Evaluating urban Residential settlement Sites Suitability Analysis Using GIS and Remote Sensing Techniques: A Case Study of Shashemene City, Oromia, Ethiopia

Beshatu Keba Desso

A Thesis Submitted To the Department of Geomatic 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

August 2022

Adama, Ethiopia

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Advisor: Roba Gemechu (PhD)

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Approval Sheet

I/we, the advisors of the thesis entitled "Evaluating urban Residential settlement Sites Suitability Analysis Using GIS and Remote Sensing Techniques: A Case Study of Shashemene City, Oromia, Ethiopia" and developed by Beshatu Keba Desso, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Beshatu Keba Desso have read and evaluated the thesis "Evaluating urban Residential settlement Sites Suitability Analysis Using GIS and Remote Sensing Techniques: A Case Study of Shashemene City, Oromia, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics.

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Declaration

I hereby declare that this Master Thesis entitled “Evaluating urban Residential settlement Sites Suitability Analysis Using GIS and Remote Sensing Techniques: A Case Study of Shashemene City, Oromia, Ethiopia” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that used for this thesis have been duly acknowledged through citation.

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Recommendation

I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled. “Evaluating urban Residential settlement Sites Suitability Analysis Using GIS and Remote Sensing Techniques: A Case Study of Shashemene City, Oromia, Ethiopia” prepared under my/our guidance by Beshatu Keba Desso, submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Geoinformatics. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

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Co-advisor	Signature	Date

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Abstract

Growth in human population is one of the major causes of urbanization all over the world where more than half of the world population lives in urban areas. Improper settlement is due to illegal and informal land acquisition and unplanned spatial development due, to the industrialization and fast population growth. This study is aimed to evaluate urban residential settlement areas using GIS and Remote sensing techniques augmented with multicriteria evaluation for Shashemene city. This study also aimed at evaluating urban residential settlement suitability in Shashemene city, using eleven factors and Four constraints were also determined. In this study Boolean overlay tool of ArcGIS 10.8, software was used to integrate all constraints layers to produce a combined constraint map. The relative importance of parameters were computed using analytical hierarchy process (AHP) methods involving experts' engagement in giving weights for each criterion by using pair wise comparison technique. Based on the suitability analysis, 400.86 hectare (2.5%) is most suitable, 7822.59 hectare (48.54 %) is suitable, 958.68 hectare (5.95%) is moderate suitable, and 6931.87hectare (43.0%) are unsuitable. The most suitable land is mostly located around the center and western part in the city. this indicates that currently, Shashemene city has 51.04 % (8223.45 hectares) of its remaining existing residential land-use plan to distribute urban land for future residential needs. The 43.00% (6931.87hectares) of the study area exists under restriction zone, which needs attention from local experts and residents to keep it as constraint zone. Therefore, this study recommended that, urban planner; government and residents can give attention, recognition and protection to this area in order to avoid any constriction and development.

Key words: GIS Model Builder, Shashemene, Analytic Hierarchy Process, Multi-criteria Evaluation

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

More than half of the world's population already lives in urban areas, and this number is expected to rise. Urbanization is one of the main causes of this situation (Harris, 1990).Unprecedented population expansion that pervaded much of the 20th century has given way to unchecked urban growth across Asia, Africa, and Latin America (Brockerhoff, 2000). By 2030, 85% of people will live in urban areas, according to a recent UN demographic prediction. Therefore, out of 8.9 billion people, it would be anticipated that 6.4 billion people live in metropolitan areas in 2050.

Migrating from the rural to urban areas is the main reason for the urban rapid. There is a more rapid increase in the poverty level in urban areas compared to the rural areas and this has caused an alteration in the spatial distribution of human settlements and changed the use of rural land to urban use.

There are several urban settlements such as industrial areas, commercial areas, mixed areas and residential areas. Residential land use is one of the significant settlement areas among them. At present, a fast growth of the residential activities observed with the social and economical development of the communities. Thus, the sharp rise in the population in a limited area has caused various shortcomings resulting in serious issues among the land users. Most of such issues originated due to the drawbacks in the planning phase. Therefore, planners need to be cautious with the social, economical, and environmental factors during the planning phase. Appropriate decisions should be made at the planning phase to overcome such issues which influenced by the growth of the population, (Ekanayaka, 2014).

According to urban planning and implementation manual of Ethiopia the location of residential settlements area should be in terms of certain predetermined factors such as physical, economic, and environmental conditions influence the suitability of the site (MUDC, 2012).

Shashemene city is a vibrant city in which many socio-economic activities are taking place, which makes the city to play major roles in the development of the region (Oromia) and the country as well. As the center of multiple business attraction, the city is growing fast both in physical size and population wise. These dynamisms are accompanied by problems like rapid population growth, high migration rate from the nearby rural areas to the cities, lack of infrastructure, illegal settlements, as well as informal land acquision that requires the city administration to match its service provision with the change of demands (Shashemene city administration 2022).

Site suitability study is identifying the best spatial layout for potential land uses in accordance with predetermined needs and preferences. Suitability analysis is typically study for a variety of topics, including planning, landscape assessment, and choosing the optimum location for both the public and private sectors (Miller, 1998).

The development of suitability analysis entails establishing acceptable suitability variables. Suitability analysis was initially created as a tool for planners to link spatially independent elements within Ensuring land suitability for residential settlement is among the main purposes of land-use planning through spatial analysis of a particular location. Residential settlement planning is one of the most important components in the urban planning tools in any country including Ethiopia (Raghunath, 2006).

The integrated in geospatial sciences and technologies like GIS, remote sensing, and GPS augmented with multicriteria evaluation and analytical hierarchy process today's have been put direction with a series of practical capabilities and applications to solve conflicts and complexities in any geospatial decision making.

1.2 Statements of the Problem

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

The migration of peoples from different rural areas to the city of the Shashemene reported yearly. This has caused for the alteration of spatial distribution of human settlements. It was because in rural areas the lack of infrastructures as water, electricity, roads and the issue unemployment was occurring. This makes for the increment of house demands and informal settlement in urban and suburb areas in the city. In addition, the scattered settlement outside the villages in rural areas and along the roads in the city is difficult to expand infrastructures with the minimum cost and has a tendency to change to the urban sprawl. According to city municipality report 2011 EC, an average of 70-80 hectares of prime agricultural land was changed to the urban land.

Evidence from the OUPI, 2010 indicates that Shashemene’s population has been rapidly expanding since the 1990s, at a pace of 6% per year. This can be partially attributable to population growth because more people are moving from rural to urban regions than would naturally occur (2.9%), and the population of the town was 102,062 (51,477 men and 50,585 women) (CSA, 2007). The precise population is currently unknown due to demographic factors such significant net migration and natural population growth.

However, the city's overall population in the structure plan was 240,540 people in 2011EC, according to projections made using a 6% annual growth rate. According to the projection by OUPI, Shashemene is expected to host 295,898 inhabitants by 2020 (OUPI, 2010). This resulted in the high demand for residential settlement following the step of population growth of the city.

1.3 Objectives of the study

1.3.1 General Objective

The general objective of this study is to evaluate urban residential settlement Suitable Site analysis using GIS and Remote sensing techniques augmented with multicriteria evaluation for Shashemene city, Ethiopia.

1.3.2 Specific Objectives

- To determine the relative importance of parameters for urban residential settlement site selection of study area using AHP and MCE methods.
- To evaluate the suitability of existing urban residential settlement sites of Shashemene city
- To show suitable site for urban residential Settlement using GIS based modeling and mapping.

1.4 Research Questions

1) Which factor is more affect potential urban residential settlement Suitable Site analysis?
2) How is the suitability of the existing urban residential settlement of Shashemene city?
3) What looks like the GIS model suitability of urban residential settlement Suitable Site analysis and mapping?

1.5 Significance of the Research

Study of site suitability analysis is an important for urban and regional planners and decision makers to assess the influences of urbanization on urban settlement areas. Findings of the study were serving as a working document for Shashemene city management officials in the identification and selection of suitable sites for urban settlement areas. The study develop Arc GIS based suitability model for settlement site analysis. The study also evaluated the suitability of the existing residential settlement comparing with the final suitability map and the result showed that the existing residential areas was classified under different suitability levels.

This scientific classification in line with the final suitability map can be used as a guide map to the proposed future residential land use plan for Shashemene city. Additionally, the adaptive approach, techniques and methodology used in this research will provide a basis for urban residential settlement suitability analysis to identify the optimal site in other urban centers of the country as well. Hence, this paper is useful for planners, policy-makers, developers, and land managers. Moreover, it helps Shashemene city planners, developers and land managers to recognize that where is optimal land for future residential development to keep urban sustainable development while utilizing the land properly.

1.6 Scope of the Study

This study focused on urban residential settlement suitability analysis in Shashemene city, Oromia, Ethiopia. Hence, Shashemene city boundary of administration as of 2021 considered as spatial scope of the present study. Whereas thematically, relevant related kinds of literature, and urban land policies have been reviewed to acquire background information, strong theoretical bases, selection of appropriate methodology, identification of gaps in the literature, and to compare the findings in the existing body of knowledge.

Based on this, the review was focused on the following themes; definition and concept of urban residential settlement, land-use zoning, compatibility of land uses and land-use suitability analysis, Suitability of urban residential settlement and influencing factors, Applications of geospatial technologies in urban residential settlement suitability analysis, multicriteria evaluation, analytical hierarchy process, weighted overlay analysis, Boolean overlay analysis and Arc-GIS based model building for suitability analysis.

1.7 Limitation of the Research

This study aimed at evaluating urban residential settlement suitability for residential areas. However, due to the existing limitation of availability of data, time, and intended depth of analysis, land uses other urban settlement was not considered in this study. Additionally, the weights or relative importance of factors was determined majorly by opinions of the various experts who would fill the questionnaires. For this reason, in case one expert provides biased information, the entire weights might be affected. This will worsen if more experts provide biased information. This problem was minimized by explaining to the experts the procedure how to filling the questionnaire and giving them enough time to go through and fill it.

1.8 Organization of the Research

This paper includes four chapters and the conclusions and recommendations section. The first chapter presents the introductory part, which describes the background of the study, statement of the problem, the objectives of this research, research question, the significance of the study, the scope of the study, limitation of the study, and organization of the paper. The second chapter discusses the literature related to the study, reviews related papers to find the scientific support and the theories behind the methodology. The third chapter includes a description of the study area, data sources, and data collection methods, software used to analyze the data. The fourth chapter presents results and discussions that focus on developing spatial data analysis using geospatial techniques with MCE and AHP methods. In this chapter, relative importance, of factors, model building, suitability mapping and existing residential settlement evaluation are key parts of the study. At the last, conclusions were drawn from the findings, and recommendations are provided to improve the analysis of urban residential settlement suitability for future decisions.

CHAPTER TWO: LITERATURE REVIEW

2.1 Theoretical Concepts of Residential Sites Suitability Analysis

Residential settlements can be defines as a land-use type that consists of pure residences and residences with mixed activities.

2.1.1 Zoning and Regulations of Residential Land use

Private landowners' rights to use their land were previously limited by land use restrictions. When using private property, the public interest protected through land use laws and regulations. These rules employed to guarantee that land was available to all groups and that the community as a whole would benefit from development (Dejene, 2015). Nearly all cities across the world have common urban land policies that include land use laws and regulations. Kono & Joshi (2018) mentioned common regulations

These are Zoning by which urban land uses are restricted zone by zone; lot size regulations that limit the size of each housing area; urban growth boundary control that separates urban development areas from urbanization control areas; and floor area ratio regulation that directly limit building sizes both in horizontal and vertical dimension.

2.1.2 Compatibility of Land Uses

Land uses in a structure plan ought to propose taking in to account compatibility of adjacent land uses or compatibility of different land uses, which would be proposed close to each other. Table below tries to provide compatibility matrix produced based on major land use functions. Since the Table presents compatibility one of the primary land uses functions, it would be necessary to consider compatibilities of sites to be reserved for different functions within the principal land usage. For instance, under the major function associated with social services, there are functions such as educational institutions (primary school) and health institutions (hospital) which are not compatible.

Table 1: Compatibility Matrix

Land Use	Residence	Commerce	Large-scale Industries	Small-scale Industries	Social Services	Cultural Center	Administration
Mixed	✓	✓	X	✓	✓	✓	✓
Center	✓	✓	X	✓	✓	✓	✓
Manufacturing & Storage	X	✓	✓	✓	X	X	X
Green Frame	X	✓	X	X	X	✓	X
Services	?	X	X	X	✓	✓	X
Transport Centers	X	✓	X	✓	X	X	?

Source: MOFA (2005)

2.2 Factors identification for residential areas suitability analysis

Site suitability is the process of understanding existing site qualities and factors which will determine the location of particular activity" (Haymanot, 2011). Therefore, it requires analysis of wide-ranging and consistent datasets to achieve the objective.

There are various factors, which influence residential areas site selection such as physical, social and economic determinants were considered when establishing a location of residence. Furthermore, physical determinants consisted of the slope, elevation, soil condition, natural hazards, and land cover. Social factors consisted of land use, distance to shops, and access to roads, hospitals, schools and religious places. Additionally, economic factors consisted of job placements, land price, and taxation. A. (Ahmed & Shiriff, 2006).

Based on different countries' experience, local expert's opinion, Ethiopia's Ministry of Urban Development and Construction manual on Revised Standards for Structure Plan Preparation and Implementation, availability of data and parameters for residential settlement analysis can considered in the context of study area. From these literature reviews, the following criteria were identifies:

- The settlement site should be on a slope range of 2-8%
- Residential be placed on vacant (open area)
- For accessibility of transportation, the new residential areas should not be far from major roads.
- For safety, the residential site should be away from the river (flooding during the summer season).
- The presence of physical hazards reduces the suitability of a site. For Selecting, it should be no residential areas within 30m of the river. Safe housing sites and avoids the risks. i.e., it should not be located in risk areas (susceptible to natural hazards.

Ministry of urban development and construction (MUDC, 2012), suggest that the activities below to allocate residential areas.

- Be free from black cotton soil, as much as possible.
- Be located in all corners of the town unless there is constraint
- Have gentle slope that, 2%-15% (a slope between 2% and 8% is highly recommendable); and,
- Be free from exposure to natural disaster such as geological hazards (land and mudslides and rock fall), flood, and malaria-affected areas).

2.2.1Land Suitability analysis

Land-use suitability analysis is the process to identify the most appropriate spatial pattern for future land uses according to specified requirements, preferences or predictors of some activity (Hopkins, 1977; Collins et al., 2001). In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully study with the aim of directing growth to the most appropriate sites.

Al-shalabi (2006) stated that, establishing appropriate suitability factor is the base for construction of suitability analysis. At the start, suitability analysis was developed as a method for planners to connect spatially independent factors within the environment and consequently to provide a more unitary view of their interactions.

Land suitability analysis is a systematic procedure for examining combined effects of a related set of factors that an analyst assumes to be the important determinants of location suitability (Kaiser et al., 1995). Specifically, a land suitability analysis examines selected land characteristics to determine the level of suitability and ranks available land accordingly. Those characteristics were represented by a set of factors. According to (Wang & Hofe, 2007) the process follows the following eight steps:

1. Select a land-use type for analysis;

2. Select factors to be considered and attribute values of each factor;

3. Determine a score for each factor attribute;

4. Weight the factors;

5. Calculate a composite score from the attribute values and weight it for each factor;

6. Rank the combined scores to establish suitability levels;

7. Identify available land-based on existing land uses;

8. Compare with comprehensive plan, zoning, or other land use controls that further remove unavailable land

2.3 Relative importance parameters for residential suitability analysis

2.3.1 Multi criteria evaluation using AHP

Multi criteria evaluation (MCE) is a procedure that typically multiplies conflicting and corresponding criteria that are essential to evaluated in decision-making. The basic advantages of using MCE method is the possibility to evaluate complex and multiple factors at different scales and aggregated to produce a composite map portray suitable land for a particular use. MCE techniques are numerical algorithms that define the suitability of a particular solution based on the input criteria and a weight together with some mathematical or logical means of determining trade- offs when conflicts arise (Heywood et al., 2002). A spatial multi-criteria decision problem involves a set of geographically defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria (Carver, 1991, Heywood et.al., 1995). The data are processed using GIS and MCE techniques to obtain information for making the decision.

2.3.2 The Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) was introduced by (Saaty,1980) and is a very popular means to calculate the needed weighting factors with the help of a preference matrix where all identified relevant criteria are compared against each other with reproducible preference factors (Malczewski 1999). AHP is a conventional land suitability analysis techniques and that provides the right decision-making use extensively for site selection process. In a parallel way, AHP has integrated with GIS for land suitability modeling.

2.3.3 Pair wise comparison

Thomas Saaty (1980) developed the Pair wise comparison method in the context of the Analytical Hierarchy Process (AHP). This method involves pair wise comparisons to create a ratio matrix. As input, it takes the pair wise comparisons of the parameters and produces their relative weights as output.

Table 2: the AHP Scales for paired comparisons

Intensity of importance	Definition
1	Equal to importance
2	Equal to moderate importance
3	moderate importance
4	Moderate to strong importance
5	strong importance
6	Strong to very strong importance
7	very strong importance
8	Very to extremely strong importance
9	extreme importance
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: Saaty (1987)

2.3.4 Buffer and proximity analysis

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

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

2.3.5 Boolean overlay analysis

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

2.3.6Weighted overlay analysis

In Weighted Overlay analysis, a series of tools can complement the Weighted Overlay tool to follow the general overlay analysis. The Weighted Overlay tool scales the input data on a defined scale (the default being 1 to 9), weights the input rasters, and adds them together. The more favorable locations for each input criterion re-classified to the higher values.

The weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Weighted overlay only accepts integer raster as input, such as a raster of land use or soil types. Continuous (floating-point) raster reclassified to integer before they used. Generally, the values of the continuous raster grouped into ranges, such as for slope, or Euclidean distance outputs. Each range assigned a single value before it used in the weighted overlay tool.

The use of this method allows the evaluation criteria 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 as shown by the formula (Al-shalabi et al., 2006);

Suitability Map = Σ [factor map (Cn) * weight (Wn) * constraint (b0/1)]…. Equation 1

Where, Cn = standardized raster cell,

Wn = weight derived from AHP pair-wise comparison, and

0/1 = Boolean map with values 0 or 1

2.3.7 Spatial multi criteria decision-making (MCDM)

Spatial multi criteria decision typically involve a set of geographically defined alternatives from which a choice of one or more alternatives are made with respect to a given set of evaluation criteria [Jankowski, 1995; Malczewski, 1996]. Spatial multicriteria analysis is vastly different from conventional MCDM techniques due to inclusion of an explicit geographic component. In contrast to conventional MCDM analysis, spatial multicriteria analysis requires information on criterion values and the geographical locations of alternatives in addition to the decision makers' preferences with respect to a set of evaluation criteria. This means analysis results depend not only on the geographical distribution of attributes, but also on the value judgments involved in the decision making process. Therefore, two considerations are of paramount importance for spatial multicriteria decision analysis:

- ❖ The GIS component (e.g. data acquisition, storage, retrieval, manipulation, and analysis capability).
- ❖ The MCDM analysis component (e.g. aggregation of spatial data and decision makers' preferences into discrete decision alternatives) [Carver, 1991; Jankowski, 1995].

In general, nine objects are the most, which an individual can simultaneously compare and consistently rank. The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion.

To ensure the credibility of the relative significance used, AHP also provides measures to determine the inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated CR< 0.1 indicates that level of consistency in the pair-wise comparison is acceptable. Saaty (1980) suggested that, if CR is smaller than 0.10, then the degree of consistency is acceptable. However, if it is larger than 0.10, then there are inconsistencies in the evaluation process, and the AHP method may not yield meaningful results (Chu & Liu, 2002).

2.3.8 Building residential suitability Model

Model Builder is a visual programming language for building geoprocessing workflows. Geoprocessing models automate and document the spatial analysis and data management processes. Create and modify geoprocessing models in Model Builder, where 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 (Esri, 2015).

The model builder tool in ArcGIS 10.8 software was used to obtain the results of land suitability for the residential settlement. This tool is capable of building existing data in multiple layers into one layer. It could also create a single layer by combining different criteria for a residential place. Models are represented as sets of spatial processes, such as buffer, classification, and reclassification and overlay techniques. Each of the input themes is assigned a weight influence based on its importance, then the result successively multiplying the results by each of the constraints. This process was used in site suitability studies where several factors affect the suitability of a site (Esri, 2015).

2.4Applications of remote sensing in urban residential suitability analysis

Remote sensing is the capability to gather information without being in direct contact with it (Lillesand et al., 2014). The modern use of the term remote sensing has more to do with technical ways of collecting airborne and space born information. Satellite based remote sensing provides valuable information that can be used in the assessment of the various aspects of atmospheric environment, climatology, meteorology, ecology, agronomy and environmental protection (Kern, 2011). The essence of remote sensing is measuring and recording the electromagnetic radiation emitted or reflected from the earth’s surface (Hardegree, 2006).

Remote sensing is one of the incomparable tools for sensing the earth surface to make the interface of object property and measurement analysis as well as inventory of environment and its resources.

2.5 Applications of GIS in urban residential suitability analysis

Geographic information systems (GIS) have emerged as useful computer-based tools for creating, handling, and storing, analyzing and managing data and associated attributes that spatially referenced to the earth. GIS is a computer system which combines the spatial and attributes data of earth and which allow people to create, edit, analysis, store, display and print the geographic information. GIS was evolved based on the computer system and spatial analysis needs (Paul Longley, 2005). For the GIS methods, as (Lakhoua2011) concluded “A GIS has considerable capabilities for data analysis and scientific modeling, in addition to the usual data input, storage, retrieval, and output functions”. GIS is an innovative integrated technology base on many disciplines such as Geography, Cartography, Remote sensing, Land surveying and Navigation. With a period of nearly 50 years of development, together with the popularization of the Internet, GIS has been widely immersed in the people’s daily life like Global Positioning System (GPS) navigation.

In the Land Management area, GIS has been applied competently to deal with the geo-spatial data for screening and evaluation, facilitating the optimal site selection. With the development of GIS, largely fuelled by the needs for efficient spatial inventory, urban managers increasingly have at their information systems in which geographic data are more readily accessible, more easily synthesized, and more readily applied to issues of land use planning (Garriga and Ratick, 1996).

2.6 Research Gap

There are different studies conducted recently about suitability analysis for residential settlement using Geographic information system and remote sensing techniques across the world. Different literature reviews, consider criteria as research gap, but there is no uniform criterion for urban residential settlement suitability analysis. Researchers selected their own criteria for urban residential settlement suitability analysis depends on their objectives, subjective judgment, statement problem, available data and theoretical knowledge.

All Most all of previous studies conducted on urban residential settlement suitability analysis consider only on finding optimal site selection for future urban residential settlement development. Mohamed A. Al-Shalabi, Shattri Bin Mansor, Nordin Bin Ahmed, Rashid Shiriff, were conduct research title under GIS Based Multicriteria Approaches to Housing Site Suitability evaluation, did not evaluate existing urban housing site. However before finding the optimal future site suitability analysis for urban residential settlement, evaluating the existing urban residential settlement is very important to know which areas are fall in to most suitable, suitable, moderate and not suitable and the problem observed in the existing urban residential settlement. The present study is evaluating the suitability of existing urban residential settlement to fill this research gap.

The other weakness of different previous studies was accessible of data they used in their research. work.Da Wei and Yijie Ding conduct research title on Selecting Housing Development Sites using Multi-Criteria Decision Analysis a Case Study of Guangzhou, China. they used freely accessible data with low resolution, like satellite, image land sat 8 with 30m resolution and DEM with 90m, simply by downloading from website. These reduce the quality of research output. To fill this gap the present research used recent Orthophoto from Shashemene, urban Land administration office with resolution high resolution 15cm and DEM with 10m resolution. This maximized the quality and benefits of the research output.

The researcher has made interviews with different local experts of the Shashemene city municipality and no studies were done on urban residential settlement analysis. Apart from this, no research has been developed a model for urban residential settlement suitability analysis and no weight derived by AHP method. Therefore, the researcher has developed Arc GIS based suitability model and derive weight by using AHP method for urban residential settlement suitability analysis.

CHAPTER THREE: MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location of the study area

Shashemene city was founded in 1903 E.C accordingly for the sake of southeast trade movement along the town. It is the capital city of West Arsi Zone of Oromia Regional State, with area of 10408ha. Geographically the city is stretched at 70 08’ 50’’ to 70 18’ 17’’latitudes and 380 32’43’’to 380 40’58’’ longitudes, with an elevation ranging from 1,845 to 2053 m above mean sea level and located at 250 km South West of Addis Ababa the capital city of Ethiopia. Presently the city has 33 administration offices and 9 kebeles having vast population. Eventually, the city is growing more in political leading aspect, social strength and economical developments.

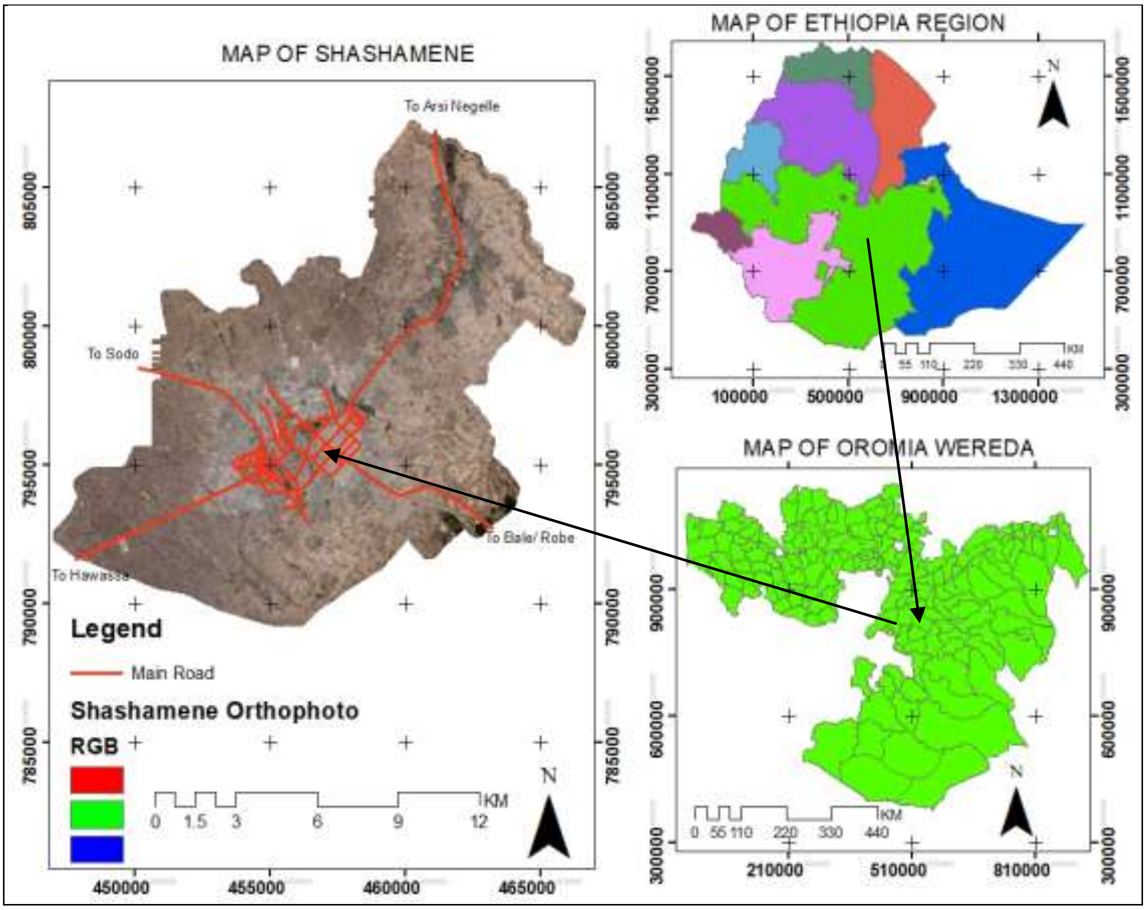


Figure 1: Location map of Shashemene city, background aerial photo

3.1.2. Establishment of the city

Shashemene was established in 1903 E.C. Shashemene has been the focus of investments both at the national and regional levels. Investment in industry, trade and hotel tourism, construction and social services constituted the largest shares. Due to the comparative advantage, the city has potential for economic growth in these and other sectors including administration, commerce and agriculture. The city has an extensive expansion area in all directions of the existing boundary of the city, (TG Fanta-2019). The population and demographic characteristics of the city showed that the population has been growing at high rate, the current population of the city (2007 E.C) is 238,310 and its population density is 42.4 people per sq.km

3.1.3. Climate

Shashemene city is characterized by the average maximum and minimum temperature of 24.3°C in May and 7.5°C in December, respectively.

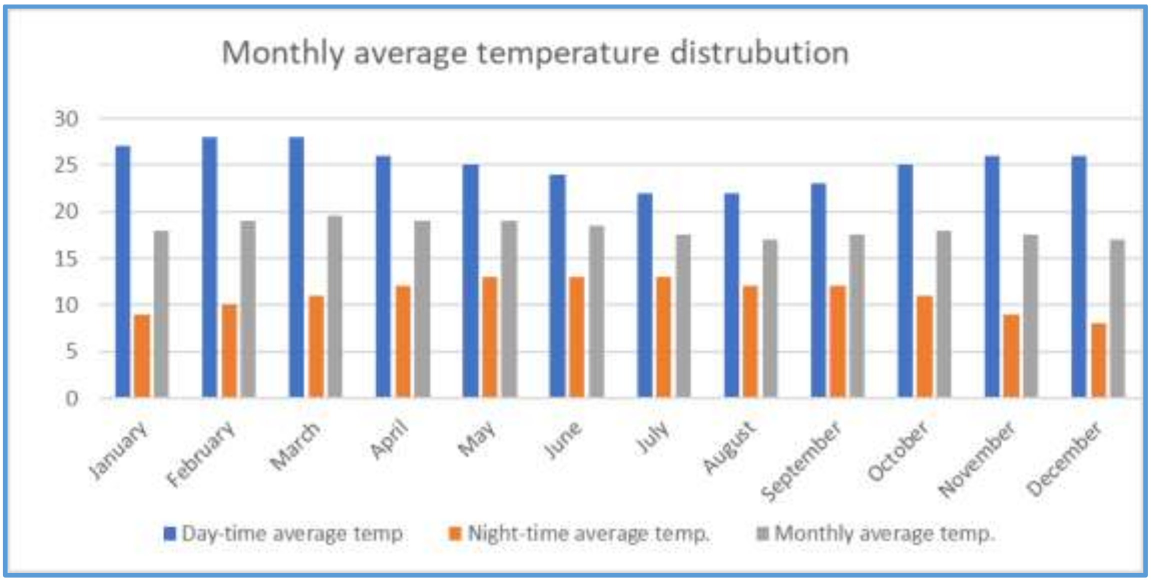


Figure 2: Seasonal distribution of temperature Shashemene city

(Source: meteorological agency, Shashemene branch)

The average annual rainfall in Shashemene amounts to 1200mm. The main wet season takes place from June to September, causing about 70% of annual rainfall with the highest peak in August. Another small peak of rainfall observed in April (OUPI, 2010). The annual amount of precipitation in Shashemene is 879mm. Figure 2 shows the monthly distribution of average precipitations of Shashemene city.

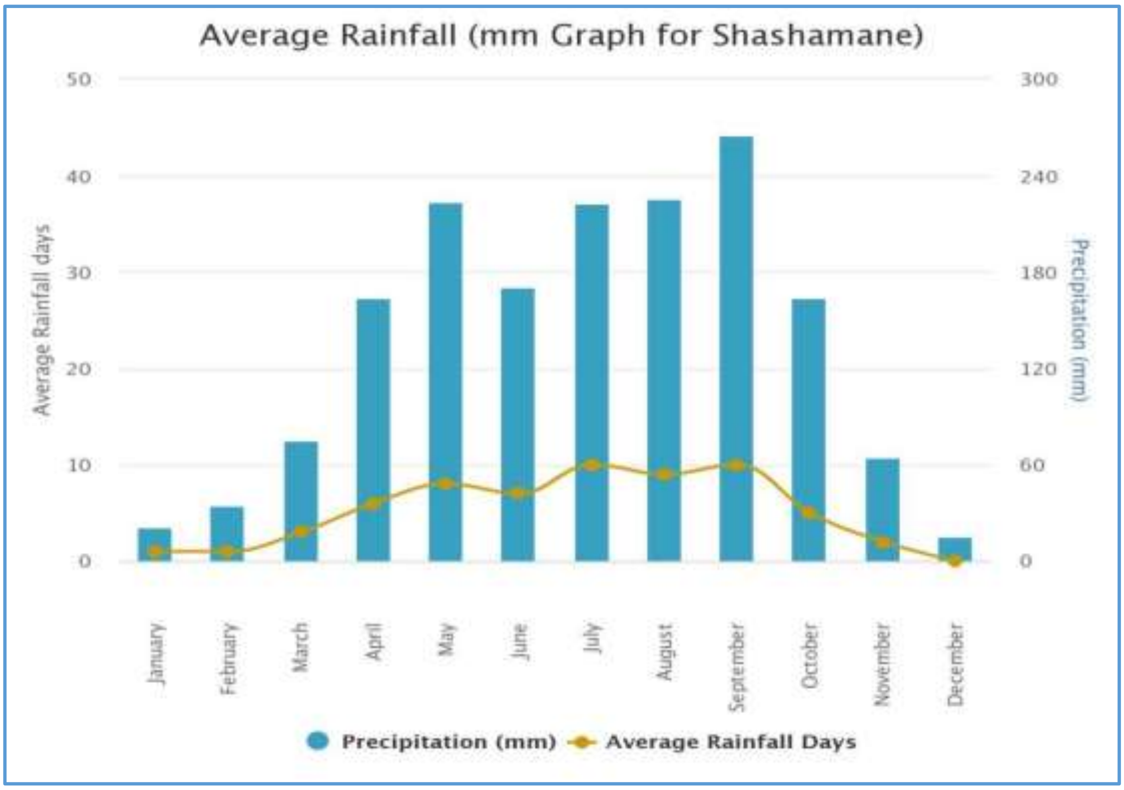


Figure 3: Seasonal distribution of average rainfall days of Shashemene city.

(Source: meteorological agency, Shashemene branch)

3.1.4. Topography

Shashemene extends to the southeastern escarpment of the Rift Valley. The city is located on a plateau with an elevation ranging from 1,845 to 2053 meters from mean sea level. The mountain ridge in the southeast of the city is called, Abaro ridge. The urbanized area of the town is slightly dissected by numerous valleys formed by the three major river systems crossing the city from south-east to north-west. Some of the general physical characteristics of the study area, the slope of the area ranges from zero (Flat) to 26 (steep) degrees (OUPI, 2010).

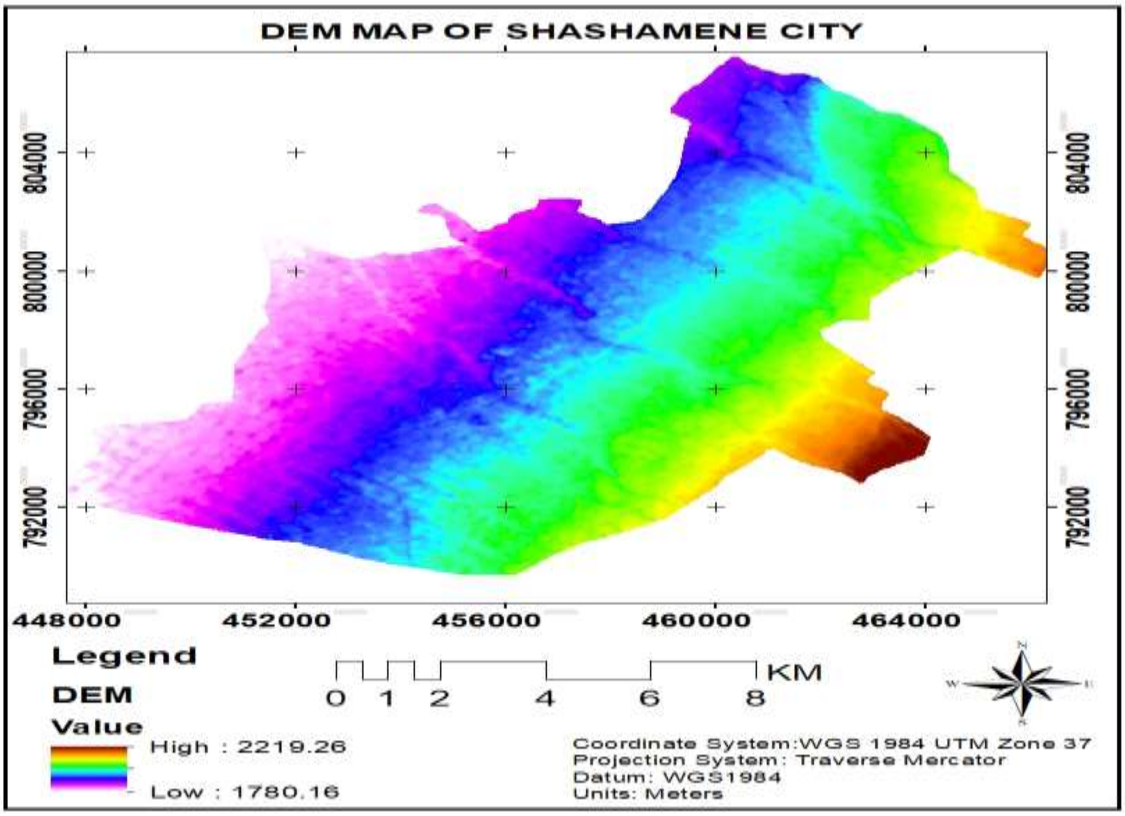


Figure 4: Digital elevation model (DEM) of Shashemene city

Source: Oromia urban planning institute

3.1.5 Socio-economic

Characteristics being one of the key centers of conurbation in the southern Oromia, and a hub for commercial activities, the city has significant economic importance. The majority of the land use pattern consists of built-up areas (residential, industrial, commercial, institutional, recreation area, road, infrastructure, and utilities) and non-built (agriculture, forest, bare land, and water bodies). As far as the establishment history of the town is concerned, Shashemene was formally founded as an urban settlement in 1915.The city, which began with small trade during this period, gradually developed into a big commercial center as communication and transport networks expanded (TG Fanta-2019).

3.2 Data and method of data collection

3.2.1 Methods of data collection

In this study, several data collection methods have been used to maximize the research benefits. Both qualitative and quantitative data were gathered through primary and secondary data collection methods. Primary data collection emphasis has been placed on field surveying using handheld GPS, and interviews with local expertise.

While secondary data collections included reviewed literature, existing policy analysis on urban land suitability analysis for residential settlement areas and gathered spatial data from different institutes, which were existed in various format. 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.

The researcher using handheld (GPS) to collected Field survey data. Secondary data, which include literature, urban land policies, reports, and different spatial data were obtained from various government offices in various digital formats as shown in the figure below.

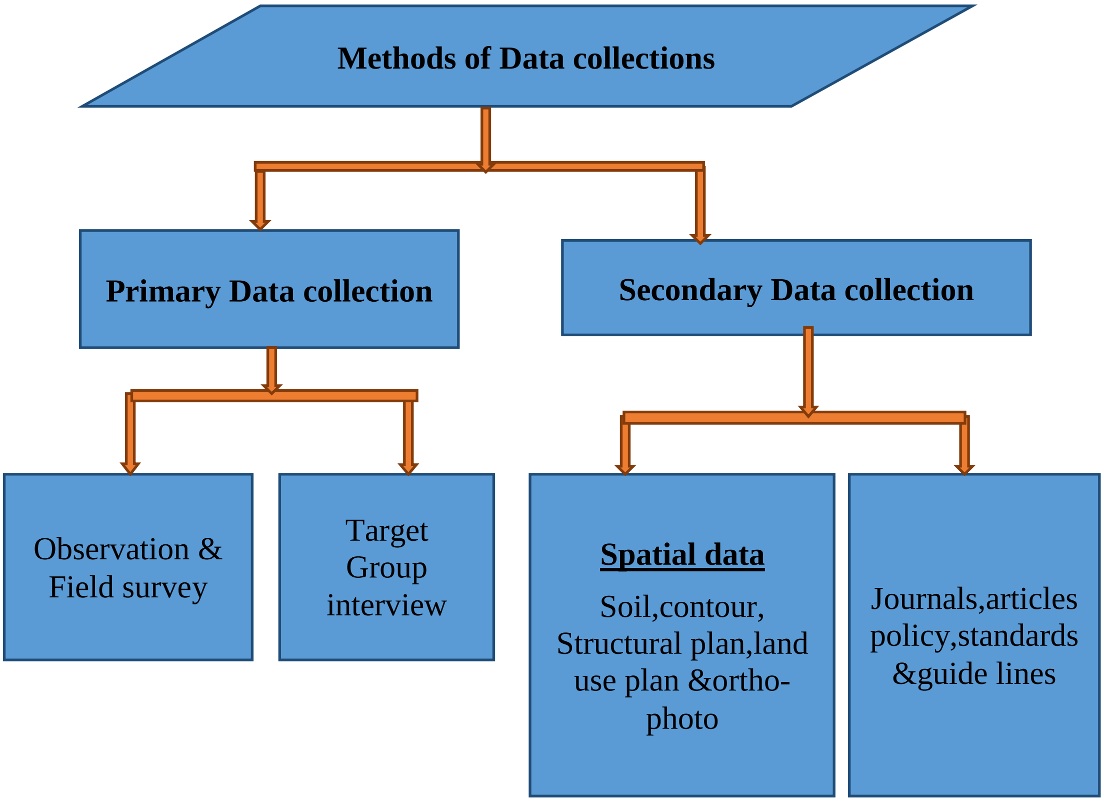


Figure 5: Methods of data collections in diagram

3.2.2 Data types and sources

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

Table 3: List of Data sets and data source

Data type	Format	Source	Resolution	Year
Point data	Text	Field survey		2022
Land use plan	Shape file	Shashemene ,urban Land administration office	1:24000	2015
Structural plan	. Dwg	Oromia urban planning institute	1:24000	2017
Orthophoto	.jpg	Shashemene ,urban Land administration office	15 cm	2020
Contour	Shape file	Oromia urban planning institute	10m	2017
Soil class-map	Shape file	Shashemene city office of Energy and Water resources	1:24000	2005

3.2.3 Instruments and Software

In this study, ArcGIS desktop is widely used software. The three components of ArcGIS desktop like Arc Map, Arc Catalog, and Arc Toolbox have been used to create the geodatabase, editing, data management and storage, geo referencing data from different sources, performing spatial multi criteria analysis, generating criteria maps and assigning weight for each criterion, overlaying, analysis and visualization of output data (Asefa and Mindahun, 2020). ERDAS imagine 2015 is also software used to process aerial photo and classify land use land cover map of study area, which was then, became input for analysis in GIS environment. Furthermore, IDRISI is a comprehensive geographic analysis and image processing system that has been developed by Clark Labs for Cartographic Technology and Geographic Analysis at Clark University, South Carolina, USA. This software has been used to perform multi criteria decision analysis using the built-in decision support module. Garmin handheld GPS was utilized in this study for collection of spatial data during field survey.

Table 4: Lists of software and instrument used

No.	Facility and software	Purpose
1	ArcGIS 10.8	Spatial data processing, analysis, and output generation
2	ERIDAS imagine 2015	Aerial photo processing and land use land cover preparation
3	Idrisi 32	To drive the eigen vector weights of each factor
4	GERMIN handheld GPS	To collect coordinate data from field
5	Google Earth Pro.	To verify and validate the result with the existing situation
6	Microsoft Word and Excel	Integrate attribute data and composite final thesis

3.3 Data preparation for analysis

3.3.1 Geo-referencing

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

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

3.3.2 Geodatabase development

A geodatabase is the physical storage of geographic information (spatial, non-spatial, metadata, and relationship) inside a relational database management system. It contains layers vector data representing features and raster data representing images and grid surfaces. The purpose of geodatabase is to make the features in GIS datasets and define a relationship among features that were displayed on maps as layers. Each layer represents particular types of features that have been used for spatial analysis. In this study, a common personal geodatabase was built using Adindan UTM Zone 37 N to store, query, and manage both spatial and non-spatial data that could be used for the final analysis to achieve the proposed objectives.

Features datasets were created for the area and line feature geometry in single personal geodatabase.

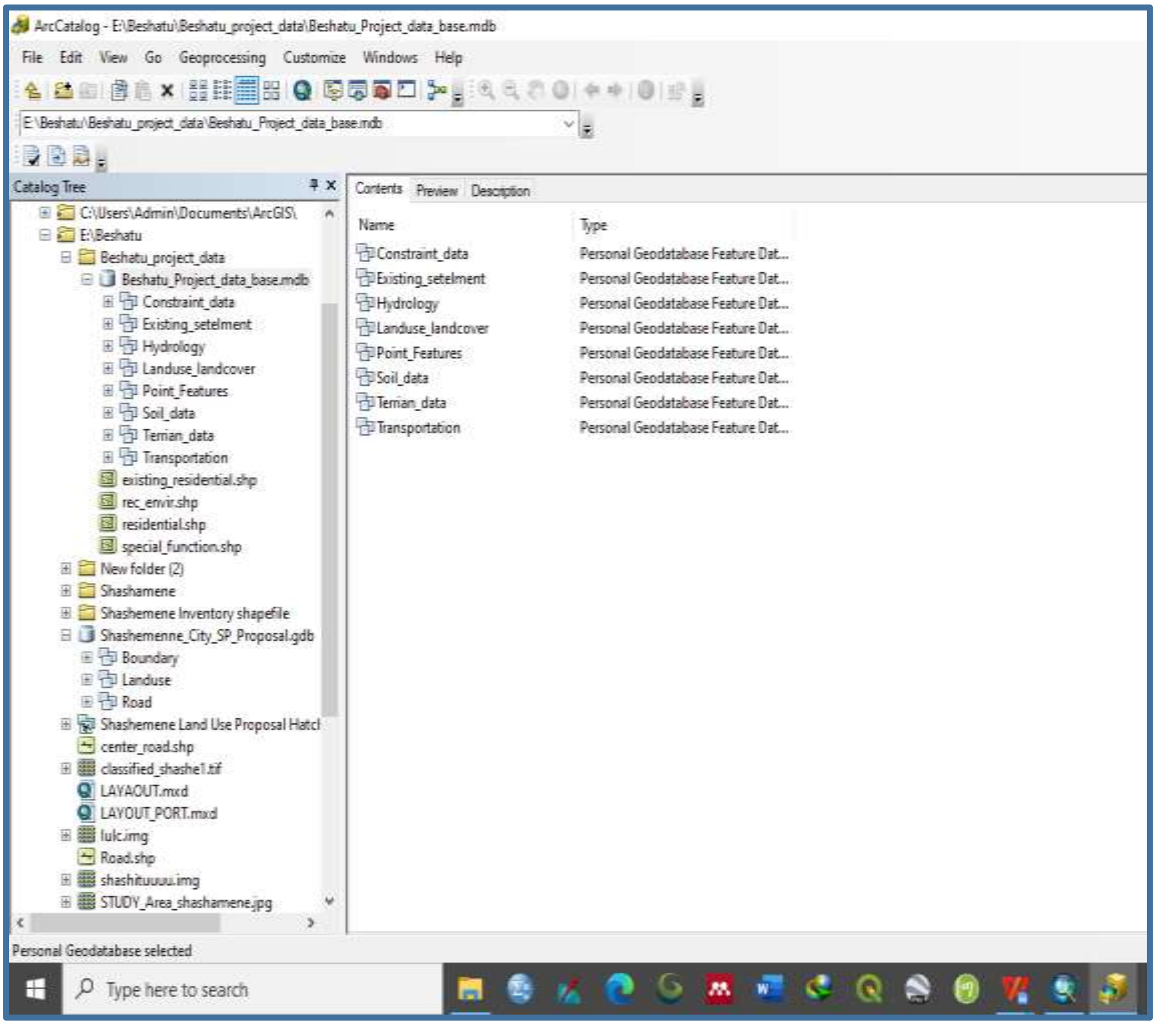


Figure 6: Developed Geo-database

3.3.3 Digitization

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

3.4. Methods of Data analysis

The data analysis process of urban land suitability analysis for residential settlements 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 evaluating urban residential settlement suitability analysis presented in Figure 7.

3.4.1 Reclassifying values of a set of raster

The Reclassify tools were used to allow the researcher to reclassify or change input cell values to alternative values. In this research, all thematic features were converted to raster datasets, and then raster reclassification using reclassify tool of ArcGIS 10.8 was adopted to reclassify the old value of the raster to the new one based on some predetermined condition. The reason behind reclassifying raster data was to:

- Replace new values with the old ones based on new information.
- Group certain values of the raster datasets.
- Reclassify values to a common scale of measurement that can be integrated

3.4.2 Spatial multi-criteria decision-making (MCDM)

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

In general, nine objects are the most, which an individual can simultaneously compare and consistently rank. The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion.

To ensure the credibility of the relative significance used, AHP also provides measures to determine the inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated $CR < 0.1$indicates that level of consistency in the pair-wise comparison is acceptable. Saaty (1980) suggested that, if CR is smaller than 0.10, then the degree of consistency is acceptable (Table 5). However, if it is larger than 0.10, then there are inconsistencies in the evaluation process, and the AHP method may not yield meaningful results (Chu & Liu, 2002).

Table 5: The preference scale for pair -wise comparison

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

Source: Saaty (1987)

3.4.3 Boolean Overlaying

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

The constraints identified in this study namely prime agriculture, Built-up, water bodies, and heavy electric line. These were integrated and composite constraint maps were produced in Boolean suitability model. The produced constraint maps have two values, value one represents for true which means the possibility of areas of interest to do suitability analysis whereas zero value represents for false which means the impossibility of the areas for suitability analysis, was multiplied with a weighted overlay map to restrict unsuitable areas from suitability index.

3.4.4 Weighted overlay analysis

The Weighted overlay approach is the most commonly used GIS-based decision rules technique ((ESRI), 2015). One of its most common applications is to solve urban settlement 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 were calculates for all of the alternatives. The one chosen was that with the highest overall score. The method executed using any GIS system with overlay capabilities.

The use of this method allows the evaluation of criterion map layer combined to determine the resulting composite map layer. Using the weighted linear combination, factors were combines 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 as shown by the formula (Al-shalabi et al., 2006);

Suitability Map = Σ [factor map (Cn) * weight (Wn) * constraint (b0/1)]…. Equation 1

Where, Cn = standardized raster cell,

Wn = weight derived from AHP pair-wise comparison, and

0/1 = Boolean map with values 0 or 1

3.4.5 Model Builder for data processing in Arc- GIS

Data processing was carried out using the Arc Toolbox tools, which consisted of ESRI Spatial Analyst, Conversion tools and Analysis tools. These tools were used together to create map, query, and do analysis of cell-based raster data. The desktop GIS are enabling by the spatial analyst tools to create spatial models, which are sophisticated using Model Builder. In this study, tools such as reclassify, buffer, slope, and weighted overlay were used for the present urban residential settlement suitability Analysis. Urban land areas are rated according to the several factors with varying weights and values derived by using AHP methods, and derive new information from existing data to determine residential settlement suitability.

The model builder is a tool for generating and managing automated spatial models in ArcGIS. The model builder is an extension in Arc-GIS, which is used to generate the flow of the process and scenarios to make the modeling process automatic. The datasets or the factors have been easily changed in modification of the criteria influences, which are set on the model. The processes involved are in form of the chain whereby the derived data from certain model is subsequently used, as input for the next model would be generated.

The spatial analyst tools from the Arc Toolbox were dragged to the model builder window, the input datasets are specified as well as the directory of the results output. Depending on the influence of a factor, the layer weights can be changed easily, and in evaluation of new results, the model may be re-run. Datasets such as proximity to roads, proximity to river, accessibility to urban center, proximity to heavy industry, land use land cover, accessibility to public schools, accessibility to healthy center and constraints including prime agriculture, Built-up, water bodies, and High-tension lines are the parameters considered in the modeling process of this study.

Multiple layers are overlaid, ranked and the weights of each criterion included. The process-flow diagram is generated which consists of operations and various layers. The Urban residential settlement suitability model combines and does reclassification of the GIS multiple layers to produce a map showing suitable and possible sites.

3.5 Conceptual framework and flowchart of the analysis

In this research, there were five important stags to evaluate urban site suitability maps for residential settlement areas of Shashemene city. These are:

- Determining influencing parameters were used in the analysis for decision-making.
- Assigning factor priority, weight, and class weight (ranking) to the parameters involved using AHP and MCE methods.
- Delineating constraints by developing a Boolean constraint model.
- Developing factors suitability model, which apply weighted overlay analysis and determine overall suitability of the entire study area.
- Mapping the most suitable site of urban residential settlement.
- At the last, evaluating the suitability of existing settlement for the study area.

Multi-Criteria Evaluation Analysis technique is applied to incorporate decision maker's judgment and preferences using the AHP method. This method includes the selection of the criteria for the spatial Multi-Criteria Evaluation (MCE) technique for the suitability analysis for residential settlement areas. The final step involved in AHP is the integration of the relative importance obtained at each level of the hierarchy to calculate the suitability index. In general, Figure 7 summarizes the overall methods, techniques, and approaches used to carry out this study, to evaluate urban residential settlement suitability analysis in Shashemene City.

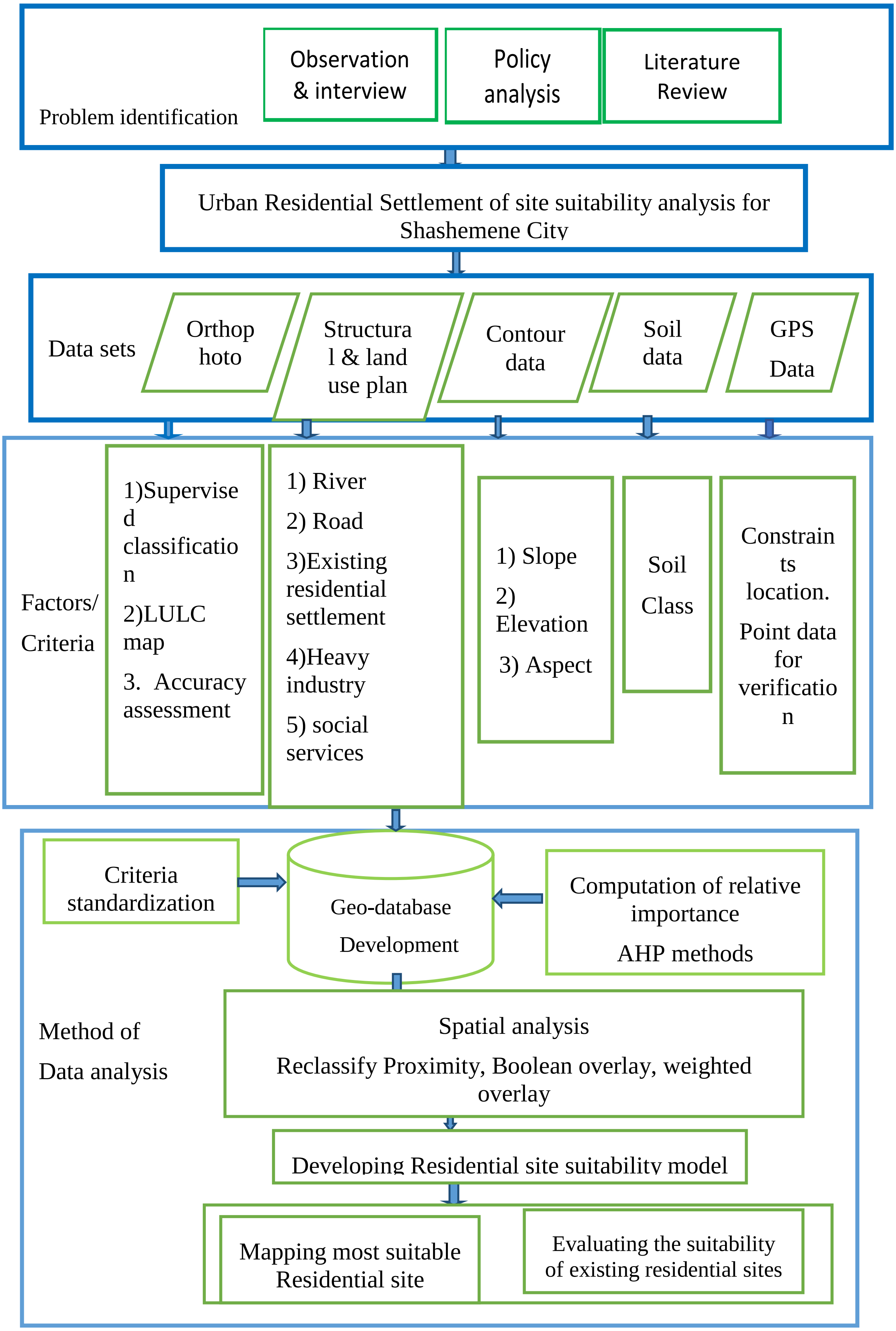


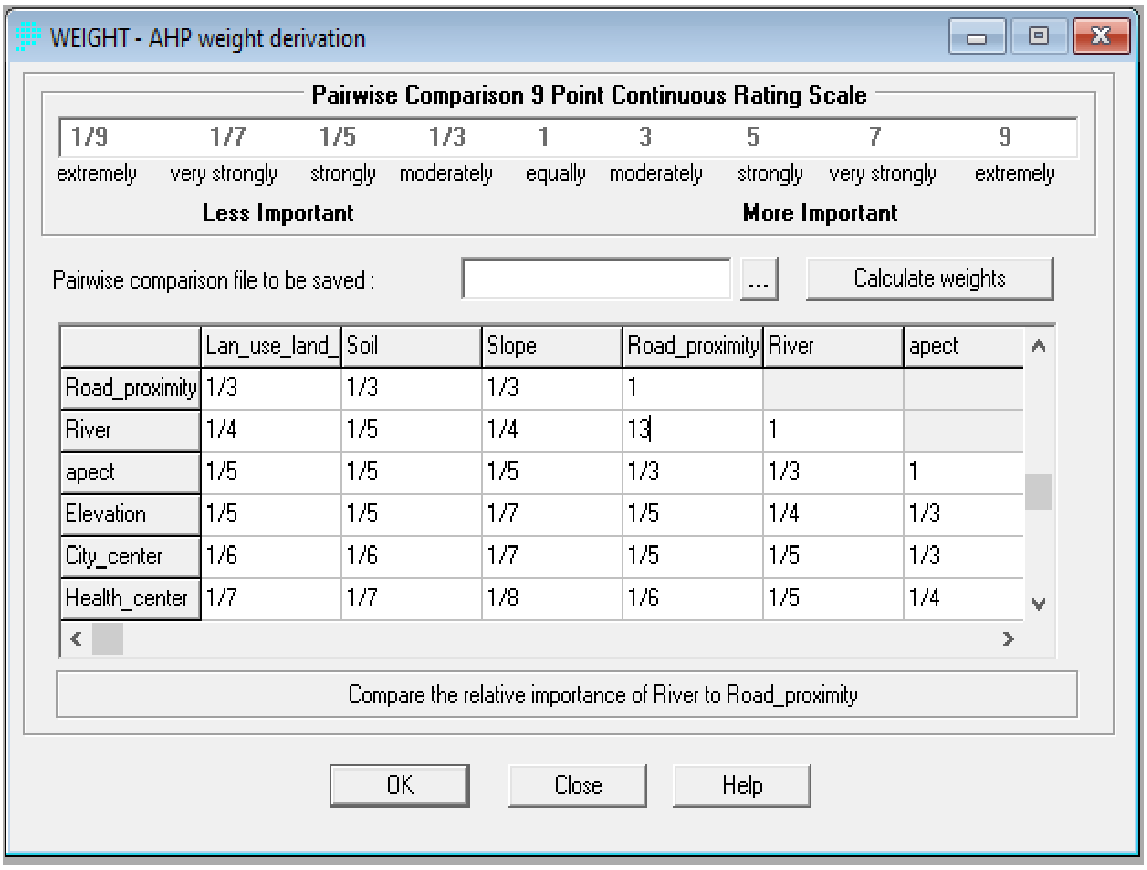
Figure 7: General Workflow of the research

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Determined Relative Importance of Parameters for Urban Residential Settlement Site Suitability Analysis Using AHP

In this study, based on the different literature and previous related studies, conducted by different researchers (e.g. Omar & Raheem, 2016) and availability of data, eleven factors were selected for urban residential settlement areas suitability analysis in Shashemene city, Oromia, Ethiopia. such as;- slope, soil types, Proximity to main road, Proximity to rivers (flood), Proximity to urban center, elevation, aspect, accessibility to health center, accessibility to public school, land use land cover (LULC), and proximity to heavy industry and four constraints were also determined including water body, prime agriculture, Built-up, heavy electric line. The weight of each factor considered was determined since not all the criteria had the same level of influence in site suitability analysis for residential settlement areas. The experts provided the criteria pair-wise comparison judgments from which their weights were determined using the generated formulas in IDRIS software. The figure 8 below shows the types of experts involved and the weights they proposed for each criterion. For each factor, the attributes were standardized by transforming the original values to a suitability value using suitability scale from 1 - 9 (Saaty T., 1997). The higher value is more favorable and vice versa. Areas with a higher suitability value have a higher score (Saaty, 2000).

Land use land cover type was taken to be the most important factor among the others when choosing the best suitable urban residential settlement in Shashemene city, Oromia Ethiopia. From the computation, the weight of the Land use -land cover type was found to be 22.4% being the highest unlike the Heavy industry factor, which had the lowest level of influence of 1.1%. The determined criteria weights of the other criteria were show in the table 6 below.



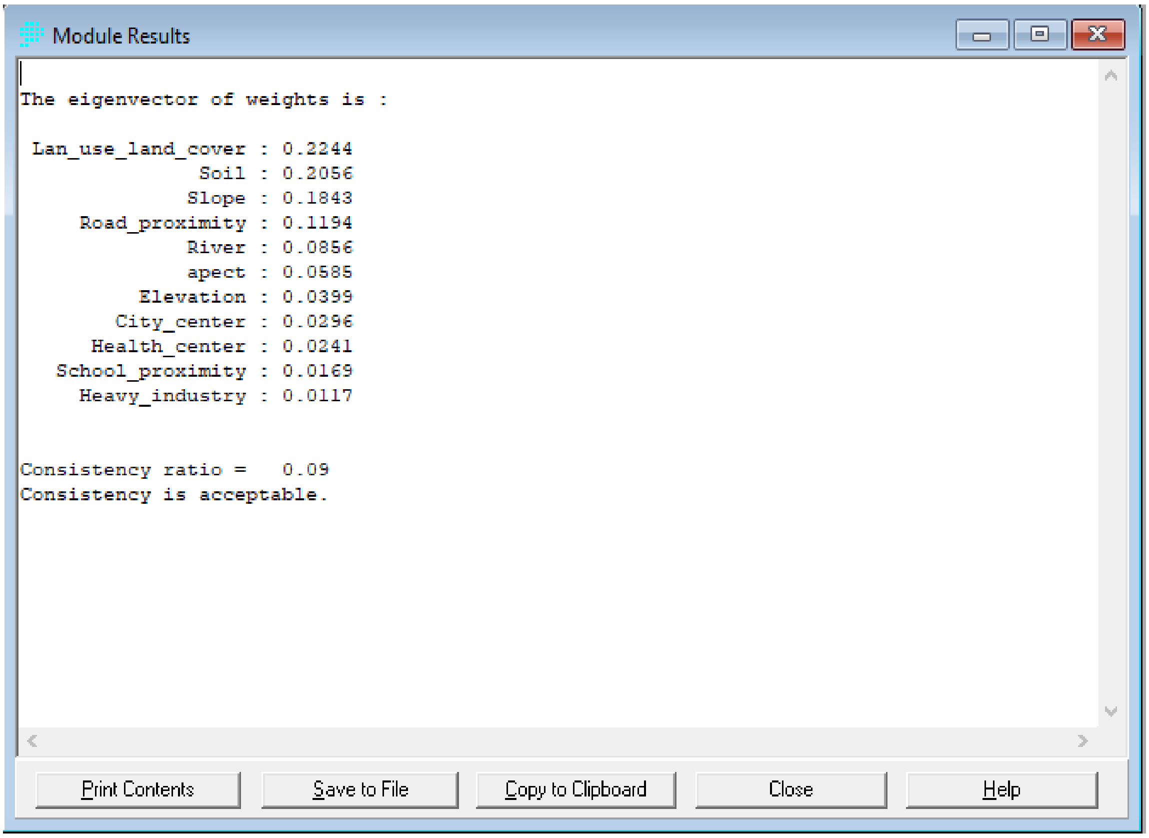


Figure 8: Weight derived by AHP methods

Table 6: Pair-wise comparison and weight derived by AHP method

criteria	LULC	So	S	Ro	R	A	E	UC	H	S	HI	weight	Weight (%)
Lulc	1											0.224	22.4
Soil	½	1										0.2	20
Slope	½	1/2	1									0.188	18.8
Main road	1/3	1/3	1/3	1								0.118	11.8
River	¼	1/5	1/4	1/3	1							0.085	8.5
Aspect	1/5	1/5	1/5	1/3	1/3	1						0.058	5.8
Elev.	1/5	1/5	1/7	1/5	1/4	1/3	1					0.04	4.0
Urban center	1/6	1/6	1/7	1/5	1/5	1/3	1/2	1				0.03	3.0
Health	1/7	1/7	1/8	1/6	1/5	1/4	1/3	1/2	1			0.024	2.4
school	1/7	1/7	1/7	1/7	1/6	1/5	1/5	1/3	1/3	1		0.016	1.6
Heavy industry	1/9	1/9	1/7	1/9	1/7	1/7	1/5	1/5	1/5	1/3	1	0.011	1.1

(Source: field survey, 2022)

So= soil, S=slop, Ro=road, R=river, A=aspect, E=elevation, UC=urban center, H= health center, HI=heavy industry, LULC=land use land cover

4.2 Developed Suitability model in Arc GIS Model Builder

Model Builder is an application used to create, edit, and manage models. Models are workflows that run together sequences of geo processing tools, feeding the output of one tool into another tool as input. Model Builder also thought of as a visual programming language for building workflows. ArcGIS Model Builder is graphical environments for building and executing multistep models with facilities for batch processing and dynamic modeling ((ESRI), 2015).

The model is the description of a decision situation to generate a solution to the problem. It used for a given decision problem which is well structured so that all decision problem-solving activities can be automated. The main characteristic of using a Model is the possibility to structure the decision problem and use well established procedures for solving the spatial problems. Model Builder provides an in-built interface where input and tools easily dragged and dropped from Arc Map, Arc Catalog and Arc Toolbox modules to ArcGIS Desktop.

A tool and its parameters form a process and each of them was represented with different symbols. The connection between data and tools generates a workflow representing a visual documentation of the spatial analysis, where rows indicate the direction to follow. As result, the software was able to run automatically this workflow by following those connections.

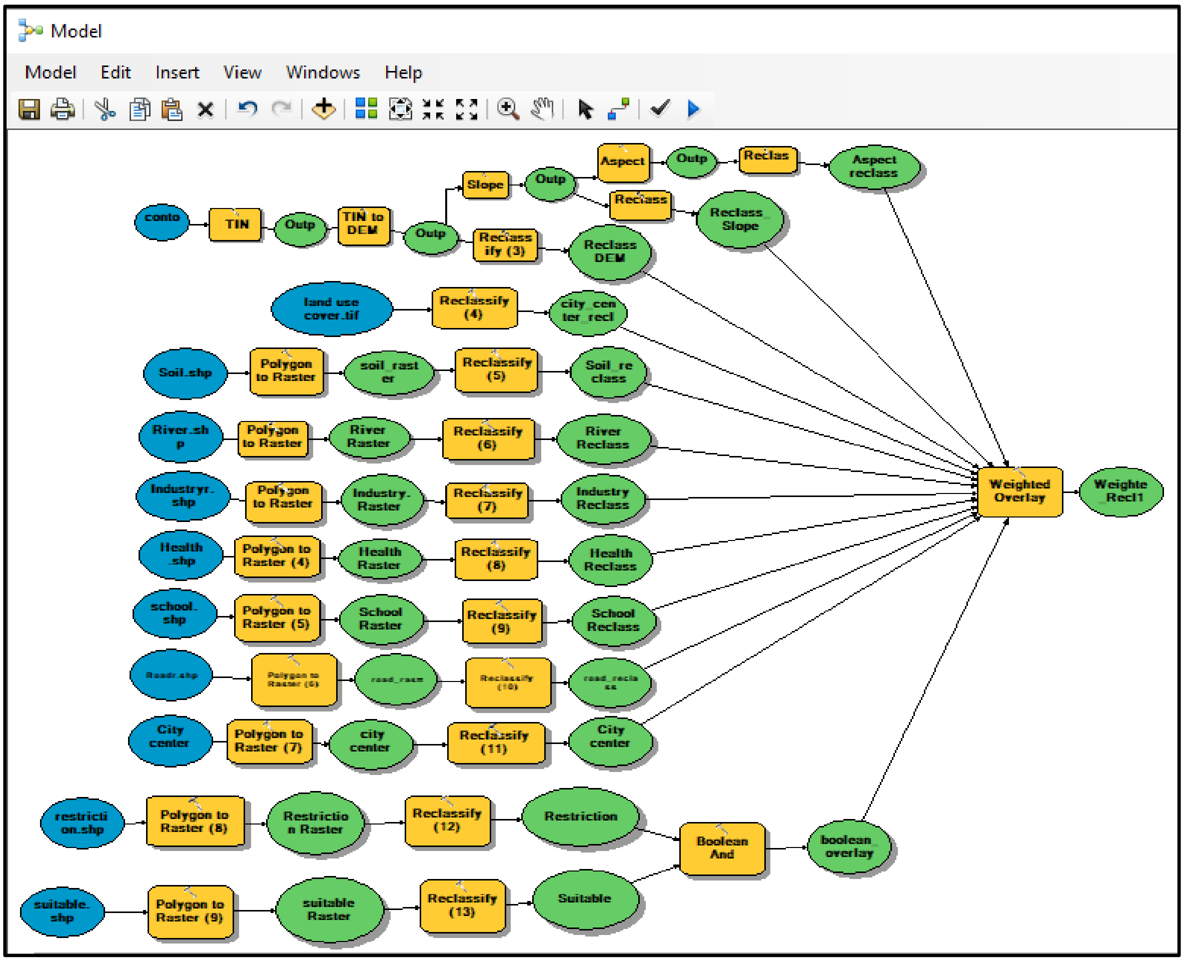


Figure 9: Urban residential settlement suitability Model

4.3 Mapped urban residential settlement site suitability for Shashemene city

4.3.1 Slope suitability

The result obtained from slope analysis was presented in figure 10. This parameter was considered so that the cost of house construction is reduced. Areas with steep slopes are avoided since it is susceptible to landslides and building a house in such areas is much costly. The suitable site for house construction was established on areas with gentle slopes, which is represented by the yellow color on the map. Areas with the Very steep slope, which represented by blue color on the map are unsuitable for residential settlement. The cutting of a hill slope (NBC, 2016), causes environmental damage and slope instability in adjacent areas. Therefore, cuttings shall not be undertaken unless appropriate measures were taken to avoid such damages to ensure site safety and reduce economic crisis. NBC, (2016) suggested that no construction should be ordinarily undertaken in areas with slopes above 30% or in areas that fall in landslide hazard zones.

Whereas, MUDC (2012) suggests that priority should be given for a comparatively gentle slope not more than 20% and a slope between 2 and 8% highly recommendable.

Table 7: Slope suitability analysis

Class	(Slope (%)	Value	Suitability	Area in hectare	Area (%)
Gently sloping	2-8	4	Most suitable	8297.09	51.40
Sloping	8-15	3	Suitable	4380.39	27.20
Moderately steep	15-25	2	Moderate suitable	969.56	6.1
Very steep	>25	1	Less suitable	2466.98	15.30
	Total			16114	100

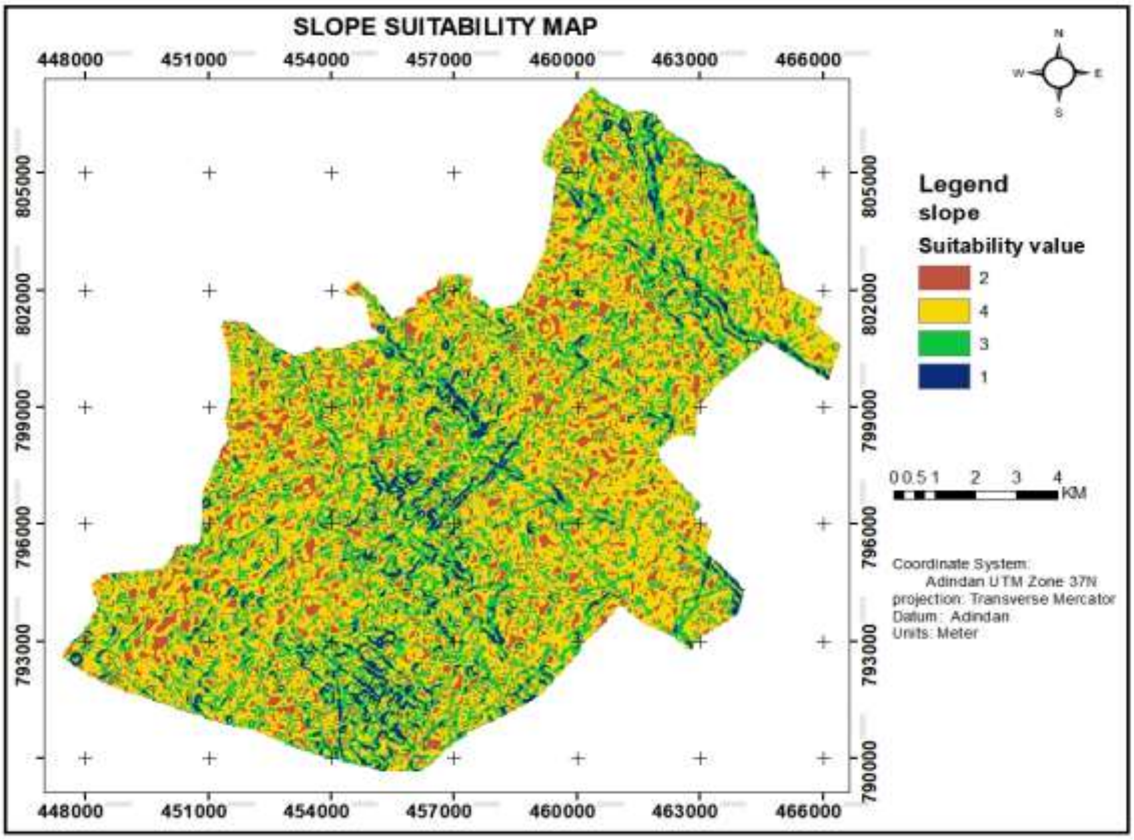


Figure 10: slope suitability map of Shashemene city

4.3.2 Elevation suitability

The result is shown in Figure 11 and table 8 derived from contour of the study area which comprise the elevations ranging (1780-2220 meter). Literature (Puntsag, 2014) suggests that the elevation is an important factor that plays a role in the variation of plant cover by causing water resource and soil changes. The higher the elevation, the less water there is (Akinci,H.; Ozalp, et al, 2013). It is difficult to store rainwater or utilize groundwater on the hills of PI. Field surfaces on hills are full of stone, which is difficult for construction, while in the plains, the soil is suitable for settlement. The master plan policy considered that, the sites on or near cliffs is not suitable for housing development. In addition, the high elevation area have to avoided, because the planning in these areas costs a lot to the government, particularly supplying the mountains area by facilities like roads, water supply, electricity, are much more costly in comparisons with the flat areas (A. Al-shalabi, etal.2006). In most places with high elevation, transportation is inconvenient, which is also unsuitable for construction.

Table 8: Elevation suitability analysis

Class	value	Suitability level	area in hectare	area in%
1780 – 1885m	4	Most suitable	4276.52	26.51
1885 – 1966m	3	Suitable	5059.08	31.39
1966 – 2050m	2	Moderate suitable	5165.40	32.10
2050 – 2220m	1	Less suitable	1613.00	10.00
Total			16114	100

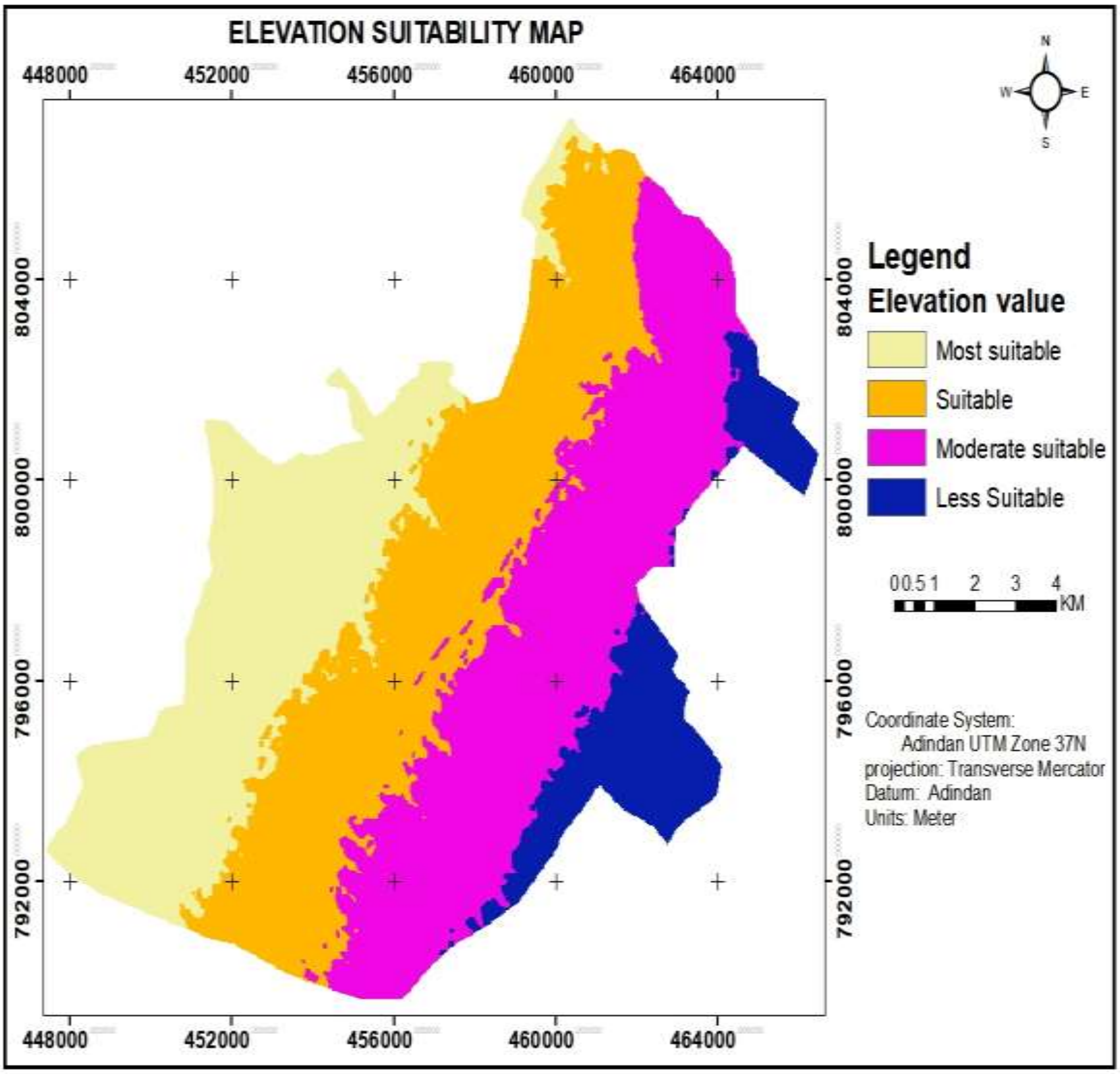


Figure 11: Elevation suitability map of Shashemene city

4.3.3 Soil suitability

According to Puntsag (2014), leptosols /lithosols, which is shallow soil, is highly suitable for settlement or urban area, where as cambicvirtisols-erenic, cambicvirtisol has moderate suitability for urban area. Brown Andosol has only low suitability for urban residential settlement. The soil map of the study area was reclassified in to three-suitability value, chromic vertisols, Eutricregosols and vitric andosol, according to its potential to the suitability for the sake of compatibility to the weighted overlay analysis in ArcGIS environment.

Table 9: Soil suitability analysis

Soil Class	value	Suitability	area in hectare	area in%
chromic vertisols	3	Most suitable	7065.09	43.84
Eutricregosols	2	Suitable	8408.91	52.20
vitric andosols	1	Moderate suitable	640.53	3.97
Total			16114	100

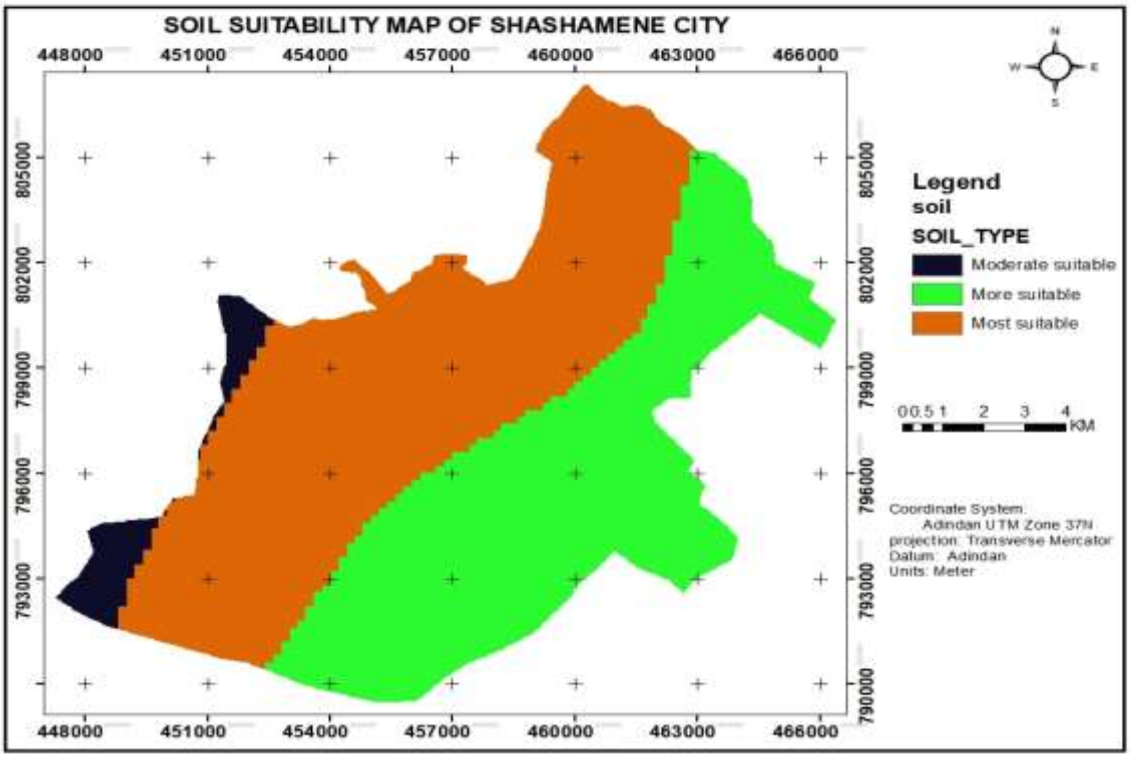


Figure 12: soil suitability map of Shashemene city

4.3.4 Proximity to main road suitability

Most literatures (Omar & Raheem, 2016; Seid, 2007) showed that proximity to the main roads network is suitable for urban residential settlement suitability in case of transportation costs and ease of accessibility. Road accessibility is an important factor to be considered in land use suitability analysis. In this study, the existing road was extracted from structural plan of the city. The distance from the roads calculated a multi ring buffer tool in Arc GIS10. Therefore, an area within 1000meter is most suitable whereas area greater than 3000m is not suitable. Based on this argument, it is around 27%

of the study area is found to be most suitable; about 50.30 % of the study area is suitable, 16.38% of the study area is moderately suitable, for settlement development, 6.28 % less suitable.

Table 10: Accessibility to main Road suitability analysis

Distance in (m)	Value	Suitability	area in hectare	area in%
1000	4	Most suitable	4329.06	26.9
2000	3	Suitable	8033.11	50.30
3000	2	Moderate suitable	2639.71	16.38
>3000	1	Less suitable	1012.58	6.28
Total			16114	100

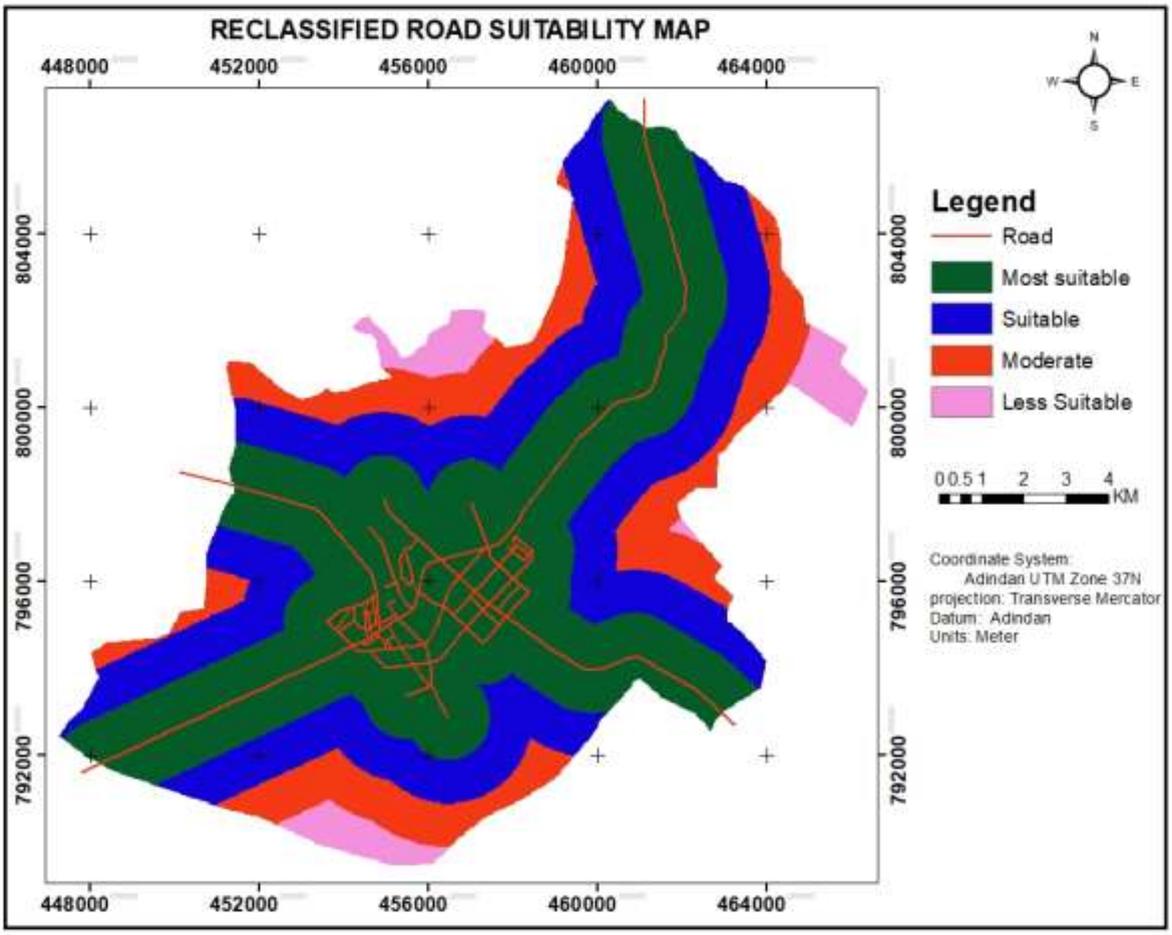


Figure 13: Road suitability map of Shashemene city

4.3.5 Proximity to flood line network suitability

In this study, it is considered that the distance from rivers is taken as a criterion for minimizing flooding because most source of drinking water is underground water from wells. Omar & Raheem (2016) noted that the area closer to the stream is not suitable which is prone to flooding but far away from the stream is highly suitable for sustainable residential settlement environment. Based on this argument, the distance greater than 1000m (41.43%) is considered as the most suitable and in between 500 and 1000m (26.21%) is suitable distance between 100-500m (23.55%) is Moderate suitable. distance between 30- 100m (5.50%) is low suitable. Whereas 0 – 30 (3.40 %) of the area is not suitable.

Table 11: Proximity to River suitability analysis

Distance in (m)	value	Suitability level	area in km2	area in%
>1000	4	Most suitable	6676.200	41.43
500-1000	3	Suitable	3795.50	26.21
100-500	2	Moderate suitable	4224.60	23.55
30- 100	1	Low suitable	916.20	5.50
0-30	0	Unsuitable	550.00	3.40
Total			16114	100

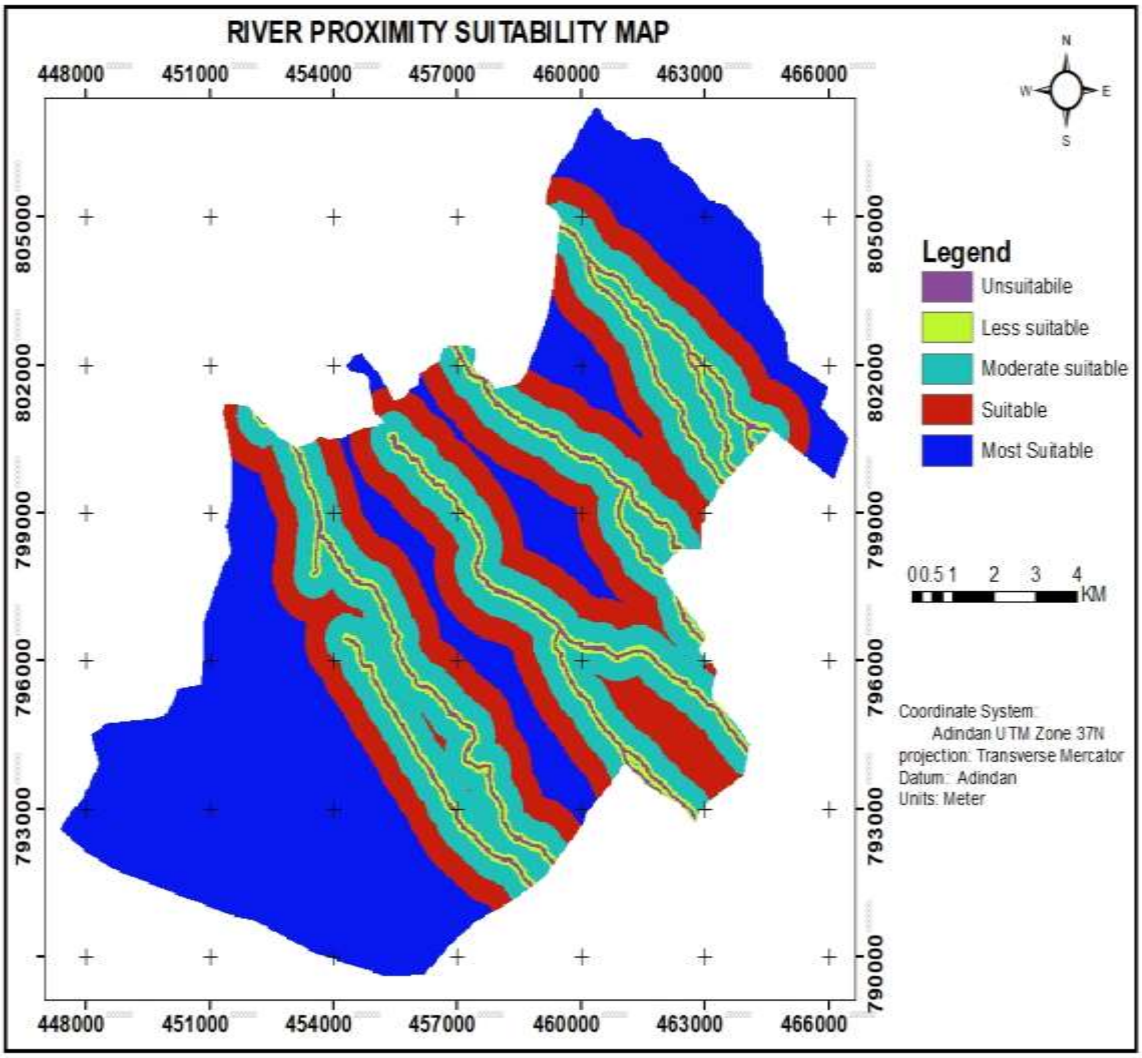


Figure 14: Flood suitability map of Shashemene city

4.3.6 Aspect suitability conditions

Aspect generally refers to the horizontal direction to which a mountain slope faces. It identifies the steepest down slope direction from each cell to its neighbors, where, the value of the output raster data set represents the compass direction. In this study, aspect was computed from contour data and reclassified into suitability classes by considering experiences of the previous study. (Al-shalabi et al., 2006), (Murseli & Isufi, 2014) used aspect conditions in their studies to find out suitable residential settlement. Hence, in this study the eastern and western direction was most suitable.

Table 12: Aspect suitability analysis

Aspect value	Value	Suitability level	Area in hectare.	area in%
East-west	4	Most suitable	4164.03	25.8
South	3	Suitable	1898.91	11.78
North-east/west	2	Moderate suitable	3955.32	25.54
North	1	Less suitable	5956.02	36.60
Flat	0	Unsuitable	139.72	0.87
	Total		16114	100

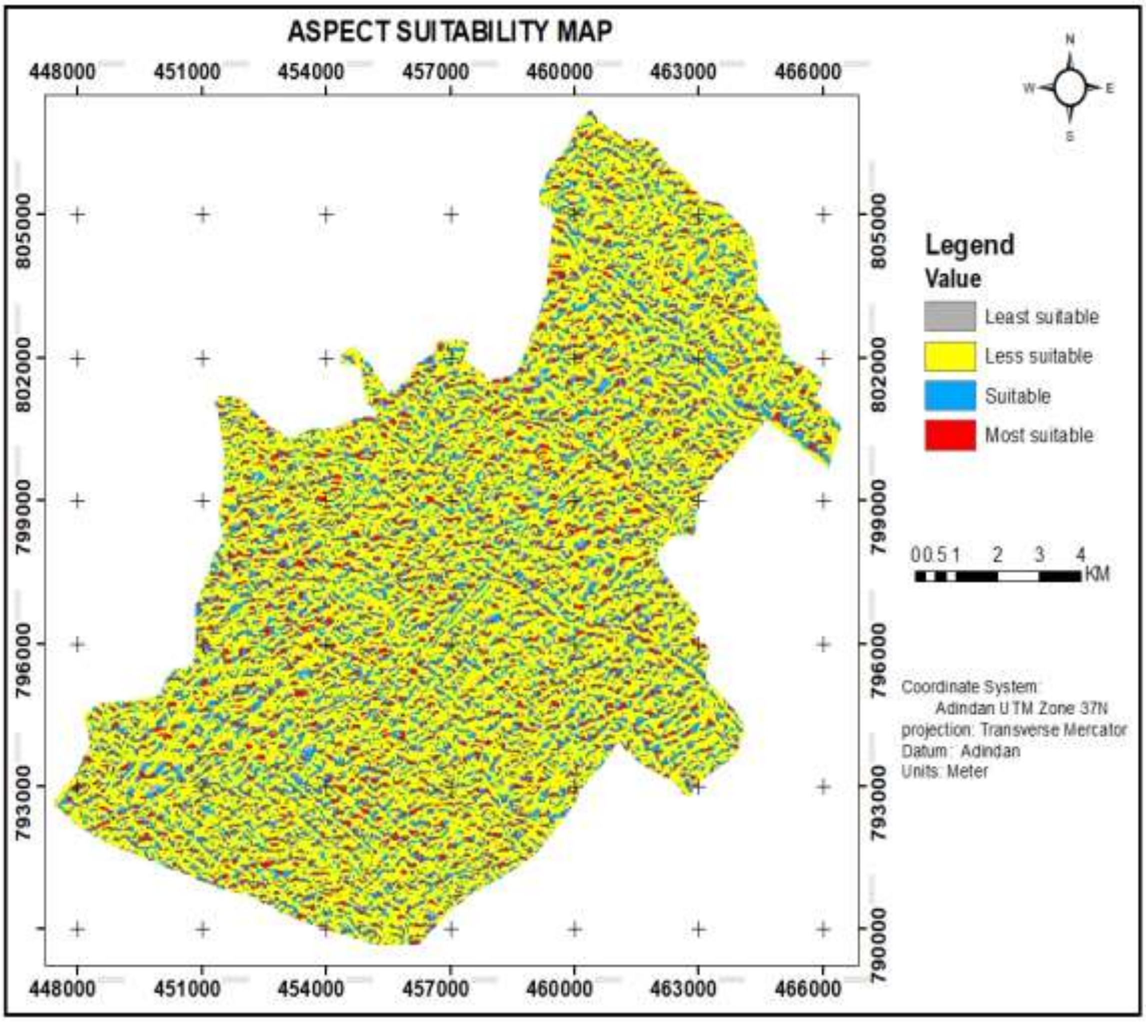


Figure 15: Aspect suitability map of Shashemene city

4.3.7 Land use land cover (LULC) suitability

According to Ethiopia's Ministry of Urban Development and Construction manual on Revised Standards for Structure Plan Preparation and Implementation, Residential settlement should be placed on bare land. The land use land- cover map of the study area is classified in to bare land, agriculture, and planting, built up and water body. The major LULC classes are agricultural land which 43.54%, bare land 18.84%, planting 6.83%. Based on this argument, bare land 18.84% is most suitable, 43.54% is suitable and 6.83% is moderate suitable, 25.84% is less suitable and the area with 4.95% is unsuitable.

Table 13: Land use land-cover suitability analysis

Class	value	Suitability	area in hectare	area in%
Bare land	4	Most suitable	2955.32	18.84
agriculture	3	Suitable	6956.02	43.54
Planting	2	Moderate suitable	1100.90	6.83
Built-up	1	Less suitable	4164.03	25.84
Water body	0	Unsuitable	798.01	4.95
Total			16114	100

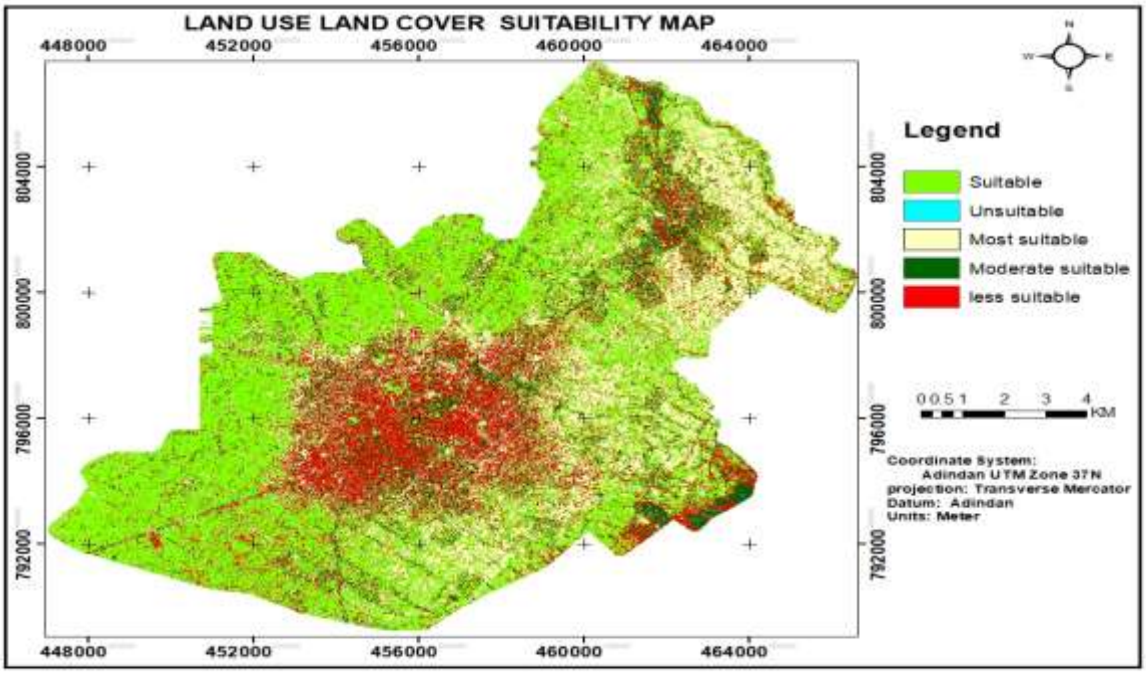


Figure 16: Land use -land cover suitability map of Shashemene city

Accuracy assessment

The aerial photo of Shashemene city was classified using a supervised image classification with an overall accuracy of 93.5% and its kappa coefficient (K) of 0.918.

The producer’s accuracy measures how well a certain area has been classified. Meanwhile, the user’s accuracy was computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (Chauhan et al., 2016). Overall accuracy was 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. In this study, the overall accuracy performed was 93.3% (table 14).

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 were 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 and Ziaulb, 2017).

Table 14: Error matrix showing classification accuracy of the land-use land cover

	Built-up	Water-body	plantation	Bare land	Agriculture	Total	User Accuracy(%)	Producer accuracy (%)
Built up	15	0	0	1	0	16	93.75	100
Water_ Body	0	14	0	0	0	14	100	93.33
plantation	0	0	13	0	2	15	86.66	100
Bare land	0	1	0	13	0	14	92.86	92.86
Agriculture	0	0	0	1	15	16	93.75	88.23
Total	16	15	13	14	17	75		

Overall accuracy= 93.3% and Kappa coefficient (T)= 0.915

4.3.8 Proximity to urban center suitability

Most literature (Omar & Raheem, 2016; Yalew et al., 2016) noted that the settlement near the town is more suitable than the area far away from the town center and the land close to the town is highly suitable for agricultural activities as it reduces food mile distance of agricultural product. Based on this argument, the distance less than 1km (3.35%) is most suitable, between1km and 2km (7.10%) is suitable and between 2km and 4km (25.89%) is moderately suitable whereas the distance greater than 4km (63.65 %) of the area is not suitable (Table 15 & Figure 17).

Table 15: Proximity to urban center suitability

Class (distance in meter	value	Suitability level	area in hectare	area in%
0-1000	4	Most suitable	540.09	3.35
1000-2000	3	Suitable	1143.98	7.10
2000-4000	2	Moderate suitable	4172.58	25.89
>=4000	1	Less suitable	10257.6	63.65
Total			16114	100

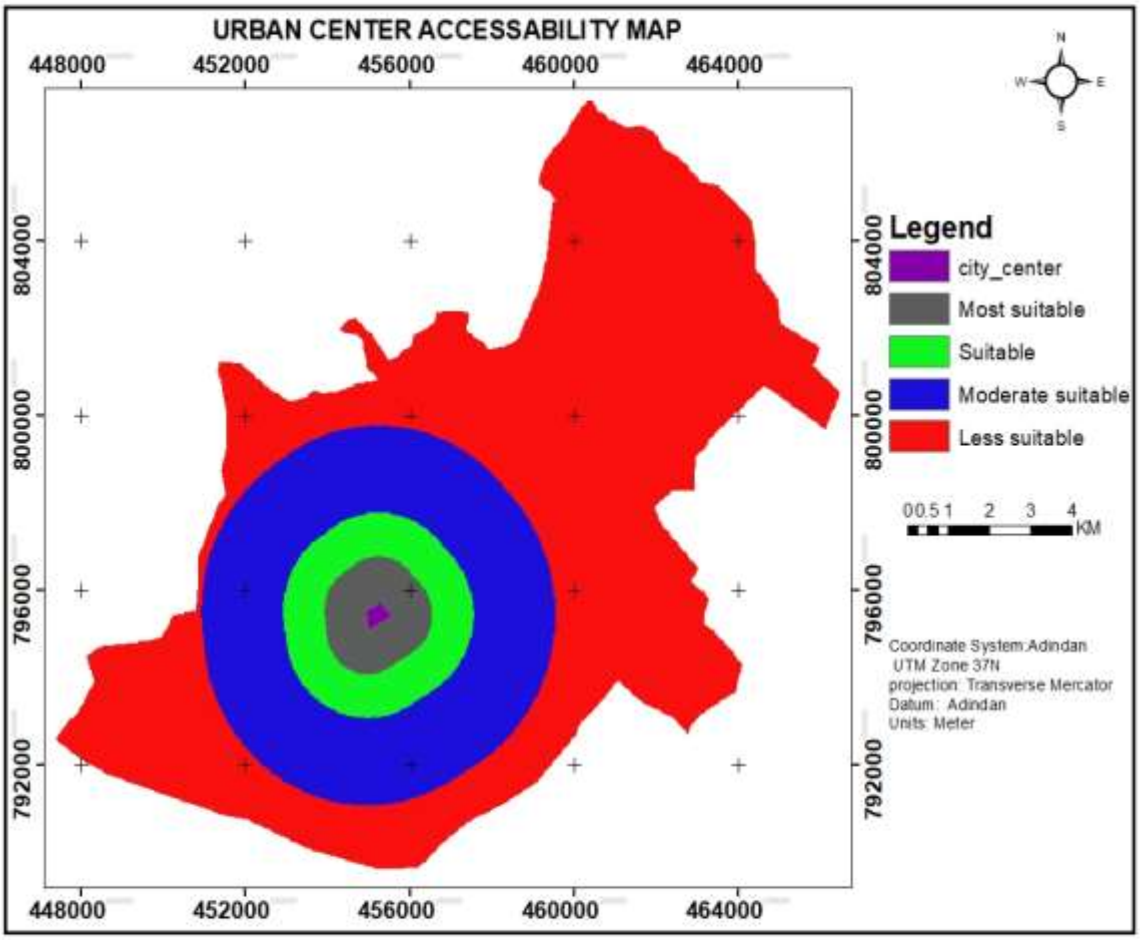


Figure 17: Urban center accessibility, suitability map of Shashemene city

4.3.9 Proximity to Health center suitability

Access to comprehensive, quality healthcare services are important for promoting and maintaining health, preventing and managing disease, reducing unnecessary disability and premature death and achieving health equity for all human beings (WHO, 2012). In this study, it is only 13% of the study area is highly suitable for healthcare facility (Table 18). In the map it is also indicate in the blue color the place where most suitable for health care facility (Figure 19). Murseli and Isufi (2014) in their study suggested that a residential settlement within 0.5 kilometer is most suitable and suitability of residential settlement decreases as the distance increase. A distance function (multiple buffer) was created around existing public health care services to evaluate the suitability of urban residential settlement in terms of accessibility level. Therefore, an area within 500-meter radius buffer from existing healthcare center was considered as the most suitable.

Table 16: Healthcare suitability condition

Class(distance in meter	Value	Suitability level	area in hectare	area in%
500m	4	Most suitable	2094.00	13
1000m	3	Suitable	4140.70	25.80
3000m	2	Moderate Suitable	6146.82	38.00
>3000m	1	Less suitable	3732.70	23
Total			16114	100

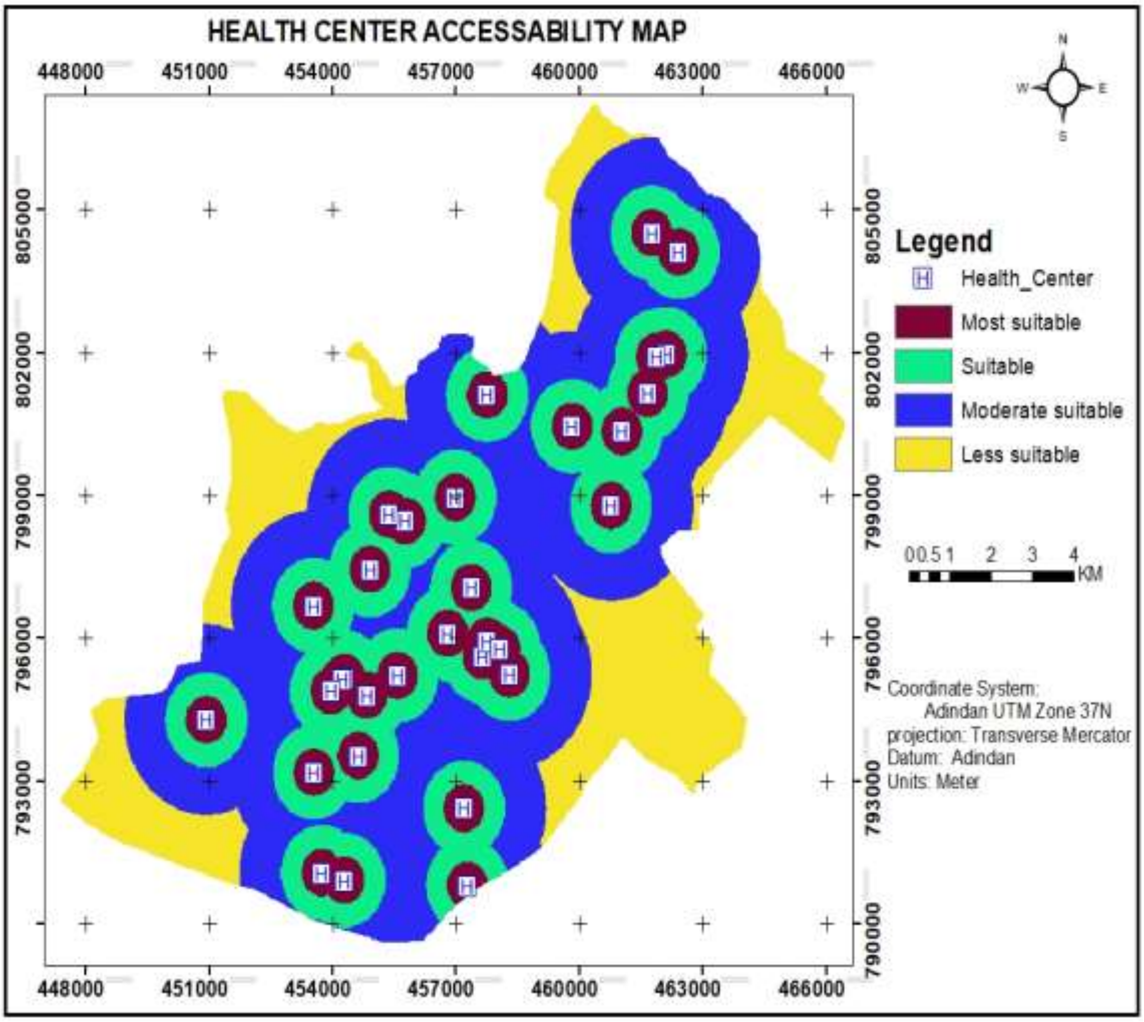


Figure 18: Healthcare suitability map of Shashemene city

4.3.10 Proximity to public school suitability

The result obtained from school accessibility analysis was presented in figure 19 below. The areas situated closer to the schools was considered the most suitable in selection process as represented by the blue spots in the map. It was realized that most schools are concentrated within the central parts of the Municipality. This is an indication of the potential more favorable sites for residential development. The location of public schools' data was in form of points. Multi-ring distance tool was used to interpolate these facilities based on distance. This result in a raster image shows proximity to public schools based on nearest distance.

Table 17 : Proximity to public school suitability

Distance in meter	Value	Suitability level	area in hectare	area in%
>3000	1	Less suitable	1605.53	9.96
3000	2	Moderate suitable	5170.40	32.0
1000	3	Suitable	5059.08	31.50
500	4	Most suitable	4279.53	26.54
Total			16114	100

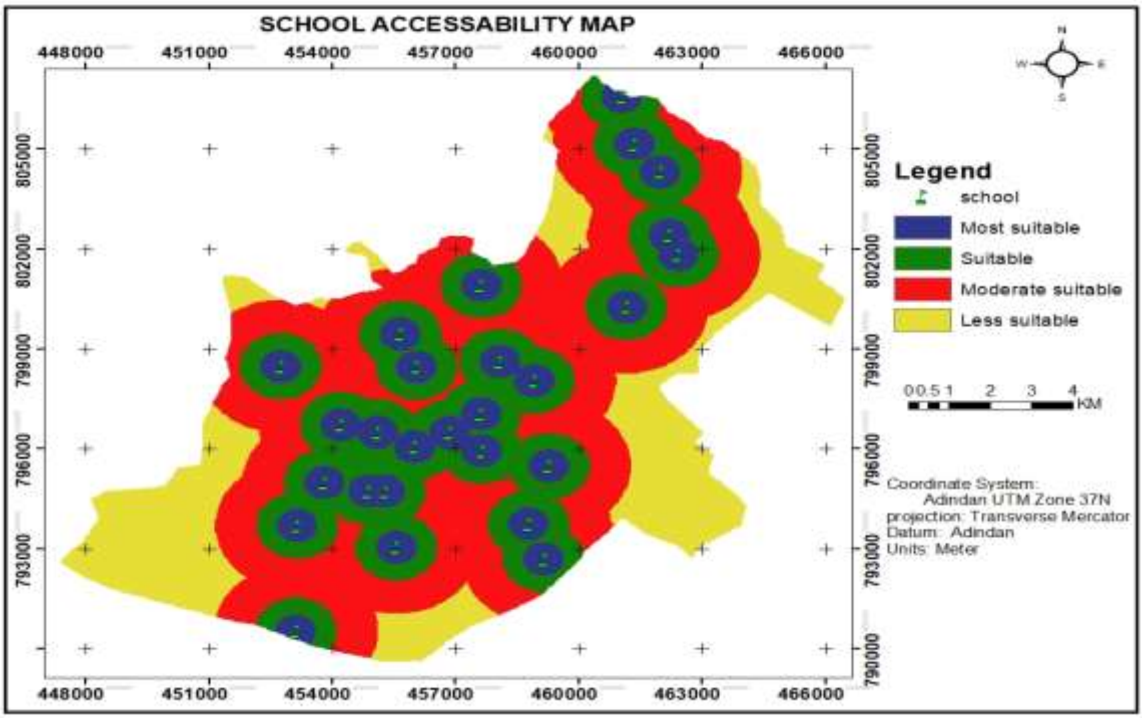


Figure 19: School suitability map of Shashemene city

4.3.11 Proximity to heavy industry suitability

The result obtained from proximity analysis to heavy industry is presented in Table 18 and figure 20 below. The areas situated closer to the heavy industry were considered the least suitable in selection process as represented by the dark color in the figure 20. The location of heavy industry data was in the form of points. Multi-ring distance tool was used to analyze this parameter based on distance. This result in a raster image shows proximity to heavy industry based on nearest distance.

Table 18: Proximity to heavy industry suitability

Class(distance in meter	value	Suitability	Area in hectares	Area in %
0-500	1	Less suitable	571	3.5
500-1000	2	Moderate suitable	742	4.5
1000-3000	3	Suitable	972	6
>3000	4	Most suitable	13829	86
Total			16114	100

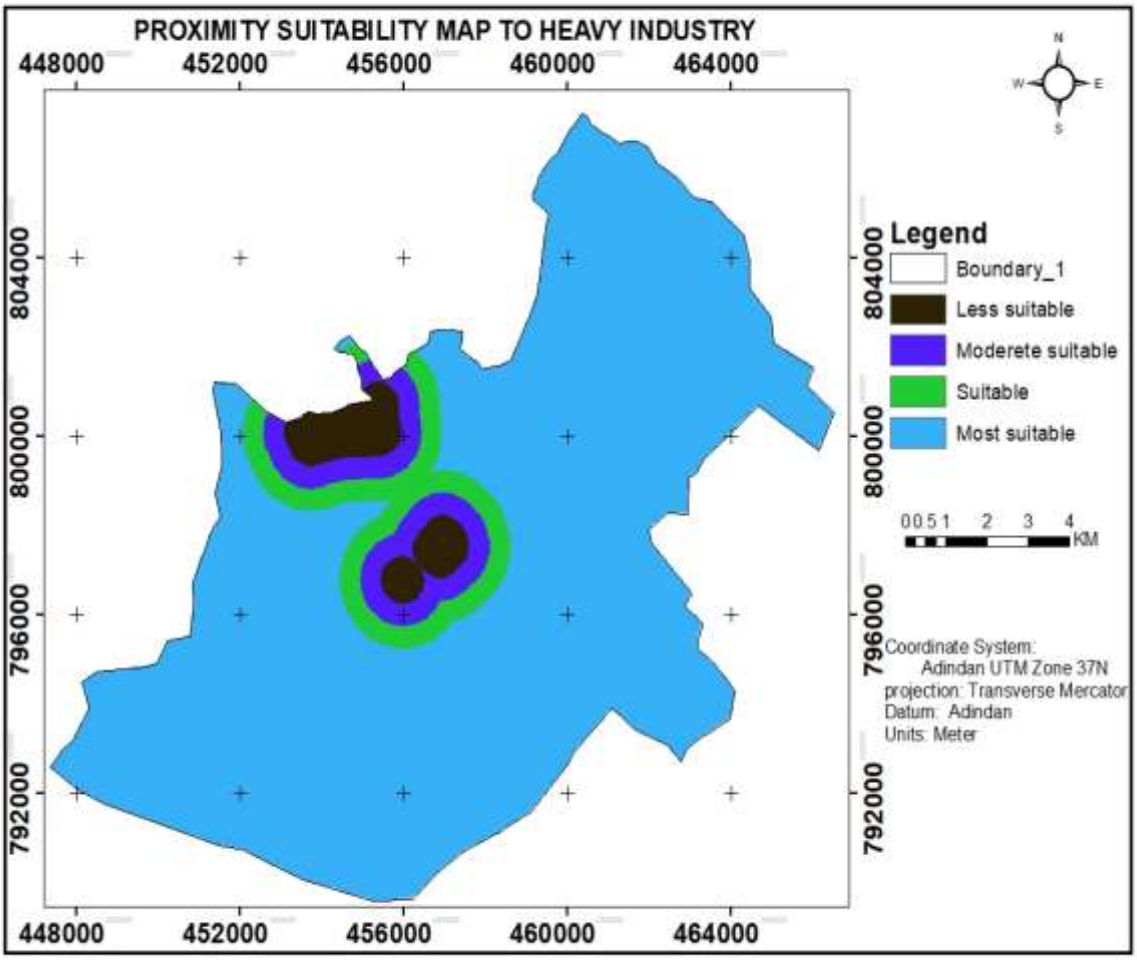


Figure 20: Proximity to Heavy industry suitability map of Shashemene city

4.3.12 Delineation of constraints and Boolean overlay analysis

Restrictions are the features that limit some areas not to be used for future residential uses or housing development due to environmentally sensitive and natural hazard. In general, prime agricultural areas, special function, environmentally buffer zones and water bodies were sited at a significant distance away from the urban residential settlement areas according to (Rahim et al., 2014; MUDC, 2012; Murseli and Isufi, 2014; Al-Shalabi et al.,2006 and Ullah and Mansourian, 2015). Based on these constraints, the study area is classified as restricted and suitable site. Accordingly, it is indicated in Figure 21 and Table 19, 57.00% of the area is suitable whereas 43.00% is restricted. This implies that in Shashemene city 6931.87 hectare of the total area is not suitable for its urban residential settlement areas.

Table 19: Boolean product suitability

Class	value	Suitability level	Area in hectare	Area in %
Constraint	0	Unsuitable/ restriction	6931.87	43.00
Not constraint	1	Suitable	9182.28	57.00
Total			16114	100

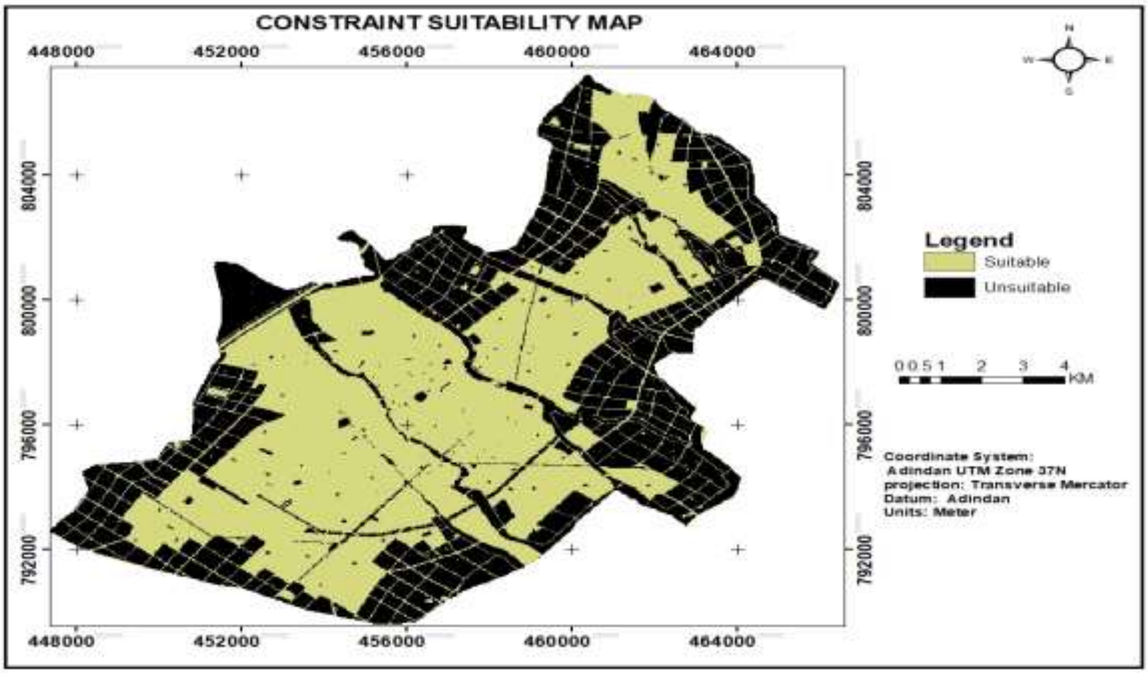


Figure 21: Boolean overlays Product

Prime agricultural land

Different literature (T. L. Daniels, 2004; Neil & Navata, 2019) stated that the prime agricultural land should be protected for agriculture not for settlement development. In this study, prime agricultural land was identified as a constraint since it is necessary to avoid residential development there. Therefore, it is not suitable for urban residential settlement development at all. Based on this argument, 57 % of the study area is highly suitable where as 43 % is not suitable as shown in the table 19.

Water body: from the goal of safety, the candidate suitable site for residential housing area should be free from risk aroused by river flooding during rainy seasons. Hence, river and river layers were clipped from the land-use plan of the city.

30- Meter buffer zones to flood sheet areas were created to restrict from future residential use. According to the structural plan of the city, no residential development is permitted within the 30-meter limit on both sides of flood sheet areas and the river. Thus, (Murseli & Isufi, 2014) suggested 30- meters buffer to rivers, should be ignored from site selection for future residential development.

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

High-tension lines: Murseli & Isufi, 2014 showed that the residential site should be located at least 100 meters from high-tension lines. In this study, high-tension electric lines were acquired from structural plan of study area. In order to avoid possible accidents that could be encountered because of the existence of high electronics movement, buffer zones of 100 meters radius were created around high-tension electric lines. Area outside the buffer zone considered as suitable for residential settlement areas. Whereas, those area within buffer zone are considered as a restriction zones. Finally, the result was incorporated to Boolean constraint map (Figure21).

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 (Figure 22). Weighted linear combination (WLC) could be computed by the following general formula.

$$s = \left(\sum_{i=0}^{n} w1 * x1 \right) * \pi cj$$

Where: S -Suitability Index for residential areas

Σ - Sum of weighted factors

n- Number of Criteria

W_i-Weights of each criterion i

X_i -Score of the criteria

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

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

Accordingly, Figure 22 reveals that Shashemene city can be divided into four suitability indexes, including unsuitable, moderate suitable, suitable and most suitable. Table 20 shows that 43 % of the whole area is unsuitable for future residential development as these areas are constraints or restrictions to the land influenced by legal and environmental conditions of the city. From the composite residential suitability map (Figure 22) areas with yellow color represents for most suitable, whereas areas with black color stands for unsuitable while purple and red color represent for moderate suitable and suitable respectively. The finding also shows that most suitable and suitable lands cover 400.86 and 7822.59 hectares respectively (Table 20 and figure 22).

Table 20: Composite suitability conditions

value	Suitability	Area hectare	Area_ (%)
0	Unsuitable	6931.87	43.00
2	Moderate suitable	958.68	5.95
3	Suitable	7822.59	48.54
4	Most suitable	400.86	2.50
	Total	16114	100

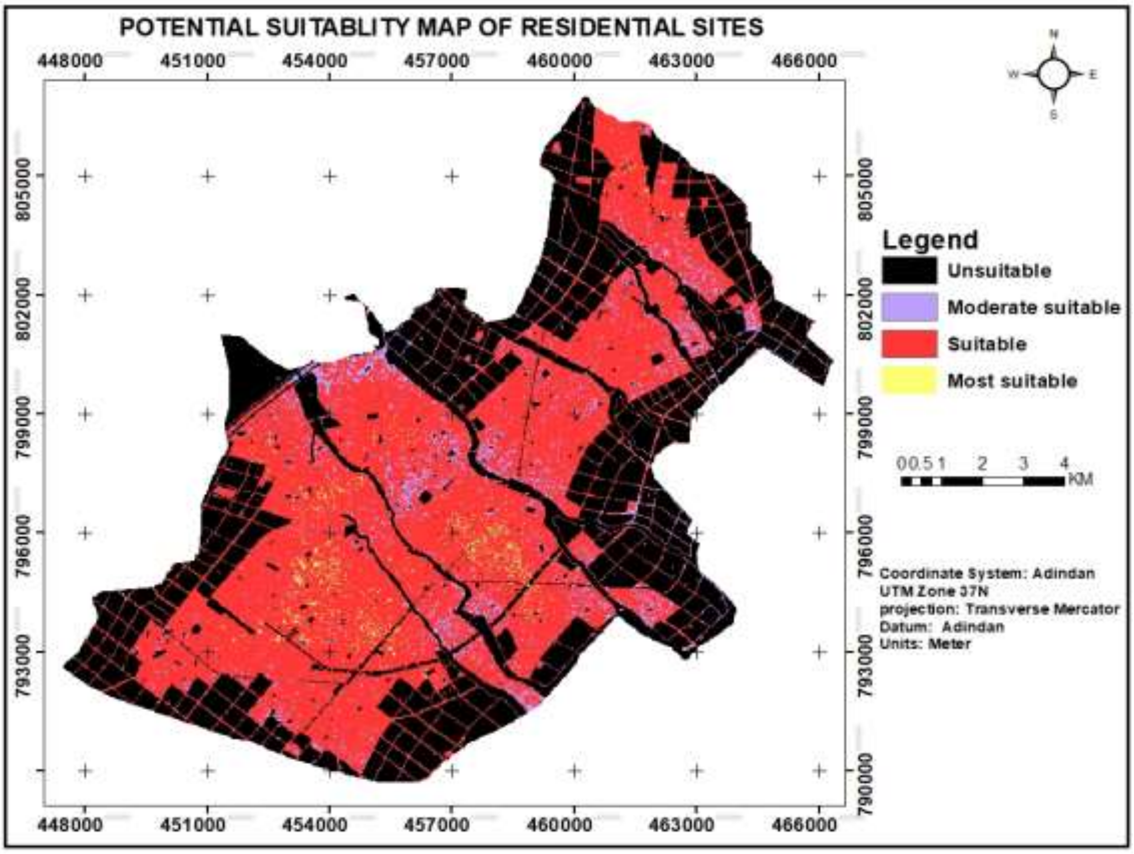


Figure 22: Final suitability map for urban residential settlement

4.4 Evaluation of existing residential settlement sites suitability of Shashemene city

The total area for existing residential areas is 2914.23 ha (Figure 25). The area zoned for residential activities is reserved for residential houses that built by individuals, cooperatives, and by the government (such as low-cost and condominium houses), for mixed activities and residential services. Areas assigned for residence are found around the vacant areas in Awasho, and Dida boke.

The existing residential settlement layers were extracted from the existing land use plan of the city and super-imposed with the final suitability map of this study to evaluate their suitability (Figure 23). The yellow colors area represents the existing residential land that overlay with the final suitability map (Figure 23).

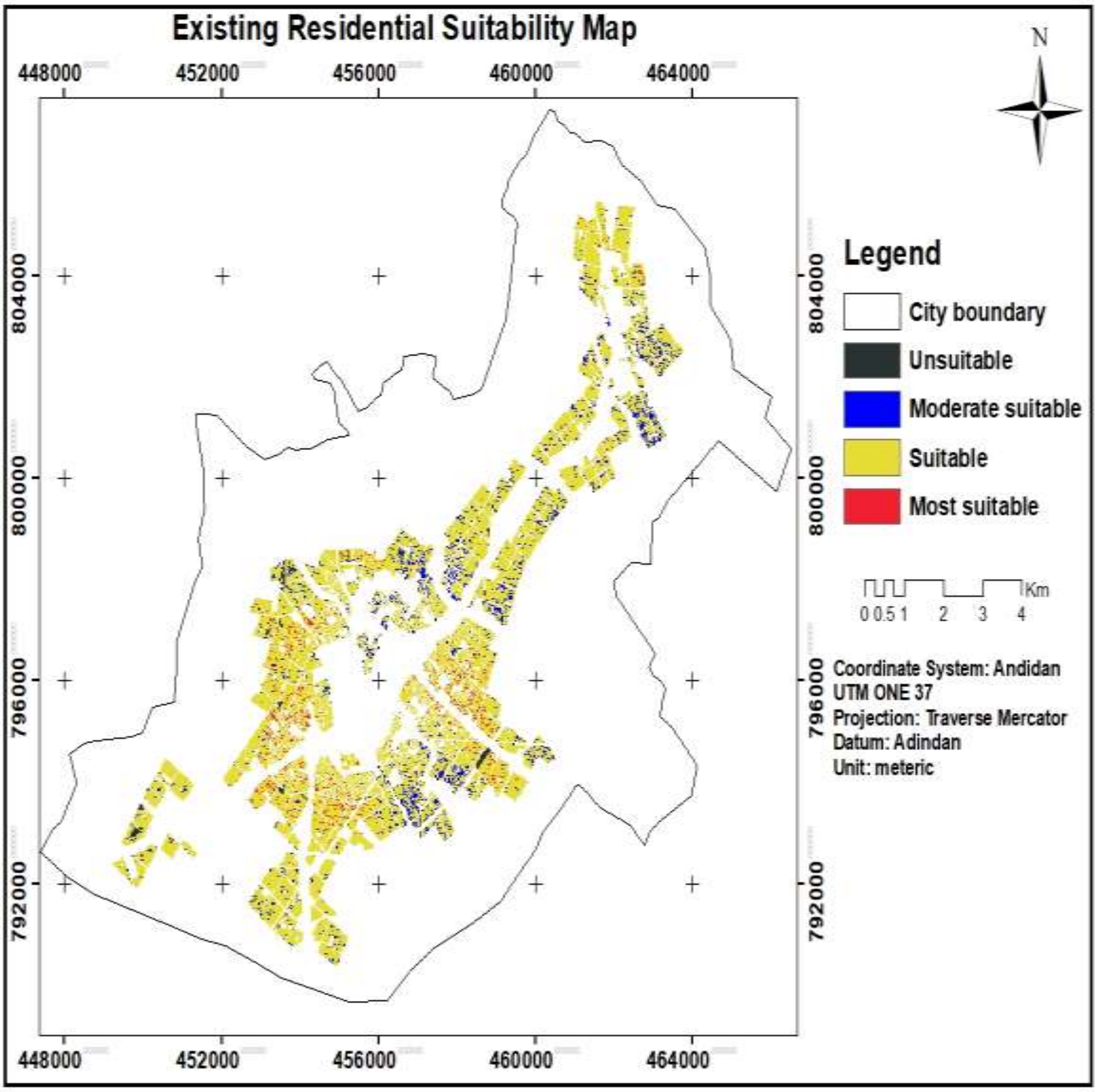


Figure 23: Existing residential settlement suitability map

The suitability indexes of the existing residential land use was, computed (Table 20). The validated result (Table 20) reveals that 2.50% of existing residential land use was classified as most suitable. Table 20 also reveals that 48.54% of existing residential land use was classified under suitable conditions. The Areas shown by purple and orange colors are categorized under most suitable and suitable respectively whereas the Area shown by light blue color is categorized under moderate suitable.

This indicates that currently, Shashemene city has 51.04 % (8223.45 hectares) of its remaining existing residential land-use plan to distribute urban land for future residential needs. The result also shows 5.95% (958.68 hectares) exist under moderate suitability, which needs further investigation before land distribution for housing purposes (Table 20; Figure 24). 43.00% (6931.87 hectares) exists under restriction (Table 20; Figure 24) due to its location under a constraints zone.

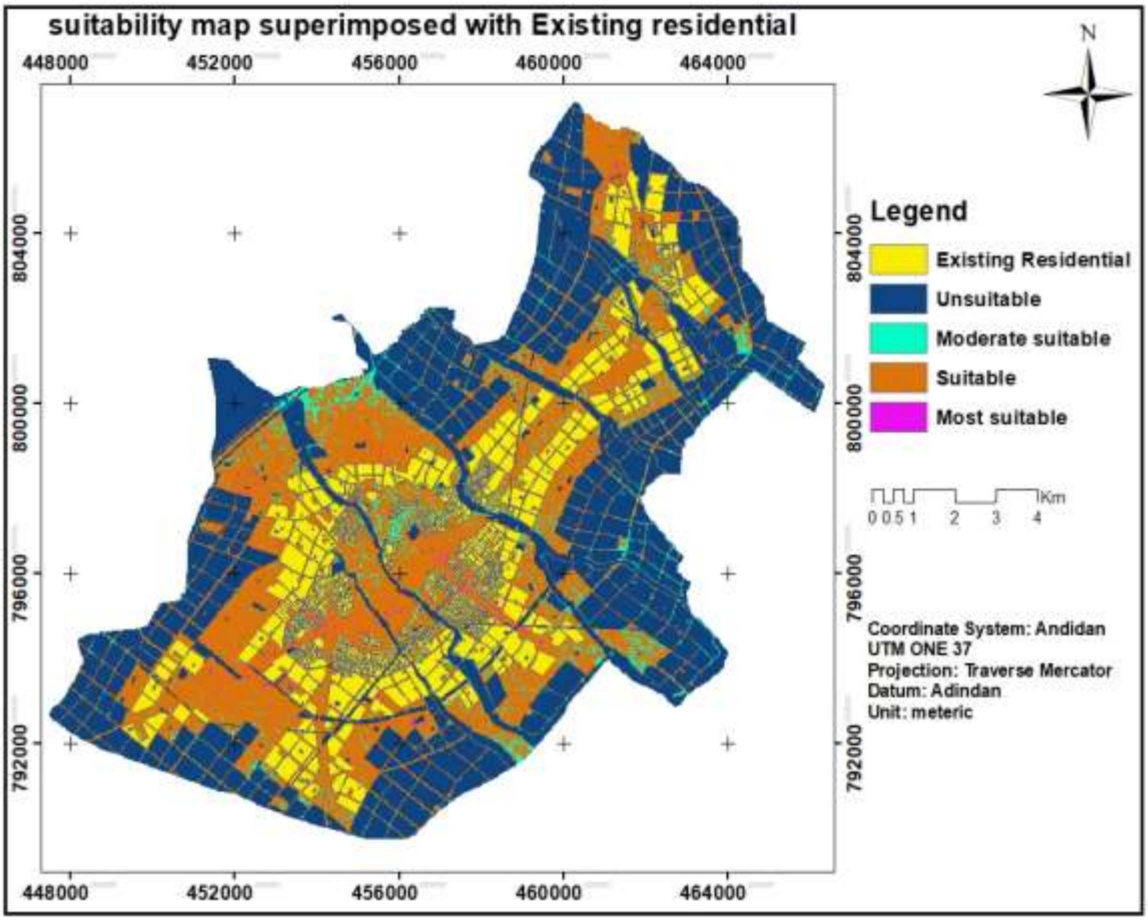


Figure 24: Final suitability map superimposed with existing residential settlement

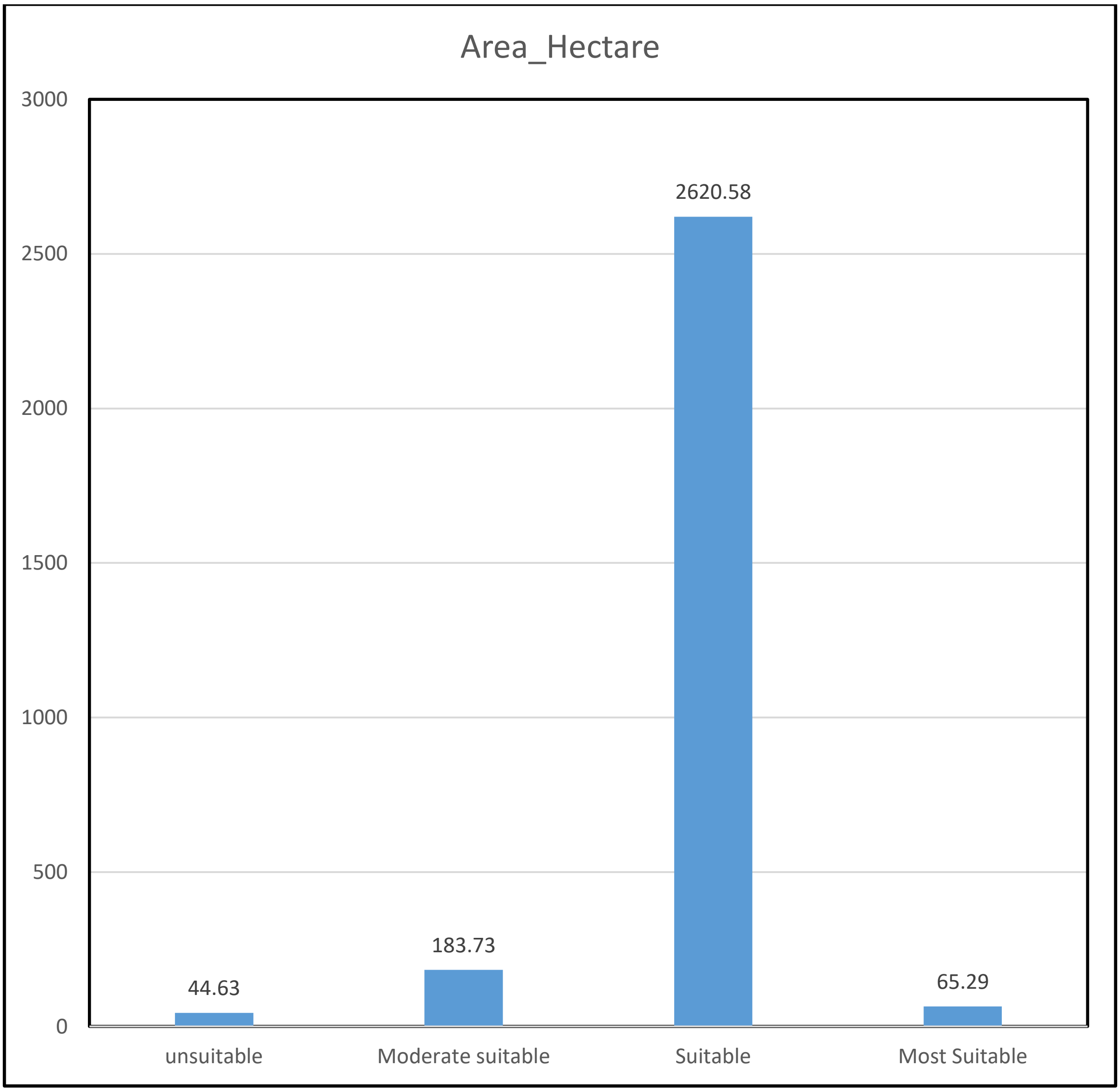


Figure 25: Suitability indexes for existing residential settlement sites

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This research was carried out to evaluate urban residential settlement areas for Shashemene city using multi criteria analysis integrated with GIS and RS techniques and AHP methods.

Eleven factors namely: land use land cover, soil type, proximity to main road, proximity to flood lines, accessibility to public school, accessibility to health center, slope, elevation, aspect, proximity to heavy industry, and proximity to urban center were identified. Four constraints including: Built-up, prime agriculture, water body and High-tension lines were determined to evaluate urban land for residential settlement areas.

Local experts were presented to order and assign relative importance of each criterion using 9 class values of satty scale and eigen vector weights of eleven factors were computed using decision support IDRISI selva software and then the overall Consistency Ratio (CR) of the module was checked as 0.09 %. In this study Boolean overlay tool of ArcGIS 10.8, software was used to integrate all constraints layers to produce a combined constraint map. This constraint map classify Shashemene city into a restricted and unrestricted areas represented by zeros (Unsuitable) and ones (suitable) respectively.

The relative importance of parameter was computed using analytical hierarchy process (AHP) methods involving experts' engagement in giving weights for each criterion by using pair wise comparison technique. Land use land cover type was taken to be the most important factor among the others when choosing the best suitable urban residential settlement in Shashemene city, Oromia Ethiopia. From the computation, the weight of the Land use- land cover type was found to be 22.4% (Table 6) being the highest unlike the Heavy industry factor, which had the lowest level of influence of 1.1% (Table 6).

Based on the suitability analysis, 400.86 hectare (2.5%) is most suitable, 7822.59 hectare (48.54 %) is suitable, 958.68 hectare (5.95%) is moderate suitable, and 6931.87hectare (43.0%) are unsuitable. The most suitable land is mostly located around the center and western part in the city.

The validated result of the study reveals that 2.50% and 48.54% of existing residential land use plan, which is still not constructed or undeveloped, exist under most suitable and suitable respectively. This indicates that currently, Shashemene city has 51.04 % (8223.45 hectares) of its remaining existing residential land-use plan to distribute urban land for future residential needs.

The result also shows 5.95% (958.68 hectares) exist under moderate suitability, which needs further investigation before land distribution for housing purposes. Whereas 43.00% (6931.87hectares) exists under restriction, zone due to its location under a constraints zone.

Land suitability analysis is a critical element in determining suitable areas for some specific purposes. As demonstrated in this study, geospatial technologies like GIS, remote sensing GPS can play a critical role in urban residential settlement suitability analysis.

Recommendation

- The present study considered many criteria such as soil type, slope, aspect, river, elevation, land use land cover, proximity to main road, urban center, health center, public school and heavy industry in urban residential settlement suitability analysis. However, other criteria such as geological hazards (land and mudslides) and market infrastructures are recommended to be included.
- 43.00% (6931.87hectares) of the study area is exists under restriction, this is due to constraint zone therefore this study recommended that, urban planner; government and residents can give attention , recognition and protection to this area in order to avoid any constriction and development.
- This study also show suitability analysis for urban residential Settlement and evaluate the suitability of existing residential settlement site of Shashemene city. However, proposed land use plan for urban residential settlement to be included in the future study.
- Generally, the findings of this study have recommended that using GIS and Remote sensing techniques augmented with multicriteria evaluation andAHP methods are important tools for studies of site suitability analysis rather than using single GIS or RS techniques.

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Appendices

Appendix I

Questionnaires prepared for experts in different level

MSC, Thesis questionnaires paper on urban residential settlement suitability analysis in Shashemene city, march 2022, for urban land administration office of Shashemene city.

Personal Information Name: ___________________ Occupation: ________________
Kebele____________ Sex ________ Age________

As part of my MSC, Thesis at Adama Science and Technology University, I am conducting a survey that investigates the perceptions of experts about urban residential settlement suitability analysis in Shashemene city. Please answer the following questions that provide inputs for my study.

1. What are the parameters you consider during urban land plan preparation for residential settlement?

   ____

   ____

   ____

2. What are the problems you observe in developing residential settlement areas in Shashemene city?

   ____

   ____

   ____

3. What are the probable recommendations you would suggest to improve the suitability of residential settlement and to reduce economic crisis in Shashemene city?

____

____

____

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

____

____

____

5. What new/ old technologies, models and approaches would you follow to prepare an urban land plan for residential settlement?

____

____

____

6. Are the infrastructures and utilities are well to be found for residents of the city?

A. Yes B. Partially C. No,

explain____

______

____

____

7. How do you control the urban land of Shashemene city?

____

____

____

____

____

8. What problems do you observe in plan implementations?

____

____

____

9. What problems are observed in the existing of residential settlement of the city?

____

____

____

____

Appendix II: Field survey using Handheld GPS

GPS data collected from the study area using a handheld GPS

No.	Easting	Northing	Land _type
1	456661	795953	Plantation
2	456025	795987	Plantation
3	453018	795990	Plantation
4	453035	795676	Plantation
5	453026	795641	Plantation
6	453012	795675	Plantation
7	453079	795543	Plantation
8	453065	795456	water body
9	453044	795543	water body
10	453037	795789	water body
11	453042	795356	water body
12	453010	795912	water body
13	453021	795345	Plantation
14	456038	795349	Plantation
15	455033	795678	Plantation
16	456012	797898	Plantation
17	456028	797134	Built-up area
18	453038	797987	Built-up area
19	456032	797238	Built-up area
20	455037	797865	Built-up area
21	455028	798769	Built-up area
22	453017	796754	Built up area
23	455106	796776	Built up area
24	455747	798765	Built up area
25	453448	795648	Built up area
26	453124	795543	Built-up area
27	453223	794876	Built-up area
28	453030	794875	Built-up area
29	453021	794762	Built-up area
30	453029	794567	Built-up area
31	453147	794978	Agricultural area
32	453175	794978	Agricultural area
33	453198	794765	Agricultural area
34	454045	794869	Agricultural area
35	454087	794854	Agricultural area
36	454078	794876	Agricultural area
37	454097	794863	Agricultural area
38	454245	794328	Agricultural area
39	454567	794367	Agricultural area
40	454678	795985	Agricultural area
41	454767	795999	Agricultural area
42	454432	797506	Agricultural area
43	453432	797800	Agricultural area
44	456789	797815	Agricultural area

45	453675	796544	Agricultural area
46	445678	796585	Bare land
47	453563	796590	Bare land
48	453875	797075	Bare land
49	455678	797071	Bare land
50	454567	797472	Bare land
51	454678	797078	Bare land
52	453367	795912	Bare land
53	454553	795922	Bare land
54	455674	797524	Bare land
55	451234	797585	Bare land
56	451286	797590	Bare land
57	452134	795960	Bare land
58	452765	796075	Bare land
59	452465	796563	Bare land
60	457864	796555	Bare land
61	454567	796870	Bare land
62	453567	796892	Bare land
63	453876	796899	Bare land
64	458765	796878	Bare land
65	458732	796667	water body
66	458714	796544	water body
67	455767	796785	water body
68	455678	796772	water body
69	454778	796787	water body
70	454667	797981	water body
71	454867	799776	water body
72	456234	799787	water body
73	456532	798788	water body
74	456744	798767	water body
75	456678	798767	water body
76	456078	798768	water body
77	456508	798795	water body