ANALYSIS OF URBAN LAND SUITABILITY FOR RESIDENTIAL HOUSING USING GIS , REMOTE SENSING AND MCA TECHNIQUE: A CASE OF ADAMA, ETHIOPIA.

YUSUF HUSIEN OGETO

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

June, 2022

Adama, Ethiopia

ANALYSIS OF URBAN LAND SUITABILITY FOR RESIDENTIAL HOUSING USING GIS, REMOTE SENSING AND MCA TECHNIQUE:

A CASE OF ADAMA, ETHIOPIA.

YUSUF HUSIEN OGETO

ADVISOR: ROBA GEMECHU (PHD)

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

June, 2022

Adama, Ethiopia

APPROVAL SHEET

I, the Major advisor of the thesis entitled as “Analysis of Urban Land Suitability for Residential Housing Using RS ,GIS and MCA Technique: A Case of Adama, Ethiopia”. and developed by Yusuf Husien, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Roba Gemechu (PHD) ____________________ ____________________

Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by YUSUF HUSEIN have read and evaluated the thesis entitled “Analysis Of Urban Land Suitability For Residential Housing Using RS,GIS and MCA Technique: A Case of Adama, 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 Geo- Informatics Engineering.

________________________________ ______________ ______________

Chairperson Signature Date

________________________________ ______________ ______________

Internal Examiner Signature Date

________________________________ ______________ ______________

External Examiner Signature Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

________________________________ ______________ ______________

Head of Department Signature Date

______________________ ______________ ______________

School Dean Signature Date

________________________________ ______________ ______________

Office of Postgraduate Studies, Dean Signature Date

DECLARATION

I declare that this thesis proposal entitled “Analysis of Urban Land Suitability for Residential Housing Using Rs and Gis Data Mce Technique: A Case of Adama, Ethiopia”.is my own work and has not been submitted to any university for similar purpose. The references used in this proposal are duly recognized by proper citations.

Yusuf Husien ____________________ ________________

Name of student Signature Date

RECOMMENDATION

We, the advisor(s) of this thesis, hereby certify that we have read the revised version of the thesis entitled Analysis of Urban Land Suitability for Residential Housing Using Rs and Gis Data Mce Technique: A Case of Adama, Ethiopia". prepared under my guidance by Yusuf Husein. submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-informatics. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Roba Gemechu (PhD)	________________	_______________
Major Advisor/Supervisor	Signature	Date
_________________	________________	_______________
Co-advisor/Co-supervisor	Signature	Date

ACKNOWLEDGEMENT

First and foremost, I would like to thank, the Almighty Allah, who made it all possible to begin and finish my study successfully.

I would like to pass my special thanks to my advisor Dr. Roba Gemechu (Adama Science and Technology University, School of Civil Engineering and Architecture) for his direct supervision, consistence advice, encouragement, invaluable guidance and patience during the course of this research. His thoughtful and kind encouragement helped me to learn more and develop my knowledge.

Also, thanks to Mr. Semu'el (Urban land manager of Adama city), Mr. Abduljelil expert of land administration from Adama city, Mr. Kebek, Urban planning experts from Adama city as all of you being part of this research and provided me your knowledge. Thank you to the Ethiopian Geological Survey, Adama city municipality, National Metrology Agency. Adama branch, central statistics agency of Adama branch, Adama city Ministry of Energy and Water resources, office for providing me all the spatial and non-spatial data used in this study.

Lastly, I would like to thank my family; I would not be where I am without your help. I also would like to thank all of my instructors and friends, whom I did not mention their name here, who were always supporting and encouraging me while I was on study during the last two academic years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AHP Analytical Hierarchical analysis

GIS Geographical Information System

LULC Land use Land cover

MCE Multi-criteria evaluation

MCDA Multi-criteria decision analysis

RS Remote sensing

UGB Urban growth boundary

ABSTRACT

Adama is among the fast-growing towns in the country. One of the critical issues in urban planning for adama is the determination of appropriate residential locations for future urban growth in and around the town. Residential site selection requires considering a comprehensive set of factors and balancing of multiple objects, however the current approach was tedious and time consuming. the general objective of this study is to find the best locations for the residential housing scheme in Adama City using geospatial Technologies and models. Nine factors (Slope, Accessibility to road, Proximity to Railway, proximity to Drainage, Proximity to built-up, Land-uses/land-cover, Recreation Area, Health Care, Water Supply) were identified for criteria evaluation. The thematic maps of these criteria were prepared and standardized using pair wise comparison matrix known as Analytical Hierarchy Process (AHP). A weight for each criterion was given by comparing them with each other according to their importance, the consistence of comparing matrix were checked by calculating the consistence ratio (CR). The consistency ratio of this study indicated that 0.06 which is less than 0.1. Thus, consistent matrix was formed which was acceptable in order to combine all the layers. Then, with the help of these weights all maps layer were integrated and overlaid for the generation of final site suitability map for future residential housing development. The final site suitability map was reclassified to five suitability classes. In addition a model tool was developed to automate and simplify the suitability analysis process. The findings of this study revealed that from the total area 12.91% area is very highly suitable, 8.14% area is highly suitable, 11.80% area is moderately suitable, 6.72% area is less suitable, and 60.43.264% area is unsuitable for Residential Housing. This result shows that the area selected as highly suitable and moderately suitable for future urban development are open area, agricultural land, shrub and bush, areas having flat slope. This study allows the planners to use automated model tool for preparing the appropriate plans of residential housing of adamacity.

Keywords: Analytical Hierarchical Process; geospatial Technologies; Site Suitability, Residential Housing; Urban Planning

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Land is an area of earth and it is a natural resource to beneficial all citizens. Land has an economic value as a factor of production, because of many purposes, such as housing, education, agriculture public services, mining and so on. Thus, land is a scare resource especially in urban area (Madurika and Hemakumara, 2017). Ensuring land suitability for residential area is one of the main purposes of land-use planning through spatial analysis of particular location. Therefore, planning of residential area is one of the most component to be planned in the urban planning tools of Ethiopia.

As it is indicated in urban planning and implementation manual (MUDC,2012) the location of residential area should be in-terms of a certain predetermined factors of physical, economic, and environmental conditions which influence the suitability of the site. However, due to lack of proper planning and limitation of effectiveness of plan regulation and implementation, urban development in Ethiopia urban centers is rarely meet the standards. Moreover, in Adama city, urban area is expanding rapidly primarily because the population is increasing and proportionally more people are congregating in its urban area. The national population and housing census record show that the number of populations in Adama city increased from 261341 in 1994 to 320224 in 2007 (CSA,2015). according to Adama Administration statistical report, in 2015 the total population of 324000. the growth has created a serious urban land demand for housing development than previous decades.

The rising demand for residential housing land in urban centers, tends to push urban dwellers to expand into different corridors of the city without considering topographic factors such steeper slopes and flood prone areas (Robi, 2011). This is true for Adama city in which urban dwellers are searching for residential land for housing with least cost around peripheral of the city. Therefore, more land will be needed to satisfy further growth of urban population in the future. So it is very important to find residential suitable area for urban development to overcome undesirable urban growth in Adama city.

A residential area is a place classified under land use categorizes in which housing predominates, as opposed to industrial and commercial areas. Therefore, the urbanization rate is growing annually and generating high demand for residential land. 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. Planners are facing new challenges in selecting suitable sites 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)

1.2. Statements of the Problem

The need to live in an urban area is increasing from time to time in both developed and developing countries. Adama is among the fast-growing urban centers in the country, the city has attractive potential that contributed to its accelerated growth. The City has been spurred by rapid population growth and industrialization, which brought unprecedented urbanization process over the past few decades (Seid, 2007). As per the national population and housing census of 1994, the city was the home of about 261,341and about 320,224 during the census period of 2007E.C respectively (CSA,2015). Consequently, in previous decades, the city has experienced an increased demand for residential land following the step of population growth of the city. The population of the city has been increased and consequently the need for homes became serious. In addition to this, the growth of the city is a continuous process, so that it is also important to locate optimal sites for housing areas for future development. Selecting the location for housing sites is a complex process that involves not only technical requirements but also physical, economic, social, and environmental requirements (AMPR, 2004).

Different research has been conducted to analyze 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. In addition, many of the studies relied on a small number of evaluation criteria and conduct the analysis with long process of geoprocessing operation for each data layer. Many Ethiopian cities suffer for selecting optimal residential area at a required time, due to Poor site selection method of not considering the existing infrastructure, facility and topography. Thus, it affects construction cost , accessibility and quality of life of the community especially the poor. In addition Residential site selection requires considering a comprehensive set of factors and balancing of multiple objects, however the current approach was tedious and time consuming to try different alternatives. Automation using model and tools is a modern approach for conducting efficient suitability analysis and it enables to try different criteria. Hence this study attempts to simply the analysis process of optimum site selection for residential housing development using automated GIS model tool and Multi-Criteria Evaluation (MCE) approach.

1.3 Objectives of the study

1.3.1 General Objective

The General objective of this study is to find the best locations for the residential housing scheme in Adama City using geospatial Technologies.

1.3.2. Specific objectives

To achieve the main objective, following specific objectives were developed.

1. To determine factors which influence the suitability of urban residential land.
2. To develop a model tool for automating the suitability analysis.
3. To find the suitable residential areas for future expansion of Adama city.

1.4. Research questions

The following research questions has devised in the study based on the stated specific objectives.

1. What are the underlying factors which influence the suitability of urban residential land?
2. How to develop a model tool for automating the suitability analysis.
3. Where is the most suitable site for future residential housing development of Adama City?

1.5 Significance of the research

The findings of this research will highlight the degree of suitability of the existing residential area in Adama town, Ethiopia. Moreover, the study focuses on the selection of an optimal site for future housing development. This can create awareness of residential land use sustainable development.

The output of this research is useful for planners, decision-makers, developers, and land managers. Moreover, specifically, it helps Adama city planner's to recognize that where is optimal land for future housing development to keep urban sustainable development while utilizing urban land properly. 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. In addition to this, the research gives suitable tool for selecting residential areas for future development and the tools enables the planners or decision makers to try different factors and weights depending on the current situation.

Additionally, the adaptive approach and techniques used in this research will provide a basis for land suitability analysis to identify the optimal site for housing development in other urban centers of the country as well.

1.6 Scope of the study

There are some bounding lines up to which this study extends. These include: time, the scope of the reviewed literature, theoretical and methodological viewpoints, and intended spatial extend to be used as input for analysis to produce the aimed results. Adama town is one of the fast-growing urban centers of this country. The population of the town is extremely increasing since its foundation. Due to rapid urbanization and spatial growth of the town, the demand for houses has become serious. Hence analyzing the level of suitability of existing residential houses and identifying optimal sites for future housing development in Adama town would be very interesting.

In line with this, the current boundary of the town as of 2020 is selected to limit the spatial scope of the study. To acquire background information, a strong theoretical foundation, and appropriate methodology, relevant related literature has been reviewed to compare the finding of this study with that of the existing body of knowledge

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Definition and concepts of residential Land use

Land use is the characterization of land based on what can be built on it and what the land can be used for. One definition of land use is “the total of arrangements, activities and inputs that people undertake in a certain land cover type.” It’s important to note that land use and zoning are not the same. Where land use is the way that people adapt land to suit their needs, zoning is how the government regulates the land. A residential area can be defined as a land-use type in which a living house predominates when compared with commercial and industrial 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

Zoning regulation is part of the development guide to establishing 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. 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. (Dejene, 2015).

2.1.2 Land-use planning and Compatibility of Land Uses

Land-use planning is the systematic assessment of land and water potential, alternatives for land-use and economic and social conditions in order to select and adapt the best land-use options 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.

2.2. Geographic information systems (GIS) and LULC Image Classification

2.2.1 Geographic information systems (GIS)

GIS Is a computer based system which 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. GIS combines computer technology with spatial and non-spatial database where it improves the planning level and management performance (Qutaiba et al, 2020). GIS technology has a variety of capabilities such as supporting location studies (Fan, 2009), and can handle spatial and nonspatial data, data management and integration, data query and analysis and data visualization (Li et al., 2003).

In a study carried out by Dai et al. (2001), GIS provides a powerful tool for geo environmental assessment in support of urban land use planning. GIS technologies have been used in housing construction and site location in different locations around the world. The use of GIS technologies for selecting best locations in construction have usually been limited to basic functions of visualization, querying and preliminary analytical functions of overlapping, buffering and network analysis (Cheng et al., 2007). However, research carried out over the years in different places in the world has shown that the use of GIS technology also has been effective in urban development and location-based problems.

Studies have shown that the use of GIS technology alone cannot provide suitable decision making in selecting best locations to build houses. According to Jankowski (1995), arguments have arisen over the use of GIS technologies alone for making better decisions. Joerin and Musy (2000) concluded that to make better decisions on land management and locations, GIS technology has to be combined with multi-criteria decision analysis (MCDA). GIS technology analyses, manages, creates and manipulates geographic data, but for better decision-making process, a combination with MCDA provides a better reliable decision.

2.2.2 LULC and Image Classification

The most commonly used methods to extract land cover is called image classification. The pixel-based classification techniques consider the spectral reflectance values of individual pixels of the images and then classify them into classes having define spectral values. There are many classification techniques to extract meaningful information from imagery. There are many classification techniques developed over past few decades. These techniques aim to classify homogenous features in the image being studied in similar classes. These classes can be defined prior classification known as supervised classification or automatically defined by software application using a clustering algorithm also known as unsupervised classification. Remote sensed images consist of pixels which are organized in rows and columns, so conventional land cover mapping is done per pixel basis (Smith & Dean A.M., 2003).

Remote sensing technology has been widely used in land use and land cover (LULC) classification and change detection.Land use and land cover dataset are very important sources for many applications and studies such as urban planning and management, socio-economic studies and environment evaluation. The timely and accurate availability of mapping land use and land cover (LULC) is often needed for such studies. The economic growth and population in urban area has resulted in the expansion in past few decades. Many approaches for remote sensing image classification has been developed in but it is still a challenge because of the complex urban landscape and limitation of in remote sensing data (Qihao Weng, 2010).

Land use and land cover are normally used interchangeably in literatures however they represent different things. The term land cover refers to a biophysical state of the earth's surface and sub-surface including soil, topography, surface water, ground water and manmade structure. Land use describes the human activities on the land, such as agriculture, forestry, building, infrastructures construction that modify the land surfaces in other term land use is the human employment of land cover type (Skole D, 1995).

2.3. GIS-based land use suitability analysis

2.3.1 Influencing factors and Land use suitability analysis

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. Accordingly, from the literature reviews of Ethiopia's Ministry of Urban Development and Construction manual on Revised Standards for Structure Plan Preparation and Implementation the following criteria are recommended: The settlement site should be on a slope range of 2-8%, Residential be placed on vacant (open area), the new residential areas should not be far from major roads, it should be away from railway line, free from black cotton soil as much as possible, located in all corners of the town unless there is a constraint.

Land suitability analysis is the process of extracting useful information about a particular land for its fitness to the intended use. Land suitability is mostly related to different criteria like physical, socioeconomic and environment (Nugegoda,2014). land-use suitability analysis aimed to identify the most appropriate spatial pattern for future land uses according to specified requirements, preferences, or predicted some activity (Hopkins, 1977; Collinset al., 2001). In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully studied with the aim of directing growth to the most appropriate sites(Mansor,et al.,2006)

Site selection requires consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for a defined land use (seid, 2007). The current spatial decision making could benefit from more systematic methods for handling multi criteria problems while considering the physical suitability conditions. Traditional decision support techniques lack the ability to simultaneously consider these aspects. The process of housing site selection begins with the recognition of an existing or projected need. This recognition triggers a series of actions that starts with the identification of geographic areas of interest. In the past, site selection was based almost purely on economic and technical criteria. Today, a higher degree of sophistication is expected. In suitable site selection for a particular project, criteria must be identified which satisfy a number of physical, social and environmental requirements, which are enforced by legislation and government regulations.

2.3.2 GIS-based land-use suitability analysis

The GIS-based multi criteria evaluation for land-use suitability analysis has been applied in a variety of situations including ecological approaches to determine land suitability habitat for animal and plant species (Store and Kangas, 2001).analyzing land suitability for agricultural activities (Cambell et al., 1992; Kalogirou, 2002), landscape analysis and planning (Miller et al., 1998).So the combination of multi-criteria analysis technique with GIS as a decision support tool for land-use suitability analysis have become essential components of urban, regional and environmental planning activities (Brail and Klosterman, 2001; Collins et al., 2001). Multi-criteria evaluation (MCE) is primarily concerned with how to combine the information from several criteria for decision making purpose ((Nugegoda, 2014). it is numerical algorithms that defines the suitability of a particular algorithms that define the suitability of a particular solution on the bases of the input criteria and weight together (pereria & Duckstein, 1993). MCA is a procedure that typically multiplies conflicting criteria that are essential to be evaluated in decision-making. It has a wide application whether in our daily lives or in professional settings.

According to (Yassine & Adel ,2011), “The principal of the MCA is to condense complex problems with multiple criteria into finest ranking of the best scenarios from which an option is selected”. The criteria are weighted according to their importance, and their weights have a more or less favorable on the final decision than another (Diakoulaki & Karangelis 2007).

The integration of MCDM 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). MCDA can incorporate both geographical data and stakeholders’ preferences into quantified values for assessment and further decisions (Malczewski2004).

AHP, which was proposed by Saaty (1980), is a structured technique for decision making based on a hierarchical framework constructed through mathematical pair wise comparisons. The weights for the decision-making criteria are derived from the pair wise comparisons of the relative importance between each two criteria (the sum of the weights equals to 1). There are several problems in applying MCDM techniques in a GIS environment (Malczewski 2004). Firstly, there is a problem associated with standardization of criteria.

Different methods standardize criteria in different way which shows various land-use suitability and there is a problem in finding a proper justification for which method is more suitable. To minimize such problems, specific MCE technique should be selected based on existing data availability time and technical experts, etc. AHP can set criteria of residential suitability analysis in a structured way and It can standardize the criteria with its simple mathematical operation. When data cannot be quantified objectively, AHP allows subjective judgments in a consistent and meaningful way. Finally, AHP integrated with GIS can overlay all the standardized criteria which helps to make ranking on site suitability level. These researches will select the use of AHP integrated with GIS for suitability analysis of urban residential land.

Several researchers have utilized GIS MCDA in site selection process. For example, Rikalovic et al. (2014) used the combination of GIS MCDA in selecting an industrial site. In their research, they created a suitability map from several criteria such as road distance, protective area, water distance, etc. The resulting suitability map was used to visualize the problem of industrial site selection. Dehe and Bamford (2015) used the same GIS-MCDA technology in planning new development for healthcare infrastructure. In their research, they compared two MCDA models (evidential reasoning model and the analytical hierarchy process). Using seven criteria such as environmental and safety, size, total cost, accessibility, design, risk and population, possible locations were decided using the evidential reason model. The result obtained was later compared with the analytical hierarchy process. They concluded that the two methods both produced a good way of selecting site location.

2.4 Importance of modeling in GIS

Geoprocessing is the methodical execution of a sequence of operations on geographic data to create new information. The process you perform may be routine Or, the operations can be quite sophisticated to create high quality maps, create a sophisticated analytic model to help you understand and solve important scientific problems, and publish geoprocessing models.The fundamental purpose of geoprocessing is to help you automate GIS tasks and to perform modeling and analysis. Almost all uses of GIS involve the repetition of work, and this creates the need to automate, document, and share multi step procedures. Geoprocessing provides the framework for automation.GIS users also compose and execute analytic and statistical models that help solve problems, predict what might happen, and better understand many scenarios and situations. A key aspect of geoprocessing is the ability to design, build, and execute many types of analytic models that support this work.

Model Builder is a visual programming language for building geoprocessing workflows. Geoprocessing models automate and document your spatial analysis and data management processes. A model is represented as a diagram that chains together sequences of processes and geoprocessing tools, using the output of one process as the input to another process. Besides, Model Builder is an application that is used to create, edit, and manage models. While Model Builder is very useful for constructing and executing simple workflows, it also provides advanced methods for extending ArcGIS functionality by allowing you to create and share your models as tool. Model Builder can even be used to integrate ArcGIS with other applications and the Tools you create with Model Builder can be used in Python scripting and other models.(ESRI, 2017)

The geoprocessing framework provides the basis for spatial analysis and modeling through numerous tools and operators that work on geographic datasets. These tools use geography as a key for data integration, helping users discover and work with spatial relationships and use geographic operators to derive new information. Individual tools can be chained together into a sequence—most often called a process. This ability to create your own processes is one of the most effective uses of GIS. You can program your own ideas quickly and efficiently. Geoprocessing models and scripts help you organize the execution of tools into an automated sequenceorprocess..

2.5 Residential land use suitability validation

Huang et al., (2019) showed 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)

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1. Location of Study Area

The study area (Fig.3.1) viz. Adama City is extending between geographic coordinates of at 8° 30′ 52.1172″N latitude and 39° 16′ 9.3252″ E longitude at some 80 Kilometers away from Addis Ababa City. The maximum elevation of the city is 1712 meters above mean sea level. Owing to its geographical proximity to international port of Djibouti within the distance of about 777 Kilometers, the city is one of the preferred destinations for trade and industry.

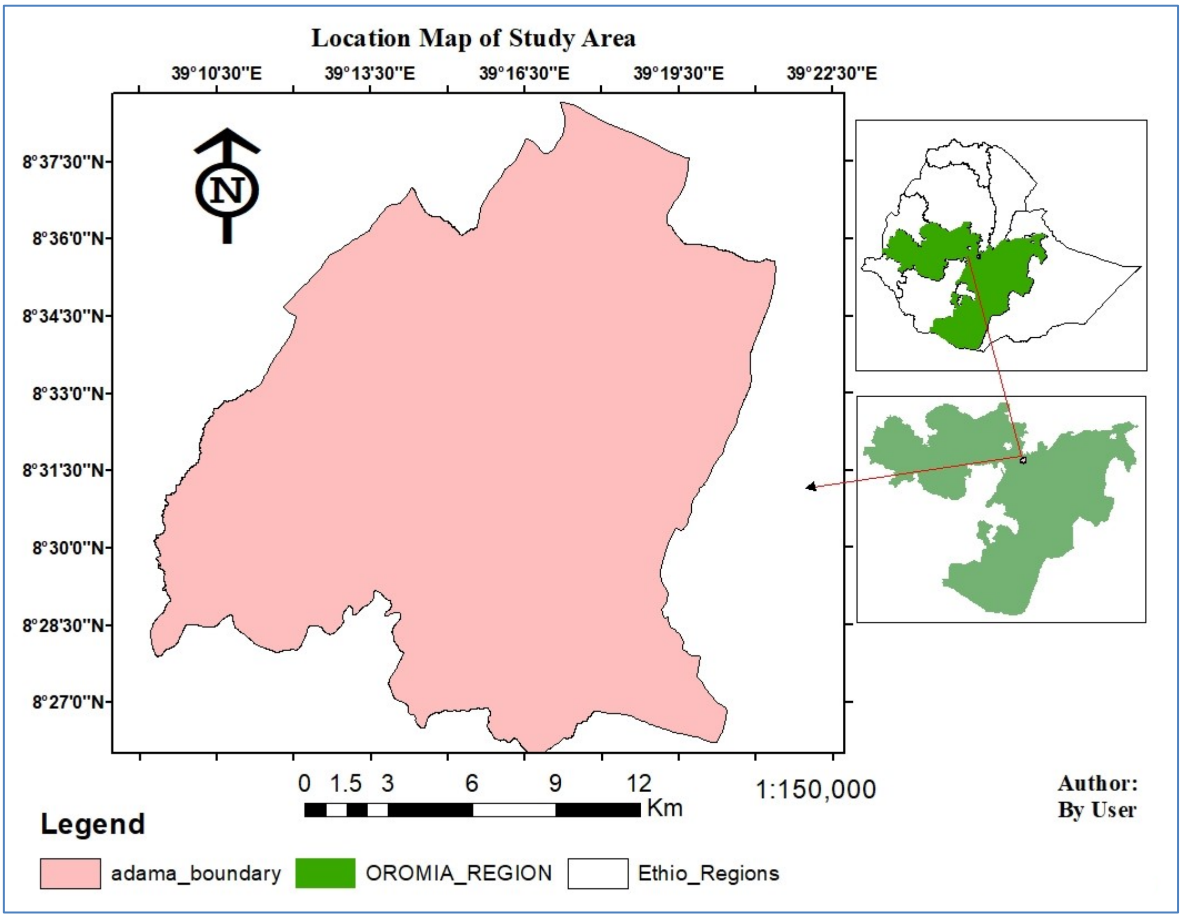

Figure 3.1. Location map Adama city

3.1.2. Population

According to the 1994 census result, Adama Administration had a total population of 252 thousand during the census period and in the year 2005; the population of the region has reached 384 thousand which exceeded the census period population by 132 thousand. The incremental within a decade time accounts more than half of the size of the 1994 population, which is tremendous in magnitude. On the other hand, the average annual growth rate of the population was 4% for the region during the years 1995-2000. The growth rate declined to 3.8% for the years between 2000 and 2005 and expected to further go down to 3.5% for the years between 2005 and 2010 IDP (2006).

The city had been restructured to eighteen urban Kebele (administration units) having the total area coverage of about 69 km2.As per the national population and housing census of Ethiopia, in 1984 the total population of the city was estimated to 99,980. In the second and third national census periods of 1994 and 2007 the total population of the city is about 173,188. the city is totally located in the Awash River Basin and the altitude ranges varies from 950 to 2,260 msl. In the south, it comprises the main escarpment of the eastern edge of Harerghe highlands. Adama is one of the largest and modern cities of Ethiopia. According to Adama Administration statistical report, in 2015 the city has a total population of 324000.

3.1.3. Climate

Adama Administrative Council is situated in Kola agro-climatic region, temperature is hot throughout the year with minor seasonal variations. Temperature progressively increases northward from somewhat Woina-Dega type along the mountain tops of the mountain ranges along the southern border and the low alluvial plains in the northwestern margin experience the lowest and the highest temperature recordings respectively in the region. The seasonal rainfall has a bimodal distribution with peak in April and August. The two seasons are 'Meher' and 'Belg' and they receive about 80% of the annual rainfall separated by a short dry spell in June. The mean annual rainfall is 657mm and mean monthly values varies between 5.7mm (December) and 119mm (April), which indicate poor temporal distribution of rainfall. The mean annual average air temperature is 25.30 and June is the warmest month of the year while December and January are the coldest.

3.2. Data collection Method

Primary data collection was conducted with open ended questionnaires and interviews with local expertise. Whereas secondary data collections includes reviewed literature and policy analysis on urban land suitability analysis for residential areas. In addition infrasture spatial data gathered from Adama municipality. Questionnaires were formulated and used as a guide to collect data from experts; a form is attached in appendix-1.

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.Secondary data which include: literature, urban land policies, reports, and different spatial data were obtained from the internet and Adama City urban Land Management office

3.2.1. Data types and sources

The study will mainly be supported by geospatial datasets gathered from different sources. In addition, primary data will be gathered from geospatial datasets such as ASTERT Global elevation Model (DEM) with 30m x 30m spatial resolution, Structural plan of the city, land-use land-cover, Orthophoto.

Table3.1: Data required and their sources

No	Data required	sources	purpose
1	Structural plan	Adama City urban Land Management office	To compare the result
2	Sentinel Image	USGS Earth Explorer	To generate land use land cover
3	DEM	ASTER Global DEM (gdem. aster. ersdac. or/jp /search.	To generate slope data
4	Orthophoto.	Adama City urban Land Management office	LULC verification

3.2.2. Software used

The mainly software used in this research are ArcGIS and Idirisi selva. ArcGIS have been used to create the geodatabase, performing spatial multi criteria analysis, generating criteria maps and assigning weightage for each criterion, overlaying, analysis, Creating model tool and visualization of output data.

Inaddition, IDRISI is a comprehensive geographic analysis and image processing system that has been developed by Clark Labs for Cartographic Technology. This software has been used to perform multi criteria decision analysis using the built-in decision support module.

Table 3.2 Summary of software used in this study

No.	Facility and software	purpose
1	ArcGIS 10.8	Spatial data processing, analysis and output generation
2	Edrisi Selva ver.17	Weight comparison for each factor
3	Google Earth Pro	To verify and validate the result with the existing Land use currently
4	Microsoft office (Word, ppt and Excel)	Report writing and final thesis presentation

3.3. 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 3.1

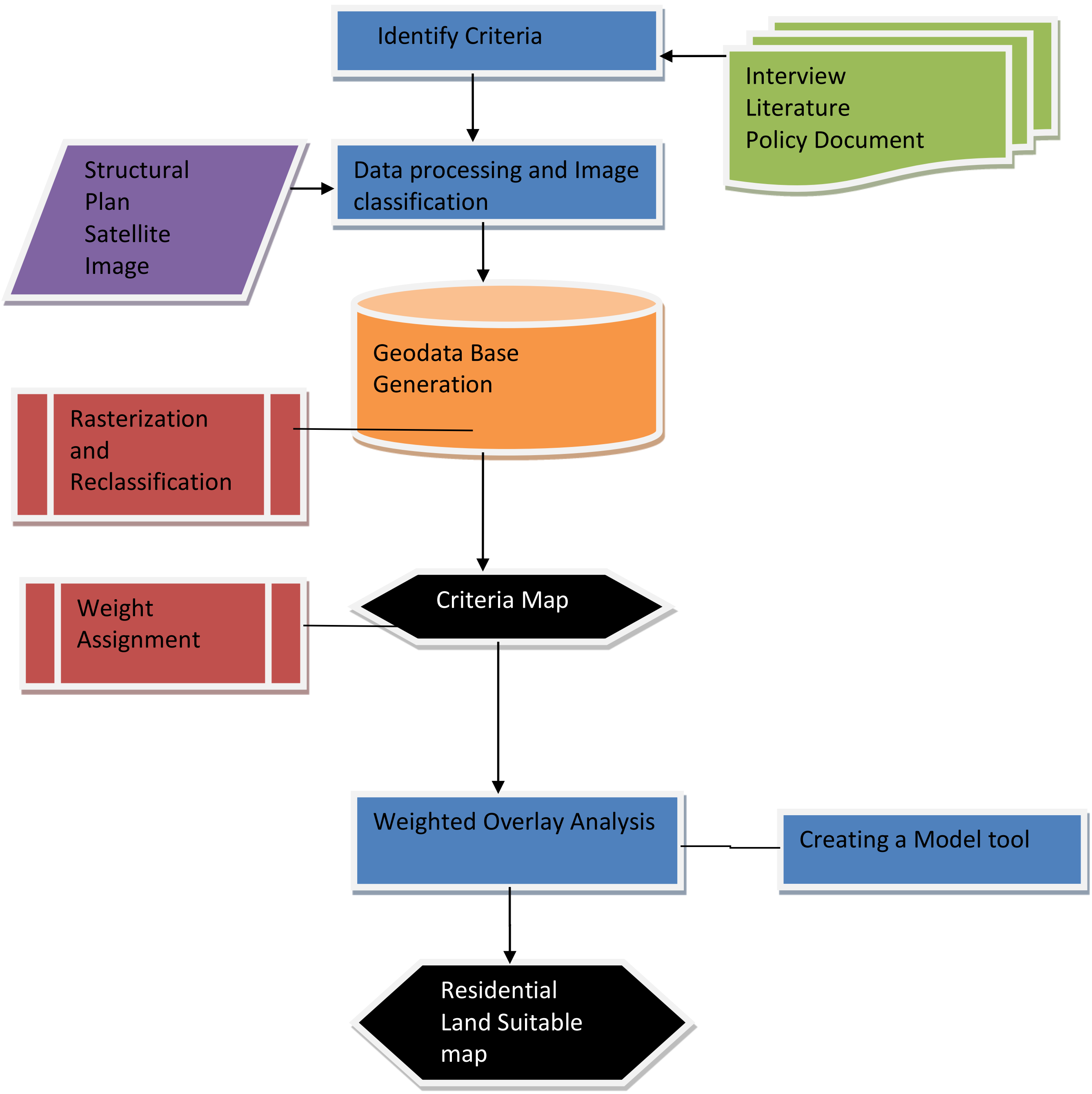

Figure 3.2 flow chart of the methodology

3.3.1 Factors Determination

Criteria mean a standard of judgment, principle for evaluating or testing something. Criteria are a general category of information concerning the site being evaluated. The criteria often considered in land suitability studies include natural environment factor like slope, soil type geologic hazards present, land cover, etc., Build environment factors like existing land use, planned land use, accessibility to roads, availability of utilities, etc., Economic factors like land value, tax rate, etc. and social factors like population present, job present, historical features present, etc. In this research criteria were selected using the literature reviews of internal and external references, Interview result and availability of data.

The land suitability assessment is the selection of the influencing factors since there are too many criteria affecting the land suitability. The selection of influencing criteria should also consider the objective of suitability analysis. Therefore, criterion was selected to easy to finding suitable residential locations in Adama city.

3.3.2. Data processing and Image classification

In this research, georefercing the structural plan and satellite image enhancement were conducted in ArcGIS 10.8. Supervised Image classification technique was used to classify the sentinel 2021 image of Adama.

3.3.3. Geodata Base Creation

A geodatabase is a physical container for storing geographic data. Fundamental elements of the geodatabase include feature classes, raster datasets and tables. In this Research, Gedatabse was created for efficient storage of the vector and raster datasets by centralizing in one location and for simplifying spatial relationship model.

The geodatabase is the primary data storage model for ArcGIS. It is a container of spatial and attribute data and enables the user to store many different types of GIS data within its structure. Its structure is implemented in an RDBMS or as a collection of files in a file system. Sample created geodatabase in this work shown below fig.3.3

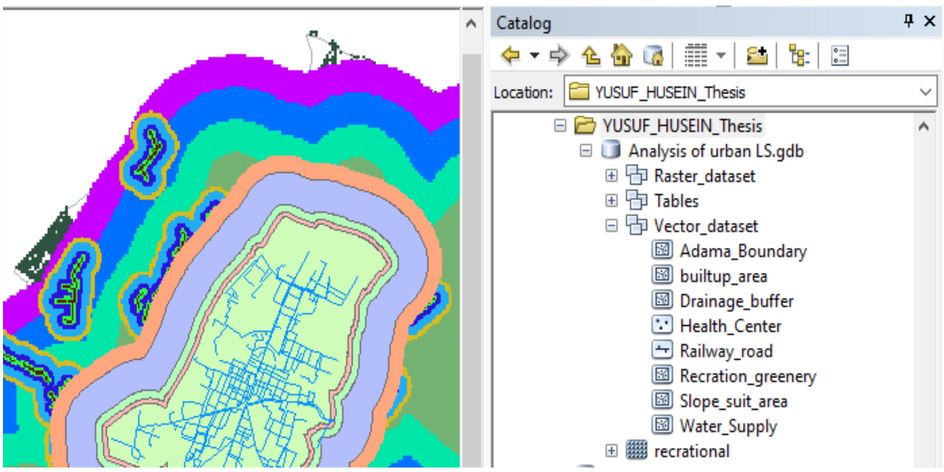

Figure 3.3: showing geodatabase created.

3.3.4. Preparing Criteria Map

Based on the given priority preferences nine criterion were identified and nine criterion maps were developed by Rasterization and Reclassification process in ArcGIS 10.8. The reclassified images are: Reclassified slope Map, Reclassified road suitability map , Proximity to railway suitability , Reclassified flood hazard suitability map, Reclassified Built map,LU/LC classification and suitability analysis, Reclassified recreational areas map, Reclassified Health care map and Reclassified Water Supply map.

3.3.5. Prioritize Criteria based on AHP

Weighting in suitability analysis refers to assigning a numeric value to each factor in order to recognize its relative importance, and usually express in percent format (Pease and Coughlin, 1996). The weights represent the relative importance of each factors attribute. The weight value for the suitability of one factor used in this research was based on interpretation of published materials as well as several experts. The weights can be determined through method such as Delphi and the pairwise comparison pioneered in the Analytic Hierarchy Process (AHP) method. Calculation of weights for criterion maps was based on the multi criteria evaluation.

Analytic Hierarchy Process was applied for that. Based on that pair wise comparison matrix was prepared according to AHP scales. For determining the relative importance of the criteria the pair wise comparison matrix using Saaty‘s nine point weighting scale has been applied. In AHP, all identified factors are compared against each other in a pair wise comparison matrix which is a measure of relative preference among the factors. Therefore, numerical values expressing the relative preference of a factor against another. Saaty (1977) suggested a scale for comparison consisting of values ranging from 1 to 9 which describe the intensity of importance which a value of 1 expresses equal importance over another factor. the factors were pair wise compared. In order to compare criteria with each other, all values need to be transformed to the same unit of measurement scale.

suitable, less suitable, moderately suitable and highly suitable. After weighting the criteria, as regards the relative importance of each criterion as well as suitability index, all the criterion maps were overlaid and final suitability map was prepared. Suitability map s resulting from Multi Criteria Evaluation (MCE).

Table 3.5: 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 on 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)

3.3.6 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 (Alshalabi et al., 2006).

In this research, weighted overlay analysis tool of ArcGIS 10.8 was used to select the area suitable for residential housing.

3.3.7 Creating a Model and Tool

In this research, a model was created in model builder tool of ArcGIS 10.8, to automate the Analysis and for better data management. Models are workflows that string together sequences of geoprocessing tools, providing the output of one tool to another tool as input. Model Builder can also be thought of as a visual programming language for building workflows. In addition a tool was developed by customizing the python script generated from the developed model to simply the residential land use site selection process in adama city

CHAPTER FOUR

4. REUSLTS AND DISCUSSION

4.1. Selecting Criteria for residential suitability analysis

Through constructing 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 slope, proximity to road, Rail way, Drainage, proximity to built-up, land use land cover, Recreation Area, Health care, water supply.Ullah and Mansourian (2015); Raghunath (2006); Ekanayaka (2014) and Huang et al., (2019).

These criteria (factors and constraints) were considered highly specific and relevant for the study area. The following 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 in Adama City.

4.1.1 Slope

As far as the topography of the study area is concerned, since the steeper slope Demands relatively gentle slopes with flat terrain were much preferable. Contrary, steep slope area eventually increased cost of construction. Thus, an area with slope between 2% -14 % is suitable for housing.

4.1.2 Accessibility to road

Accessibility to road is one of important criterion in site suitability to facilitate the mobility and linkage between the settlement sites. Hence, Evaluation of accessibility to public infrastructure in terms of distance from a particular location using particular transportation must be taken into consideration while selecting suitable site for housing. At any rate, the road accessibility is the most important factor and any housing development project must be confined within 1-5 km radius. However, revealed that road distance may not strongly affect suitable site i.e., the more the site is closer to the street the more likely suitable for residential house because of transportation access with short distances. For this particular study, the Euclidian distance from both sides of the main road is generated and reclassified.

4.1.3 Proximity to Railway

Moreover, stated that housing should 200 meters far away from the railway line to minimize noise disturbance and safety of the residents. Hence, buffer distance of 200 meter on both side of the rail line was analyzed and reclassified.

4.1.4 Proximity to Drainage

From the goal of safety, the candidate suitable site for residential housing area should be free from risk provoked by flooding during rainy seasons. According to the structural plan of the city, no any development is permitted within 30-meter limit in both sides of flood sheet areas. Thus, the distance far away from ditch channels were more suitable for housing.

4.1.5 Proximity to built-up (developed) Area:

The built-up area was extracted from land Uses to incorporate in the analysis. Hence, Urban built-up areas were considered since the new urban development for housing should be located closer to the existing built-up to minimize the occurrence of urban sprawl and create coherence with predeveloped area. Thus, an area adjacent to existing built up area is much preferable for residential housing.

4.1.6 Land-uses/land-cover:

The next important parameters considered was land-uses/land cover map analyzed from Sentinel 2 satellite image of 2021. The land use of the city has been classified as follows: Urban Agriculture, Built-up, Green area, and open forest. In this study, built-up area is restricted (unsuitable) since it is already developed area, whereas, Urban Agriculture is given high preference followed by Green area for new housing development.

4.1.7 Proximity to Recreation Area

Public and private areas that are predictably used for bird watching, bike riding, hiking, or camping or other recreational use also would be considered recreational areas. Parks, open spaces and trails play a key role in preserving water and air quality, reducing congestion and protecting wildlife. Through the provision of parks, open spaces and protected natural environment, recreation contributes to the environmental health of our community. Planning now to protect important open space and recreational facilities can greatly enhance the attractiveness of your community and encourage compatible growth in the future. Planning allows the City to confront and manage aspects of growth and development in ways that preserve, protect, and enhance the environment.

Generally, experts and different scholars forwarded, for recreational area lands within 500meter 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).

4.1.8 Proximity to Health Care

Urban residents who live near parks report better mental health. The nearer away from the residential area, the better, According to researcher (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.

4.1.9 Proximity to Water Supply

The final criteria are water supply in which People depend on water for drinking, cooking, washing, carrying away wastes, and other domestic needs surrounding their living residential. Water supply systems must also meet requirements for public, commercial, and industrial activities. In all cases, the water must fulfill both quality and quantity requirements. Different scholars and article 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 (Murseli,2014).

4.2 Determined weight values and Presentation of Results

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.

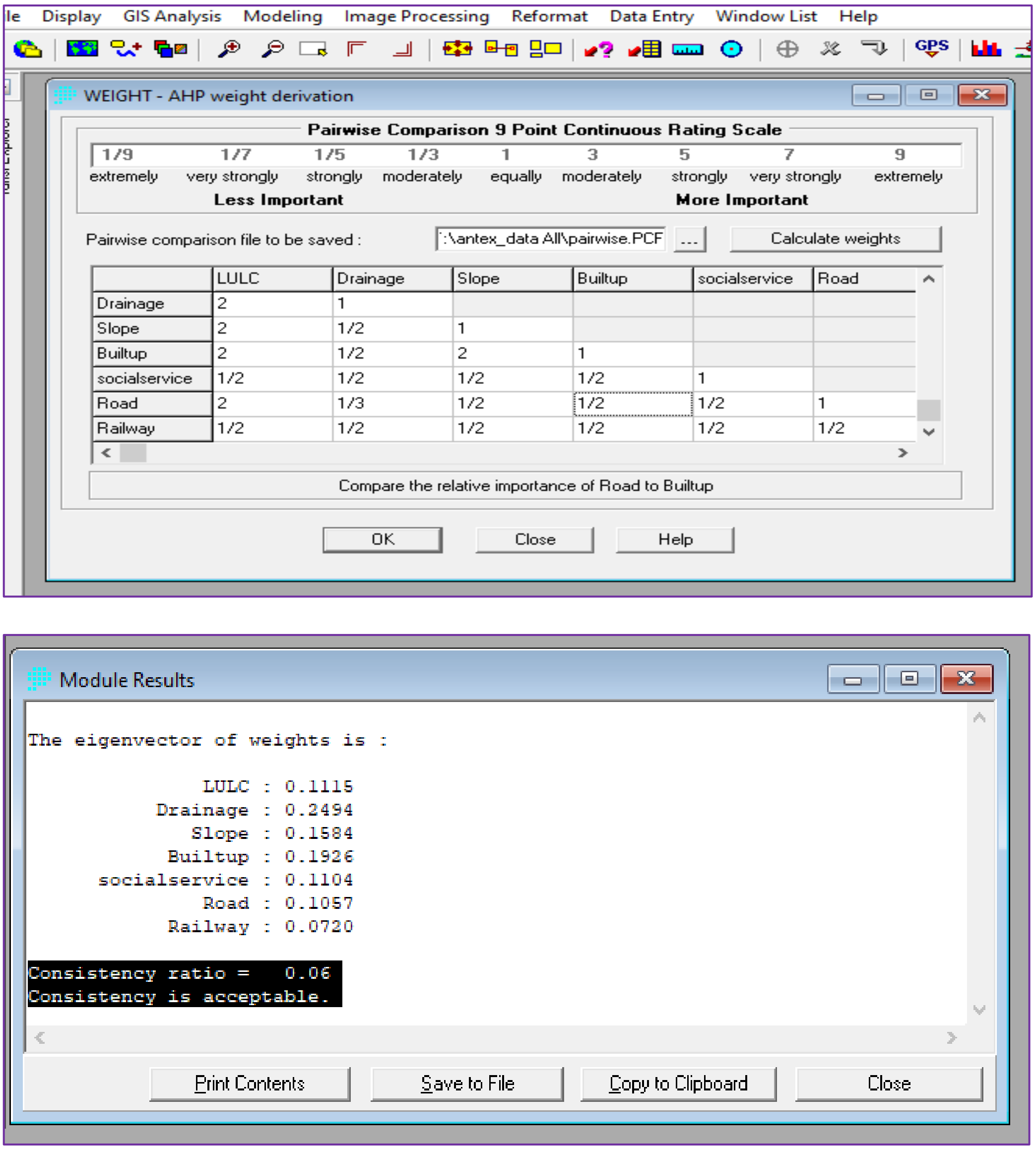

Figure 4.1 Ranking the Suitability of influencing criteria

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).

The maps were valuable to the consortium as guides to locations that should be evaluated further. However, more data are available that could be very useful in any further evaluation. This GIS- formatted data includes nearby roads or streams, proposed residential areas, school district boundaries, other social facility in the areas, etc. Adding it to these maps would make the maps so cluttered as to make them almost usefully. What was needed was a method to quickly examine the data by analyzing and reclassifying. Being able to view this ancillary data would add greatly to the use of the analysis as a tool in ArcGIS.

4.2.1. Slope suitability conditions

Slope can be described as the ratio of rising/fall divided by the run between two points. In this study, slopes calculated as percent rise a maximum slope of 24% is assumed. Accordingly, the area was classified in to five slope classes:<2%, 2-8%, 8-14%, 14-24%, and >24% (Table 7; Figure 8). 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 costlier in comparison with the flat areas (gilo,2021) sited in (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 4.1: Slope conditions suitability

s/no	Slope (%)	Score	Suitability index	Area (Sq km)	Area (%)
1	0-2	4	Very high	69.88	22.52
2	2-8	3	High suitable	112.27	36.18
3	8-14	2	Moderate	58.25	18.77
4	14-24	1	Low suitable	69.07	22.26
5	>24	0	Restricted	0.87	0.28
Total				310.34	100

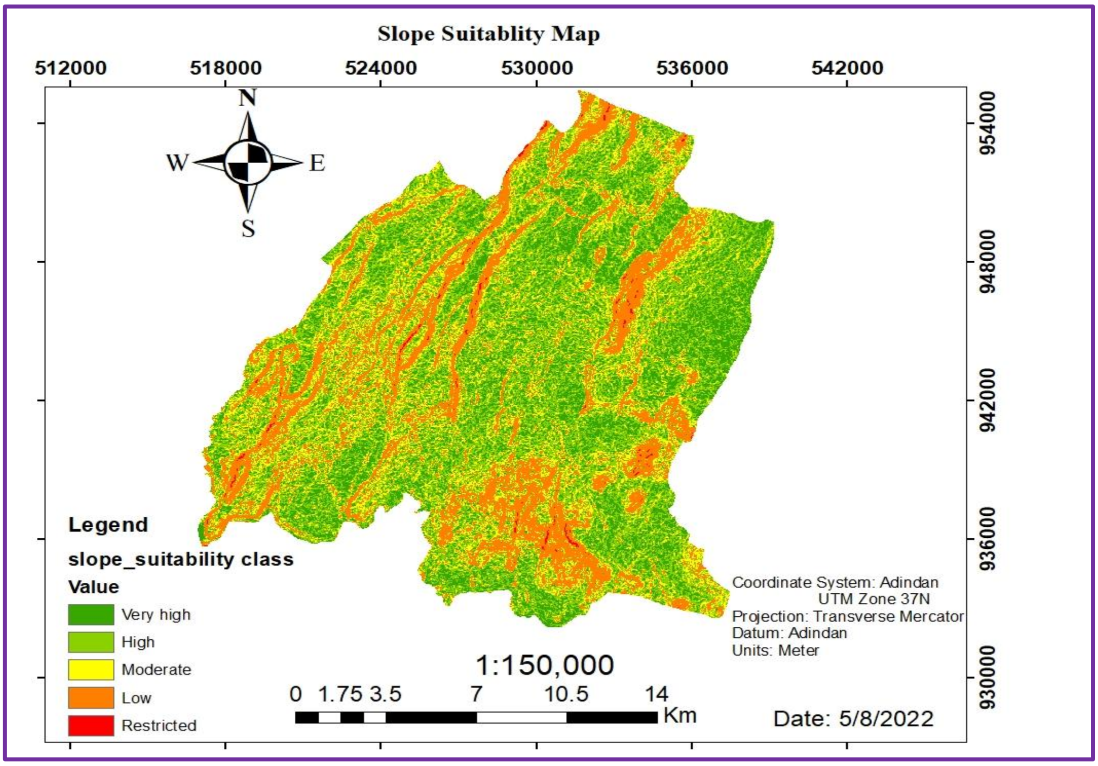

Figure 4.2. Reclassified slope

4.2.2. 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).

Table 4.2: Proximity to main road suitability analysis

S/No	Buffer(M)	Score	Suitability Index	Area (Sq. Km)	Area (%)
1	<1000	4	Very high suitable	230.9737	46.70
2	1000-2000	3	High suitable	93.72961	18.95
3	2000-3000	2	Moderate suitable	85.17579	17.22
4	>3000	1	Low suitable	84.75484	17.13
Total				494.63	100

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.

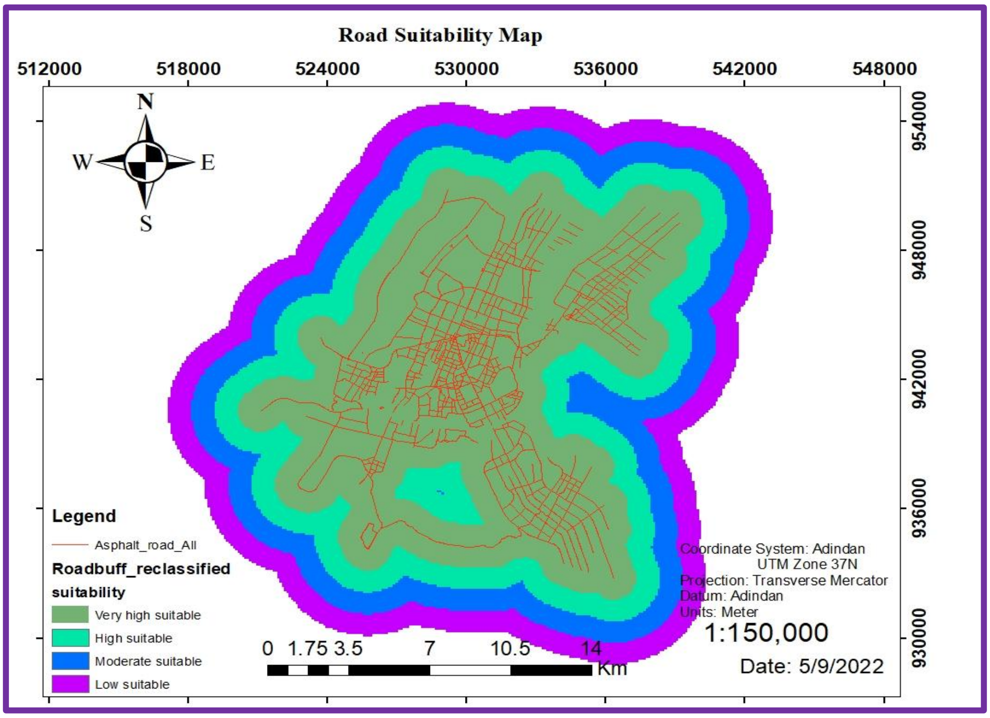

Figure 4.3. Reclassified road suitability map

4.2.3. Proximity to the railway suitability

For this study, the Euclidian distance from both sides of the main road is generated and reclassified. Moreover, stated that housing should 200 meters far away from the railway line to minimize noise disturbance and safety of the residents. Hence, buffer distance of 200 meter on both side of the rail line was analyzed and reclassified. (Table 4.3 and figure 4.3)

Table 4.3: Proximity to rail road suitability analysis

S/No	Buffer(M)	Score	Suitability Index	Area (Sq. Km)	Area (%)
1	<100	1	Very Low	7.48	10.24
2	100-200	2	Low	7.22	9.89
3	200-500	3	Moderate suitable	21.80	29.85
4	>500	4	Very high suitable	36.53	50.02
Total				73.04	100

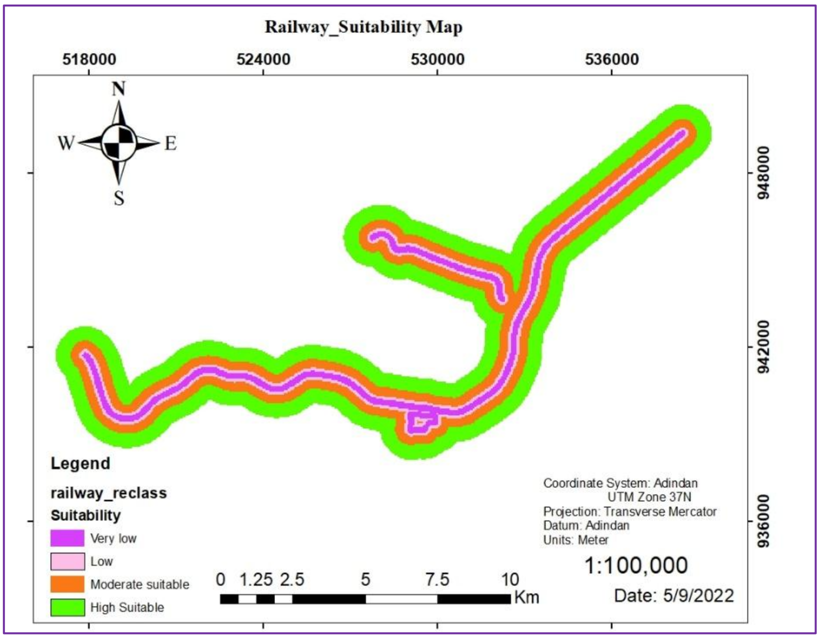

Figure:4.4 Proximity to railway suitability

4.2.4. Proximity to Drainage line suitability

For a *residential* installation, the *sewer pipe* typically starts where the home's main *drain* exits the *house* foundation. A buffer of 30 meters radius to existing drainage line areas were created to restrict from future residential housing development. Table below shows 15.08 % of total lands are falls under very high suitable. It is only 9.79 % of land is unsuitable (Table 4.4; Figure 4.5.). Murseli & Isufi, (2014) also suggested that no residential housing development is permitted within 30 meters on both sides of drainage line areas. Therefore, areas greater than 500-meter from the river are more suitable for urban development than areas within 500 M buffer limit.

Table 4.4: Proximity to drainage line area suitability analysis

S/no	Buffer(m)	score	suitability index	Area (km2)	Area (%)
1	<30	0	Unsuitable	10.97408	9.79
2	30-100	1	Low suitable	20.01936	17.86
3	100 -250	2	Moderate suitable	30.53102	27.23
4	250-500	3	High suitable	33.68893	30.05
5	>500	4	Very high suitable	16.90287	15.08
Total				112.12	100

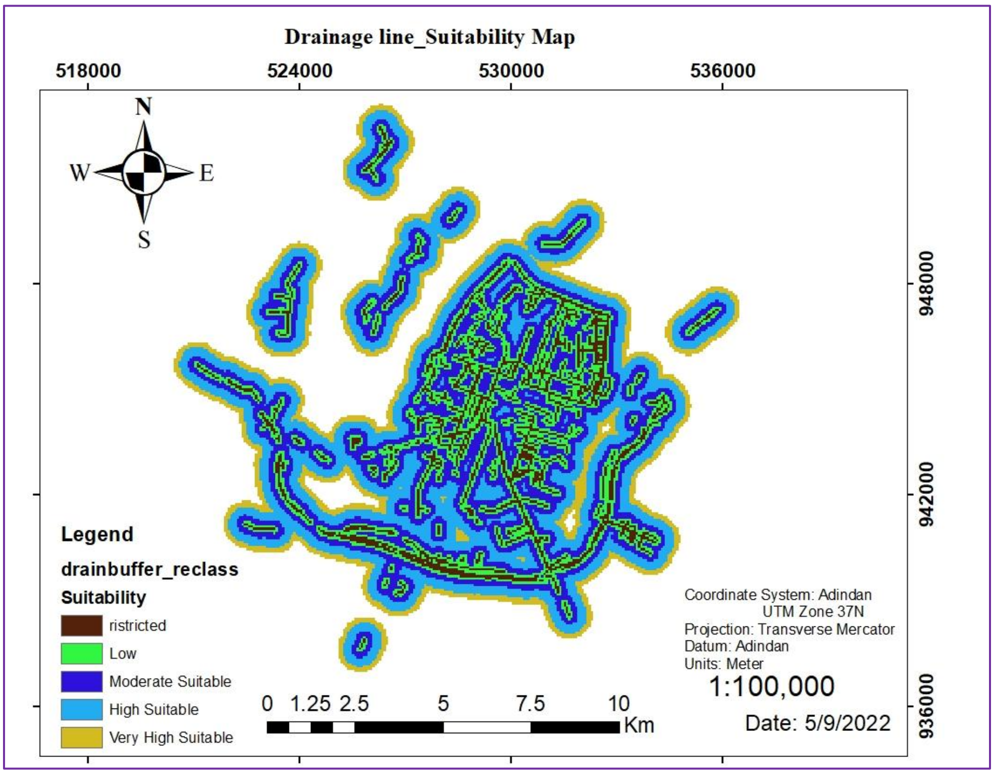

Figure: 4.5. Reclassified flood hazard suitability map

4.2.5. 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 15% of the land of the study area fall under low suitable. It is only 52.96 % of the land is very high suitable (Figure 4.7). 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 (gilo,2021) sited in (Raghunath, 2006).

Table 4.5: Proximity to Urban built-up area suitability analysis

				132.6268	52.96
				41.65485	16.63
				38.37677	15.32
				37.77817	15.08
				250.44	100

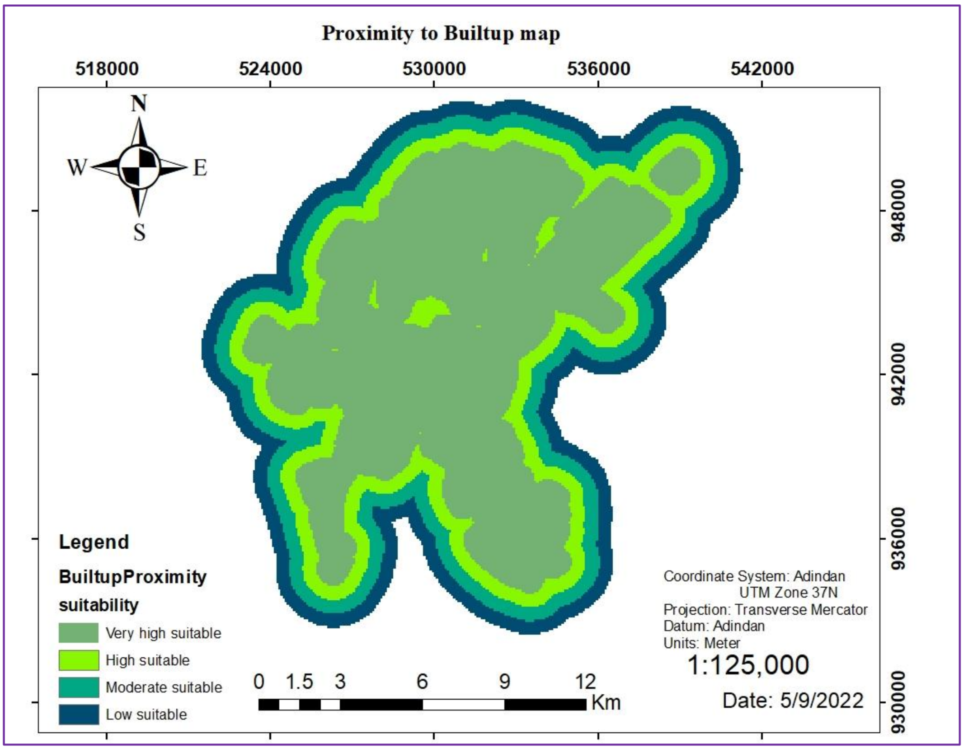

Figure 4.6. Reclassified built-up suitability map

4.2.6. Land-uses land-cover suitability

According to national urban planning institute experiences, vacant (bare) lands are more preferable for future urban development. Therefore, open 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 4.6; Figure 4.8).

Table 4.6 LU/LC classification and suitability analysis, 2022

S/No	Category	Score	Suitability Index	Area (Sq Km)	Area (%)
1	Built up area	1	Very Low suitable	103.853	33.10
2	Urban agricultural	2	Moderate suitable	183.463	58.48
3	Green area /Shrub land	3	High suitable	7.90394	2.52
4	open forest	4	Very high suitable	18.5172	5.90
Total				313.74	100

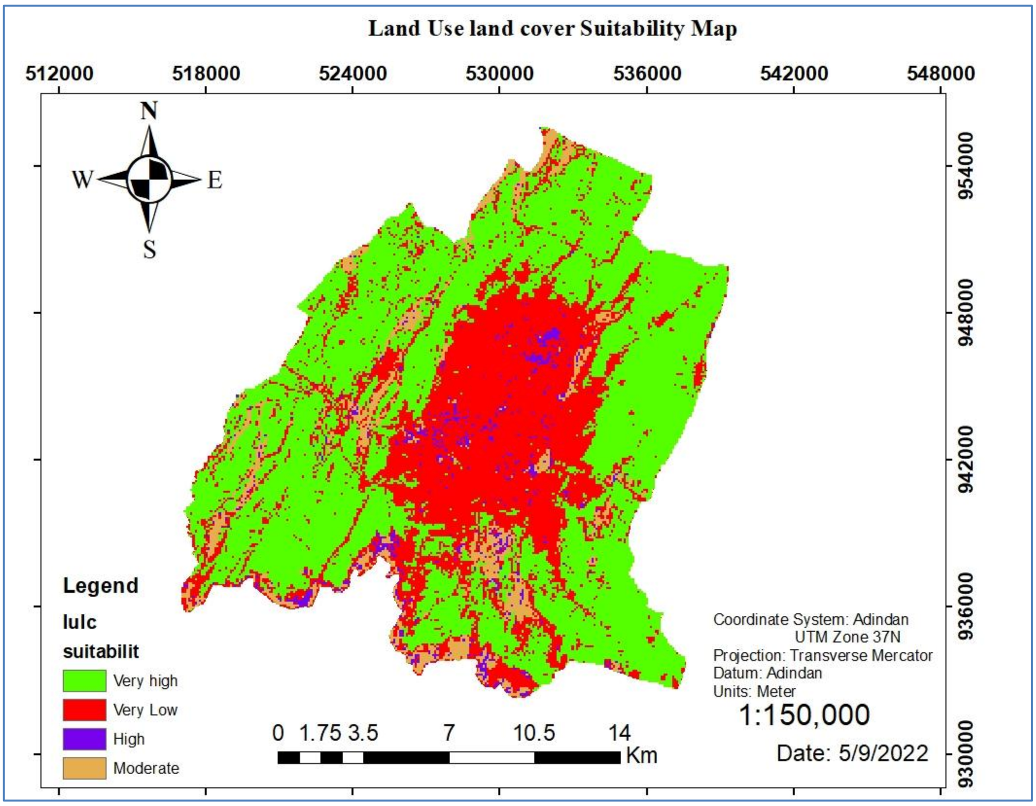

Figure 4.7: LU/LC classification and suitability analysis, 2022

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 4.8). 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).

Classified Data	Reference Data				Row Total	User (100%) Accuracy
	Green area /Shrub	Built-up Area	Open Forest	Urban agricultural		
Green area /Shrub	7250	9.12	12.68	31	7302.8	99.3%
Built-up Area	43	1371	0	0	1414	97.0%
Open Forest	12.96	67	754	0	833.96	90.4%
Urban agricultural	14.3	63.5	0	954	1031.8	92.5%
Column Total	7320.26	1510.62	766.68	985	10583	
Producer Accuracy(100%)	99%	91%	98%	97%		

4.2.7 Accessibility to recreational area

In study area the result of recreational reveals that 4.64%, 16.23%, and 29.71% are high suitable, moderate suitable, and very high suitable respectively (Table 4.6; Figure 4.7). 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 4.7: Recreational area suitability

S/No	Buffer(M)	Score	Suitability Index	Area (Km^2)	Area (%)
1	≤500	4	Very high suitable	7.94	4.64
2	500-1500	3	High suitable	27.78	16.23
3	1500-3000	2	Moderate suitable	50.87	29.71
4	>3000	1	Low suitable	84.61	49.42
Total				171.19	100

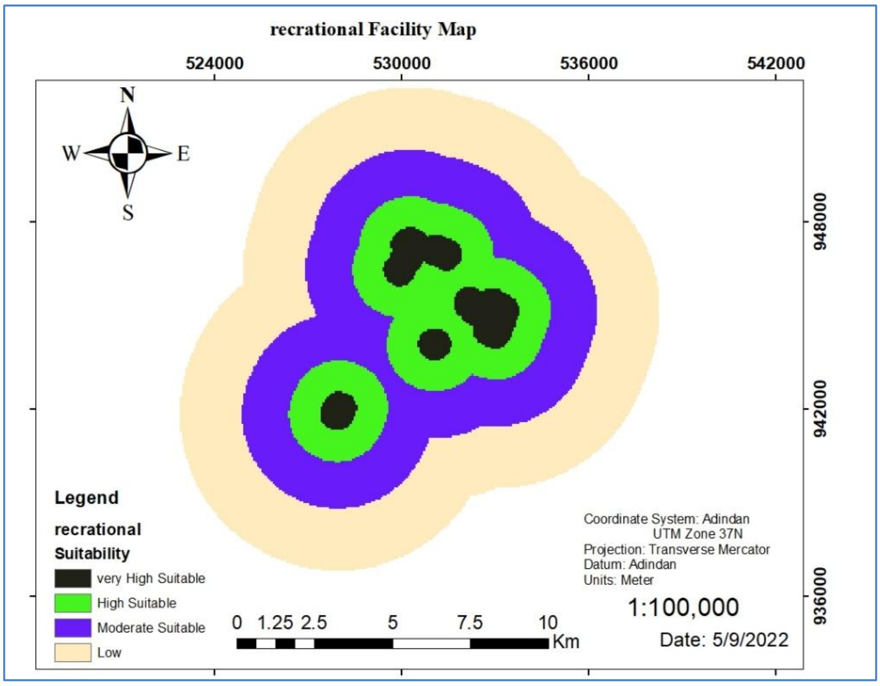

Figure 4.8. Reclassified recreational areas map

4.2.8. Health care accessibility conditions

Based on collected data from city administration health center in the study area, 2.69 % of the area is highly suitable for healthcare facilities (Table 4.13). In the map it is also indicated in the green color the place where very high suitable for health care facility (Figure 4.12). 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 4.8: Healthcare suitability condition

S/No	Buffer(m)	Score	Suitability Index	Area (Sq. Km)	Area (%)
1	≤500	4	Very high Suitable	5.18	2.69
2	500-1500	3	High Suitable	34.05	17.70
3	1500-3000	2	Moderate suitable	61.72	32.08
4	>3000	1	Low suitable	91.47	47.54
Total				192.42	100

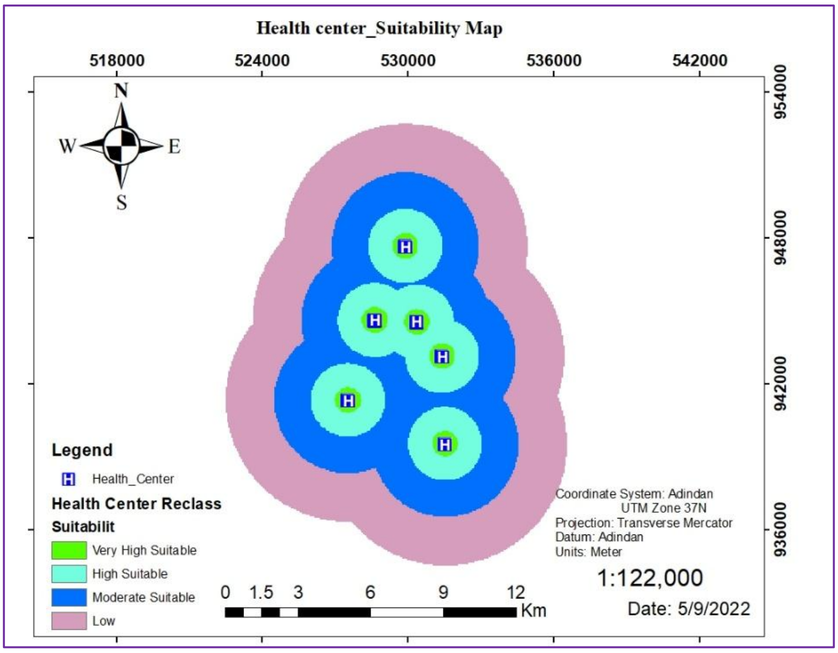

Figure 4.9. Reclassified healthcare suitability map

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 32.05 % and 41.19 % are low suitable and very high suitable respectively (Table 4.9; Figure 4.11). 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 4.9: Proximity to Water supply Zone

S/No	Buffer(m)	Score	Suitability Index	Area (Sq. Km)	Area (%)
1	<100	4	Very high suitable	57.42	41.19
2	250	3	High suitable	8.20	5.88
3	1000	2	Moderate suitable	29.10	20.88
4	>= 1000	1	Low suitable	44.68	32.05
Total				139.40	100

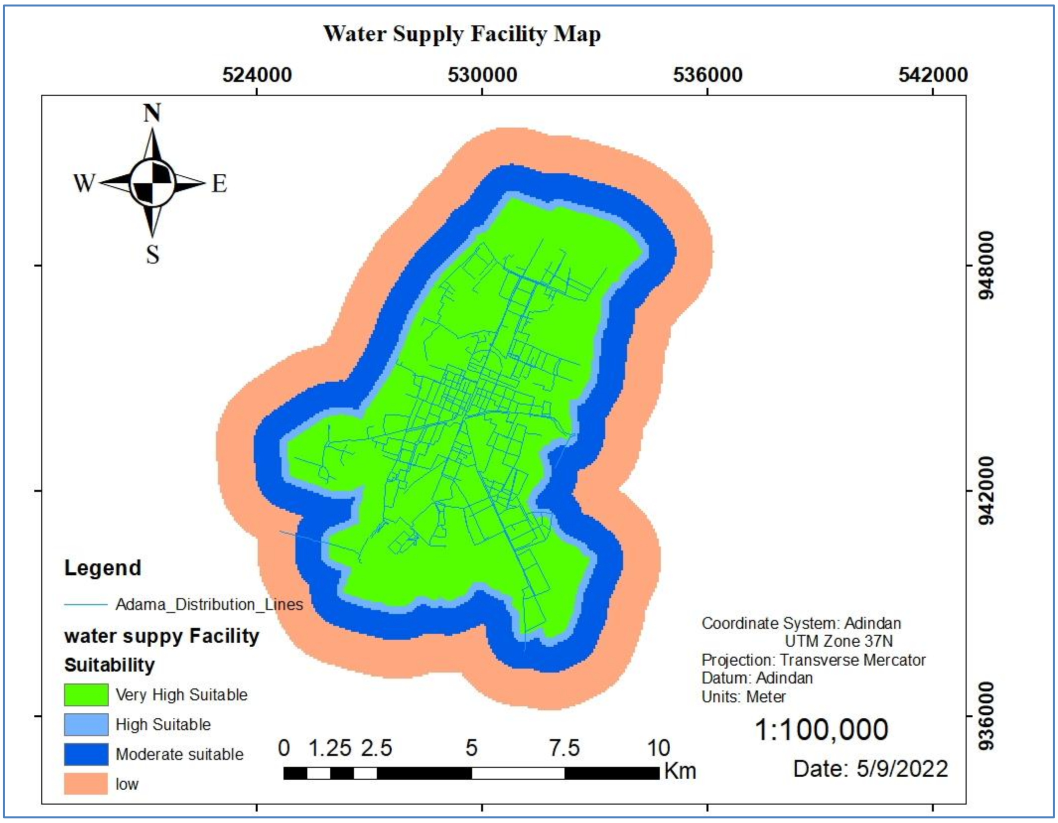

Figure 4.10. Reclassified water supply line map

4.3. 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 4.12). Weighted linear combination (WLC) could be computed by equation 4.

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

Where: S - Suitability Index for residential areas

S - 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] * 0.0115) + ([reclassed slope] *0.1639) + ([reclassed Proximity to built-up] * 0.19839) +([re-classed proximity to Drainage] * 0.02499) + ([re-classed proximity to road]* 0.118)+ ([re-classed proximity to healthcare services] * 0.1965) + ([re-classed proximity to railway] * 0.07))* Π (b0/1)).

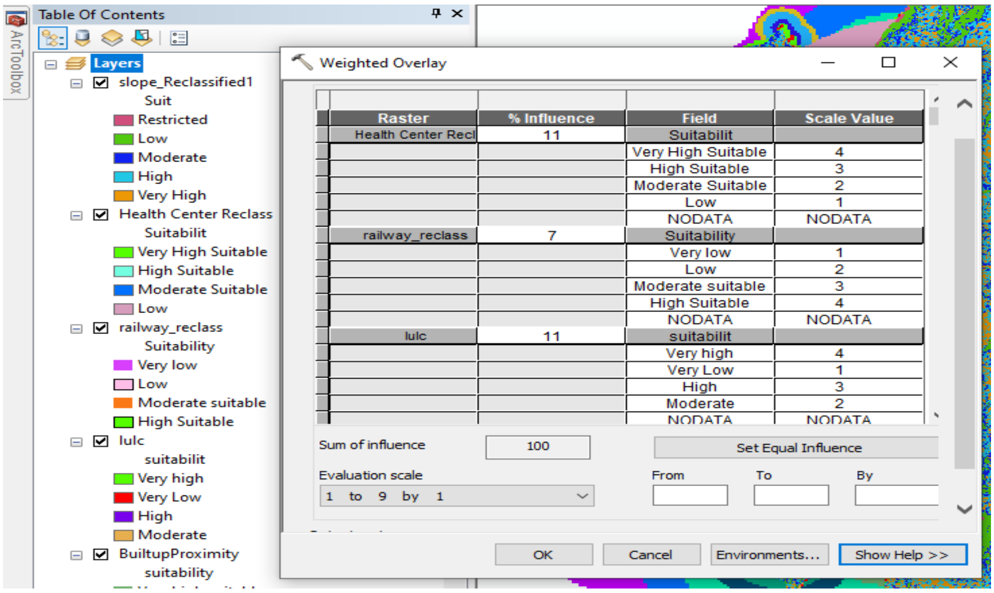

Figure 4.11. Weighted overlay analysis toolbox

Accordingly, Figure 4.12 reveals that Adama city can be divided into five suitability indexes. Table 4.10 shows that 60.43% 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 4.13) areas with yellow color represents for very high suitable, whereas areas with blue color stands for high suitable while loam and orange color represent for moderate suitable and low suitable respectively. The findings also show that very high and high suitable lands cover 12.91% and 8.14 % are respectively while low and moderate suitable covers 6.72 and 11.80 % of the whole area (Table 4.10).

Table 10: Composite suitability conditions

1	0	Unsuitable	1694.3	60.43
2	1	Low suitable	188.46	6.72
3	2	Moderate suitable	330.803	11.80
4	3	High suitable	228.153	8.14
5	4	Very High suitable	362.042	12.91
Total			94.61	100

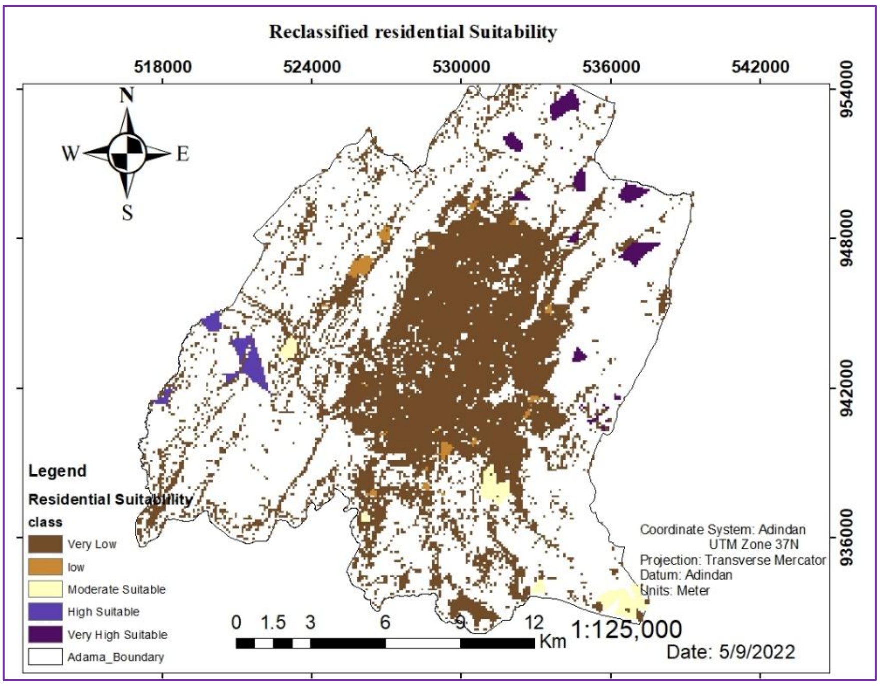

Figure 4.12: weighted overlay map of Residential suitability in Adama city

4.4. Developed Model and tool for Adama residential land suitability Analysis.

In this research, a model was developed in ArcGIS model builder to automate and simply a long process of GIS Operations for Adama residential land suitability Analysis. Model Builder was used in this research for creating, editing, and managing models. Models in ArcGIS are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into the next. ArcGIS Model Builder was chosen in this research for better data organization, improved workflows and faster analysis. By standardizing processes in this way, any future repeat analysis is also made much easier, enabling replication and direct comparison of results.

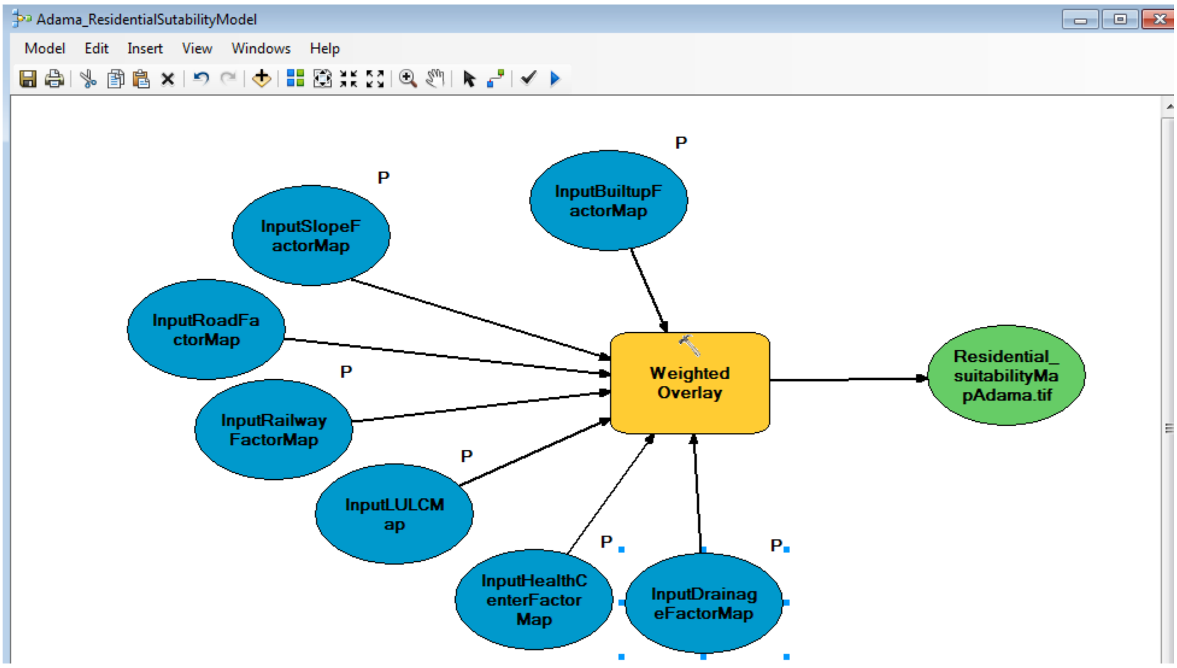

Figure 4.13: weighted overlay model of Residential suitability for Adama city

Figure 4.13 shows, weighted overlay model created for Residential suitability for Adama city, The Blue color represents, the model input parameters and the yellow color is a method. The output of the analysis is saved in the output folder, which is represented in green. This is a simple model developed for conducting weighted overlay analysis for the existing prepared factor maps.

Geoprocessing model allows you to chain together sequences of tools, feeding the output of one tool into another. You can use this ability to compose any number of geoprocessing models (tool sequences) that help you automate your work, solve complex problems, build repeatable workflows, and document your methodology. Figure 4.14 shows the model process developed, to identify potentially suitable areas for Residential Housing of Adama City. This sequences of process was built using the graphical modeling program in ArcGIS called ModelBuilder and then the model was converted to python script and further customized to create a tool for Residential suitability for Adama city

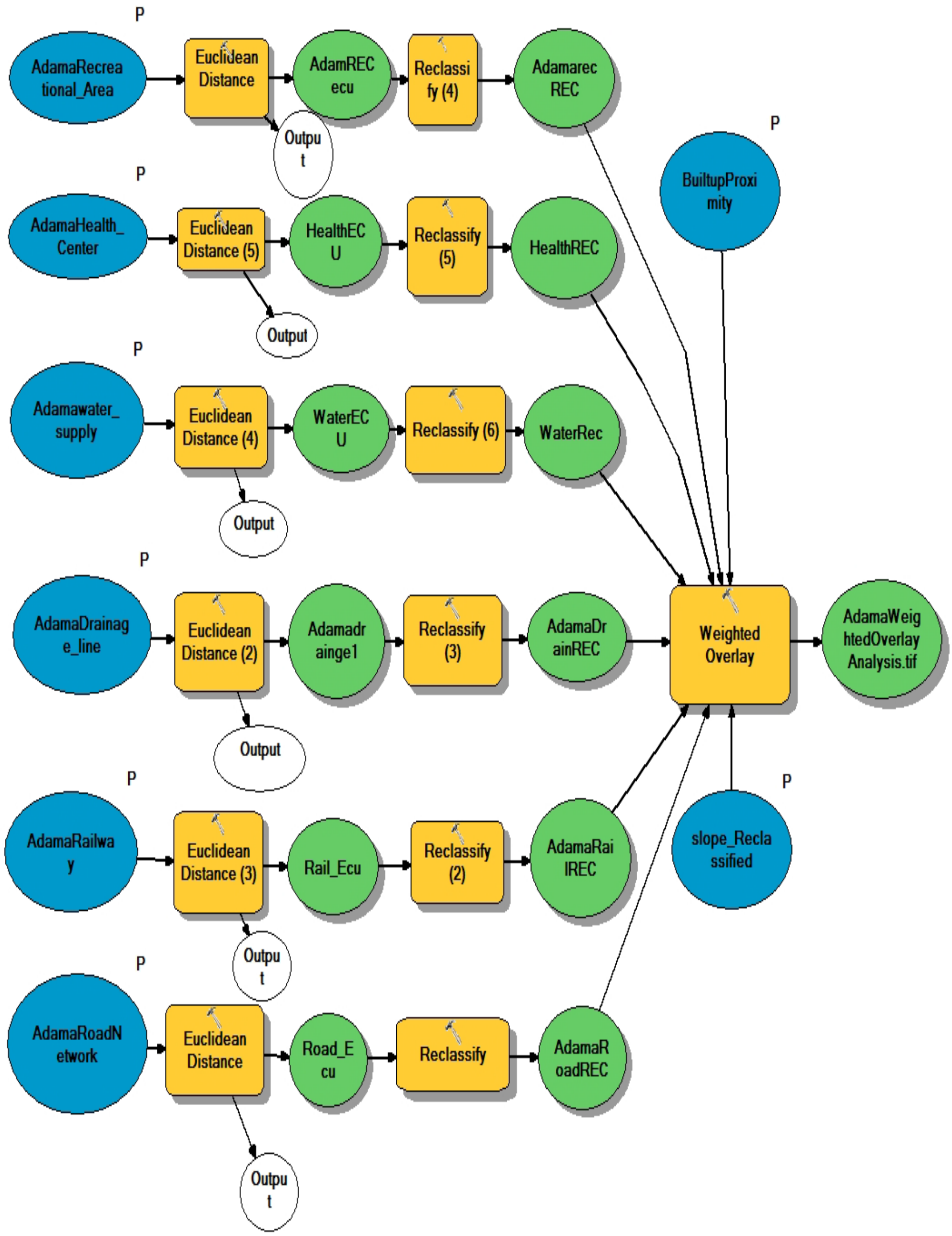

Figure 4.14: Model for Residential suitability Analysis of Adama city

In this research, a script tool was developed in ArcGIS that allows, to turning the python scripts and functionality in to geoprocessing tools, tools that look and act like system geoprocessing tools. To create a Tool a script, a custom toolbox and precise definition of the parameter of the script was used. Figure 4.16 shows the developed tool for conducting suitability analysis for Future residential housing area selection of adama city. The tool requires the input data of Roads, slope, Built-up proximity, Railway,LULC,health center,Health Center, recreation Area for performing the analysis and then save the result. See appendix II of the python script for the tool

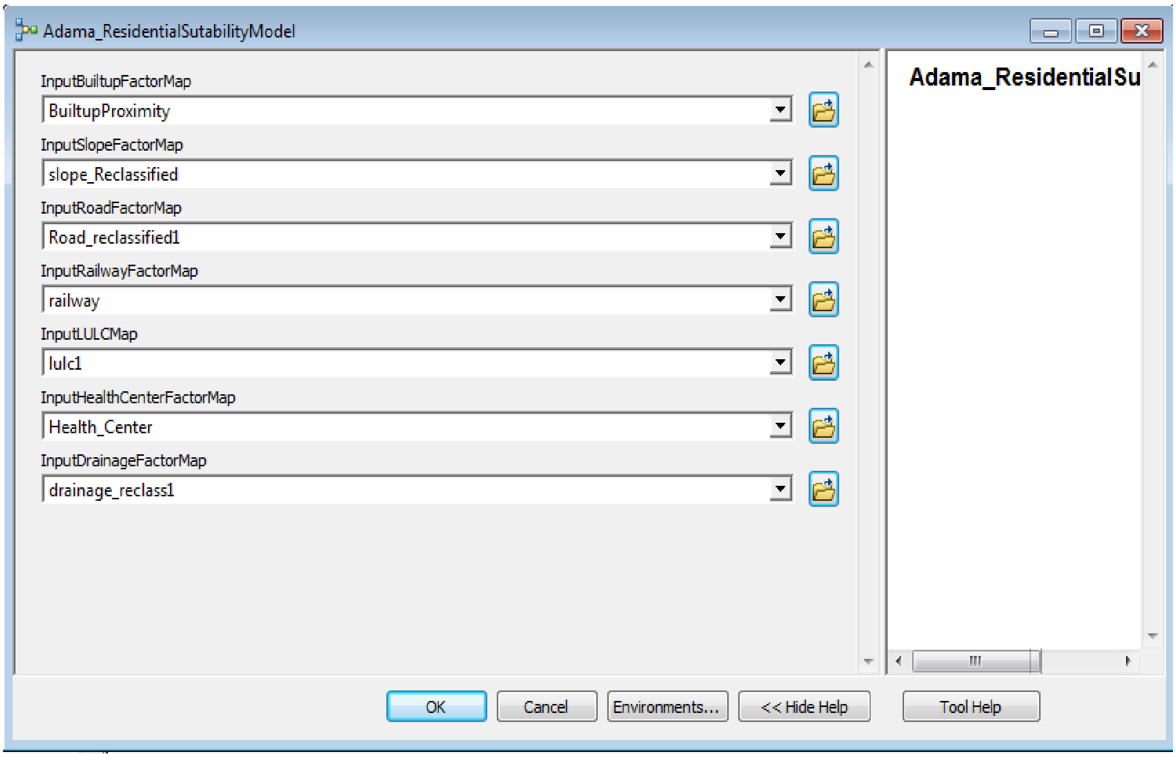

Figure 4.15: weighted overlay Tool of Residential suitability for Adama city

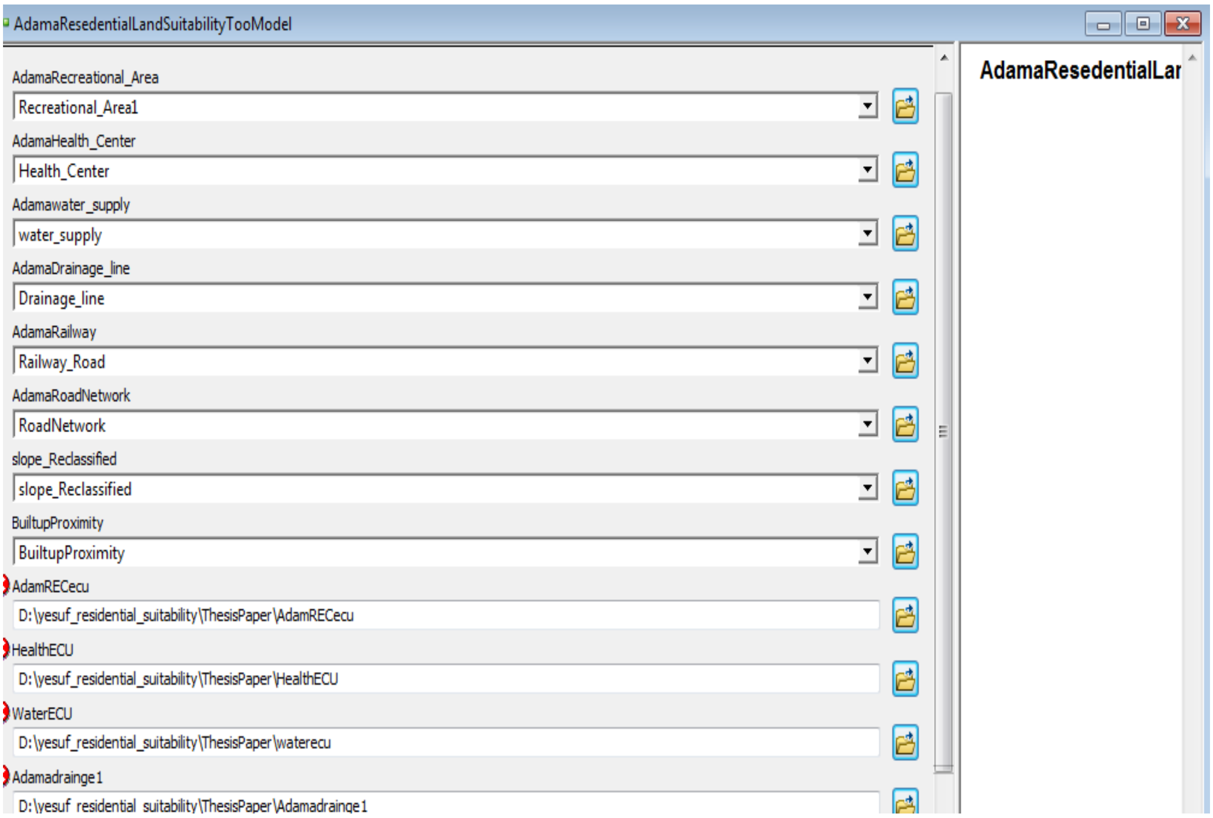

Figure 4.16: Tool for Residential suitability Analysis of Adama city

Figure 4.16: shows the extended capability of the tool, it gives the option to stores the intermediate output like Euclidian distance and reclassify in file location. The developed tool provides an option to store intermediate results in file for individual checking of the outputs. The advantage of this tool is, it gives the option to save and visualize the individual output to trace back especially unexpected result was found. See appendix III of the python script for the tool

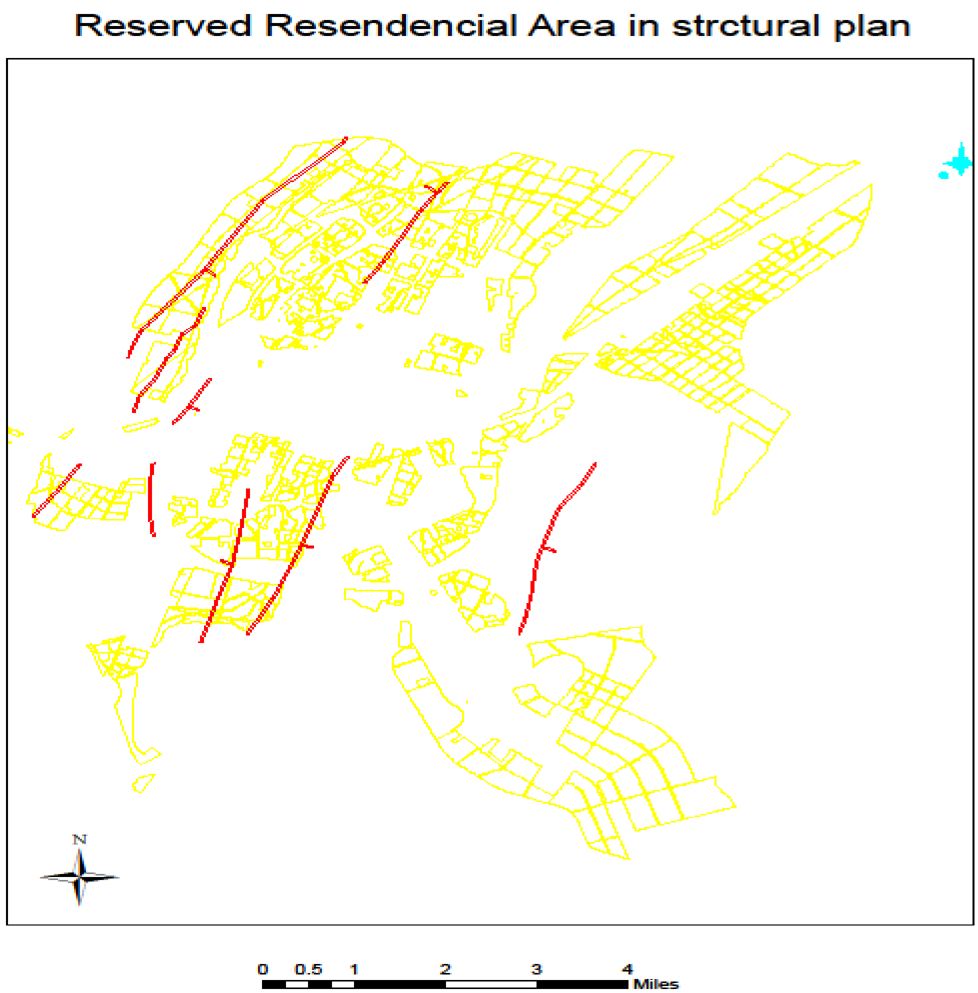

Figure 4.17: Reserved Residential Area structural plan of Adama city

Figure 4.17 shows structural plan of Adama city reserved Residential Area. The result obtained from the weighted overlay analysis was compared to the areas in the structural plan for future residential housing development with visual interpretation. The result of this research classifies the suitability of the area as very high suitable, high suitable, moderate suitable, low suitable and very low suitable. Hence the municipality could use this result analysis for prioritizing the land for future residential housing development.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The main objective of this study is to find the best locations for the residential housing scheme in Adama City using geospatial Technologies. Residential housing units in Ethiopia are serious and considerable challenges, especially in cities such as Adama for low-income households. On the master plan of Adama city, housing expansion units are clearly stated on the plan. Nonetheless, selecting the most appropriate site for housing is an important consideration for dwellers of the city. 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, different factors namely: land use land cover, proximity to major roads, slope conditions, proximity to the built-up area, proximity to drainage line, accessibility to a water supply line, proximity to recreational areas and proximity to healthcare serviceswere considered as a suite of physical, environmental and economic criteria which have principal effects on suitability analysis for residential areas in the study area. 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 weight factors were computed using decision support wizard IDRISI 32 software and then the overall Consistency Ratio (CR) of the module was checked as 0.06 % 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 10.8 software was used to incorporate all constraints layers to produce a composite constraint map.

The weighted overlay analysis tool of ArcGIS 10.8 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. The final suitability map findings also show that very high and high suitable lands cover 12.91% and 8.14 % are respectively while low and moderate suitable covers 6.72 and 11.80 % of the whole area.

The final suitability result was used to validate the proposed residential land use plan which was prepared by the urban development planning agency of Adama city. The final map shows suitability indexes and an in-depth picture of proposed residential land. The result checks that geospatial techniques and multicriteria evolution with analytical hierarchy process are very applicable and effective in analyzing, mapping, and interpreting urban land suitability. More over the developed model tool simplifies the tedious and time consuming geoprocessing operation for selecting suitable residential site section process.

5.2. Recommendations

The study demonstrated that utilization of geospatial technique, MCE and model toll for residencial land suitability analysis are appropriate and necessary and a need in urban planning and development under Ethiopian contexts. 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. Generally

- 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.
- 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 finding will be useful for 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.

- 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.
- Finally, the study recommended further research, which considers 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.

REFERENCES

Aburas, Maher et al. (2017). Land Suitability Analysis of Urban Growth in Seremban Malaysia, Using GIS Land suitability analysis of urban growth in Seremban https://doi.org/10.1016/j.proeng.2017.07.155

Al-shalabi, Mohamed et al, (2006). GIS-Based Multicriteria Approaches to Housing Site Suitability Assessment. 1–17.

Alesheikh, A.A., Soltani, M.J., Nouri, N., & Khalilzadeh, M. (2008). Land assessment for flood spreading site selection using geospatial information system. *InternationalJournal of Environmental Science and Technology* 5(4), 455–462.

Ananwa,B. (2006). Housing Problem and Congestion in Onitsha.Unpublished B.Sc, Thesis, Department of Geography and Regional Planning, Delta State University, Abraka, pp. 3-6.

Carver,S.J. (1991) "Integrating Multi-criteria Evaluation with Geographical Information Systems". *International Journal of Geographic Information System*, vol.5, pp.321-339.

Central Statistical Authorit(CSA) ,(2015)"Summary and statistical report of the 1994 and 2007 population and housing census". *Results for Adama city*. Addis Ababa, Ethiopia,

Chandio, A.N, Bin Matori. K.Yusof, M. A. Hussain & Talpur, M. Aminu, (2014) GIS-based Multi-criteria Decision Analysis of Suitability Hillside Development. *Fourth International Symposium on Infrastructure Engineering in Developing Countries*, 2013. vol.77, pp.87-94.

Collins, M.G.; Steiner, F.R.; Rushman, M.J.,(2001) Land-Use Suitability Analysis in the United States: *Historical Development and Promising Technological Achievements. Environmental Managemen*t , 28, 611–621.

Collins, Michael G., et al. (2016). Land-Use Suitability Analysis in the United States: Historical Development Land-Use Suitability Analysis in the United States:

Dejene, Getabicha (2015). Residential Land Shortage and Planning Implication in Hossana. Ethiopian Civil Service University.

Division, N., et al., (2005). Land Suitability Analysis User Guide. Data Processing, December, 1–72

Duc, T. (2006). Using GIS and AHP technique for land-use suitability analysis. ". International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences) Ho Chi Minh City, Vietnam.

Diakoulaki, D.and Karangelis, F.,(2007). Multi-criteria decision analysis and cost-benefit analysis of alternative scenarios for the power generation sector in Greece. *Renewable and Sustainable Energy Reviews* 11(4), 716–727.

Eastman.J.R (2012.) "ERDS Selva Tutorial".Clark University: Worcester, MA, USA, pp. 267-275

Eastman, J.R. (2001). "IDRISI 32 Guide to GIS and Image Processing". Clark Labs, Clark University, Worcester, USA, 2

Ezzat, M & Hamoud, S (2016). Analytic hierarchy process as a module for productivity evaluation and decision-making of the operation theater. Journal of Medicine, 1(6)3–7.

Eastman.J.R (2001) "IDRISI 32 Guide to GIS and Image Processing". Clark Labs, Clark University, Worcester, USA. vol. 2.

Eastman.J.R.,.et al. (1995). Raster Procedures for Multi-criteria/MultiObjective Decision's. *Photogrammetric Engineering and Remote Sensing*, vol.61, no.5, pp.539-547

EbistuT.A,& Minale A.S.(2016)"Solid waste dumping site suitability analysis using Geographic Information system (GIS) and Remote Sensing for Bahir Dar Town,

Forman,E.H, & SellyM.A (2001). "Decision by objective and how to convince others that you are right". Singapore: World Scientific.

IDP, I. D. P. (2010). Integrated development plan of Adma city Administration.

M. Huang, and X. Tian, X., Reflection on urban growth boundary in the new urban planning formulation means. Planner, 6, 13-15., DOI (2008).

Malczewski, Jacek. (2004). GIS-based land-use suitability analysis: a critical. 62, 3–65. https://doi.org/10.1016/j.progress.2003.09.002

Gezahegn, W., & Anteneh, I. (2016). Identification of Potential Sites for Housing Development Using GIS-Based Multi-Criteria Evaluation in Dire Dawa. 4531.

Huang, H., et al., (2019). Urban Residential Land Suitability Analysis Combining Remote Sensing and Social Sensing Data: A Case Study in Beijing, China.

IDP. 2006. Integrated development plan of Adama Administration, 2006/7- 2010/ 2011. 92 pp.

Kallali, H., Anane, M., Jellali, S., Tarhouni, J., (2007). GIS-based multi-criteria analysis for potential wastewater aquifer recharge sites. *Desalination* 215, 111–119.

Malczewski, J (1999) “GIS and Multi-criteria Decision Analysis”. John Wiley & Sons Inc. New York, .

Malczewski, J (2004). GIS-based land-use suitability analysis: A critical overview.

Prog. Plan,62, 3–65.

Ministry of Urban Development and Construction (MUDC) (2012). Urban planning, sanitation, and beautification bureau. Revised Standards for Structure Plan Preparation and Implementation. Addis Ababa, Ethiopia

Saaty, T.L. (1980). The Analytic Hierarchy Process: Planning, Priority Setting, Resource

Allocation. McGraw-Hill, New York, NY.

Saaty. U.L. (1997)“A scaling method for priorities in hierarchical structure”. Journal of mathematical psychology, vol.15, pp.34-39.

Seid.Y. (2007) Urban expansion and suitability analysis for housing of Adama City using Remote Sensing and Geographic information systems techniques. M.Sc thesis, Addis Ababa University, Ethiopia

Steiner, McSherry et al. (2000). "Land suitability analysis for the upper Gila

Sharifi, M., et al., (2006). Spatial Multiple Criteria Decision Analysis in Integrated Planning for Public Transport and Land-use Development Study in Klang Valley, Malaysia. ISPRS Technical Commission 2nd Symposium, pp 85–91.

Wondimu.R. (2011)“Rapid Urbanization and Housing Shortage in Africa: The Opportunity within the Problem for Ethiopia”. MSc. Thesis. KTH Royal Institute of Technology. Stockholm, Sweden,

Yang, J et al (2007). An overview of the methods of GIS-based land-use suitability analysis. Proc. SPIE , 6754, 6754

Yassine, C.and Adel. G., (2011). PV site suitability analysis using GIS-based spatial fuzzy multi-criteria evaluation. Renewable Energy 36, 2554–2561.

APEENDIX

Appendix I. Questionnaires prepared for experts in different level

For Urban land management and Development of Adma city

Personal Information

Name: ___________________ Occupation: ________________ Kebele____________

Sex ________ Age________

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 Adama city?

____

____

____

3. What are the possible recommendations you would suggest to improve the suitability of residential land Adma city?

____

____

Questionnaires for Heads of the Municipality and Officials

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 Adama city?____

Appendix II

AdamaResidentialSuitabilityToolCode.py - D:\yesuf_residential_suitability\AdamaResidentialSuitabilit...

File Edit Format Run Options Window Help

```python
# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")

# Script arguments
InputBuiltupFactorMap = arcpy.GetParameterAsText(0)
if InputBuiltupFactorMap == '#' or not InputBuiltupFactorMap:
    InputBuiltupFactorMap = "BuiltupProximity" # provide a default value if unsp

InputSlopeFactorMap = arcpy.GetParameterAsText(1)
if InputSlopeFactorMap == '#' or not InputSlopeFactorMap:
    InputSlopeFactorMap = "slope_Reclassified" # provide a default value if unsp

InputRoadFactorMap = arcpy.GetParameterAsText(2)
if InputRoadFactorMap == '#' or not InputRoadFactorMap:
    InputRoadFactorMap = "Road_reclassified1" # provide a default value if unspe

InputRailwayFactorMap = arcpy.GetParameterAsText(3)
if InputRailwayFactorMap == '#' or not InputRailwayFactorMap:
    InputRailwayFactorMap = "railway" # provide a default value if unspecified

InputLULCMap = arcpy.GetParameterAsText(4)
if InputLULCMap == '#' or not InputLULCMap:
    InputLULCMap = "lulc1" # provide a default value if unspecified

InputHealthCenterFactorMap = arcpy.GetParameterAsText(5)
if InputHealthCenterFactorMap == '#' or not InputHealthCenterFactorMap:
    InputHealthCenterFactorMap = "Health_Center" # provide a default value if un

InputDrainageFactorMap = arcpy.GetParameterAsText(6)
if InputDrainageFactorMap == '#' or not InputDrainageFactorMap:
```

```python
InputDrainageFactorMap = arcpy.GetParameterAsText(6)
if InputDrainageFactorMap == '#' or not InputDrainageFactorMap:
    InputDrainageFactorMap = "drainage_reclass1" # provide a default value if un

# Local variables:
Residential_suitabilityMapAdama_tif = InputDrainageFactorMap

# Process: Weighted Overlay
arcpy.gp.WeightedOverlay_sa("('drainage_reclass1' 27 'Suitability' ('ristricted'
```

Appendix III

AdamaResidencialLandsuitabilityFullCode.py - D:\yesuf_residential_suitability\AdamaResidencialLandsuitabilityFullCode.py (2.7.17)

File Edit Format Run Options Window Help

```python
# Import arcpy module
import arcpy

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")

# Script arguments
AdamaRecreational_Area = arcpy.GetParameterAsText(0)
if AdamaRecreational_Area == '#' or not AdamaRecreational_Area:
    AdamaRecreational_Area = "Recreational_Area1" # provide a default value if unspecified

AdamaHealth_Center = arcpy.GetParameterAsText(1)
if AdamaHealth_Center == '#' or not AdamaHealth_Center:
    AdamaHealth_Center = "Health_Center" # provide a default value if unspecified

Adamawater_supply = arcpy.GetParameterAsText(2)
if Adamawater_supply == '#' or not Adamawater_supply:
    Adamawater_supply = "water_supply" # provide a default value if unspecified

AdamaDrainage_line = arcpy.GetParameterAsText(3)
if AdamaDrainage_line == '#' or not AdamaDrainage_line:
    AdamaDrainage_line = "Drainage_line" # provide a default value if unspecified

AdamaRailway = arcpy.GetParameterAsText(4)
if AdamaRailway == '#' or not AdamaRailway:
    AdamaRailway = "Railway_Road" # provide a default value if unspecified

AdamaRoadNetwork = arcpy.GetParameterAsText(5)
if AdamaRoadNetwork == '#' or not AdamaRoadNetwork:
```

AdamaResidencialLandsuitabilityFullCode.py - D:\yesuf_residential_suitability\AdamaResidencialLandsuitabilityFullCode.py (2.7.17)

File Edit Format Run Options Window Help

```python
# Local variables:
Road_Ecu = AdamaRoadNetwork
AdamaRoadREC = Road_Ecu
AdamaWeightedOverlayAnalysis_tif = AdamaRoadREC
Output_direction_raster = AdamaRoadNetwork
Rail_Ecu = AdamaRailway
AdamaRailREC = Rail_Ecu
Output_direction_raster__2_ = AdamaRailway
Adamadrainge1 = AdamaDrainage_line
AdamaDrainREC = Adamadrainge1
Output_direction_raster__3_ = AdamaDrainage_line
WaterECU = Adamawater_supply
WaterRec = WaterECU
Output_direction_raster__4_ = Adamawater_supply
HealthECU = AdamaHealth_Center
HealthREC = HealthECU
Output_direction_raster__5_ = AdamaHealth_Center
AdamRECecu = AdamaRecreational_Area
AdamarecREC = AdamRECecu
Output_direction_raster__6_ = AdamaRecreational_Area

# Process: Euclidean Distance
arcpy.gp.EucDistance_sa(AdamaRoadNetwork, Road_Ecu, "3000", "72.2731475999998", Output_direction_raster)

# Process: Euclidean Distance (2)
arcpy.gp.EucDistance_sa(AdamaDrainage_line, Adamadrainge1, "500", "59.1659168000035", Output_direction_raster__3_)

# Process: Euclidean Distance (3)
arcpy.gp.EucDistance_sa(AdamaRailway, Rail_Ecu, "500", "41.0415231999904", Output_direction_raster__2_)
```

```
# Process: Euclidean Distance (6)
arcpy.gp.EucDistance_sa(AdamaRecreational_Area, AdamRECecu, "3000", "21.6278824", Output_direction_raster__6_)

# Process: Reclassify
arcpy.gp.Reclassify_sa(Road_Ecu, "Value", "0 749.561767578125 4;749.561767578125 1499.12353515625 3;1499.12353515625 2248.6853027

# Process: Reclassify (2)
arcpy.gp.Reclassify_sa(Rail_Ecu, "Value", "0 129.78469848632812 1;129.78469848632812 262.79397583007812 2;262.79397583007812 389.3

# Process: Reclassify (3)
arcpy.gp.Reclassify_sa(Adamadrainge1, "Value", "0 31.069556155658457 1;31.069556155658457 105.32534410745043 2;105.32534410745043

# Process: Reclassify (4)
arcpy.gp.Reclassify_sa(AdamRECecu, "Value", "0 749.9918212890625 4;749.9918212890625 1499.983642578125 3;1499.983642578125 2249.97

# Process: Reclassify (5)
arcpy.gp.Reclassify_sa(HealthECU, "Value", "0 749.490478515625 4;749.490478515625 1498.98095703125 3;1498.98095703125 2248.471435

# Process: Reclassify (6)
arcpy.gp.Reclassify_sa(WaterECU, "Value", "0 146.15116257610561 4;146.15116257610561 379.56002467345979 3;379.56002467345979 737.6

# Process: Weighted Overlay
arcpy.gp.WeightedOverlay_sa("('D:\\yesuf_residential_suitability\\ThesisPaper\\AdamaRoadREC' 10 'VALUE' (1 1; 2 2; 3 3; 4 4;NODATA
```