuracy performed in the study was 93.5% (table 15). According to a reliable land cover classification, the minimum overall accuracy value computed from an error matrix should be 85% (Anderson et al. 1976). The pixel that has been categorized from the image was compared to the same site in the field (Anna et al., 2018). The result of an accuracy assessment typically provides the users with an overall accuracy of the map and the accuracy for each class in the map (anna et al., 2018). Besides, the overall accuracy, the classification accuracy of individual classes was calculated in the same way. The producer's accuracy is derived by dividing the number of correct pixels in one class divided by the total number of pixels derived from reference data (Pala & Ziaulb, 2017).

Table 15: Error matrix showing classification accuracy of the land use land cover

| | Built-up | Plantation | Agriculture | Shrub | Bare land | Total (user) | User accuracy | Producer accuracy |
|---|---|---|---|---|---|---|---|---|
| Built up | 14 | 0 | 0 | 0 | 1 | 15 | 93.33% | 100% |
| Plantation | 0 | 15 | 0 | 0 | 0 | 15 | 100% | 93.75% |
| Agricultural | 0 | 0 | 13 | 0 | 2 | 15 | 86.66% | 100% |
| Shrub | 0 | 1 | | 13 | 0 | 14 | 92.86% | 92.86% |
| Bare land | 0 | 0 | 0 | 1 | 17 | 18 | 85.71% | 85% |
| Total (producer) | 14 | 16 | 13 | 14 | 20 | 77 | | |

Overall accuracy= 93.5% and Kappa coefficient (T)= 0.918

### 4.2.9 Accessibility to Water supply lines suitability

A clean water supply is the most important determinant of public health. so, access to clean safe water is a basic human need. The result of the study reveals that 61.86% and 13.17% are low suitable and very high suitable respectively (Table 16; Figure 16). This implies that more than half of the area of Dire Dawa city falls under the least accessibility of water supply. However, a minimum level of service is vital to meet people's basic needs such as water for drinking, washing, and cooking and disposal of excreta and other wastes in a safe manner, for direct beneficiaries and the wider community (Seid, 2007). Murseli & Isufi, (2014) suggested that areas that are less than 100 meters to water supply lines are the most suitable site, whereas areas greater than 2000 meters are the least suitable for residential areas development.

Table 16: Proximity to Water supply line

| s/no | Buffer(m) | score | Suitability index | Area (Sq. km) | Area (%) |
|---|---|---|---|---|---|
| 1 | <100 | 4 | Very high suitable | 12.46 | 13.17 |
| 2 | 250 | 3 | High suitable | 11.36 | 12.01 |
| 3 | 1000 | 2 | Moderate suitable | 12.26 | 12.96 |
| 4 | >1000 | 1 | Low suitable | 58.53 | 61.86 |
| Total | | | | 94.61 | 100 |

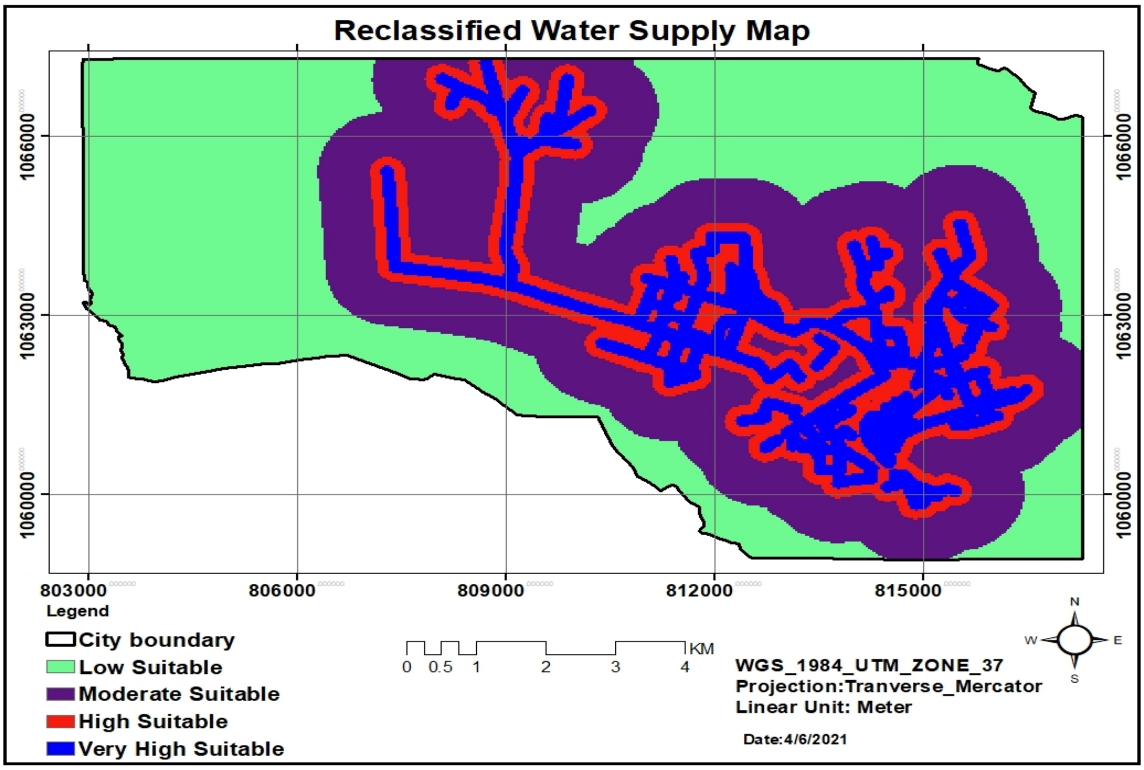



Figure 16. Reclassified water supply line map

### 4.2.10 Accessibility to recreational area

The result of the study reveals that 37.40%, 32.94%, and 20.32% are high suitable, moderate suitable, and very high suitable respectively (Table 17; Figure 17). It improves the climate, abates the heat-island effect by their ecological-balance function, reduces environmental damages, and ensures safety (IDP, 2006). Therefore, lands within 500-meter radius buffer to recreational areas are the most suitable for residential development while areas greater than 3000- meters are the least suitable Murseli & Isufi, (2014). Finally, a proximity analysis using multi buffer tools was applied to each layer of recreational areas for further analysis with others.

Table 17: Recreational area suitability

| s/no | buffer(m) | score | suitability index | Area ($km^2$) | Area (%) |
|---|---|---|---|---|---|
| 1 | ≤500 | 4 | Very high suitable | 19.23 | 20.32 |
| 2 | 500-1500 | 3 | High suitable | 35.39 | 37.40 |
| 3 | 1500-3000 | 2 | Moderate suitable | 31.17 | 32.94 |
| 4 | >3000 | 1 | Low suitable | 8.82 | 9.34 |
| Total | | | | 94.61 | 100 |

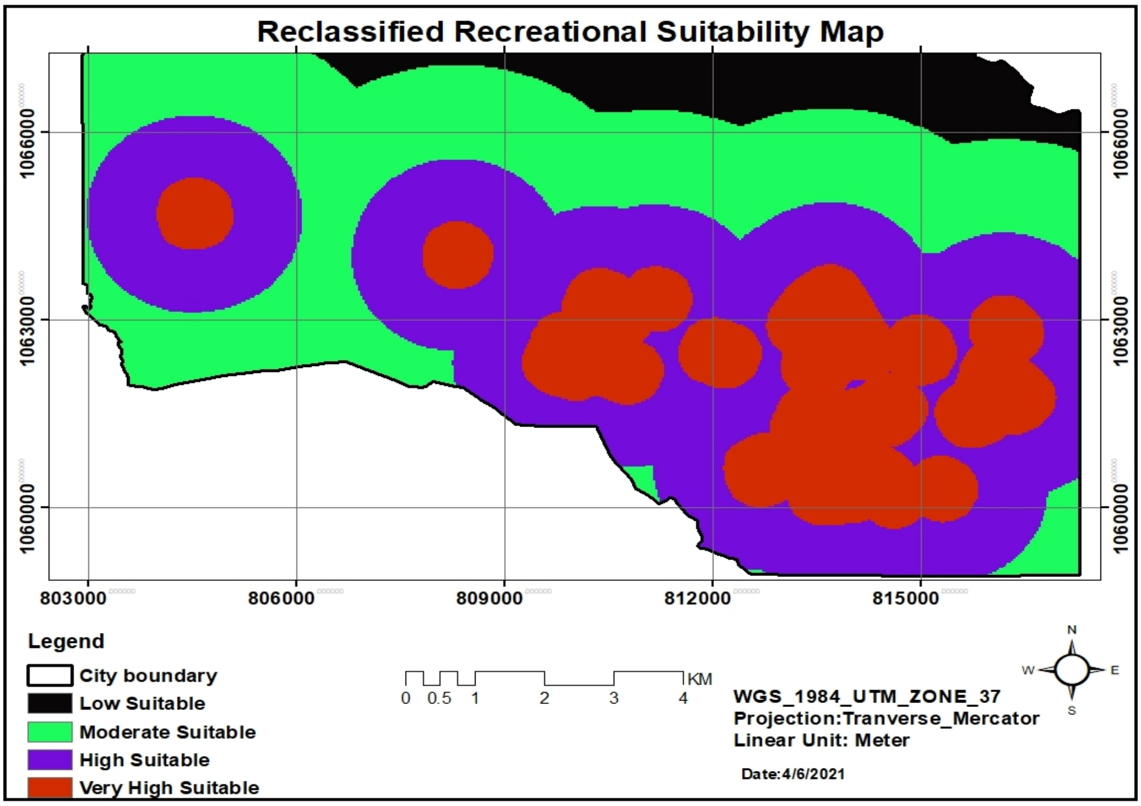



Figure 17. Reclassified recreational areas map

### 4.2.11 Health care accessibility conditions

In the study area, 44.39% of the area is highly suitable for healthcare facilities (Table 17). In the map it is also indicated in the blue color the place where very high suitable for health care facility (Figure 18). Murseli & Isufi (2014) in their study suggested that a residential area within 0.5 kilometer is very high suitable and suitability of residential area decreases as the distance increase**.** Therefore, areas within 500-meter radius buffer from the health care are the most suitable for urban residential development, whereas areas greater 3000 Meter radius are the least suitable.

Table 18: Healthcare suitability condition

| s/no | Buffer(m) | score | suitability index | Area (sq. km) | Area (%) |
|---|---|---|---|---|---|
| 1 | ≤500 | 4 | Very high suitable | 16.26 | 17.186 |
| 2 | 500-1500 | 3 | High suitable | 42 | 44.39 |
| 3 | 1500-3000 | 2 | Moderate suitable | 30.79 | 32.54 |
| 4 | >3000 | 1 | Low suitable | 5.56 | 5.876 |
| Total | | | | 94.61 | 100 |

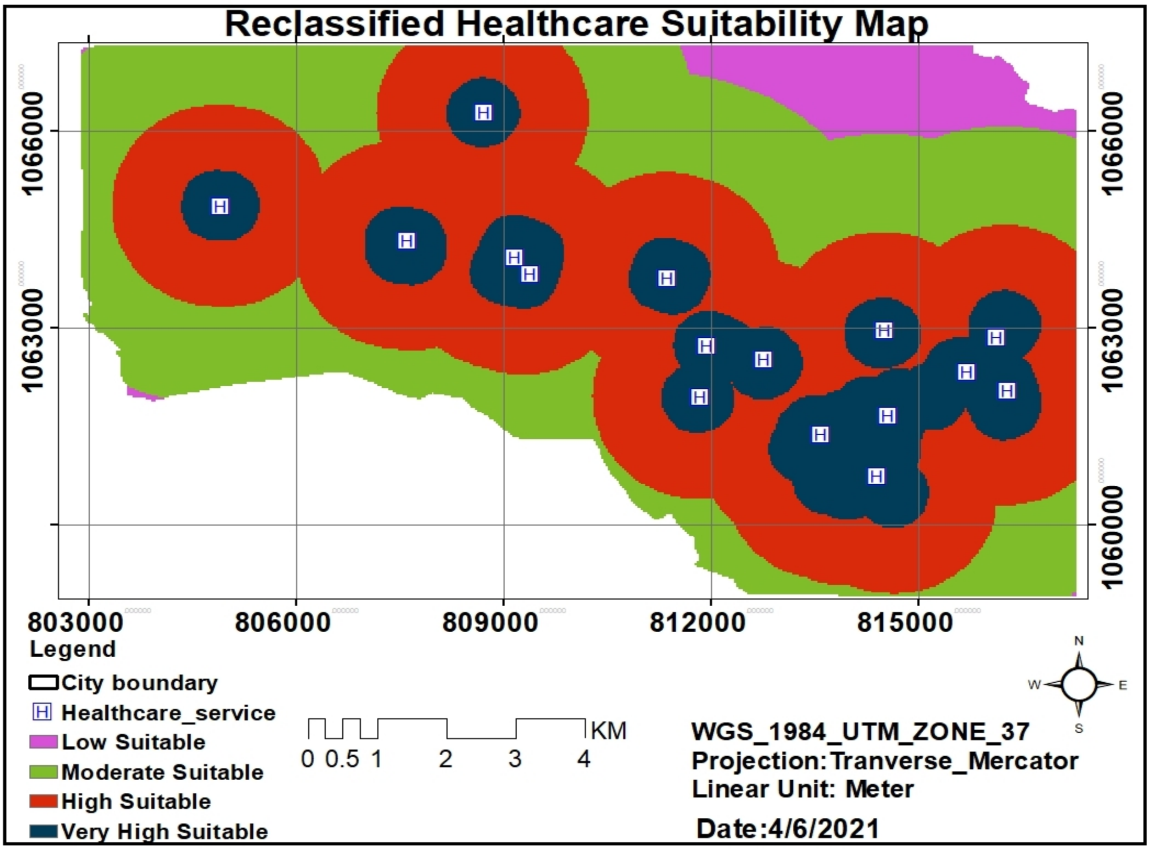



Figure 18. Reclassified healthcare suitability map

#### 4.2.12 Delineation of constraints land and Boolean overlay of constraints

The constraints in this study include; According to Rahim et al., (2014); (MUDC, (2012); Murseli & Isufi (2014; Al-Shalabi et al., (2006) and Ullah and Mansourian (2015) explained, high voltage electric lines, high tension electric stations, industrial areas, cemeteries, airport site, railway stations, waterbody, built up area military camp, and fault lines are constraints to there was delineated and restrict an area. These constraints are explained as follow

**High tension lines**: In this study, high tension electric lines were acquired from topographical map of study area. To avoid possible accidents that could be encountered because of the existence of high electronics movement, a buffer zones of 100 meters radius were created around high-tension lines. Area outside of the buffer zones are considered as suitable for future residential areas. Whereas, those areas within buffer zones are unsuitable. The result was incorporated to Boolean constraint map (Figure19). The residential site should be located at least 100 meters from high tension lines (Murseli & Isufi, 2014).

**High voltage electric stations:** these are high voltage power station which harms near settlement as it emits electronic pollution to the environment that causes different diseases like cancers. To avoid these problems a buffer zone of 100 meters was created for existing high voltage stations to exclude from the analysis (Murseli & Isufi, 2014). Therefore, lands within the buffer zones are unsuitable for future residential housing development. Whereas lands outside of the buffer zones are suitable.

**Military camps:** Military camps locations were collected from the field using handheld GPS. Their plots were digitized from aerial photo of the study. Buffer zones of 1000-meter radius were created around each existing military camp to exclude the area from future residential use for the safety purpose. From the goal of safety, the location of the settlement must be far at least 1 km far from the military camps. (Al-Shalabi et al.,2006). Therefore, area within 1 kilometer buffer zones of military camps is unsuitable for residential development. Finally, the result become part of Boolean map (Figure 19).

**Industrial areas:** to minimize the adverse impact of heavy industries due to their noise disturbance and environmental contamination and create safer and attractive health conditions, the location of residential areas is separated from the existing heavy industrial areas by creating buffer zones of restriction. (Rahim et al., 2014) suggested that residential area should be at least 500 meters far away from heavy industry. In this study, the locations of existing heavy industries like national cement, warehouses, textile factory, manufacturing plants were identified and a buffer distance of 500 meters was created to exclude from the analysis.

**Airport:** according to MUDC (2012), Residential areas should not be located around the airport due to the sound produced by airplanes and for safety reasons in case of a plane crash. To minimize noise disturbance of aircraft during landing and takeoff operation the candidate suitable site for housing development should be far away from airport sites. Hence, the residential site must be situated at the minimum buffer distance of 3 km away from the airport (Al-Shalabi et al.,2006). therefore, in this study, a distance function (buffer zone) of 3 km was created around the airport site to exclude from the analysis.

**Railway station:** Railway station plot was extracted from structural plan of the city. Residential areas should not be located near the railway stations to minimize noise disturbance and the safety of the residents (MUDC, 2012). Hence, a buffer distance of 400 was created and protected to be free of residential development (Murseli & Isufi, 2014). So, areas within the buffer zones are unsuitable while areas outside of the buffer zones are suitable for future residential housing development.

**Cemeteries:** the locations of cemeteries in the study area were identified from the structural plan and their coordinates were collected from the field using handheld GPS. Then the parcels of all existing cemeteries were extracted from aerial photo as of 2020 of the study areas. According to MUDC (2012), Cemeteries should be outside the central part of towns; Cemeteries should not be located in the direction of future expansion areas. In this study, a buffer zones of 100-meters radius were created around each of existing cemeteries. Due attention should be given to its negative externalities affecting the beauty of the town and other activities in its surrounding areas. Addis Ababa City Structure Plan, (2017) green buffer strip of 100m should be maintained between residential housing areas and cemeteries. Therefore, areas within the buffer zones are restricted from future residential uses. The restriction zones become part of Boolean constraint map (Figure 19).

**Waterbody:** from the goal of safety, the candidate suitable site for residential housing area should be free from risk aroused by river flooding during rainy seasons. Hence, river and river layers were clipped from the land-use plan of the city. A 30- meter buffer zones to flood sheet areas were created to restrict from future residential use. According to the structural plan of the city, no residential development is permitted within the 30-meter limit on both sides of flood sheet areas and the river. Thus, (Murseli & Isufi,2014) suggested 30- meters buffer to rivers should be ignored from site selection for future residential development.

**Built-up:** new residential development cannot take place on the developed area as the area has been improved, future residential development requires vacant or bare land (Raghunath,2006). From the land use, land cover map, built-up area was considered as a constraint. So existing built-up area was considered as a constraint to prohibit it from new residential housing development.

**Fault lines:** it is safer if settlement sites can be located away from the fault system. This can prevent the leachate from finding a way to percolate into the groundwater. In this study, the fault system was extracted from the geologic maps of study area through on-screen digitization process. In order to create a safer residential area, a buffer of 250 -meters distance was created around the fault lines to exclude from future residential development as this area is a dangerous for settlement of its influence on the groundwater, which can lead to a negative effect on the community (Ullah and Mansourian, 2015).

Based on the above constraints, the study area is classified as restricted and suitable site (Figure 19). Accordingly, it is indicated in Figure 20, 45.02% of the area is suitable whereas 54.98% is restricted. This implies that in Dire Dawa city more than half of the total area is not suitable for future residential housing development. The Boolean overlay of constraints, the ten Boolean constraint layers, described above, by performing the Boolean and overlay operation, the resulting raster of the Boolean overlay computation is presented in figure 19.

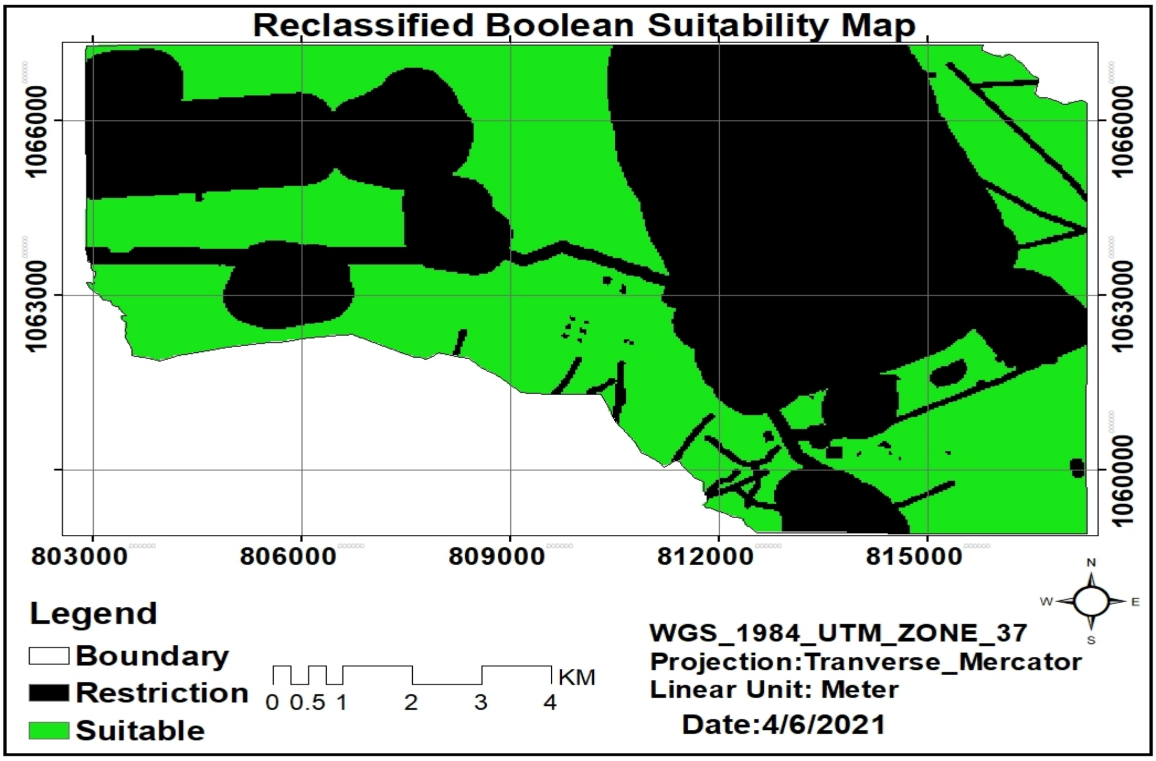



Figure 19. Product of Boolean map

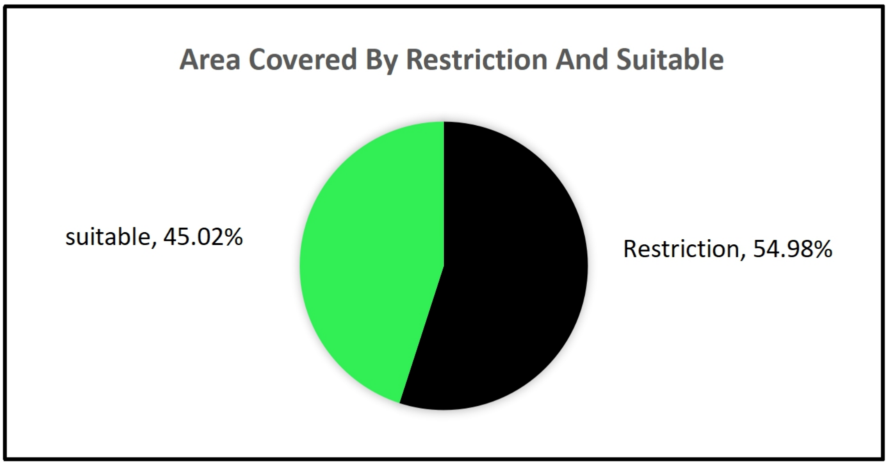



Figure 20. Area covered by suitable and restriction

### 4.2.13 Weighted overlay analysis

The weighted overlay tools of Arc-GIS functions from arc tool box with scale 1 to 5 has been computed to generate composite map of factors and then Boolean map was multiplied to the composite map to produce suitability maps of residential areas (Figure 21). Weighted linear combination (WLC) could be computed by equation 4.

.

$$\mathbf{s = (\sum_{i=0}^{n} x1 * w1) * \pi cj} \quad \text{Equation 4}$$

Where:

S -Suitability Index for residential areas

Σ - Sum of weighted factors

n- Number of Criteria

Wi-Weights of each criterion i

Xi -Score of the criteria

Cj - constraints (Boolean map represented with values of 0 or 1)

Π - Product of constraints (1-suitable, 0-unsuitable)

The equation could be rewritten as:

Suitability index = (([reclassed land-use/land cover] * 0.2598) + ([reclassed slope] * 0.1639) + ([reclassed soil] * 0.1601) + ([reclassed Proximity to built-up] * 0.1039) + ([re-classed proximity to flood plain] * 0.1315) + ([re-classed proximity to road]* 0.0573) + ([reclassed water supply] * 0.0387) + ([reclassed proximity to transmission line ] * 0.0300) + ([re-classed proximity to healthcare services] * 0.0225) + ([re-classed proximity to recreational area] * 0.0175) + ([re-classed aspect]* 0.0147))* Π (b0/1)).

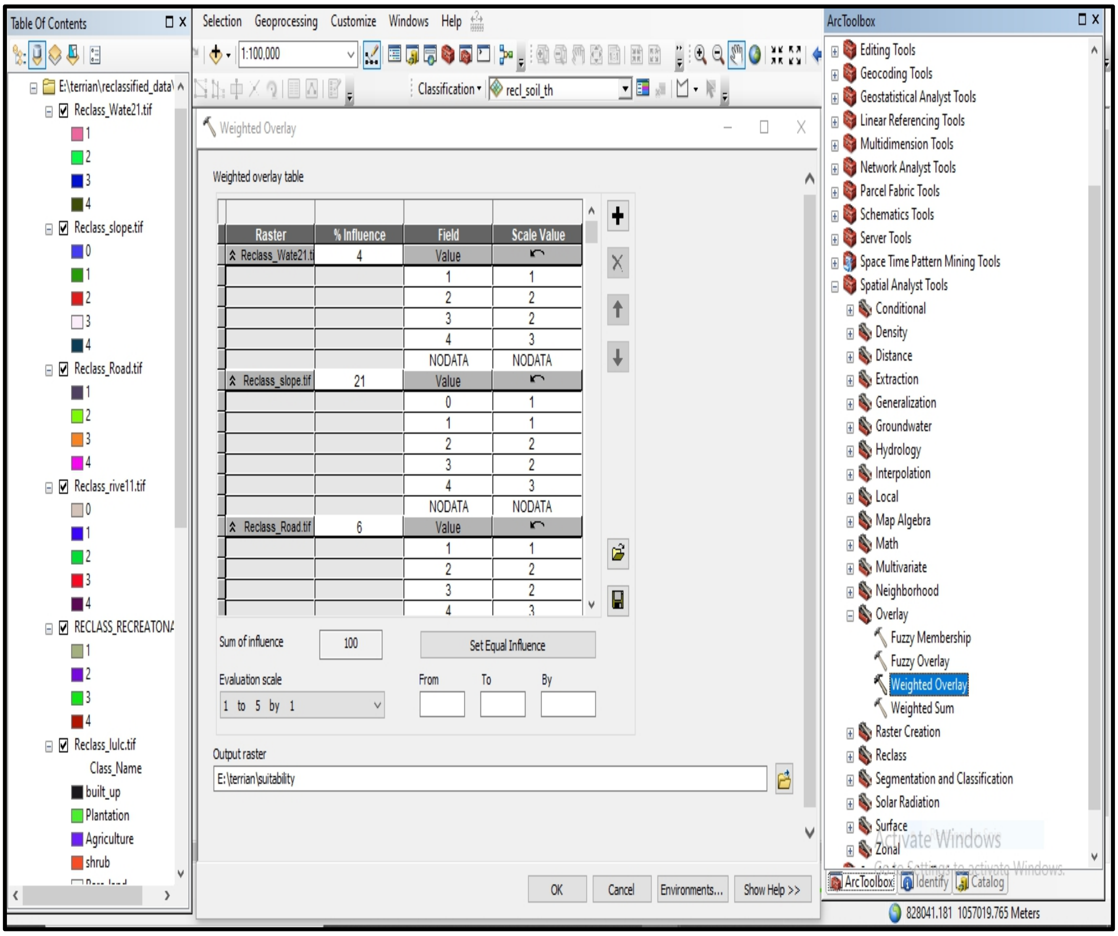


Figure 21. Weighted overlay analysis toolbox

Accordingly, Figure 22 reveals that Dire Dawa city can be divided into five suitability indexes. Table 19 shows that 57.28% of the whole area is unsuitable for future residential development. This is due to constraints or restrictions to the land influenced by legal and environmental conditions of the city. From the composite residential suitability map (Figure 22) areas with yellow color represents for very high suitable, whereas areas with green color stands for high suitable while blue and red color represent for moderate suitable and low suitable respectively. The findings also show that very high and high suitable lands cover 3.61 and 32.76% are respectively while low and moderate suitable covers 1.15 and 4.31 % of the whole area (Table 19).

Table 19: Composite suitability conditions

| s/no | Score | suitability index | Area (sq. km) | Area (%) |
|---|---|---|---|---|
| 1 | 0 | Unsuitable | 54.20 | 57.28 |
| 2 | 1 | Low suitable | 1.14 | 1.22 |
| 3 | 2 | Moderate suitable | 4.03 | 4.260 |
| 4 | 3 | High suitable | 32.20 | 34.034 |
| 5 | 4 | Very High suitable | 3.04 | 3.213 |
| Total | | | 94.61 | 100 |

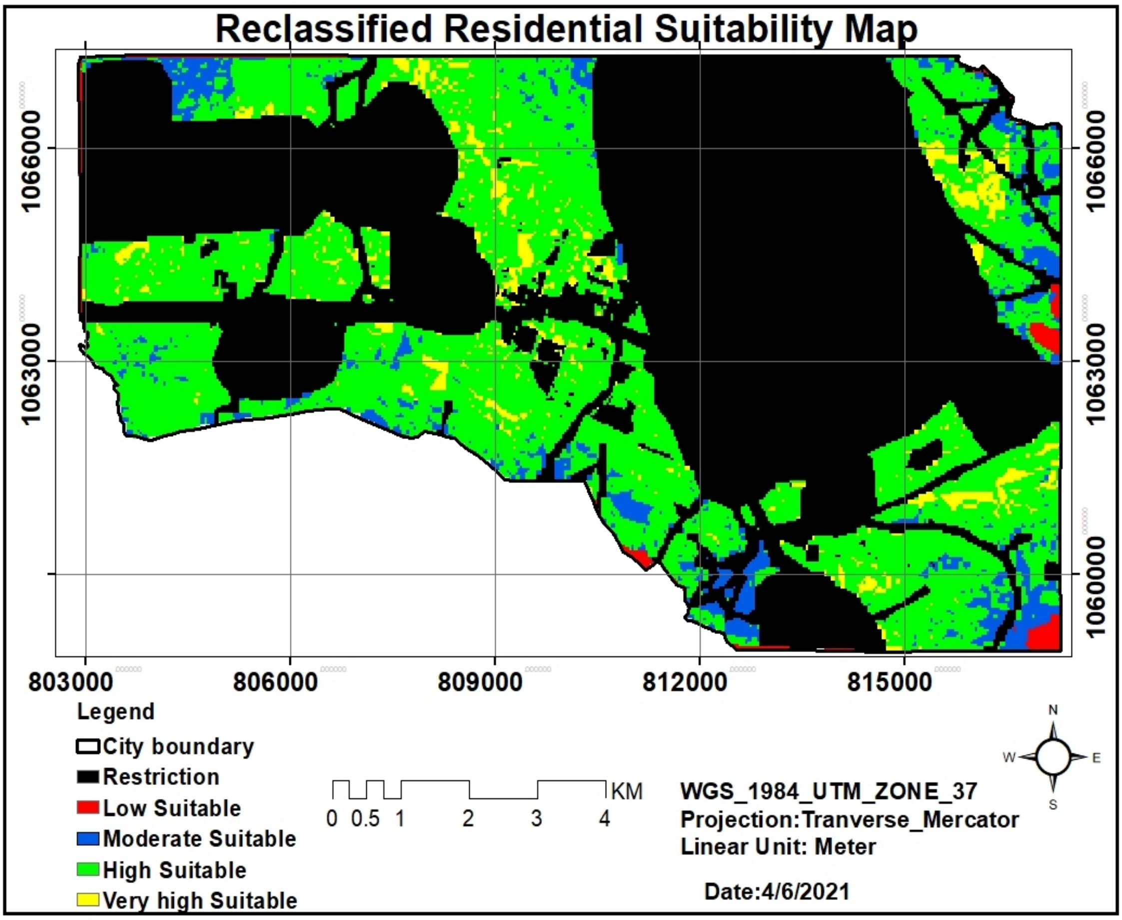



Figure 22. Residential suitability map of dire dawa city

### 4.3 Urban land suitability index for new residential development in Dire Dawa city

The finding of the study (Table 19; Figure 23) indicate 3.213 % (3.04 km$^2$) and 34.02% (32.2 km$^2$) of entire Dire Dawa areas categorized under very high suitable and high suitable respectively. Very high and high suitable areas are considered as suitable land for future residential development to achieve budgeting for residential land provision. Hence, Dire Dawa city has 37.243% (35.24 km$^2$) of its total land which is suitable for future residential land provision. The result is moderately less than that of (Ekanayaka, 2014) which was indicated as 57% of the total land in the study area that KMC area could fulfill future demand for residential needs resulted in the analysis of locational suitability for residential development in Colombo suburban areas: Applications of Analytical Hierarchy Process. The difference might be due to differences in the level of urbanization, planning, and data used. For instance, in this study, eleven criteria along with ten constraints were considered whereas in the above study only six criteria were used.

The result of the findings (Figure 22; 23) show that most of the areas with very high suitable and high suitable are located to the west of the city between Sabian and Malk Jebdu while some other suitable areas also exist to the East of airport around Magala. This indicates that the suitable areas that incorporate very high and high suitable areas should be used for future residential housing development than others. The findings of the study (Figure 22; 23)
also reveal that most of moderate and low suitable area are located around peripheral of the city which are imposing constraints that can be difficult to overcome and need massive investments during residential development

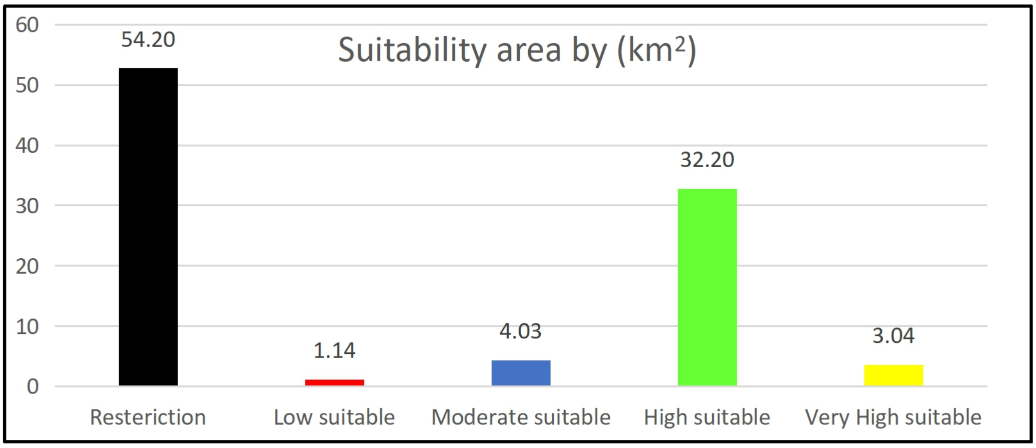



Figure 23. Residential areas suitability indexes

**4.4 Suitability validation for Proposed Residential land use plan**

Dire Dawa City Urban Planning and Development Authority had prepared proposed land uses to guide future urban development by addressing particular locations proposed for specific projects within the boundary of the city. They classified urban land into different zonal categories like a proposed residential area, commercial area, and industrial area. Here residential use areas considered as residential areas generally assigned for pure residential and mixed activities. The total area proposed for residential areas development is 674.57 ha (Figure 24). The area zoned for residential activities is reserved for residential houses that will be built by individuals, cooperatives, private (such as real estate), and by the government (such as low-cost and condominium houses), for mixed activities and residential services. Areas assigned for residence are found around the main Centre the vacant areas in Sabian, and Melka Jebdu

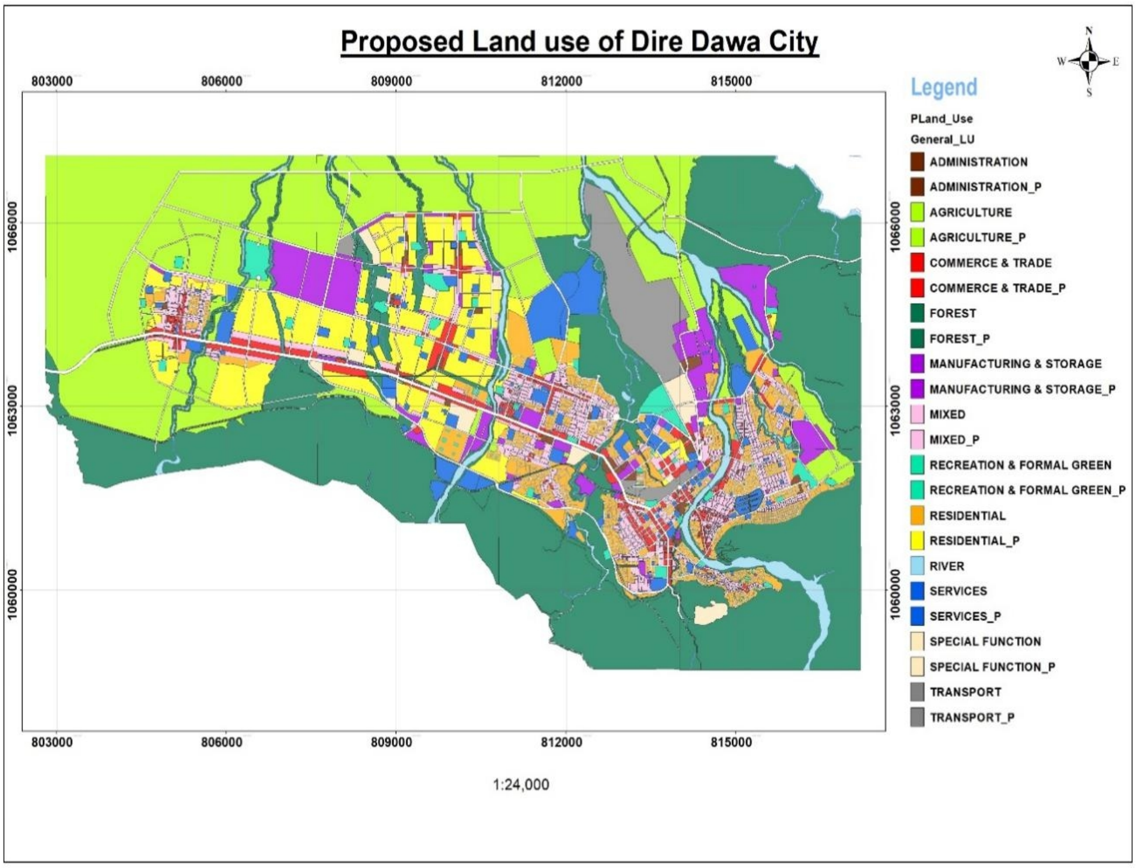



Figure 24. Proposed land-use plan of dire dawa city as of 2015 (Source: Dire Dawa City Municipality,2015)

Proposed residential land layers were extracted from the proposed land use plan of Dire Dawa city and superimposed with the final suitability map of this study to validate their suitability (Figure 25). The yellow colors area represents the proposed residential land that overlayed with the final suitability map (Figure 25).

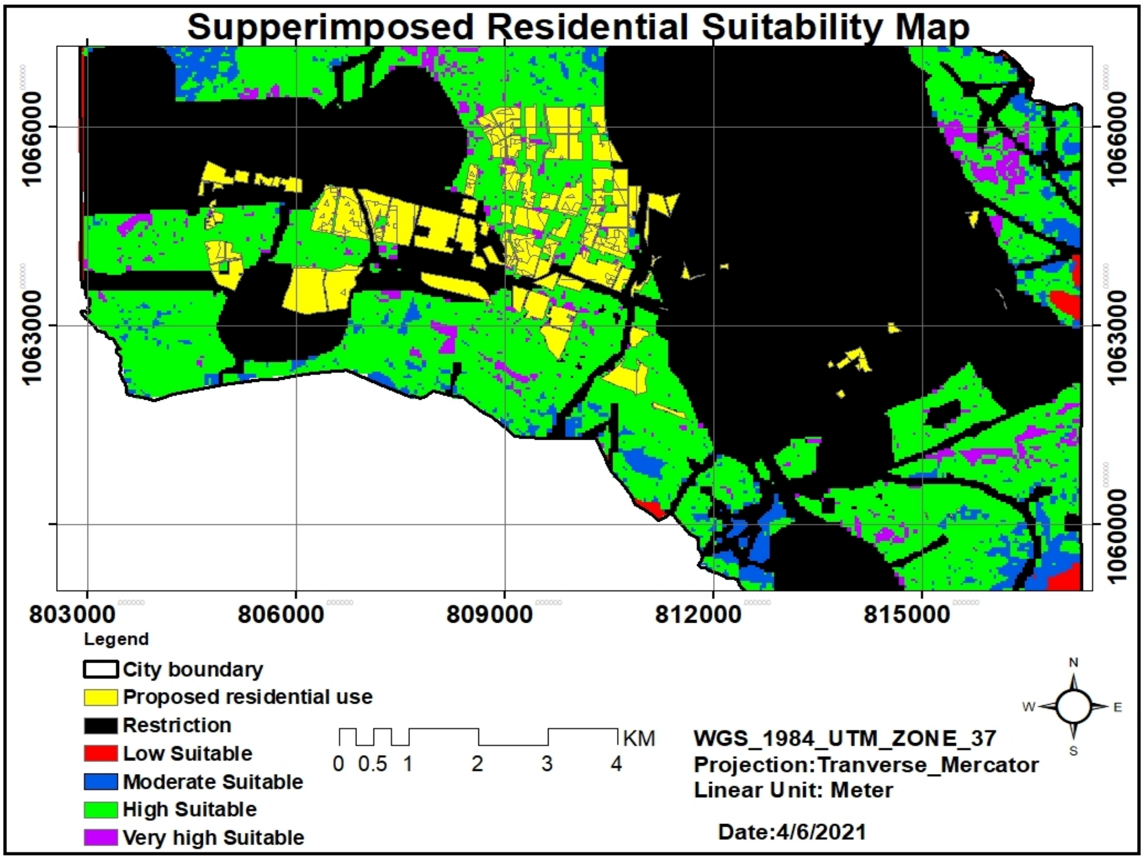



Figure 25. Final suitability map superimposed with proposed residential land use

The suitability indexes of the proposed residential land use were computed (Table 20). The validated result (Table 20) reveals that 8.156% of proposed residential land use is classified as very high suitable. The result is moderately greater than that of (Ekanayaka, 2014) which was 2% resulted in the analysis of locational suitability for residential development in Colombo sub-urban areas: Applications of Analytical Hierarchy Process. Table 20 also reveals that 33.376% of proposed residential land use is classified under high suitable conditions. The Areas shown by yellow and red colors are categorized under very high suitable and high suitable whereas the Areas shown by dark green and brown colors are categorized under restriction and moderate suitable respectively.

The validated result of the study reveals that 8.156 and 33.376% of proposed residential land use plan which is still not constructed or undeveloped exist under very high suitable and high suitable respectively (Table 20; Figure 26). This indicates that currently, Dire Dawa city has 41.53 % (280 hectares) of its remaining proposed residential land-use plan to distribute urban land for future residential needs. The result also shows 0.0311% (2.1 hectares) exist under moderate suitability which needs further investigation before land distribution for housing purposes (Table 20; Figure 26). Currently, no proposed residential land exists under low suitability, whereas 58.157% (392.1 hectares), the largest area exists under restriction (Table 20; Figure 26). This is due to either its location under a constraints zone or being constructed or developed.

Table 20: Suitability conditions of proposed residential land use plan

| Suitability index | Area by sq. km | Area by Percent |
|---|---|---|
| Restriction zone | 3.921 | 58.157 |
| Low Suitable | 0 | 0 |
| Moderate Suitable | 0.021 | 0.311 |
| High Suitable | 2.25 | 33.376 |
| Very High Suitable | 0.55 | 8.156 |
| Total | 6.742 | 100 |

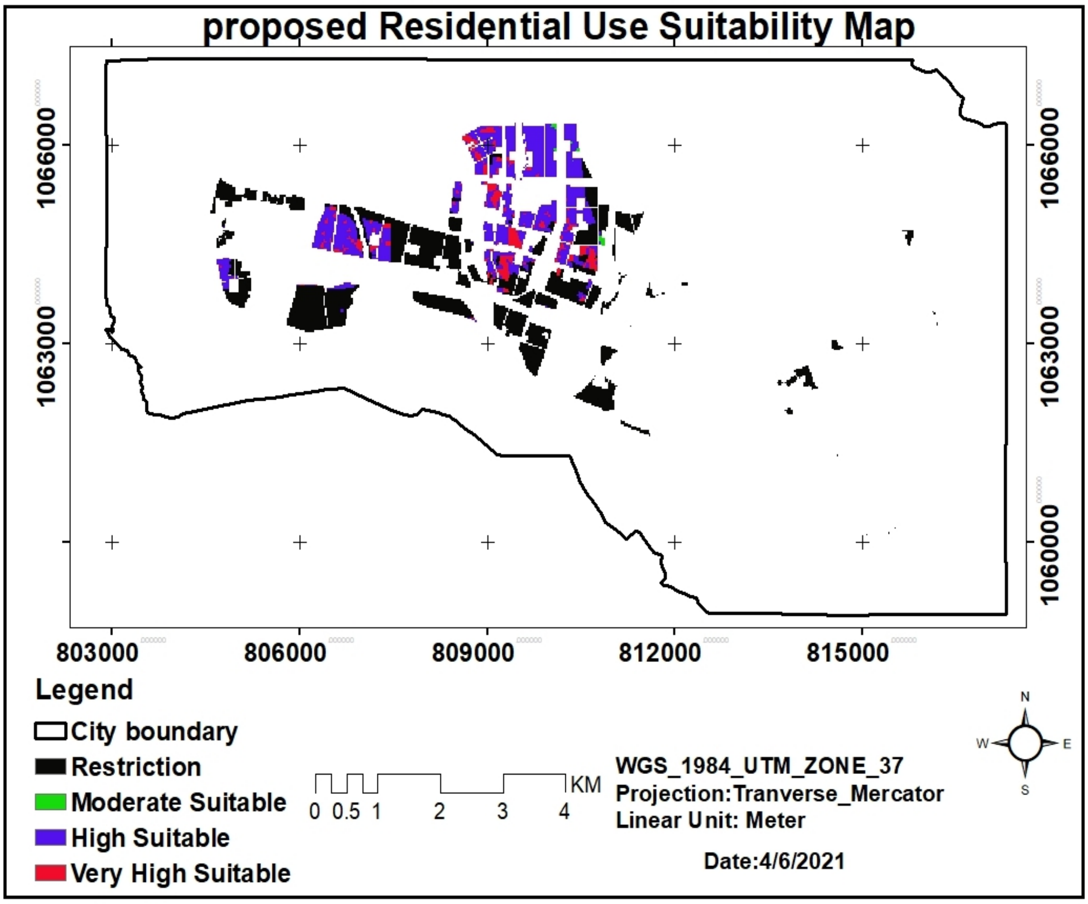



Figure 26. Proposed residential land suitability map

The validated result of proposed residential land was verified from Google Earth pro and aerial photo of the city. Aerial photo of study area was captured in 2020. It has a resolution of 15 cent meter that it has the detail spatial resolution to show very fine features existed in study area. In the same way Google Earth pro has a resolution of 15 cent meter and high temporal resolution with sixteen days revisiting time of the same area. Both Google Earth pro and aerial photo of the study were used to show the current status of proposed residential suitability indexes. Hence the suitability indexes of proposed residential land layers obtained in Figure 26 were exported to Google Earth and superimposed with aerial photo and then the following result (Figure27; Figure 28) were obtained to give the depth picture of proposed residential land use status. In comparison of google earth pro with aerial photo of the city, after aerial photo acquired no change was occurred at all from Google Earth pro. So, this study used aerial photo of the city as of 20 20 as a field verification to understand the current nature and status of the proposed residential land use plan.

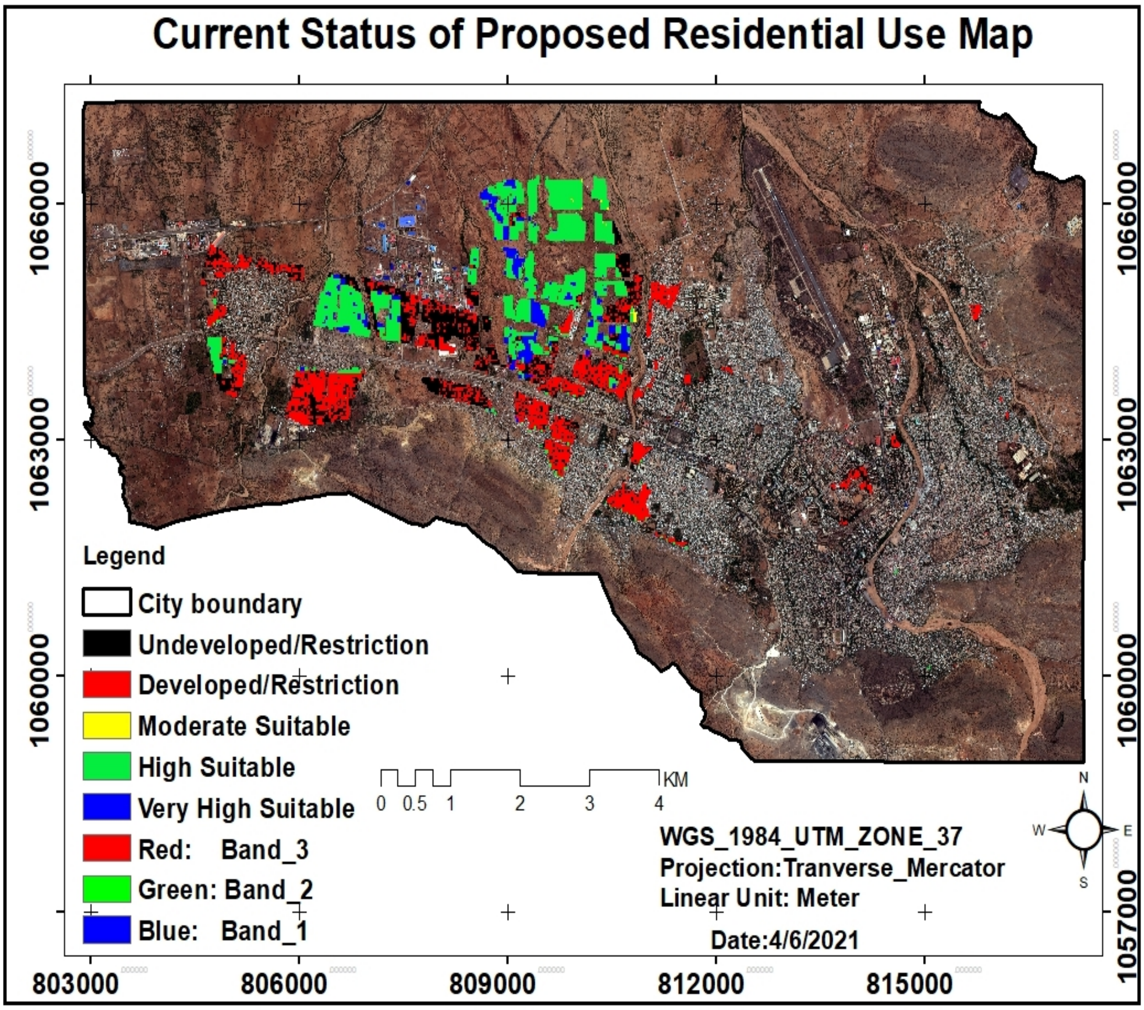



Figure 27. Current status of proposed residential land

The validated result of the study (Figure 27; Figure 28) reveal 55 and 225 hectares of proposed residential land use plan which is still not constructed or undeveloped exist under very high suitable and high suitable respectively. This indicates that currently, Dire Dawa city has 41.53 % (280 hectares) of its remaining proposed residential land-use plan to distribute urban land for future residential needs. The finding (Figure 28) reveals 2.1 hectares exist under moderate suitability which needs further investigation before land distribution for housing purposes. Currently, no proposed residential land exists under low suitability, whereas 392.1 hectares, the largest area exists under restriction (Figure 28). This is due to either its location under a constraints zone or being constructed or developed.

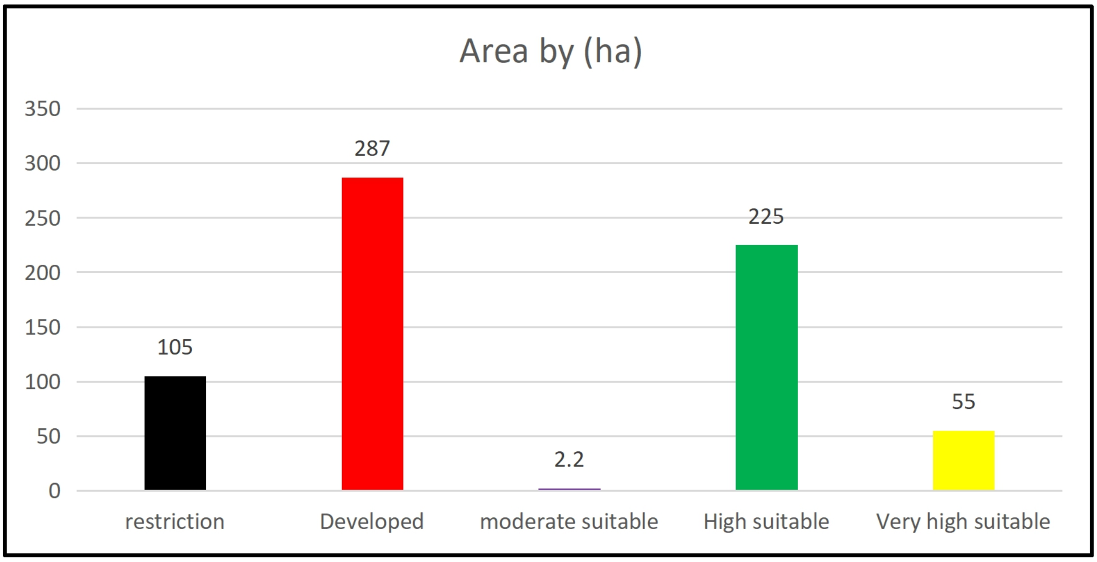



Figure 28. Areas of proposed residential suitability indexes

# 5. CONCLUSION AND RECOMMENDATION

## 5.1 Conclusions

The main objective of the study was to analyze urban land suitability for future residential areas in Dire Dawa City, Eastern Ethiopia, using geospatial techniques augmented with MCE and AHP approach.

The rapid progress made in geospatial technologies augmented with multicriteria evaluation and analytical hierarchy process nowadays have been put forward with a series of functional capabilities and applications to solve conflicts and complexities in any geospatial decision making

Spatial parameters upon which suitability decisions could be made were determined based on the expert's opinion, relevant literature, and availability of data. Accordingly, eleven factors namely: land use land cover, soil conditions, proximity to major roads, slope conditions, aspect conditions, proximity to electric transmission lines, proximity to the built-up area, proximity to flood plain, accessibility to a water supply line, proximity to recreational areas and proximity to healthcare services and ten constraints including cemeteries, waterbody, military camps, airport and railway station, fault lines, built-up area, heavy industries, high voltage power station, and high-tension electric lines were considered as a suite of physical, environmental and economic criteria which have principal effects on suitability analysis for residential areas in Dire Dawa city.

Each criterion was standardized, reclassified, and assigned a suitability score. Criterion standardization was based on literature review and policy analysis. All criteria were reclassified to a common scale of measurement.

Local experts were offered to order and assign relative importance of each criteria using 9 class values of satty scale and eigenvector weights of eleven factors were computed using decision support wizard IDRISI 32 software and then the overall Consistency Ratio (CR) of the module was checked as 0.08 % to ensure that the judgments made by experts whether consistent or not and the result fulfilled the tolerable threshold ($CR \leq 0.10$).

Boolean overlay tool of ArcGIS 10.7 software was used to incorporate all constraints layers to produce a composite constraint map. This constraint map classified Dire Dawa city into a restricted buffer and unrestricted areas represented by zeros (impossibility) and ones(possibility) respectively.

The weighted overlay analysis tool of ArcGIS 10.7 software was adopted to integrate all weighted factors and multiplied by constraint map to produce the final suitability map. The resultant map was computed as all reclassified factors were multiplied by their weights and summed up together and then multiplied by a Boolean map which incorporated all constraints under consideration.

This analysis developed five levels of suitability indexes of influencing factors for future residential land suitability based on literature reviews. Very high suitable, high suitable, moderate suitable, low suitable, and unsuitable areas where the classified study area for future residential development suitability indexes. Among these very high suitable areas have the highest potential for future housing development and should be used first. They provide the most public services necessary for future residential development and would cause the least environmental harm and natural hazards.

The final suitability map result classified the whole Dire Dawa city area into five suitability classes. Accordingly,55.78% (54.2 $km^2$) area covers unsuitable for residential area,1.22% (1.14 $km^2$) area covers less suitable, 4.56% (4.03 $km^2$) area covers moderate suitable, 34.63% (32.2 $km^2$) area covers high suitable and 3.81% (3.03 $km^2$) area covers very high suitable.

Most of the areas with very high suitable and high suitable are located to the west of the city between Sabian and Malk jebdu whereas most of moderate and less suitable are located around peripheral of the city

.

The final suitability result was used to validate the proposed residential land use plan which was prepared by the urban development planning agency of Dire Dawa city. Accordingly, 8.156 and 33.376% of proposed residential land use plan which are still not constructed or undeveloped area located under very high suitable and high suitable respectively. This indicates that currently, Dire Dawa city has 41.53 % (280 hectares) of its remaining proposed residential land-use plan to distribute urban land for future residential needs.

The validated result also reveals those 287 hectares of restriction lands of proposed residential land use are already developed whereas 105 hectares of restriction lands of proposed residential land use are undeveloped but located under restriction zones due to it is located within the restriction buffer zones of natural hazards and environmentally sensitive areas. Therefore, planners and developers should have to give attention to undeveloped areas which are located in restriction buffer zones. The above scientific classification used is in line with the proposed residential plan of Dire Dawa city and it can be used as a guide map to the proposed land use for residential areas in the study area. The final map shows suitability indexes and an in-depth picture of proposed residential land.

The result confirms that geospatial techniques and multicriteria evolution with analytical hierarchy process are very applicable and effective in analyzing, mapping, and interpreting urban land suitability.

**5.2 Recommendations**

In this study, an attempt is made to analyze urban land suitability for future residential use using geospatial technique augmented with MCE, in Dire Dawa city. The study demonstrated that utilization of geospatial technique and MCE in urban land suitability analysis are appropriate and necessary and a need in urban planning and development under Ethiopian contexts

- The finding of the study, apart from demonstrating the applicability and effectiveness of geospatial technique based multicriteria evaluation approach it may serve as a decision supporting system having potentials to clarify and address uncertainty in spatial complexities and contradiction about where additional residential housing should be developed.

- The suitability analysis was done in the area using a number of criteria related to residential areas suitability and their weight of influence was performed from local experts.
- The scientific classification was used in line with the existing proposed residential land use of the study area. Thus, final residential suitability map (Figure shows suitability locations for future residential areas and it shows in depth picture to proposed residential land use of the city.

- The findings of this study will be beneficial to various parties. From the finding, planners, decision-makers, and developers can identify and recognize that where is optimal land for future housing development to keep urban sustainable development while utilizing the land properly.

- The finding will be useful for the people who are looking for suitable and profitable places to purchase residential properties and to identify the nature and level of development of the area. Moreover, this paper helps the government of the country to prepare spatial policies to the context to improve urban land planning and management and to mitigate unplanned development patterns related to residential areas.

- In this study, urban land suitability analysis was done for residential areas only which by itself is not sufficient for sustainable urban land use and development. It is recommended that suitability analysis for all other land use types should be conducted, as a comprehensive and comparative analysis would provide an increased understanding of the nature and effectiveness of urban land uses.

- The present study considers major physical, environmental, and economic factors for residential land suitability analysis. However, other factors such as affordable shopping (especially supermarkets), public libraries, post offices, and banks influence land suitability for future residential areas. Therefore, they should be included as evaluating criteria to make this research more applicable.

- For urban land suitability to be more feasible, a land and land-related resources database should be established and implemented. If the public has easy access to these databases, it will contribute to wider public participation in the urban planning process.
- The government should also prepare proper policies and standards related to the context, the land compatibility database, for example, environmentally sensitive, natural hazards and prime agricultural lands should not be transformed into other land uses due to their special features. This method will help to improve the efficiency of using limited land resources and minimizes the adverse impact of urban spatial development.

- Web-based mapping applications should be developed for residential land suitability analysis and to show potential for improving information dissemination, increasing public participation, and awareness in land suitability analysis.

- Finally, the study recommended further research, which consider both hydrogeology and groundwater table data as suitability criteria. The concerned institution should work on gathering and compiling the information necessary in order to incorporate these data for suitability analysis of an area.

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# Appendices

**Appendix I. Questionnaires prepared for experts in different level**

MSC, Thesis questionnaires paper on Urban land suitability analysis in Dire Dawa April 2021

For Urban land management and Development of Dire Dawa city

Personal Information

Name: __________________ Occupation: _______________ Kebele___________

Sex ________ Age________

As part of my MSC. thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about Urban land suitability for residential areas in Dire Dawa city. Please respond to the following questions that provide inputs for my research. Hence give your idea on space provided

1. What are the parameters you consider during urban land plan preparation for residential areas and are enough for the purpose?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

__________________________________________________________________________

2. what are the challenges you faced before, in developing residential areas in Dire Dawa city?

______________________________________________________________________________

______________________________________________________________________________

___________________________________________________________________________

3. What are the possible recommendations you would suggest to improve the suitability of residential land and to reduce human loss and economic crisis in Dire Dawa city?

______________________________________________________________________________

______________________________________________________________________________

___________________________________________________________________________

MSC, Thesis questionnaires paper on Urban land suitability analysis in Dire Dawa April 2021

A. For Urban land management and Development of Dire Dawa city

Personal Information

Name______________________ Occupation; _______________Kebele___________

Sex ________ Age________

As part of my MSC. thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about Urban land suitability for residential areas in Dire Dawa city. Please respond to the following questions that provide inputs for my research. Hence give your idea on space provided

1 Do you notice any changes occurring in the need trend of residential land demand and supply in Dire Dawa city?

Yes ☐ ☐ No

2 If yes, how the need trend in land demand tends to change?

Increasing ☐ ☐ Decreasing

3. If yes, how the need trend in land supply tends to change?

Increasing ☐ ☐ Decreasing

4. What are the rules, regulations, proclamations adopted for the urban land delivery for housing development that the municipality has regulated to achieve the common goals?

___________________________________________________________________________

___________________________________________________________________________

________________________________________________________________________

5. what new/ old technologies and approaches would you follow to prepare an urban land plan?

___________________________________________________________________________

___________________________________________________________________________

________________________________________________________________________

MSC, Thesis questionnaires paper on Urban land suitability analysis in Dire Dawa April 2021

________________________________________________________________________

B. For Urban land management and Development of Dire Dawa city

Personal Information

Name______________________ Occupation; _______________ Kebele___________

Sex ________ Age________

As part of my MSC. thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about Urban land suitability for residential areas in Dire Dawa city. Please respond to the following questions that provide inputs for my research. Hence give your idea on space provided

1. Are the infrastructures and utilities are distributed well for residents of the city?

A. Yes B. Partially C. No Please describe

___________________________________________________________________________

___________________________________________________________________________

________________________________________________________________________

2. What do you recommend to improve the suitability of urban land for residential areas of the city for the future?

___________________________________________________________________________

___________________________________________________________________________

________________________________________________________________________

3. How do you manage the Urban land of Dire Dawa City?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

______________________________________________________________________

4. what problems do you observe in plan implementations and regulations

___________________________________________________________________________

___________________________________________________________________________

________________________________________________________________________

5. What problems are observed in the development of residential housing in Dire Dawa?

6. What is the main weakness that causes a shortage in urban residential land provision of Dire Dawa city municipality?

A) Inadequate institutional capacity

B) Inefficient & ineffective land management practice

C) Poor know-how in rules, proclamation, and other legal frameworks

If any other, explain

7. What do you think the possible and significant negative effect of a poor land delivery system?

A) Informal transaction B) Expansion of informal settlements

C) Land speculation

D) Illegal sub-division E) All

8. What are the plan implementation gaps and reasons for weaknesses of available residential land provision?

A) Plan gaps to meet the need for residential land
B) Weak community participation and interference
C) Awareness shortage of residences
D) Municipality weakness in land administration and management
E) Knowledge and capacity shortage of municipality officials
F) The plan preparation doesn't consider demand size.

**Questionnaires for Heads of the Municipality and Officials**

MSC, Thesis questionnaires paper on Urban land suitability analysis in Dire Dawa

Personal Information

Name______________________ Occupation; _______________ Kebele___________

Sex ________ Age________

As part of my MSC. thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about Urban land suitability for residential areas in Dire Dawa city. Please respond to the following questions that provide inputs for my research. Hence give your idea on space provided.

1. Do you believe that your organization (the municipality) gives attention to the management of the land delivery system according to the legal frames to be followed?

   ________________________________________________________________________
   ________________________________________________________________________
   _____________________________________________________________________

2. Do you believe that in your municipality, the land development and management process structure is favorable to provide adequate residential land?

   ________________________________________________________________________
   ________________________________________________________________________
   _____________________________________________________________________

3. Is proposed land use plan enough in your municipality to provide suitable land for residential housing development?

   ________________________________________________________________________
   ________________________________________________________________________
   ________________________________________________________________________

4. Is the existing urban land policy that your municipality is using to manage its urban land enough for its contents?

   ________________________________________________________________________
   ________________________________________________________________________
   _____________________________________________________________________

5. What are the possible recommendations you would suggest to improve the suitability of future residential land and to reduce human loss and economic crisis in Dire Dawa city?_________________________________________________________________

   ________________________________________________________________________

## Appendix II. Field survey using Handheld GPS

GPS data collected from the study area using a handheld GPS instrument.

| Name | Easting | Northing | Category |
|---|---|---|---|
| Dire dawa palace | 814037 | 1061330 | Hist+Cult_Clean |
| Prince Makonen palace | 813677 | 1060998 | Hist+Cult_Clean |
| franch Hospital | 813415 | 1061197 | Health Infra |
| Mekonen bar and hotel | 814019 | 1061628 | Hotels |
| Besrate Gebriel | 814443 | 1061910 | Schools |
| Kefira open market | 814503 | 1060587 | Major Indoor and Open Market areas |
| African Soldiers Grave Yard | 814508 | 1061958 | Cemetery |
| Millennium park | 813933 | 1062772 | recreational area |
| Muslim cemetery | 815224 | 1061438 | Cemetery |
| Christian cemetery | 815053 | 1063404 | Cemetery |
| Christian cemetery | 815070 | 1063778 | Cemetery |
| Dire Itl Air Port | 813068 | 1064989 | Transportation |
| Ethiopia Airline Ticket office | 814126 | 1061457 | Transport Compa_Stations |
| Dire Dawa stadium | 813674 | 1060300 | Sport and recreation |
| Bus station | 814089 | 1060790 | Transport Compa_Stations |
| Post office | 814059 | 1061657 | Major Gov'tal Bureaus and offices |
| Dire Dawa university | 811829 | 1064502 | Higher educational |
| Dire Dawa Health bureau | 813567 | 1061088 | Major Gov'tal Bureaus and offices |
| Dilchora Hospital | 813848 | 1060949 | Health Infra |
| Bilal Hospital | 814498 | 1061305 | Health Infra |
| Mariam work Hospital | 811682 | 1062211 | Health Infra |
| Art-general Hospital | 812689 | 1062234 | Health Infra |
| Defiance Hospital | 810042 | 1062950 | Health Infra |
| Dire Dawa administration Council | 814081 | 1062459 | Major Gov'tal Bureaus and offices |
| Dire Dawa Comprehensive 2nd &prep Scholl | 813625 | 1060101 | Schools |
| Sabian 2nd&pre-Scholl | 812511 | 1062890 | Schools |
| Old Rail Way station | 813989 | 1061727 | Hist+Cult_Clean |
| New Referral Hospital | 809097 | 1063723 | Health Infra |
| New National cement factory | 813592 | 1058968 | Industry |
| Cotton factory | 816308 | 1062431 | Industry |
| Ethiopian Electric corporation | 813598 | 1060418 | Major Gov'tal Bureaus and offices |
| Sami Recreational center | 813521 | 1062265 | Sport and recreation |
| Deybune Jungle land Recreational | 812647 | 1062272 | Sport and recreation |
| Papa Recreational area | 810874 | 1062642 | Sport and recreation |

| | | | |
|---|---|---|---|
| Prime minister Mele Zenawi Memorial park | 813603 | 1063286 | Hist+Cult_Clean |
| Dire Dawa millennium recreational centers | 813575 | 1061253 | Sport and recreation |
| Taiwan indoor market | 814743 | 1061708 | Major Indoor and Open Market areas |
| Ashewa market | 814883 | 1062099 | Major Indoor and Open Market areas |
| Indian community school | 814439 | 1061211 | Hist+Cult_Clean |
| Greek community school | 813610 | 1061211 | Hist+Cult_Clean |
| Adisu 2nd &pre-Scholl | 815013 | 1064294 | Schools |
| Etio-Talian TVET COLLE GE | 811537 | 1063166 | Higher educational |
| Dire Dawa Meleszenawi Memorial TVET college | 812985 | 1062356 | Hist+Cult_Clean |
| Republic of Djibouti Consulate | 813482 | 1061243 | |
| National Hotel | 814193 | 1061457 | Hotels |
| Aman kuter 3 | 811767 | 1062562 | |
| Commercial Banks | 813976 | 1061468 | Banks and Insurance Buildings |
| Abyssinia bank | 814329 | 1061220 | Banks and Insurance Buildings |
| Jumma Mosque | 814782 | 1061177 | Religious |
| Italian mosque | 815210 | 1061201 | Religious |
| Michael orthodox's church | 813962 | 1061242 | Religious |
| old cement factory | 812324 | 1061709 | |
| Pioneer Cement factory | 805511 | 1062970 | Industry |
| Ture Cement factory | 805886 | 1062956 | Industry |
| Industrial zone | 807885 | 1064530 | Industry |
| Bololakos Grave yard | 813602 | 1061231 | Cemetery |
| Henry de-on fried | 814372 | 1061332 | |
| Greek Orthodox Church | 813618 | 1061222 | Religious |
| Roman catholic church | 814363 | 1061838 | Religious |
| St, Lazare printing press | 814343 | 1061865 | |
| Dire Dawa Mass-media agency | 813677 | 1060831 | Major Gov'tal Bureaus |
| Ethiopian Electric corporation | 814356 | 1061302 | Major Gov'tal Bureaus |
| Family restaurants | 814563 | 1061903 | bars+Rest+Night Clubs |
| Just cafe & restaurants | 814503 | 1062057 | bars+Rest+Night Clubs |
| Ogaden pension | 814523 | 1062193 | guest house and Pensions |
| Pampan modern night club | 813886 | 1061108 | bars+Rest+Night Clubs |
| Cinema Majestic | 813941 | 1061566 | Sport and recreation |
| Cinema Empire | 813622 | 1061295 | Sport and recreation |
| Aerobic sport club | 813520 | 1061389 | Sport and recreation |
| Ashewa market | 814956 | 1062194 | Major Indoor and Open Market areas |
| Tsai Travel agent (on gard BLD) | 814480 | 1061178 | Transport Compa_Stations |

| | | | |
|---|---|---|---|
| Nebit Rest | 813843 | 1060612 | bars+Rest+Night Clubs |
| Lyos Hotel | 813070 | 1061281 | Hotels |
| Gez | 813030 | 1061365 | Hotels |
| Gendekore Mosque | 813188 | 1061106 | Religious |
| Shola hotel | 813155 | 1061317 | Hotels |
| Tourist Pension | 813271 | 1060995 | guest house and Pensions |
| Fresh Hotel | 813531 | 1061032 | Hotels |
| Select Night Club | 813829 | 1061159 | bars+Rest+Night Clubs |
| Gad Tour and Car rent | 813735 | 1061241 | Transport Compa_Stations |
| Dashen building | 814087 | 1061621 | Banks and Insurance Buildings |
| Nib Bank and Insurance | 814059 | 1061582 | Banks and Insurance Buildings |
| Al Hashim Sweet | 814586 | 1061251 | Hotel |
| Sheck Isse mosque | 814905 | 1061574 | Religious |
| Balian Crematorium | 816519 | 1061682 | Hist+Cult_Clean |
| Shopping Mall | 812287 | 1062307 | |
| Bangalo | 812813 | 1061901 | Sport and recreation |
| Civic Center | 812998 | 1061761 | |
| CDE Sport Club | 813440 | 1061410 | Sport and recreation |
| Peakoc Hotel | 813736 | 1060415 | Hotels |
| Shell Fuel station | 813831 | 1060772 | Transport Compa_Stations |
| Oillibya Fuel Station | 813715 | 1060947 | Transport Compa_Stations |
| NOC Fuel station | 813826 | 1060656 | Transport Compa_Stations |
| Total Fuel Station | 813324 | 1062927 | Transport Compa_Stations |
| Military camp | 813634 | 1062717 | Military camp |
| Military camp | 814419 | 1062216 | Military camp |
| Military camp | 814077 | 1063684 | Military camp |
| Higher Court | 814424 | 1062184 | Major Gov'tal Bureaus |
| Sallom Hotel (XX) | 814703 | 1062277 | Hotels |
| oromo cultural center | 813360 | 1062663 | Hist+Cult_Clean |
| Samrat Hotel no2 | 813232 | 1062773 | Hotels |
| Moenco Company | 813281 | 1062922 | Transport Compa_Stations |

**Appendix III. GPS based field survey for accuracy assessment of LULC**

| 1 | easting | northing | Land _type | Remark |
|---|---|---|---|---|
| 2 | 816752 | 1062320 | plantation | Haramaya_green area |
| 3 | 816673 | 1062410 | plantation | papa green area |
| 4 | 816976 | 1062330 | plantation | sabategn green area |
| 5 | 816970 | 1062290 | plantation | recreational green genda tesfa |
| 6 | 816928 | 1062360 | plantation | recreational green gara |
| 7 | 816904 | 1062330 | plantation | recreational green |
| 8 | 817262 | 1062180 | plantation | recreational green |
| 9 | 806133 | 1065700 | Shrubland | green area |
| 10 | 805793 | 1065500 | Shrubland | green area |
| 11 | 805706 | 1065480 | Shrubland | green area |
| 12 | 805852 | 1065670 | Shrubland | green area |
| 13 | 805906 | 1065880 | Shrubland | green area |
| 14 | 817281 | 1062210 | plantation | green area |
| 15 | 817266 | 1062290 | plantation | green area |
| 16 | 817160 | 1062490 | plantation | green area |
| 17 | 817130 | 1062550 | plantation | Asphalt |
| 18 | 817273 | 1062710 | Built-up area | Building |
| 19 | 817238 | 1062800 | Built-up area | gas station |
| 20 | 815236 | 1064220 | Built-up area | bus station |
| 21 | 815131 | 1064180 | Built-up area | Building industrial zone |
| 22 | 814887 | 1064690 | Built-up area | Building industrial zone |
| 23 | 812180 | 1064440 | Built up area | Building melka jebdu |
| 24 | 811586 | 1064330 | Built up area | Building melka jebdu |
| 25 | 811512 | 1064210 | Built up area | Building melka jebdu |
| 26 | 811223 | 1063880 | Built up area | Building melka jebdu |
| 27 | 811294 | 1063940 | Built-up area | Building airport |
| 28 | 811366 | 1064110 | Built-up area | Building airport |
| 29 | 811221 | 1064140 | Built-up area | Building airport |
| 30 | 811063 | 1064080 | Built-up area | Building airport |
| 31 | 811218 | 1063460 | Built-up area | Building airport |
| 32 | 811221 | 1063430 | Agricultural area | Agricultural around industrial zone |
| 33 | 811495 | 1063150 | Agricultural area | Agricultural around industrial zone |
| 34 | 811717 | 1062980 | Agricultural area | Agricultural around industrial zone |
| 35 | 812015 | 1062660 | Agricultural area | Agricultural around industrial zone |
| 36 | 812531 | 1062750 | Agricultural area | Agricultural around industrial zone |
| 37 | 812705 | 1062410 | Agricultural area | Agricultural around industrial zone |
| 38 | 812482 | 1062370 | Agricultural area | Agricultural around industrial zone |
| 39 | 811858 | 1062490 | Agricultural area | agricultural around melka jebdu |
| 40 | 811906 | 1062390 | Agricultural area | agricultural around melka jebdu |
| 41 | 811720 | 1062050 | Agricultural area | agricultural around melka jebdu |
| 42 | 811287 | 1062090 | Agricultural area | agricultural around melka jebdu |
| 43 | 811087 | 1061900 | Agricultural area | agricultural around melka jebdu |

| | | | | |
|---|---|---|---|---|
| 44 | 811009 | 1061660 | Agricultural area | agricultural around melka jebdu |
| 45 | 810948 | 1061620 | Agricultural area | agricultural around melka jebdu |
| 46 | 810868 | 1061640 | Agricultural area | agricultural around melka jebdu |
| 47 | 810917 | 1061710 | Bare land | Bare land around melka jebdu |
| 48 | 810908 | 1061730 | Bare land | Bare land around melka jebdu |
| 49 | 809638 | 1062290 | Bare land | Bare land around melka jebdu |
| 50 | 809646 | 1062410 | Bare land | Bare land around melka jebdu |
| 51 | 809586 | 1062390 | Bare land | Bare land around melka jebdu |
| 52 | 808895 | 1062940 | Bare land | Bare land around melka jebdu |
| 53 | 808795 | 1062920 | Bare land | bare land around genda tesfa |
| 54 | 808730 | 1062940 | Bare land | bare land around genda tesfa |
| 55 | 808494 | 1063090 | Bare land | bare land around genda tesfa |
| 56 | 808442 | 1063260 | Bare land | bare land around industrial zone |
| 57 | 808423 | 1063320 | Bare land | bare land around industrial zone |
| 58 | 808406 | 1063180 | Bare land | bare land around industrial zone |
| 59 | 807462 | 1063510 | Bare land | bare land around gand gooro |
| 60 | 807716 | 1063720 | Bare land | bare land around gand gooro |
| 61 | 807761 | 1063650 | Bare land | bare land around gand gooro |
| 62 | 807511 | 1063830 | Bare land | bare land around gand gooro |
| 63 | 807324 | 1063640 | Bare land | bare land around gand gooro |
| 64 | 807158 | 1064230 | Bare land | bare land around gand gooro |
| 65 | 807132 | 1064480 | Bare land | shrub around national cement |
| 66 | 807097 | 1064680 | Shrubland | shrub around national cement |
| 67 | 806999 | 1064910 | Shrubland | shrub around back of airport |
| 68 | 806775 | 1064940 | Shrubland | shrub around back of airport |
| 69 | 806766 | 1065200 | Shrubland | shrub around back of airport |
| 70 | 806742 | 1065520 | Shrubland | shrub around back of airport |
| 71 | 806571 | 1065690 | Shrubland | shrub around the back of airport |
| 72 | 806133 | 1065700 | Shrubland | shrub around melka jebdu |
| 73 | 805793 | 1065500 | Shrubland | shrub around melka jebdu |
| 74 | 805706 | 1065480 | Shrubland | shrub around melka jebdu |
| 75 | 805852 | 1065670 | Shrubland | shrub around melka jebdu |
| 76 | 805906 | 1065880 | Shrubland | shrub around melka jebdu |
| 77 | 805777 | 1065960 | Shrubland | shrub around melka jebdu |