REMOTE SENSING AND GIS BASED SITE SUITABILITY ANALYSIS FOR FUTURE URBAN DEVELOPMENT: A CASE OF AMBO TOWN AND SURROUNDING AREA

Achalu Kedida Beyene

A thesis submitted to

The department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment for the degree of Master's in Geo-Informatics

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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APPROVAL OF BOARD OF EXAMINERS

I/we, the advisors of the thesis entitled "Remote Sensing and GIS Based Site Suitability Analysis for future Urban Development: in Case of Ambo Town and Surrounding Area" and developed by Achalu Kedida Beyene, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Roba Gemechu (Ph.D.)	________________	____________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Achalu Kedida Beyene, have read and evaluated the thesis entitled "Remote Sensing and GIS Based Site Suitability Analysis for future Urban Development: in Case of Ambo Town and Surrounding Area" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-Informatics Engineering, the Graduate program of the department of Geomatics Engineering.

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

Department Head	Signature	Date
School Dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

CANDIDATE'S DECLARATION

I hereby declare that this Master Thesis entitled "Remote Sensing and GIS Based Site Suitability Analysis for future Urban Development: in Case of Ambo Town and Surrounding Area" 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 are used for this thesis have been duly acknowledged through citation.

Achalu Kedida Beyene ______________________ ________________

Name of the student Signature Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Remote Sensing and GIS Based Site Suitability Analysis for future Urban Development: in Case of Ambo Town and Surrounding Area" prepared under my guidance by Achalu Kedida Beyene submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-Informatics Engineering, the Graduate program of the department of Geomatics Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Roba Gemechu (Ph.D.)	______________________	_______________
Major Advisor	Signature	Date

ACKNOWLEDGEMENT

First and foremost, I would like to thank almighty God, who gives me strength in all of my work. Next, my special thanks to my advisor, Dr. Roba Gemechu for his constructive and fruit full guidance and help throughout this thesis work.

My appreciation would also go to my wife Shumate Sintayehu for her support and encouragement in every situation of my life and Mr. Yirgalem Gerbaba and Mr. Adamu Dessalegn for their support in software operation and in sharing useful information and Mr. Jara Tadese for giving me his valuable time in data collection.

Besides my thanks also go`s to my families who have morally and financially helped me to succeed in this long process of learning program. This acknowledge also goes to all my classmates as well as all ASTU Geomatics Department staff members who gave moral supports to accomplish my thesis.

Finally, I grateful to Adama Science and Technology University School of Civil Engineering and Architecture, Geomatics Engineering Department for they letting me to done this thesis.

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LIST OF ACRONYMS AND ABBREVIATIONS

AHP	Analytic Hierarchy Process
ASTE	Advanced Space born Thermal Emission and Reflection Radiometric
CAD	Computer Aided Design
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EGS	Ethiopian Geological Survey
EIA	Environmental Impact Assessment
ERDAS	Earth Resource Data Analysis System
GII	Geospatial Information Institute
GIS	Geographic Information System
GPS	Global Positioning System
LSA	Land Suitability Analysis
LULC	Land Use Land Cover
MCDA	Multi-Criteria Decision Analysis
PNG	Portable Graphics Format
TIFF	Tagged Image File Format
USGS	United States Geological Survey
WLC	Weighted Linear Combination

ABSTRACT

One of the critical issues in urban planning is the determination of appropriate locations for future urban growth in and around the town. This study demonstrates the use of Remote sensing and Geographic Information System (GIS) based Multi-Criteria Decision Analysis (MCDA) techniques for selection of suitable sites for urban development of Ambo Town. Nine factors (proximity to lineament, proximity to road, proximity to river, proximity to school and health center, land use land cover, slope, soil, geology and proximity to existing built-up area) were identified for criteria evaluation. The thematic maps of these criteria were prepared and standardized using pair wise comparison matrix known as Analytical Hierarchy Process (AHP). A weight for each criterion was given by comparing them with each other according to their importance, the consistence of comparing matrix were checked by calculating the consistence ratio (CR). The consistency ratio of this study indicated that 0.045 which is less than 0.1. Thus, consistent matrix was formed which was acceptable in order to combine all the layers. Finally using these weights all maps layer were integrated and overlaid to generate final site suitability map for the urban development. The final site suitability map was reclassified to five suitability classes (highly suitable, moderately suitable, less suitable, very less suitable and unsuitable). The findings of this study revealed that from the total area of 83.91Km^2 found in study area, 16.13% (13.35km^2) of total area was occupied by existing built-up and not considered for this study. From the rest of 70.38 km^2 total area, 36.13% (30.32Km^2) area is highly suitable, 31.59% (26.51Km^2) area is moderately suitable, 9.80% (8.22Km^2) area is less suitable, 2.63% (2.20Km^2) area is very less suitable and 3.74% (3.14Km^2) area is unsuitable for future urban development. This result shows that most of the area selected as highly suitable for future urban development are open area, shrubs, bushes and agricultural land, areas having flat slope, area far away from river and areas far away from lineaments. This study allows the local people as well as planners for the appropriate plans of land use planning in sustainable urban development of Ambo town.

Keywords: GIS; Site Suitability analysis; Multi-Criteria Decision Analysis; Urban development; Ambo town.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Cities and urbanized areas are the social centers of our modern life and they provide all of our daily needs (Moeller, 2000). In the last few decades, substantial growth of urban areas has occurred worldwide with population increase being one of the most obvious agents responsible for this growth (BARBARA, 2012). The world population has increased from 2.58 billion in 1950 to 7.8 billion people in 2020 and is projected to 9.7 billion by 2050 (UNDESA, 2020). According to the World Urbanization Prospects reported by the United Nations (UNDESA, 2020), the global population living in the urban area increased from 30% in 1950 to 56.2% in 2020 of the world's population and by 2050, 68% of the world's population is projected to be urban. Because of the ongoing urbanization and growth of the world's population, there will be about 2.2 billion or more people are expected to be added to the urban population by 2050, mainly in Africa and Asia. This overall growth is mainly driven by the growth of the population in less developed countries.

According to the World Urbanization report (2020), The level of urbanization in Africa is low (43.5%) when compared with developed countries like Europe (74.9%) and North America (83.6%). The fast rate of urbanization in the developing world is attributed to rural-urban migration, economic growth and development, technological change, and rapid population growth. Along with the population growth, more and more people chose to live in urban areas and over half of the population on the earth will live in urban areas by 2050. Due to the increasing population and economic growth, human activities have continuous impacts on land use (Chen, 2014). Those impacts might lead to a series of complexities toward environment and land resources development (Huang and Xia, 2001). Urbanization is a global trend that reflects the growth of the urban population of the world. The urban populations of less-developed countries are currently increasing greater than that of more-developed countries. Urbanization results from two reasons the first one is a natural increase in the population and the second one is rural to urban migration of population.

Ethiopia is one of the least urbanized countries in the world (World Health Organization African Region: Ethiopia, 2014, Demography section). It has only 16% of total population living in urban centers in 2008 and the number of urban residents increased to 21.7% of total population in 2020 (PCC, 2008; world bank, 2020). However, given the 2.73% total annual population growth rate, high rate of in-migration to towns and an increase in the number of urban centers, the rate of urbanization is increasing at a rate of 4.4% (Tsegaye, 2010). Furthermore, the country's urban population is expected to grow on average by 3.98% and by 2050, about 36.3% of the total population is expected to be inhabited in urban centers (UNDESA, 2019). According to the Ministry of Urban Development, Housing and Construction report (2014), there are more than 900 urban centers in Ethiopia. Ambo Town is one of 900 urban centers in Ethiopia and has about 70,000 people living in the town (UN-HABITAT, 2016). The concentration of people in very densely populated urban areas mainly located in less developed countries. This situation highly recommends the introduction of sophisticated monitoring systems for these regions (Moeller, 2004). The increasing urban population causes an increasing demand for urban land use. This movement leads to tremendous rural-urban land conversion, which has become a significant research topic in recent decades (Zhang, 2016).

At present, remote sensing and GIS has been recognized as a valuable technology for viewing, monitoring, analyzing, and mapping suitable site for urban growth and expansion. According to Al-Bilbisi (2019), it has been widely used in detecting and monitoring urban development on various scales which gives useful results. Thus, Remote sensing is an important source of information for urban expansion analysis based on its high spatial and temporal accuracy and consistency (Weng, 2002). Moreover, remote sensing data are very useful because of their repetitive coverage, and real-time data acquisition (Al-Bilbisi, 2019). Digital data or satellite images, enable the accurate differentiation of land use land cover and help to maintain the spatial data infrastructure, which is very important in the selection of suitable sites for urban development. AHP is categorized under MCDA approach and is an effective technique that helps planners and decision-makers to analyze all data before arriving at a final decision for future land-use changes (Bagheri et al., 2013; Nguyen Hieu et al., 2006). Satellite data, remote sensing, and Geographic Information Systems (GIS) are the most relevant technologies for meeting these needs in the most effective manner (Al-Bilbisi, 2019).

The suitability analysis of urban growth is considered as one of the most important and effective techniques for identifying the best urban growth locations. This technique employs different types of criteria and weights (Alexander et al., 2012). Land suitability evaluation involves the selection of suitable locations of development via mapping of the suitability index of a specific area (Joerin et al., 2001). GIS techniques have become a significant tool for controlling and monitoring changes in urban development and their impact on ecosystems (Rosli, 2014). Land suitability analysis based on GIS is a process that aims to identify the best locations of development while considering environmental sustainability (Park, 2011). In setting the importance of the criteria used and computing the weights of factors, GIS tools must be integrated with other methods to improve the results of land suitability analysis. The integration of GIS tools and MCDA is a powerful approach for evaluating land suitability (Bagheri, 2013). The concept of sustainability generally leads to improved suitability analysis, which is a complex operation due to various types of factors and criteria that must be considered in the process (T. Duc, 2006).

Several articles have been published in addressing urban land suitability using MCDA integrated with a Geographical Information System environment. For example, Chen (2014), uses such a technique in generating land-use suitability of the city of Regina in Canada. Also, Santosh et al. (2018), illustrate the use of GIS tools and numerical MCDA techniques to identify suitable sites for urban development of a hill town. Similarly, Maher M. et al. (2016), used a comprehensive method of GIS and MCDA to analyze Land suitability analysis of future urban growth in Seremban Malaysia city using GIS-based Analytical Hierarchy Process. Mesfin (2019), conducted a study on Site Suitability Analysis for Urban Development Using Remote Sensing and GIS-Based Multicriteria Evaluation Technique in Wolaita Sodo Town and Surrounding Area, Ethiopia. However, no systematic study is available yet on suitable site selection for future urban development in Ambo Town, by employing remote sensing and GIS-based MCDA techniques. This study attempts to evaluate and conduct site suitability analysis in the study area for future urban development using remote sensing and Geographic Information system with the integration of the MCDA approach, which could benefit decision-makers, stakeholders, and city administration in general.

1.2 Statement of the problem

Today, more than half of the world's population resides in urban areas, and this is due to socio-economic reasons which lead people to move from rural areas to urban areas (UNDESA, 2018). Therefore, the trend towards urbanization is increasing, which results in the growth of the urban population and the extent of urban areas (UNDESA, 2018). In recent decades, due to concerns over clean air, water, climate and land-use change, sustainability has attracted attention, especially sustainable urban planning (Wheeler and Beatley, 2014). Since changes in urban population result in land-use change, effective land use planning is needed to evaluate the best sites for future urban development.

Urbanization leads to the outward expansion of cities and results in changes in land use and its effect is very clear which is the conversion of peri-urban areas to urban. Unprecedented urbanization causes rapid urban expansion, which can be unhealthy without reasonable urban planning. The term "urban sprawl" is used to describe unhealthy urban expansion (Jat et al., 2008; Angel et al., 2011; Yue et al., 2013). Unhealthy urban expansion or urban sprawl, refers to an uncontrolled and dispersed process of urban growth which is characterized by low urban area density and low population density (Zhang, 2016). Urban sprawl causes many environmental, economic and social problems such as: traffic problems, decreases the urban employment rate, decreases access to public services like health and educational centers, loss of open space, loss of agricultural land, uneven distribution of local resources, increased illegal construction, lack of jobs, homelessness, expanding squatter settlements, inadequate services and infrastructure, high levels of pollution and increased crime (Bhatta et al., 2010b; Jiang et al., 2007; Lambin et al., 2001; Sudhira et al., 2004). Also, urban sprawl is associated with problems such as air pollution, water contamination, arable land loss, and climate change (Bhatta et al., 2010a; Xu & Min, 2013; Yu & Ng, 2007). So, to bring solution for those problems urban planners and city administrator have to prepare suitable site for future development of the town in planned manner.

With fast economic development and rapid increase in population after the 1980s, fast urbanization occurs and the cities are expanding rapidly, which leads to remarkable contradictions between population and existing land use (Ma & Xu, 2010). However, the diversity of residents and intensive use of land resources through the increasing number of populations joined with economic activities drive unprecedented land-use changes in an urban and rural environment for further environmental protection and wise use.

The CSA (2008), projection made from 2008 (2016) and Ambo Town Mayor Office report (2020), shows that Urban population of ambo town is increasing very rapidly. The population of ambo town was increased from 48,171 in 2008 to 74,120 in 2016 and 95,628 in 2020. This increasing urban growth putting pressure to join more land for urban development and LULC change. At this time planner's role becomes important to find out the potential site for urban development in/around the town in sustainable manners to reduce the problem raised by unplanned urban expansion. Therefore, this study focuses on urban development site selection for study area by using remote sensing and Geographic Information system with the integration of the MCDA approach.

1.3 Objectives of the Study

1.3.1 General objective

- The general objective of this study is to identify suitable site for future urban development using remote sensing and GIS based MCDA approach for Ambo Town and surrounding area.

1.3.2 Specific Objectives

The Specific objective of this study are to:

- ✓ Identify necessary factors that influence urban development site selection in Ambo Town and surrounding area.
- ✓ Identifying suitable site using MCDA approach for urban development of Ambo Town and surrounding area.
- ✓ Prepare urban development site suitability map of Ambo Town and surrounding area

1.4 Research Question

- What are the main influencing factors for urban land suitability analysis in study area?
- How to identify the suitable sites for future urban development?
- How to prepare map showing suitable sites for future urban development?

1.5 Significance of the Study

The main significance of this study will be to bring desirable changes in selecting suitable site for future urban development. Hence, the findings and suggestions of this study can be used by urban planners and city administration to exercise right judgment on the provision of preferable location for future urban development, organizations working on environmental issues and researchers also used as a baseline study for further studies.

1.6 Scope of the Study

This study was conducted in Ambo town administration and surrounding area. Research on urban development potential site selection requires a wide scale of study in all cities and towns of the country. But, with the available time and resource in order to make the study more manageable and due to the difficulties of urban development site selection, the scope of my study has delimited to Ambo town and surrounding area.

1.7 Limitation of the Study

No research, has complete and free from limitations. Some of the limitations in this study were absence of kebele boundary, master plan of the town, ground water table data of the town and difficulty of getting high resolution satellite images required to undertake this study.

1.8 Organization of the Study

The study has organized in to five chapters. The first chapter contains brief description of introduction. The second chapter deals with literature review and addresses the relevant literature that was associated with the study. The third chapter has described the materials and methods. The fourth chapter was concerned with results and discussion of the study. Finally, the fifth chapter covers the conclusion and recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Urban Area

The urban area commonly refers to towns and cities or an urban landscape (Bhatta B., 2010). As Bhatta (2010), mentions in his book urban area have many definitions and the definition changes from country to country or from author to author. for example, Wikipedia defines an urban area as a human settlement with a high population density and infrastructure of the built environment. An urban area is a region surrounding a city or town (National Geographic Society).

This confusion can be eliminated if the urban land-use is differentiated from urban land-cover. "Land-cover" corresponds to the physical condition of the ground surface, for example, forest, grassland, cropland, and water; while "land-use" reflects human activities such as the use of the land, for example, industrial, residential, recreational, and agricultural (Bhatta, 2010). According to Bhatta (2010), Land-cover is directly observable by a remote sensor. Whereas, land-use refers to activities on land, or classification of land according to how it is being used. Not always directly observable by a remote sensor, inferences about land-use can often be made from land-cover. However, from the perspective of land-use, urban areas 'may also include several non-developed and vegetated pixels such as parklands and urban forests, and may exclude developments that are components of other land-uses' (Martinuzzi et al., 2007). In this sense urban area refers to the urban landscape, towns and cities.

2.2 Urban Development, Urban Growth and Urbanization

Urban development is the process of emergence of the world dominated by cities and by urban values (Bhatta, 2010). It is important to draw a clear distinction between the two main processes of urban development, urban growth and urbanization. According to Pandey et al. (2017), urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. Urbanization, on the other hand, is aspatial (non-spatial) and social process which refers to the changes of behavior and social relationships that occur in social dimensions as a result of people living in towns and cities.

However, nowadays, the word “Urbanization” is defined as the process through which cities grow, and higher and higher percentages of the population come to live in the city (National Geographic Society). Rapid urbanization is responsible for many environmental and social changes in the urban environment and its effects are strongly related to global change issues. The rapid growth of cities strains their capacity to provide services such as energy, education, health care, transportation, sanitation, and physical security. However, the direct implication of urbanization is attributed to spatial growth of towns and cities or in other words growth in urban areas that are commonly referred to as urban growth (Mikias, 2015).

Urban growth, urban expansion, and urban sprawl are sometimes used synonymously, although they are different. Urban growth is a sum of the increase in developed land. One of its forms is expansion. Whereas, urban sprawl is an urban growth which has some negative implication. According to Forman (1995), urban growth can be defined as landscape transformation processes. Although the processes themselves are quite similar, the urban growth defines growth from the perspective of a growing urban patch while the landscape transformation processes define fragmentation types as a reduction of non-developed land-cover types. Wilson et al. (2003), have identified three categories of urban growth: infill, expansion, and outlying, with outlying urban growth further separated into isolated, linear branch, and clustered branch growth. The relation to existing developed areas is important when determining what kind of urban growth has occurred.

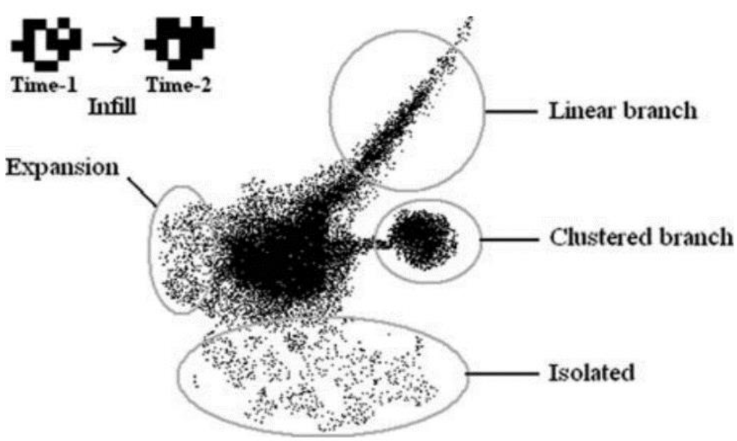

Figure 1: Schematic diagram of urban growth pattern (Source: Bhatta, 2010)

2.2.1 Infill growth

An infill growth is characterized by a non-developed pixel being converted to urban use and surrounded by at least 40% existing developed pixels. It can be defined as the development of a small tract of land mostly surrounded by urban land-cover (Wilson et al., 2003). Infill development usually occurs where public facilities such as sewer, water, and roads already exist (Wilson et al., 2003). Forman (1995), describes infill attrition as the disappearance of objects such as patches and corridors.

2.2.2 Expansion growth

An expansion growth is characterized by a non-developed pixel being converted to developed and surrounded by no more than 40% existing developed pixels. This conversion represents an expansion of the existing urban patch (Wilson et al., 2003). Expansion type development has been called metropolitan fringe development or urban fringe development (Heimlich and Anderson, 2001). Forman (1995), discusses expansion as edge development, defined as a land type spreading unidirectionally in more or less parallel strips from an edge. The analogous land transformation is shrinkage, defined as the decrease in the size of objects, such as patches (Forman, 1995).

2.2.3 Outlying growth

An outlying growth is characterized by a change from non-developed to developed land-cover occurring beyond existing developed areas (Wilson et al., 2003). This type of growth has been called development beyond the urban fringe (Heimlich and Anderson, 2001). The outlying growth designation is broken down into the following three classes: isolated, linear branch, and clustered branch (Wilson et al., 2003). Isolated growth is characterized by one or several non-developed pixels some distance from an existing developed area being developed. This class of growth is characteristic of a new house or similar construction surrounded by little or no developed land (Wilson et al., 2003). Forman (1995), defines it as perforation, which is the process of making holes in an object such as a habitat. Linear branch growth can be defined as an urban growth such as a new road, corridor, or new linear development that is generally surrounded by non-developed land and is some distance from existing developed land.

A linear branch is different from isolated growth in that the pixels that changed to urban are connected in a linear fashion (Wilson et al., 2003). Forman (1995), defines it as a corridor, which means a new corridor such as a road that bisects the initial land type. Clustered branch defines a new urban growth that is neither linear nor isolated, but instead, a cluster or a group. It is typical of a large, compact, and dense development (Wilson et al., 2003).

2.3 Urban Land Suitability

Urban land suitability can be defined as the fitness of a given use of urban land for a defined purpose based upon a scientific study and defined parameters (Teklit Berhe, 2015). According to Teklit (2015), Land may be considered in its present situation or after some arrangements are made on it. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for the defined purpose to be used" (FAO, 1976). In general, the urban land area can be classified as "Suitable" or "Not Suitable" for specific use: Suitable areas can be divided into three classes, which reflect the degree of suitability, one from the other. The number of classes can vary but it should be kept to the minimum necessary and should never exceed the number of classes from five (Teklit, 2015). FAO (1976), recommends three suitability classes and two not suitable classes.

Class S1 Highly Suitable: Land having no significant limitations to the sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2 Moderately Suitable: Land having limitations which in the aggregate are moderately severe for sustained application of a given user; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use.

Class S3 Marginally Suitable: Land having limitations which in the aggregate are severe for sustained application of a given user and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

Class N1 Currently Not Suitable: Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.

Class N2 Permanently Not Suitable: Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner. There can be many reasons why an area is classified as suitable and not suitable, for example, technical considerations like slope, soil, groundwater potential, urban infrastructure, road network and other (Teklit, 2015).

2.4 land use suitability analysis

One of the most useful applications of GIS for planning and management is the land-use suitability analysis and mapping (McHarg, 1969; Hopkins, 1977; Collins et al., 2001). Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specific requirements, or predictors of some activity (Hopkins, 1977; Collins et al., 2001). The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability for animal and plant species (Pereira and Duckstein, 2001), geological favorability (Bonham Carter, 1994), the suitability of land for agricultural activities (Kalogirou, 2002), selecting the best site for the public and private sector facilities (Church, 2002), and selecting the best site for urban development (mesfin girma, 2019; Teklit Berhe, 2015; Ishaq and Hakan, 2019).

2.5 Basic Concepts of Geographic Information System as a Tool

GIS is defined as a computerized system designed to store, retrieve, manipulate, analyze, and map geographical data. The central element of a GIS is the use of a location referencing system so that data about a specific location can be analyzed in its relationship to other locations. This makes it possible to take data stored in one form and combine it with data entered and stored in some other form (Church, 2002). Such powerful facilities of the GIS have been used to perform spatial analysis for different purposes like suitability analysis. Nishanth et al. (2010), also emphasize the capability of GIS to combine spatial data (maps, aerial photographs, satellite images) with the other quantitative, qualitative, and descriptive information databases facilitating suitability analysis like site selection.

Moreover, the surface and overlay analysis capabilities in GIS can effectively facilitate handling the vast amount of spatial information. It is estimated that 80% of data used by managers and decision-makers is related to spatial data. Most of The Information is used by the decision-maker are derived from data (Malczewski, 1999). Accordingly, geographical information can be defined as geo-referenced data that has been processed into a form that is meaningful to the decision-makers and it is of real or perceived value in the decision-making process. Traditionally, spatial data has been acquired and rendered in pictorial form to accomplish a variety of activities related to land suitability analysis. But this traditional system is not efficient and cost-effective for handling land resources and perform land suitability analysis. To solve this problem database systems for spatial data, commonly named Geographic Information Systems were designed and developed enabling the acquisition, compilations, analyzing, and display of topographical interrelations. And to analyze different spatial features using different methods or approaches to GIS techniques.

2.6 Basic Concepts of Remote Sensing as a Science

Remote sensing can be defined as a science and art of acquiring information spectral, spatial, and temporal information about material objects, or phenomenon above and below the earth's surface, without coming into physical contact with the objects or phenomenon under investigation (Lillesand and Kiefer, 2004). Without direct contact means the information is obtained or transferred through the interpolation of image and electromagnetic radiation pattern. In remote sensing, information transfer is accomplished by the use of electromagnetic radiation (Lillesand and Kiefer, 2004). The advancement of remote sensing technology to provide multi-spectral, multi-temporal, and multi-spatial images is very helpful to increase the speed and frequency with which one can analyze a landscape (Idowu and Ukoje, 2009). Nishanth et al. (2010), also states remote sensing as one of the excellent tools for inventory and analysis of environment and its resources, owing to its unique ability of providing the synoptic view of a large area of the earth’s surface and its capacity of repetitive coverage.

Furthermore, remote sensing contributes to the development of objective and comprehensive assessments over larger geographic extents and inaccessible areas than is possible with fieldwork alone (Steininger and Horning, 2007). Moreover, the use of remotely-sensed data in natural resources mapping and as the source of input data for environmental analysis has been popular in recent years. The availability of remotely sensed data from different sensors of various platforms with a wide range of spatiotemporal, radiometric, and spectral resolutions has made remote sensing one of the best sources of data for large scale applications and study (Assefa Melesse et al., 2007).

2.7 Integration of GIS and Remote Sensing for urban development Site Selection

Since the 1990s, GIS and remote sensing have offered a sophisticated system of generating, storing and analyzing geometric and semantic information about spatial elements. GIS and remote sensing methods have been used in various scientific disciplines like in Environmental Science (Akar, 2009). For example, geospatial technology (GIS and Remote sensing) is an essential component of the Environmental Impact Assessment (EIA) process, as environmental resources are directly affected by changes in the shape and extent of the proposed disturbance (Satapathy et al., 2008). This is because, with the use of spatial techniques, EIA has enhanced substantial viewing, movement, query and even map-making capabilities (Satapathy et al., 2008).

Moreover, they have the capacity to provide valuable and timely information about natural resources, urban change and the extent of environmental change being experienced in earth as an important basis for sustainable planning for land management and decision making (Twumasi et al., 2016). Therefore, geospatial information technologies are the key to planning, management and administration of land. Remote sensing and GIS can contribute substantially in a more supplementary fashion to some of the interactive operations that should become an asset for assessing, understandings, mapping utility and solving complex urban environmental issues like urban development suitable site selection (Akanbi et al., 2013). Generally, combination of the GIS and Remote Sensing systems provide multi-spectral, multi-temporal and multi-scales (spatial resolution), which can be adopted according to the degree of details needed. This technique plays an important role in selecting suitable site for future urban development.

2.8 Multi-Criteria Decision Analysis (MCDA) for urban development Site Selection

Multi-criteria analysis is a set of mathematical tools and methods allowing the comparison of different alternatives according to many criteria, often conflicting, to guide the decision-maker towards a sensible choice (Chakhar and Mousseau, 2008). MCDA consists of a series of techniques that permit a range of criteria relating to a particular issue to be scored, weighted, and then ranked by, for example, experts, interest groups or stakeholders according to their degree of suitability or importance for locating a particular facility or service (Malczewski, 2004) like an urban development site.

The integration of MCDA techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis (Eastman, 1997; Malczewski, 1999; Thill, 1999). The MCDA procedures define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision maker's preferences, and the manipulation of the data and preferences according to specified decision rules. Accordingly, two considerations are of critical importance for spatial MCDA: (i) the GIS capabilities of data acquisition, storage, retrieval, manipulation, and analysis, and (ii) the MCDA capabilities for combining the geographical data and the decision maker's preferences into unidimensional values of alternative decisions. Several multicriteria decision rules have been implemented in the GIS environment for tackling land-use suitability problems. Analytic Hierarchy Process (AHP) is one of the most commonly used MCDA tools.

This tool is applied in site selection processes as it assists the decision-making process by allowing decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model (Eldrandaly et al., 2005). Furthermore, Multi-criteria approaches have the potential to reduce the costs and time involved in siting facilities by narrowing down the potential choices based on predefined criteria and weights while also permitting sensitivity analysis of the results from these procedures (Higgs, 2006).

Therefore, the role of MCDA in urban development site selection can be completed by integrating it with GIS. Eldrandaly et al. (2005), emphasize, integrating GIS and MCDA can solve the challenges of site selection which involves highly complex spatial decision-making processes.

2.8.1 Analytic Hierarchy Process

AHP, which was developed by Saaty (1980), is currently one of the important techniques for analyzing land suitability. AHP is categorized under the multi-criteria decision analysis approach and is an effective technique that helps planners and decision-makers to analyze all data before arriving at a final decision for future land-use changes (Bagheri et al., 2013; Nguyen Hieu et al., 2006). AHP has been integrated with GIS tools to identify the importance of the criteria used and to calculate weights by using a scale of importance and the opinion of experts (M. Mohammad et al., 2013). AHP has the ability to allow a hierarchical structure of the criteria, when allocating the weights, it gives users a better focus on specific criteria and sub-criteria.

AHP is commonly applied to identify the weights of influencing factors on urban growth based on the analysis functions of GIS. AHP is also a structured approach that can be used for complex cases of making decisions that include competing criteria (M. Javadian et al., 2011). The weights of factors in AHP can commonly be identified by using driven knowledge and driven data. The weights of factors can also be calculated by using a questionnaire given to specialists who have considerable experience in the field of urban growth and can then be determined by using pairwise comparison method to measure their relative importance regarding one another (M. Bagheri et al., 2013; M. Mohammad et al., 2013; M. Javadian et al., 2011; E. Zebardas, 2002)

The main challenge in applying the AHP model is that AHP needs the right experts with the widest knowledge and experience in the fields of suitability analysis and application to judge the factors in terms of their importance and weights (Maher M. et al., 2016; Aburas et al., 2015). Identifying the relative weights of the factors used in land suitability analysis is generally difficult (Maher M. et al., 2016). Thus, the use of a technique that has a powerful capability to identify the weights is important to minimize the difficulties of weighting factors. AHP is one of the significant techniques used in analyzing issues related to spatial nature (M. Javadian et al., 2011).

2.8.2 Weighted linear combination (WLC)

WLC is the most prevalently used multi-criteria evaluation analysis method in GIS (Siefi et al., 2017; Malczewski, 2000). Land-use suitability analysis using weighted overlay method leads to more rational urban planning decision-making. Weighted overlay analysis includes different data layers with various aspects. In this method, manipulation of the overlay process is allowed by assigning different weights for each input layers, so the factors that play a more critical role will have a more significant impact on shaping the outcome of the overlay analysis. This is the advantage of weighted overlay over other methods such as fuzzy overlay, binary overlay, or ranking overlay (Malczewski, 2006). However, this method is highly dependent on the determination of factor weights, where highly favored factors will result in higher values in the final output raster. This issue is critical, so expert's opinion is crucial in the defining scales applied to input layers and weights given to factors in the AHP process.

2.9 Urban development Site Selection Criteria

Criteria of land-use suitability for urban development are derived from multi-disciplinary scientific theories related to physical, socio-economical, and ecological attributes. All criteria or factors for analysis of land-use suitability fall within two categories, namely the opportunities and limitations or constraints of the environment (Geddes, 1915; McHarg, 1969, 1981; Zong et al., 2007). Suitability analysis essentially involves the identification of opportunities and constraints for prescribed land use in a city. However, most physical and socio-economic factors have both permissive and restrictive features for given land use, which are determined by spatial location. For example, the factor slope, with a high gradient location restrictive and a low gradient location permissive for urbanization.

The resulting factor maps are used to reflect the degree of opportunity or suitability with ranked values allocated to all mapping units. An ecological factor (e.g., forest value or historic value) is usually taken to represent the development of constraint or unsuitability employing ranked values for a subset of mapping units in a specific area. The composite map of ecological factors is variously called the suitability map for conservation (McHarg, 1969) or the protection map (McHarg, 1981).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of study Area

3.1.1 Geographic Location

This research was conducted in Ambo Town which is established in 1889. Ambo Town is among a few privileged towns of its time to have its own municipal administration since 1931. The town covers the total area of 83.912 km^2 with an average elevation of 2100m above sea level. Ambo Town is located in west Shewa Zone of the Oromia national Regional State in central Ethiopia; and it is the capital town of West Shewa Zone. Relatively Ambo town is located 114km faraway West of Addis Ababa, 60 km North West of Waliso town and 12km east of Guder town (Ambo municipality, 2010). The geographical location of ambo town is approximately between 08^0 56'30''N - 08^0 59'30''N latitude and $37^0$47'30''E - $37^0$55'15''E longitude.

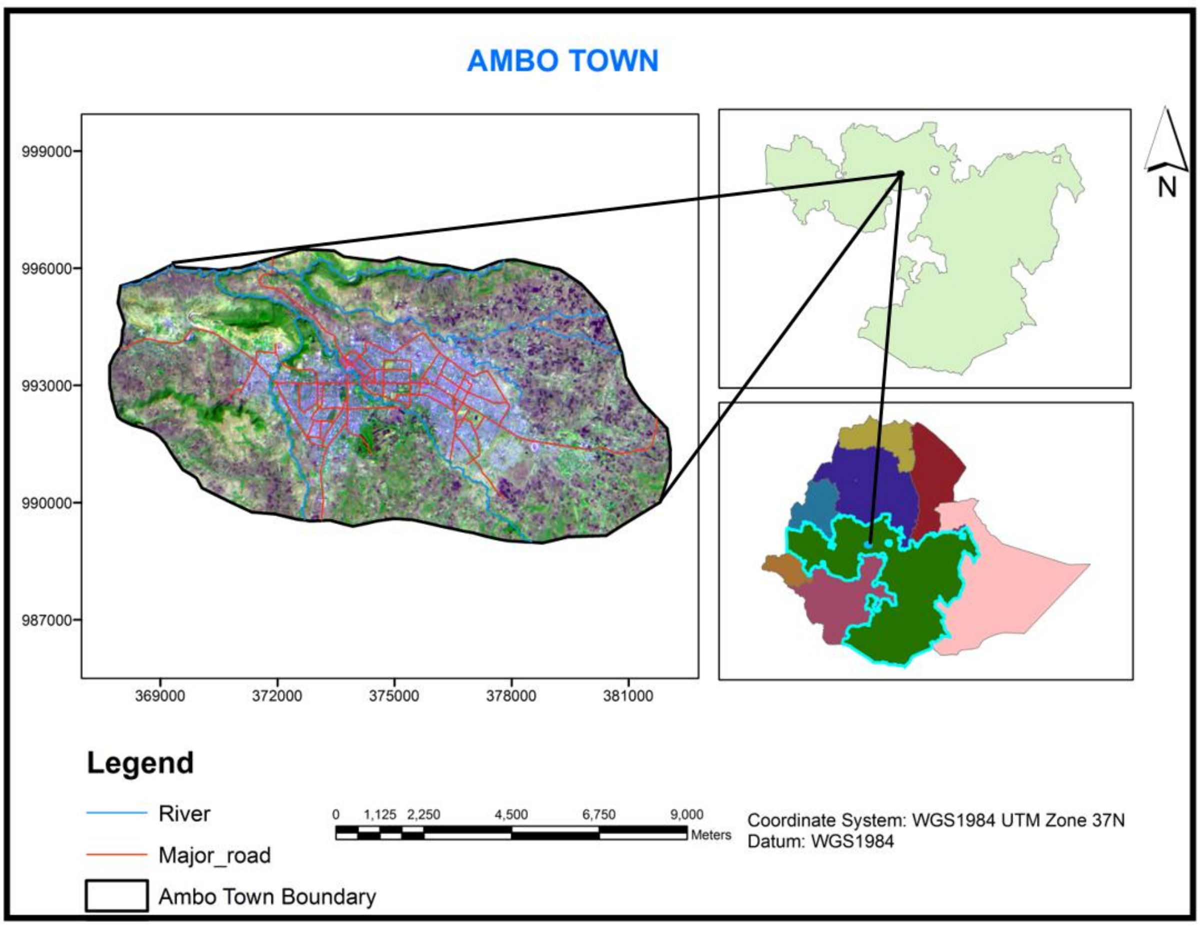

Figure 2: Location of study Area

3.1.2 Demographics

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), Ambo Town has a total population of 48,171, of whom 24,634 were men and 23,537 were women. The city has through recent years seen a robust annual growth rate and population counts as of 2020 are growing closer to 95,628 people (Ambo town Mayor Office report, 2021). The 1994 census reported this town had a total population of 27,636 of whom 13,380 were males and 14,256 were females. When compare the three reports the population of the town are highly increasing from time to time.

3.1.3 Climatic Conditions

The max, min and average temperature of Ambo town over 10 years (2010 – 2021) is shown by below graph in ^{0}c.

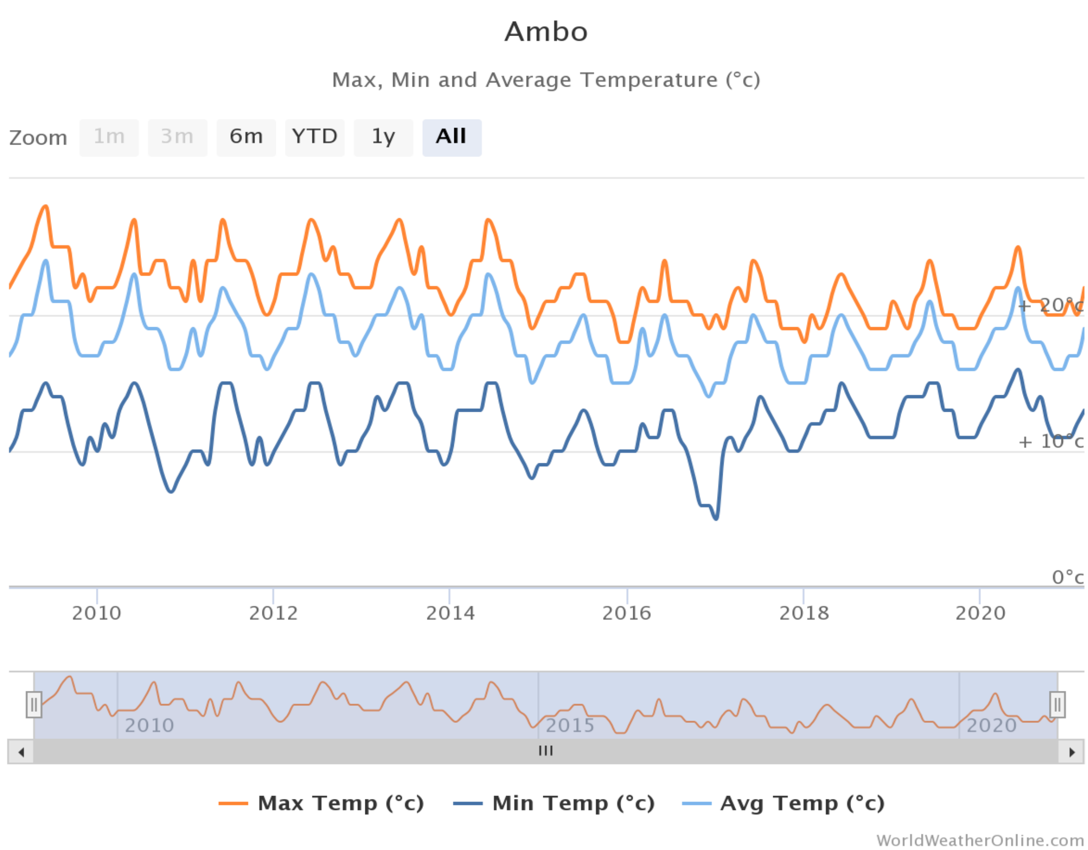

Figure 3: Max, min and average temperature of Ambo town from 2010 – 2021

3.1.3 Topography

Altitude of Ambo Town varies from 1861 meter in the north, northwest and some of west part to 2361 meter above mean sea level in the south east part.

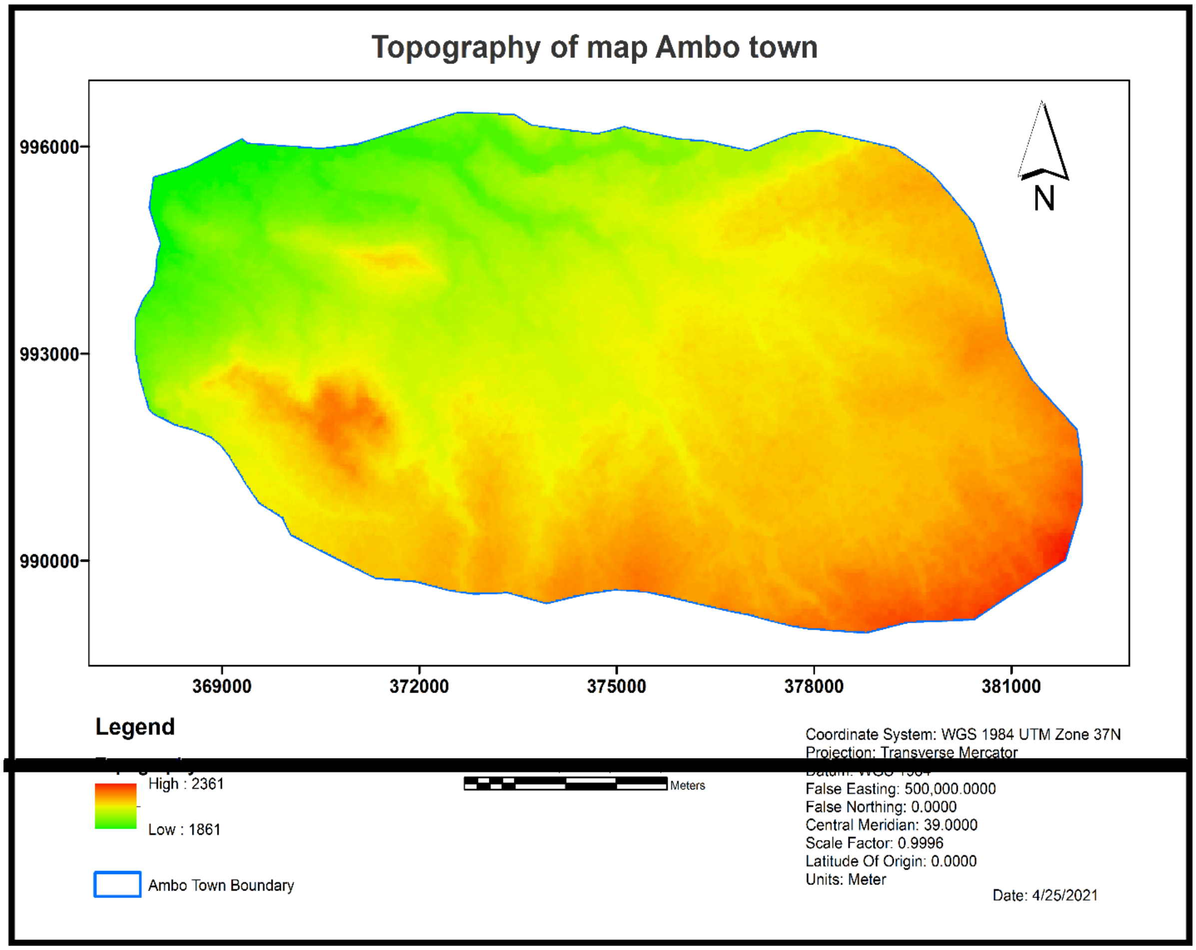

Figure 4: Topography of Ambo town

3.1.4 Land Use land cover

In Ambo Town and the surrounding area major land use categories residential, commercial, mixed-use, agricultural, grasslands, open space, forest and others. The major land use category found in proposed Ambo Town boundary is agricultural land. Likewise, surrounding area encompasses mixed land cover types which are built up, forest, shrublands, open space and grasslands.

3.2 Data Sources

In this study both spatial and non-spatial data from primary and secondary sources were collected and used. The table 1 shows types, formats, resolution and sources of data used in this study.

Table 1: Data input and source

S.NO	Data	Source	format	Resolution
1	Satellite image of 17th march 2021	USGS	TIFF	30m
2	Road network & River network	Google earth pro	Vector	-
3	DEM	Ethiopian GII	GRID	20m
4	Soil map	FAO	Vector	-
5	Educational & Health centers	GPS data	Vector	-
6	Geological map	EGS	PNG	-
7	Ambo structural plan	Ambo municipality	CAD	-

3.3 Software used

Software are program used for collecting, organizing, analysis, interpretation and presentation of data. In order to meet the objective of this study the software listed in table 2 below are used.

Table 2: Software used

S.NO	Name of software	Purpose
1	ArcGIS 10.8	Data processing and thematic map preparation
2	ERDAS Imagine 2015	For processing and analyzing satellite Image
3	Google Earth Pro	Use as a base map in visual image interpretation, and generate coordinate points for the images georeferencing
4	Microsoft Word and Excel	Integrating attribute data and writing the report
5	IDRISI selva 17	for weight module determination
6	SPSS 22	For making graphs and charts

3.4 Data Collection methods

In order to conduct this study, a step-by-step method were followed from data collection to analysis. First of all, preliminary studies of literatures were done and parameter affecting the urban land use suitability were identified. Those parameters affecting urban land use suitability are proximity to lineament, proximity to main road, proximity to river, land use land cover, proximity to school and health care center, slope, soil, geology and proximity to existing urban area. most of parameters were obtained from secondary source and others were collected from primary source.

The primary data were obtained through field observation and field survey directly by researcher and other surveyors at time of data collection. Accordingly, location of existing school and health care center were collected from the field by GPS survey. On other hand Secondary data, such as geologic map, river network, road network, LULC, slope, lineament, structural plan of town and soil map were obtained from their respective sources as mentioned in table 1. After all data were collected from their respective source, the data were organized, manipulated and analyzed using software mentioned in table 2 to be used for further analysis.

As it mentioned in table 1, some of the data are in TIFF, CAD, PNG and GRID format. For example, geological map was in PNG format and two scenes of map cover the town. So, the two scenes were georeferenced, mosaicked, clipped and digitized to convert the data to vector format. The road network and river network were digitized from google earth pro in kml format and converted to vector format in ArcMap 10.8 extension environment. LULC were obtained from satellite image of Landsat 8 by supervised image classification. Slope were generated from DEM by using ArcMap 10.8 spatial surface analysis extension. Proposed Boundary of Ambo Town were digitized from proposed structural plan of the town. Soil map were downloaded from FAO database, georeferenced and clipped by study area boundary.

3.5 Data preparation methods

Once the data were collected from their respective sources the next step is preparation of collected data for further analysis. Data preparation methods used in this study are georeferencing, mosaicking, clipping, digitization, image classification and accuracy assessment.

3.5.1 Georeferencing

Georeferencing is the process of assigning locations to geographical objects within a geographic frame of reference. It is fundamental to geospatial technologies in general and geographic information system (GIS) in particular. The main purpose of georeferencing is to relate internal coordinate system of a digital map, aerial photo, satellite image and scanned map to a ground reality of geographic coordinates. All data used in this study were georeferenced in ArcMap 10.8 using Ground control point (GCP) to relate data layer to ground reality and facilitate the spatial analysis.

3.5.2 Mosaicking

A mosaicking is the process of combining or merging two or more adjacent images and scanned map to make them single scene. The main objective of mosaicking is to merge more than one scene of image or scanned map that covers the study area. In this study the two scenes of geologic map obtained from Ethiopian Geological survey were mosaicked together.

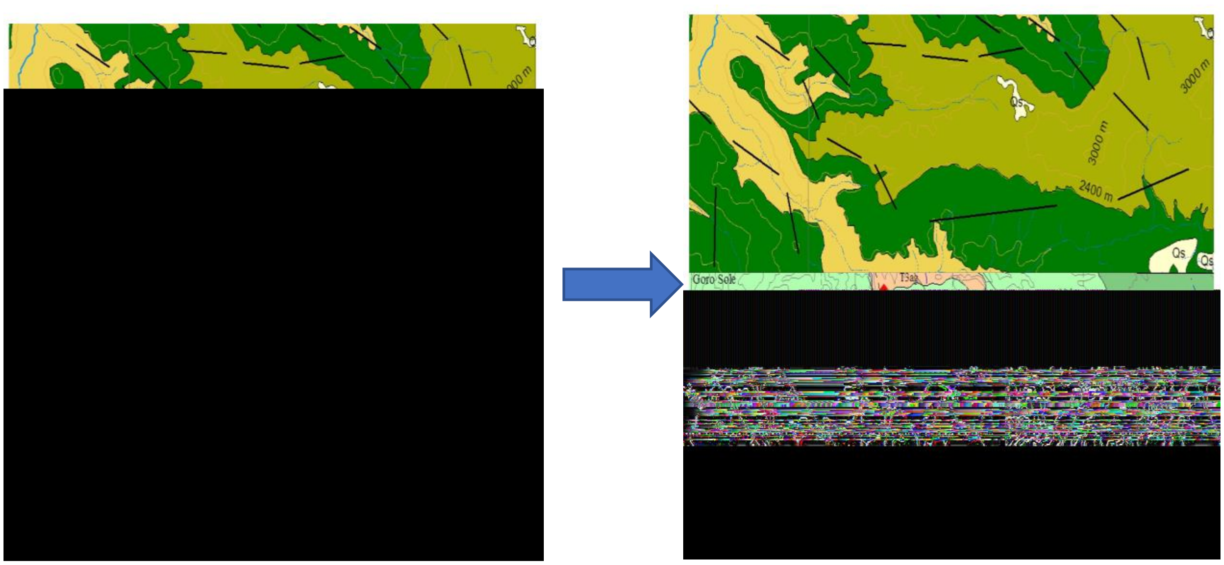

Figure 5: Mosaicked geological map

3.5.3 Clipping

Clip is the process of cut the features in area of interest from image, scanned map, digital map and any GIS layers. To clip features in study area overlay a boundary of study area on target features to be clipped and perform GIS operation. In this study most of data collected were clipped in ArcMap 10.8 by using Ambo town boundary. Accordingly, satellite image, soil map, geological map, road network, river network and DEM used in this study were clipped.

3.5.4 Digitization

Digitization simply defined as the process of converting analog data in to digital data. Geologic map used in this study is in PNG format and digitized in ArcMap 10.8. Similarly, road network and river network used in this study also digitized from google earth in kml format and converted to shapefile in ArcMap 10.8.

3.5.5 Image classification

Image classification is the process of categorizing and labeling groups of pixels or vectors within an image based on specific rules. It plays an important role in remote sensing images and is used for various applications such as environmental change, agriculture, land use/land planning, urban planning, geographic mapping, disaster control and object detection. Two general methods of classification are 'supervised' and 'unsupervised'. Supervised digital image classification method is the process of visually selecting samples (training data) within the image and assigning them to pre-selected categories (i.e., built-up, water body, vegetation, agriculture, bare land etc.) in order to create statistical measures to be applied to the entire image. To use this method the researcher, has to know the area and take correct training sample. Supervised digital image classification was used in this study to map the existing LULC of study area from Landsat image (see figure 13)

3.5.6 Accuracy assessment

Accuracy assessment was employed for determining whether the output map meets or does not meet level of acceptance. Error matrices are a common method of expressing classification accuracy, and were created to compare category by category basis, the reference data (ground truth) and the corresponding results of classification (Lillesand et al., 2008). In this study the accuracy of the classification results for was calculated from Error matrices (see table 3).

Table 3: Accuracy of classified LULC

		Reference data					
		Danse Forest	shrub and bush	Agricultural land	Bare land	Built-up Area	Row Total
Classified Data	Danse Forest	143	2	0	0	0	145
	shrub and bush	4	46	0	0	0	50
	Agricultural land	0	0	242	0	0	242
	Bare land	0	0	0	175	0	175
	Build-up Area	0	0	0	0	72	72
	Column Total	147	48	242	175	72	Total of diagonal = 678

After creating the error matrix for each classification, user accuracy, producer accuracy, overall accuracy and Kappa coefficient were computed. According to Lillesand et al. (2008), user's accuracies are computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). Producer's accuracies result from dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training set pixels used for that category (the column total). The overall accuracy result from dividing total of diagonal by sum of row or column total. To check the accuracy of LULC used in this study, overall accuracy was computed from error matrix.

Overall accuracy = (678 /684) *100% = **99.123%**

The Kappa coefficient of agreement was used for multi-variate statistical measure that can be used to test LULC classification accuracy. Computing Khat is the ability to use this value as a basis for determining the statistical significance of any given matrix or the differences among matrices.

$$K\hat{} = \frac{n \sum_{i=0}^{r} xii - \sum_{i=0}^{r} (xii + .\ x+i)}{N^2 - \sum_{i=0}^{r} (xii + .\ x+1\ )} \text{ --3.1}$$

Where r = number of rows in the error matrix; Xii = number of observations in row i and column i (on the major diagonal); Xi+ = total of observations in row i (shown as marginal total to right of the matrix); X·+i = total of observations in column i (shown as marginal total at bottom of the matrix) and N = total number of observations included in matrix.

3.6 Data analysis methods

Urban site selection requires effective criteria assessment according to the governmental legislations, policy, existing relevant literatures and practices to reduce social, economic, environmental and health effects (Siddiqui, 1996). In this study, by taking into account these criteria the overlaying method of influencing parameters was used to analyze suitable urban development sites. After all data were collected from various sources and prepared for analysis, the analysis was performed using different software like ArcMap 10.8, IDIRS selva 17 and ERDAS Imagine 2015 (see table 2). Once data were prepared before starting final urban site suitability analysis, the data prepared for analysis were buffered by specified distance, data in vector format were rasterized and all parameters were reclassified for further analysis.

3.6.1 Buffering

Buffering is a spatial analysis also called proximity analysis. It is used to generate areas of a given distance around the specified criteria that has been used for urban development site selection. In this study buffer zones were created around roads, river, lineament, existing built-up and existing school and health care center based on the specified distance for each parameter.

3.6.2 Rasterization

Rasterization can be defined as the process of converting information in vector format to raster format. As mentioned under data preparation section most of data used in this study were digitized from secondary sources. Those data in vector format (geology, road, river, soil, lineament, existing built-up and school and health care center) were converted to raster format in ArcMap 10.8 for further analysis.

3.6.2 Reclassification

Is the process of classifying something (map) again and again. In this regard the parameters considered in this study were slope, geology, soil, lineament, river, existing built-up area, LULC, Road, school and health care center. Finally Based on FAO (1976) classification, all those parameters were internally classified in to five classes (highly suitable, moderately suitable, less suitable, very less suitable and unsuitable) with values ranging from 5 to 1, where 5 denotes the highly suitable and 1 denotes the unsuitable for all factors and constraints considered.

3.6.3 GIS Based Multi Criteria Decision analysis

GIS-based MCDA involves the utilization of geographical data, the decision makers preferences and the combination of the data and preferences according to specified decision rules (Malczewski, 2006). MCDA have the potential to reduce the costs and time involved in urban development site analysis by narrowing down the potential choices based on predefined criteria and weights (Carver, 1991). AHP and WLC are the two most widely used MCDA methods that were used for this study.

3.6.4 Analytic Hierarchy Processes (AHP)

The Analytic Hierarchy Process is a decision-making method for prioritizing alternatives when multiple criteria must be considered. It offers a methodology to rank alternative courses of actions based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each of the alternatives (Nydick and Hill, 1992). AHP is a powerful and flexible decision-making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. AHP was used in this study to derive weights for each parameter (see Table 14).

3.6.5 Estimation of the consistency ratio

The aim of estimating consistency ratio is to determine whether comparisons matrixes are consistent or not to use for overlay analysis. According to Lawal et al. (2011), if the consistency ratio is less than or equal to 0.1, it is significantly acceptable reciprocal matrix. Thus, to check the consistence of comparisons matrixes used in this study consistence ratio were calculated and discussed under result and discussion part of this report.

To calculate the consistency ratio: First Determine the weighted sum vector, next Determine the consistency vector, next Compute lambda max (**λmax**) using 3.2 formula and finally, calculate consistency ratio (CR) by using 3.3 formula.

$$CI = \frac{\lambda \max - n}{\text{n}-1} \text{--3.2}$$

$$CR = \frac{\text{CI}}{\text{RI}} \text{---3.3}$$

Where, CI is consistence index, n is number of parameters, CR is consistence ratio.

3.6.6 Weighted Linear Combination (WLC)

Weighted Linear Combination is a type of MCDA Method in GIS environment used to evaluate the suitability of a region for urban development. The approach allows the decision maker to assign weights according to the relative importance of each suitability map and combines the reclassified maps to obtain an overall suitability score (Malczewski, 2004). In this study, GIS based MCDA was employed. This methodology is best suited for selection of suitable urban development site accurately in time and cost-effective manner and hence it is used by many researchers.

$$\text{S} = \sum_{i=0}^{n} wi\ xi * \Pi\ cj \text{ ---3.4}$$

where **s** is the composite suitability score, w_i is weights assigned to each factor, x_i is factor scores (normalized cell values), c_j is constraints (built-up and protected area), and Π is the product of constraints.

The overall process performed to find suitable site for urban development in Ambo Town is illustrated by the below general work flow (Figure 6). This work flow shows source of data, generated input data, operation performed to urban development site suitability analysis.

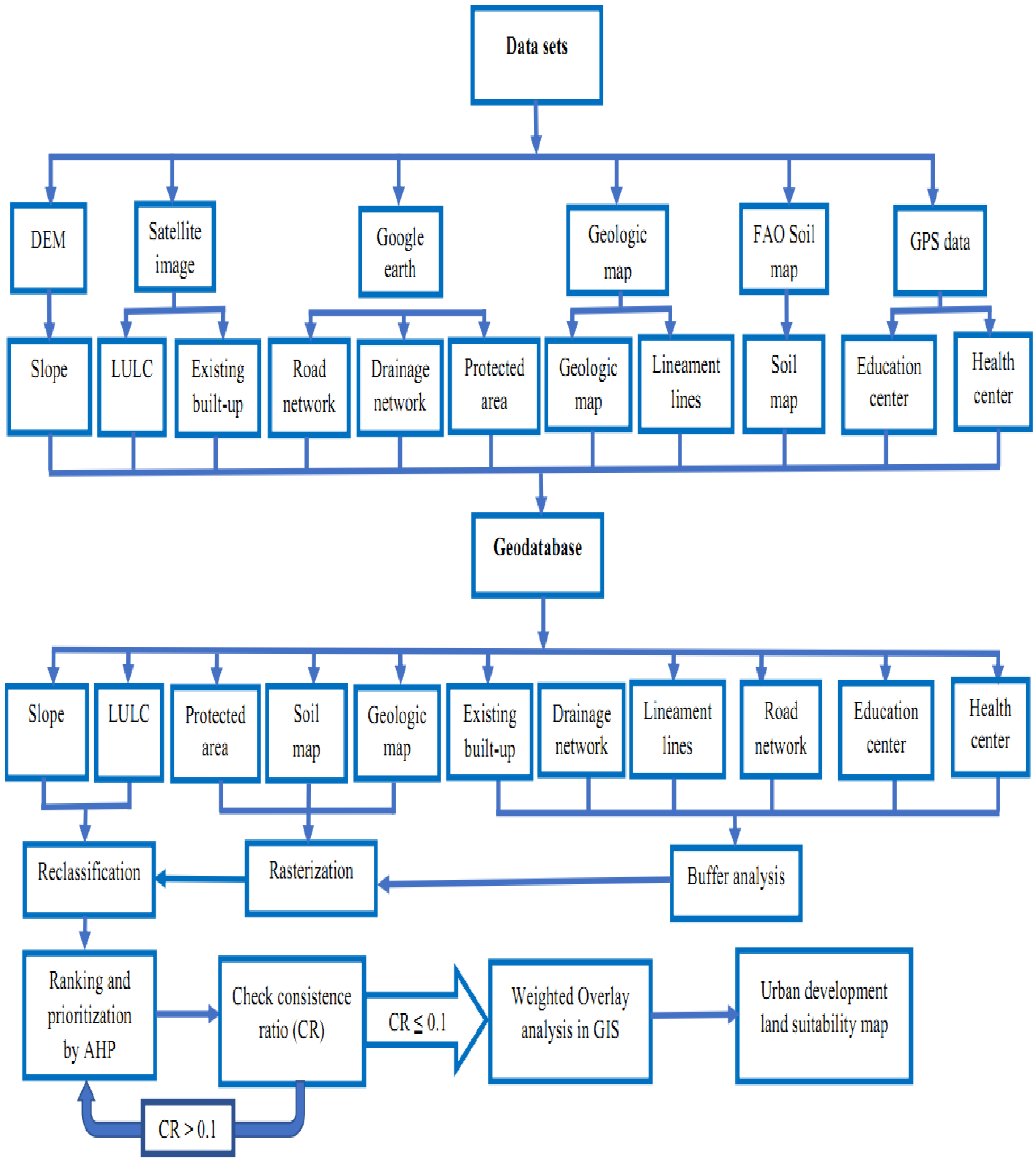

Figure 6: General work flow

CHAPTER FOUR: RESULTS AND DISCUSSION

In this study, suitable urban development sites were determined for Ambo Town and surrounding area by using the GIS tool and weighting product of AHP method. An urban development site should be kept close to existing built-up area, road, school and health care center to get service of existing infrastructure. On other hand urban development site should kept far away as possible from river, lineaments and highest slope to reducing impact that may happen on socio-economic and health of towns people.

4.1 The Existing Condition of urban expansion in Ambo Town and surrounding area

As result of field survey and observation done in Ambo Town and surrounding area the town is expanding from time to time, illegal construction is constructed rapidly, fertile agricultural land is occupied for built-up purpose, scatter settlements are ongoing, existing urban development were in unsuitable areas by some parameters and other related problems are seen in ambo town and surrounding area (see figure 7 - 9).

4.1.1 Area < 100m from river were used for urban housing

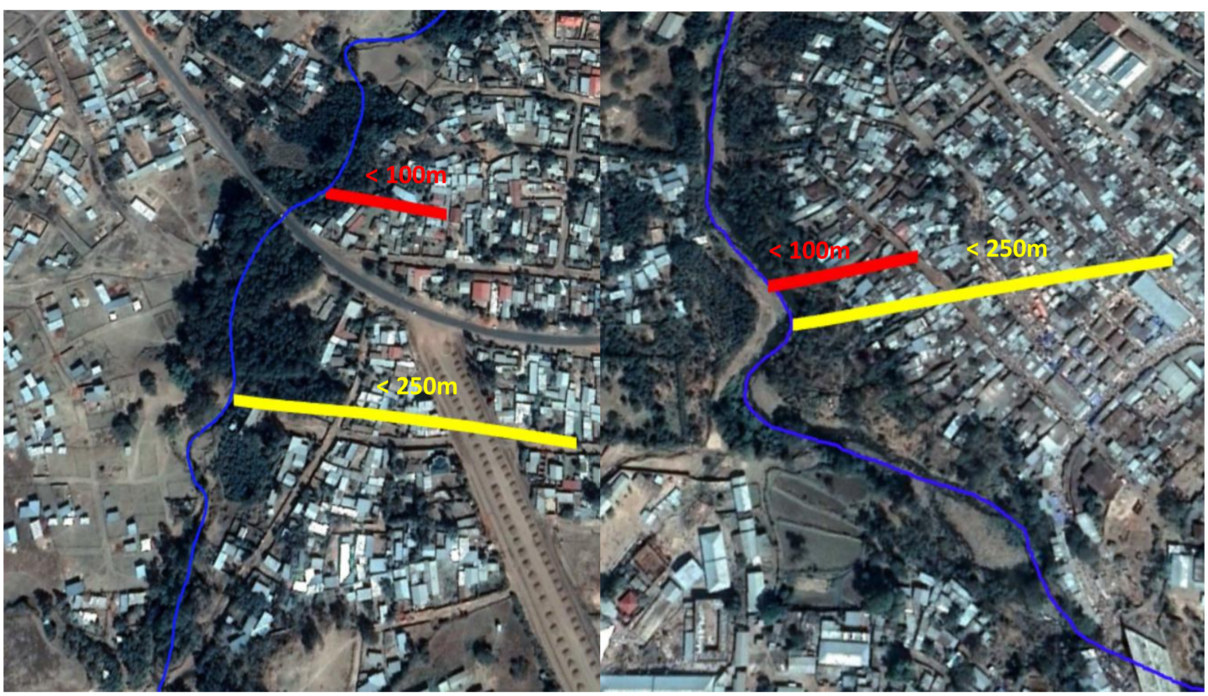

Figure 7: Urban housing located in unsuitable buffer zone from river

4.1.2 Area < 100m from lineaments were used for urban housing

Figure 8: Urban housing located in unsuitable buffer zone from lineaments

4.1.3 scatter settlement and conversion of agricultural land to built-up

Figure 9: Scatter settlement and conversion of agricultural land to built-up

4.2 Selection and Preparation of Criteria Maps

This chapter discusses different data sets that were used to determine suitable urban development site. In this study, suitable site of urban development of Ambo Town by using the GIS environment and weighting product of AHP method was discussed in detail. Significant criteria are commonly used in designing the framework of AHP to identify the best locations for urban growth (Chakma Salit, 2014; Kumar M. and V.R. Shaikh, 2013). However, selecting the criteria used may depend on other causes that are related to data availability (Maher M. et al., 2015). Most significant data that has been used in AHP studies to identify the appropriate sites for urban growth are accessibility factors such as distance from main roads, highways, railways, urban areas, school and health care center and physical factors such as slope and elevation and environmental criteria such as distance from rivers and water surface, geology, soil categories, land cover and distance from fault line or lineaments (Salit, 2014; Kumar and Shaikh, 2013; Maher et al., 2015; Duc, 2006).

For this study based on the presence of influencing factors and availability of data nine parameters were identified (proximity to lineament, proximity to main road, proximity to river, land use land cover, proximity to school and health care center, slope, soil, geology and proximity to existing urban area) to determine the suitability of site for urban development in Ambo Town and surrounding area. Those parameters were selected based on the relevant literatures, multi-criteria evaluation procedure, standards of Ethiopian Ministry of Urban Development and Construction, in addition to international practices. After all necessary data were collected from their respective sources and prepared in GIS environment, buffer zones were created by using standard distance (existing urban area, lineaments, river, road, school and health center), next all parameters in vector format were converted to raster format in ArcMap 10.8 and reclassified in to five suitability classes (unsuitable, very less suitable, less suitable, moderate suitable and highly suitable) based on their suitability order. Finally, Maps were created for each suitability criterion and the final composite map was produced by weighted overlaying of the individual parameters map. The map of each parameter and final composite were discussed below in detail.

4.2.1 Proximity to major Road

Road is one of the criteria that should be considered in site suitability analysis for urban development. It plays an important role in urban planning and development as it connects different settlements and also important for conveying goods and services. The road networks used in this study were digitized from the Google earth pro in kml format and converted to shape file in ArcMap 10.8. As more settlement develops near the road because of the transportation facilities and very easy access to the nearby places and city centers (Mesfin Girma, 2019; C Santosh et al, 2018). As R. Z. Liu et al. (2014), discussed in their study Buffer zone falling under 500m distances is highly suitable for urban development. The suitability decreases as the area far away from the road and area > 2000m away from major road is considered as unsuitable for urban development. Finally, the buffered zone was converted to raster and the map was reclassified in to five classes and scored based on their suitability order.

Table 4: Reclassified distance from road and area coverage of suitability levels

Proximity to major Road	Level of Suitability	Rank	Area (km^2)	By %
<500m	highly suitable	9	22.65	32.19
500-1000m	moderately suitable	7	19.90	28.28
1000-1500m	less suitability	5	13.71	19.49
1500-2000m	very less suitability	3	8.38	11.91
>2000m	unsuitable	1	5.72	8.13
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 4, above out of 70.38 km^2, 32.19% of the area is highly suitable, 28.28% of the area is moderately suitable, 19.49% of the area is less suitable, 11.91% of the area is very less suitable, 8.13% of the area is unsuitable for future urban development.

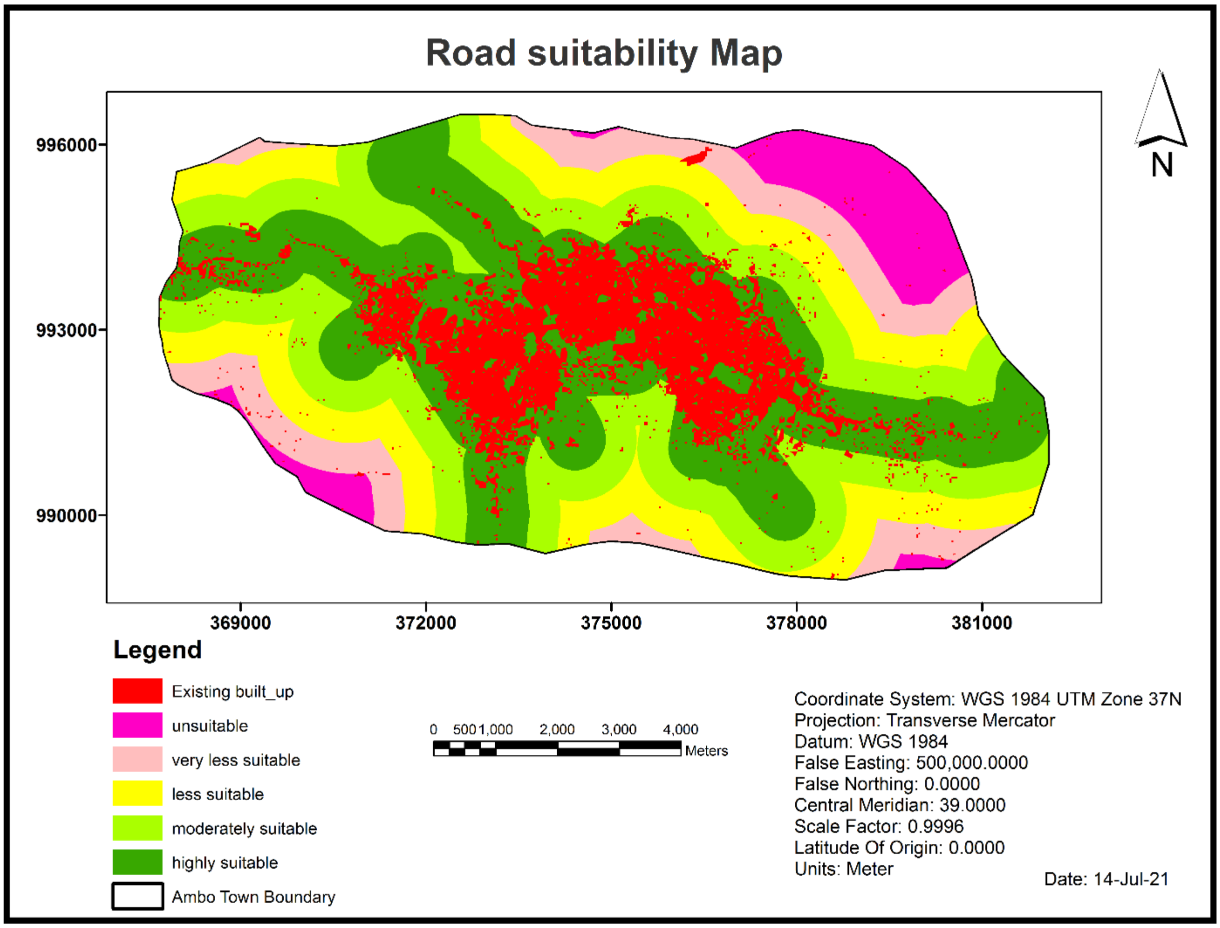

Figure 10: Road Suitability map

4.2.2 Proximity to Rivers (streams)

The river (stream) network used in this study were digitized from google earth pro in kml format and converted to shape file in ArcMap 10.8. As kamal jain & Y. Venkata subbaiay (2007) and Ishaq & Hakan (2019), mention in their research the area near the river is vulnerable to flood. To avoid flood hazards and related problem caused by river and stream buffer zones were created using stream map of the study area and after the vector stream map were converted to raster, the map was reclassified in to five classes and scored based on their suitability order. Areas < 100m away from streams was considered as vulnerable to flood and ranked as unsuitable. The ranking score was increased with the increase of distances from river, where the highest score was given to the areas > 750m away from river.

Table 5: Reclassified distance from river and area coverage of suitability levels

Proximity to river	Level of Suitability	Rank	Area (km^2)	By %
<200m	unsuitable	1	8.52	12.11
200-400m	very less suitability	3	9.86	14.01
400-600m	less suitability	5	11.36	16.13
600-800m	moderately suitable	7	8.12	11.53
>800m	highly suitable	9	32.52	46.21
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 5 above out of 70.38 km^2, 46.21% of the area is highly suitable, 11.53% of the area is moderately suitable, 16.13% of the area is less suitable, 14.01% of the area is very less suitable and 12.11% of the area is unsuitable for future urban development or growth.

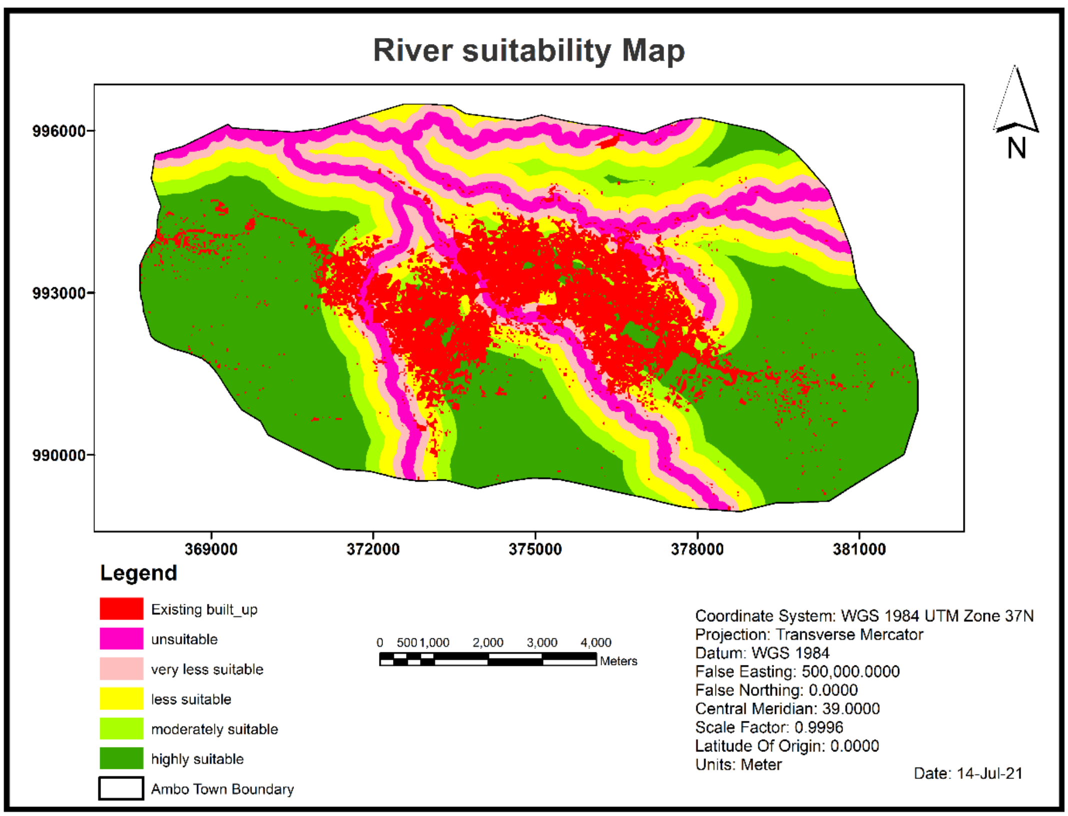

Figure 11: River Suitability map

4.2.3 Slope

Slope is one of the basic factors to be considered in site suitability analysis for urban development. urban area should be located on relatively flat land because areas with steep and high slope are prone to landslides (Culshaw and Price, 2011; Akbulut et al., 2018; Mesfin Girma, 2019). Due to issues such as flooding, erosion, runoff, limit for the floor and as well as the cost of construction steep slopes should be avoided. The slope of the study area was generated from DEM obtained Ethiopian Geospatial information institute with the help of ArcGIS 10.8. The slope of study area ranges from 0 - 60.0856 degree and it was classified into five classes based on suitability range obtained from different literatures and standards. Flat slopes are highly suitable for urban development where steeper slopes are not suitable. According to (Maher M. et al., 2016; Youssef A. et al., 2010; Gerlee Puntsag, 2014; M. Kumar and V. R. Shaikh, 2012) the type of slope highly suitable for urban development should be gently slope.

Table 6: Reclassified slope and area coverage of suitability levels

Slope in degree	Suitability class	Rank	Area (km^2)	By %
<5	highly suitable	9	35.85	50.93
44326.00	moderately suitable	7	22.76	32.34
44484.00	less suitability	5	6.99	9.93
15-20	very less suitability	3	3.00	4.26
>20	unsuitable	1	1.79	2.54
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 6 above out of 70.38 km^2, 50.93% of the area is highly suitable, 32.34% of the area is moderately suitable, 9.93% of the area is less suitable, 4.26% of the area is very less suitable and 2.54% of the area is unsuitable for future urban development.

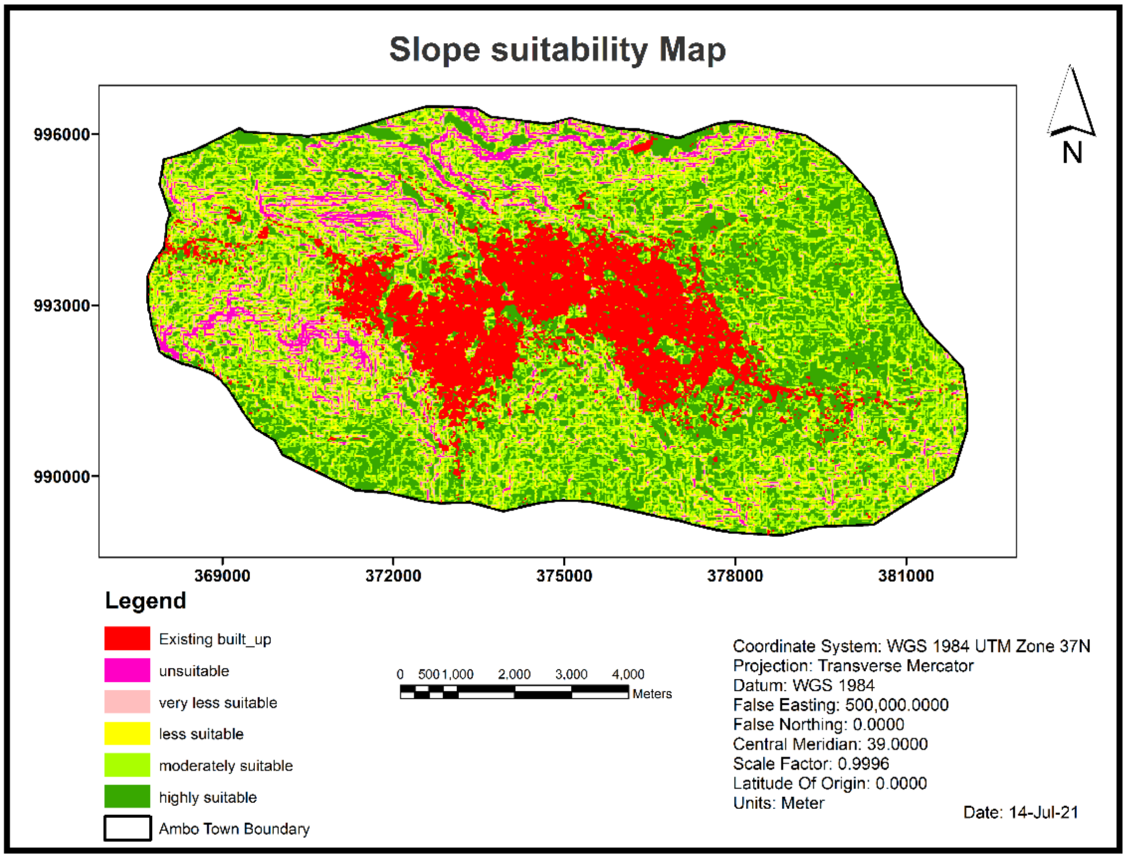

Figure 12: Slope Suitability map

4.2.4 Land use & Land Cover of 2021

LULC is the main basis for urban land suitability analysis. LULC map of the study area were prepared from Landsat 8 image acquired on 17th march 2021 and supervised classification was employed using ERDAS IMAGINE 2015. To check the accuracy of the classification the error matrix was used and the overall accuracy was 99.122 since this value is greater than 85 it is acceptable. Five different classes of LULC were categorized (closed forest, agricultural land, shrub and bush, built-up and bare land). The future urban area should not affect the environment, especially ecologically sensitive areas; flora and fauna. To develop the town with less negative effects on environment, forests, green areas and restricted areas should be protected (Chen, 2016; Bozdağ et al., 2016). To achieve this goal, the land use land cover map of the study area was reclassified and ranked as per their suitability order. Accordingly Built-up area is not suitable for the future development because once a building is constructed, it remains for minimum of 50 –75 years (Kumar and Shaikh, 2012). Thus, barren land is considered as highest suitable for the urban development.

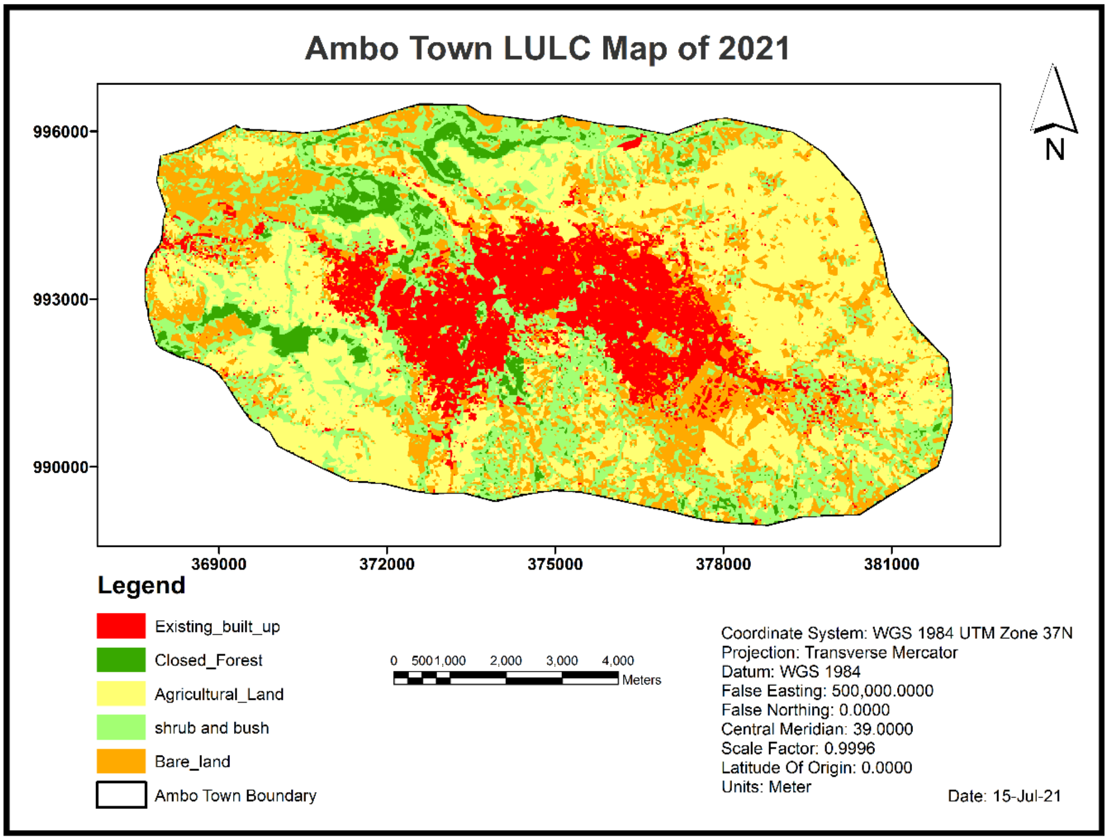

Figure 13: Ambo Town LULC map of 2021

Table 7: Reclassified LULC and area coverage of suitability levels

LULC	Suitability class	Rank	Area in km^2	Area By %
Bare land	highly suitable	9	17.527	20.887
shrubs and bushes	moderately suitable	7	29.942	35.683
Agricultural land	Less suitable	3	19.442	23.170
Closed forest	very less suitable	1	3.468	4.133
built-up Area	Not considered	0	13.533	16.127
Total			83.912	100.000

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 7 above out of 70.38 km^2, the closed forest covers an area of 3.468 km^2, agricultural land covers an area of about 29.942 km^2, shrub and bushes cover an area of about 19.442 km^2, built-up area covers an area of about 13.53 km^2 and the bare land covers an area of about 17.527 km^2.

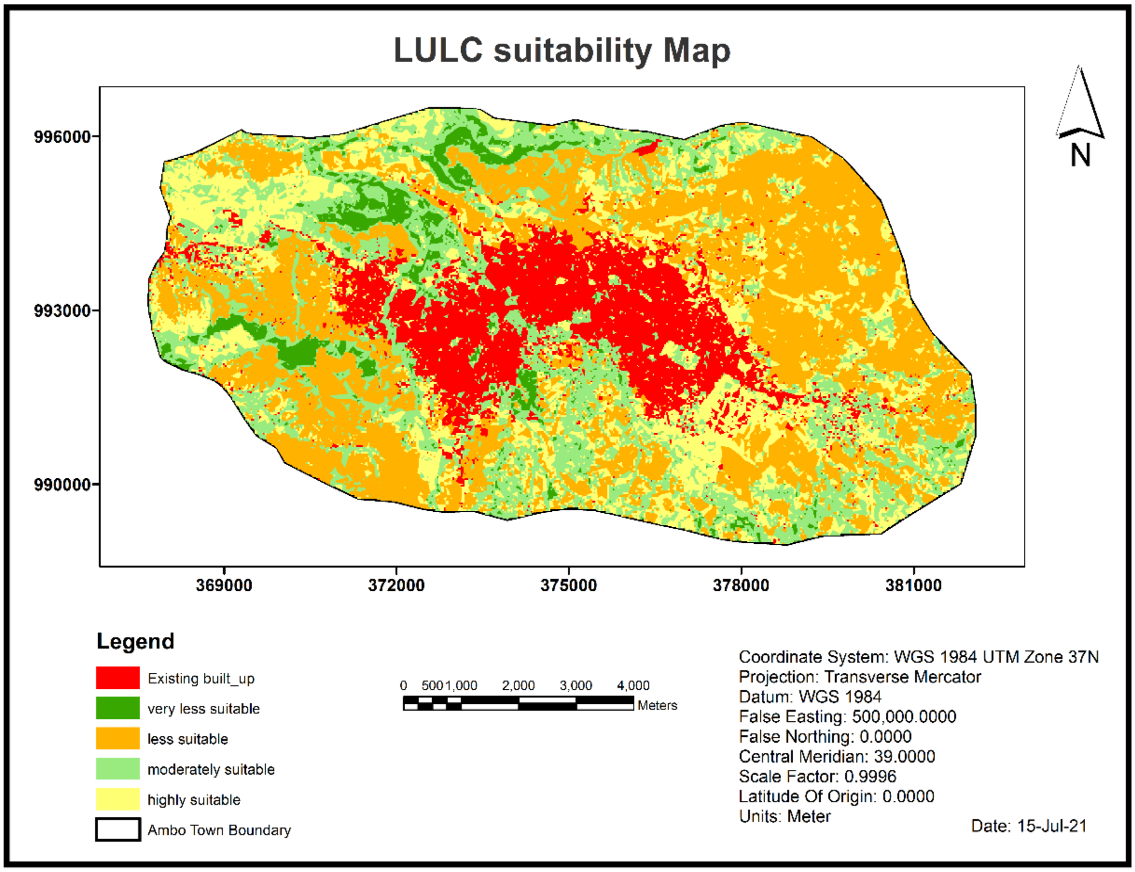

Figure 14: LULC Suitability map

4.2.5 Soil

Soil is the most important parameter for determining an area's suitability for urban construction. soil types which have high fertility, nutrient deficiency and highwater holding capacity can be used for urban areas (Puntsag G., 2014). The soil types of the study area were obtained from FAO data base. The soil types in the case study area are Eutric Nitosols and Pellic Vertisols. These soil types are classified according to their suitability for urban development (table 8).

Nitosols are deep, red, well-drained soil with a clay content of more than 30% and a blocky structure formed from fine-textured material weathered from intermediate to basic parent rock, kaolinite, halloysite and iron oxides dominate their clay mineralogy (Wikipedia). Nitisols are deep, stable soils with favorable physical properties. Thus, Nitosols soil is more suitable than Vertisols soil for urban construction.

Vertisols are soils with a high content of clay minerals that shrink and swell as they change water content (plant and soil science eLibrary, lesson 5). The clay minerals adsorb water and increase in volume (swell) when wet, shrink as they dry and forming large, deep cracks (plant and soil science eLibrary, lesson 5). Surface materials fall into these cracks and are incorporated into the lower horizons when the soil becomes wet again. Thus, pellic Vertisols soil is less suitable when compared with eutric Nitosols soil for urban construction.

Table 8: Reclassified soil and area coverage of suitability levels

Soil types	Suitability class	Rank	Area (km^2)	By %
Eutric Nitosols	highly suitable	9.00	36.89	52.42
Pellic Vertisols	less suitable	7.00	33.49	47.58
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 8 above out of 70.38 km^2, 52.42% of the area is highly suitable and 47.58% of the area is less suitable for future urban development.

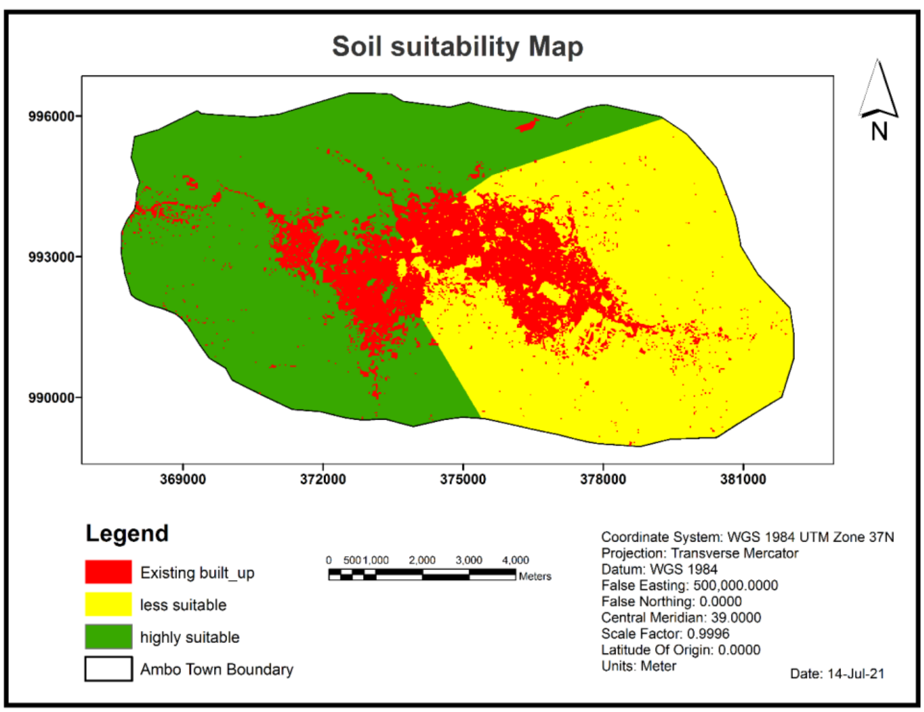

Figure 15: Soil Suitability map

4.2.6 Proximity to existing built-up areas

To take advantage of existing resources, such as infrastructure and facilities, to reduce the costs of housing development and to prevent scatter settlement the future urban area should be in reasonable near to the existing built-up areas to consolidate the urban zone and reduce the impacts of urban sprawl (Chen, 2016). To achieve this goal and have a more compact urban form the existing urban area was extracted from Landsat 8 image acquired on 17th march 2021 and supervised digital image classification technique was employed using ERDAS IMAGINE 2015 software. Then buffer zones were created around existing urban areas and the buffer zones were scored based on their proximity to existing urban area, where the highest score was assigned to the area near to existing urban areas which means areas fall in < 500m away from existing urban area and the lower score was assigned to area far away from urban area.

Table 9: Reclassified distance from existing built-up and area coverage of suitability levels

Proximity to existing built-up areas	Suitability class	Rank	Area (km^2)	By %
<500m	highly suitable	9.00	61.43	87.28
500-1000m	Moderately suitable	7.00	7.81	11.09
1000-2000m	less suitable	5.00	1.14	1.62
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 9 above out of 70.38 km^2, 87.28% of the area is highly suitable, 11.09% of the area is moderately suitable and 1.62% of the area is less suitable for future urban development.

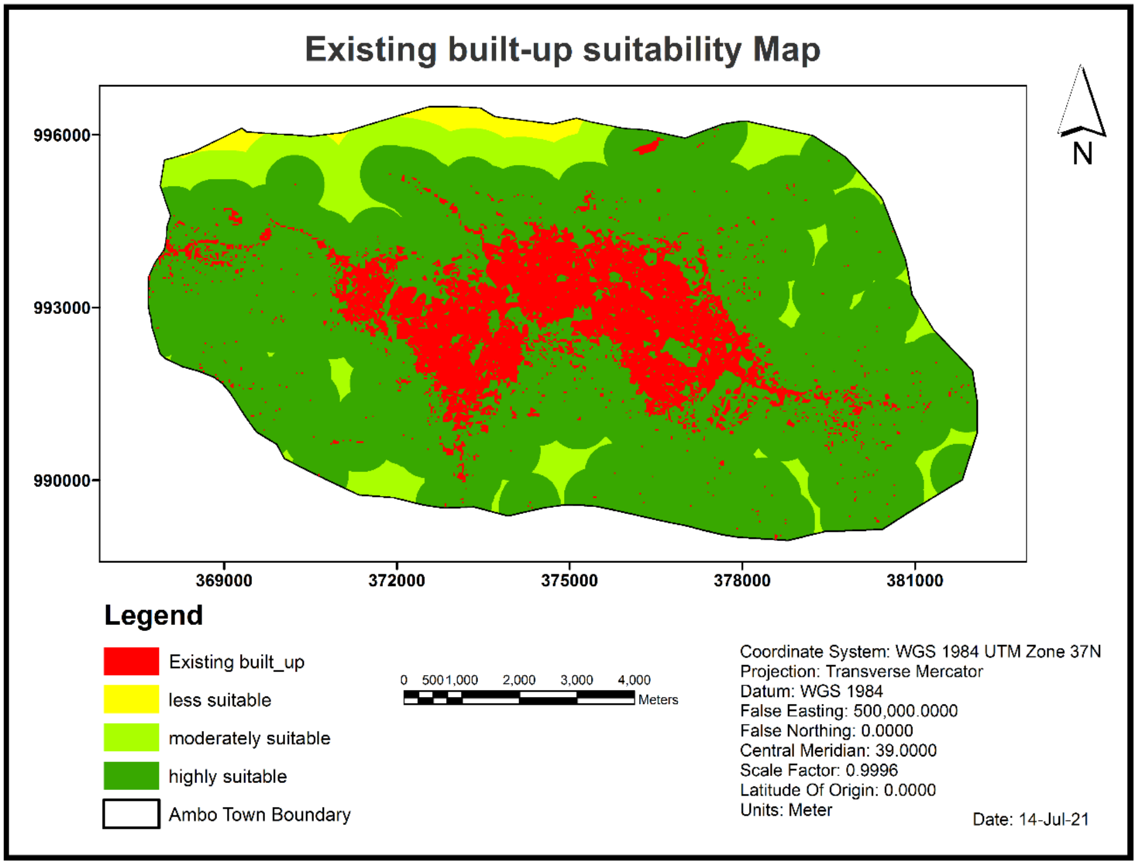

Figure 16: Existing built-up Suitability map

4.2.7 Lineaments

Lineament is a linear feature in a landscape which is an expression of underlying geological structure and indicators of weak zone such as joints, fracture and faults (Wikipedia). Typically, lineament appear as a fault-aligned valley, a series of fault or fold-aligned hills, a straight coastline or indeed a combination of these features. Lineaments are often apparent in geological or topographic maps and can appear obvious on aerial or satellite photographs. The Lineament map of the study area were digitized from geological map of the study area obtained from Ethiopian geological survey. After the Lineaments lines digitized, Buffer zone were created with an interval of 100m and ranges to 400m. class with more than 400m from Lineament line was considered as highly suitable for the urban development whereas areas located in 100m buffer zone is unsuitable for the urban development (C Santosh et al., 2018).

Table 10: Reclassified distance from lineament line and area coverage of suitability levels

Proximity to Lineament	Suitability class	Rank	Area (km^2)	By %
<100	unsuitable	1	3.81	5.42
100-200m	very less suitability	3	4.01	5.70
200-300m	less suitability	5	4.20	5.97
300-400m	moderately suitable	7	4.35	6.18
>400m	highly suitable	9	54.00	76.73
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 10 above out of 70.38 km^2, 76.73% of the area is highly suitable, 6.18% of the area is moderately suitable and 5.97% of the area is less suitable, 5.70% of the area is very less suitable and 5.42% of the area is unsuitable for future urban development.

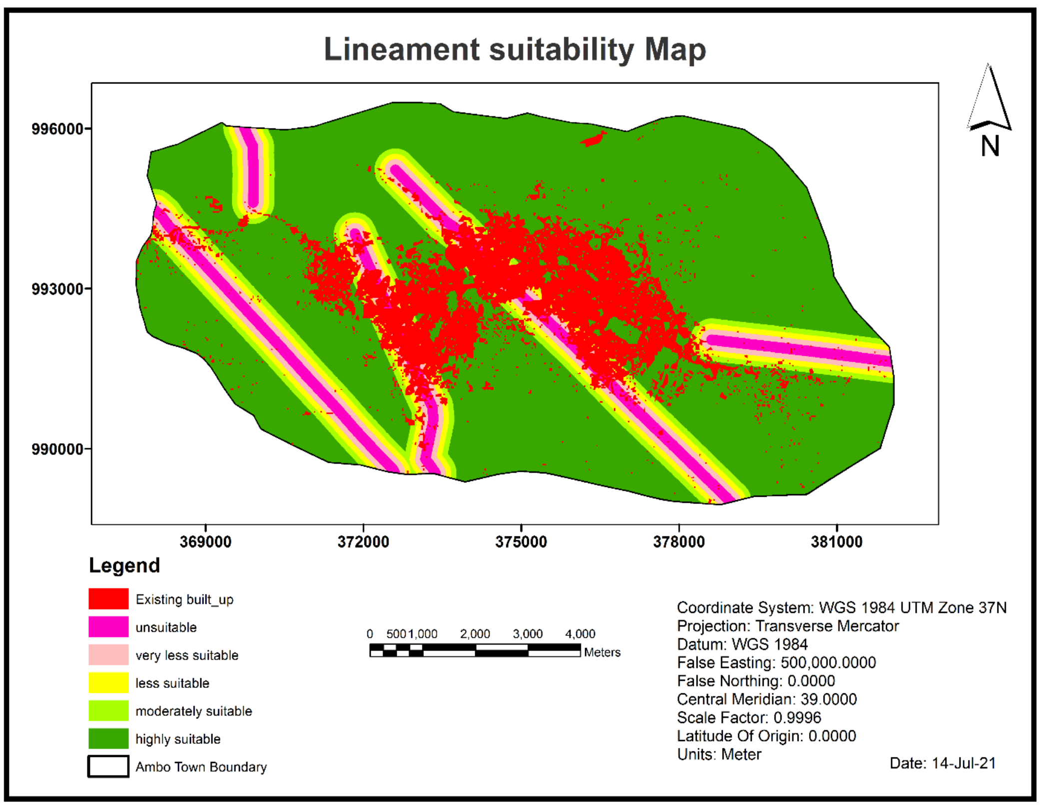

Figure 17: Lineament Suitability map

4.2.8 Proximity to education and health center

Undoubtedly, education and health are the basic requirements of each person; thus, areas for future urban growth should be reasonably close to existing educational institutions and health services (Chen, 2016). This goal is of great importance for urban development to save land required for those new projects and reduce cost of constructing new school and health care center. To this end, maps of schools and health services were prepared from GPS data and buffer zones were created in five classes. Areas with the closest distance to school and health center were considered as highly suitable for urban development.

Table 11: Reclassified distance from School & health care and coverage of suitability levels

Proximity to school and health care center	Suitability class	Rank	Area (km^2)	By %
<1000	highly suitable	9.00	9.87	14.02
1000-2000m	moderately suitable	7.00	22.37	31.79
2000-3000m	less suitability	5.00	23.66	33.62
3000-4000m	very less suitability	3.00	12.06	17.14
>4000m	unsuitable	1.00	2.42	3.44
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 11 above out of 70.38 km^2, 14.02% of the area is highly suitable, 31.79% of the area is moderately suitable and 33.62% of the area is less suitable, 17.14% of the area is very less suitable and 3.44% of the area is unsuitable for future urban development.

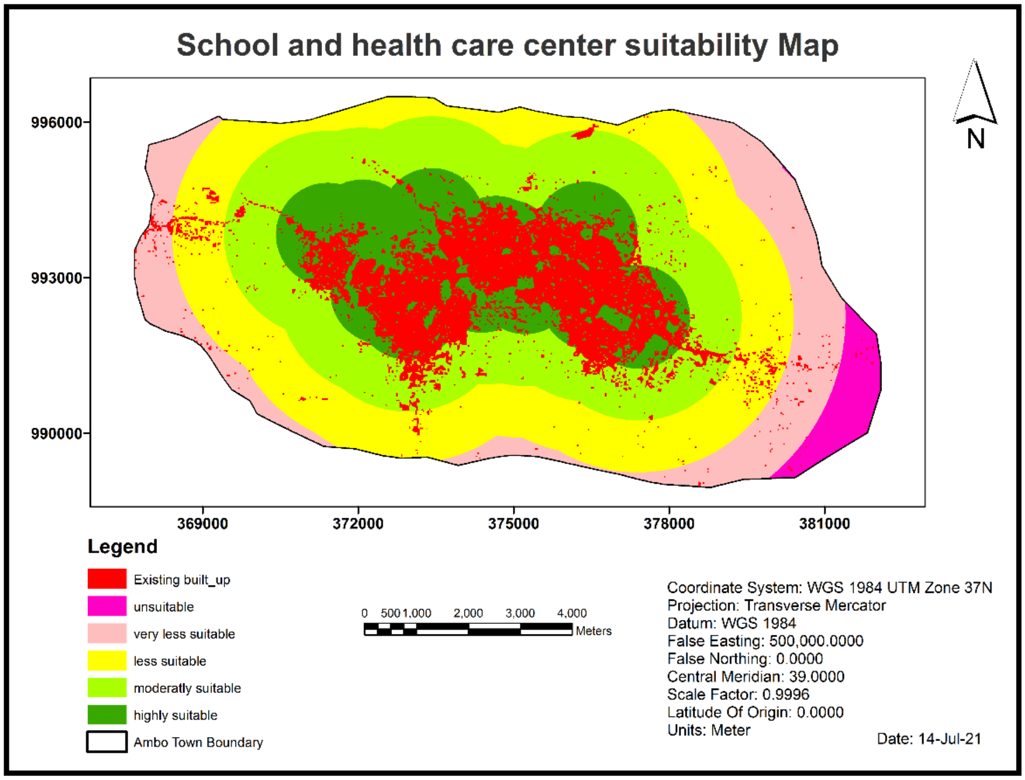

Figure 18: School and health care center Suitability map

4.2.9 Geological stability

Any engineering structure requires detailed knowledge of engineering geological properties of the foundation as well as the material used for construction (Tudes, 2012; Culshaw and Price, 2011). To prevent related hazards, the new urban area should be placed on the most stable geological formation. To select the most stable geological formation the geological map of the study area was obtained from Ethiopia Geological Survey (EGS). The geologic types in the case study area are Adigrate sandstone (T3ag), Babicha guder basalts (Npb), Debre libanos sandstone (Kdst) and Lower basalts (Tv1). Finally, the geologic map was reclassified and scored based on their engineering properties whether they stable or not to support foundation. During reclassification Adigrate sandstone (T3ag) and Debre libanos sandstone (Kdst) were grouped to same category and Babicha guder basalts (Npb) and Lower basalts (Tv1) were grouped to same category. The highest value was given to area having most stable geologic formation. Accordingly basaltic rock is more stable than sandstone to support foundation and higher score was given to area covered by basaltic rock.

Sandstone is a sedimentary rock composed of sand-size grains of mineral, rock, or organic material. It also contains a cementing material that binds the sand grains together and may contain a matrix of silt or clay-size particles that occupy the spaces between the sand grains. The grains of sand in a sandstone are usually particles of mineral, rock, or organic material that have been reduced to "sand" size by weathering and transported to their depositional site by the action of moving water and wind. Thus, this type of geology is vulnerable to erosion and land slide.

Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow, but can also form in small intrusive bodies, such as an igneous dike or a thin sill. Basalt is used for a wide variety of purposes in construction projects such as road base, concrete aggregate, asphalt pavement aggregate, filter stone in drain fields, dimension stone, floor tiles, building veneer, monuments, and other stone objects.

Table 12: Reclassified geology and area coverage of suitability levels

Geologic type	**Suitability class**	**Rank**	**Area (km^2)**	**By %**
Basalt Rock	highly suitable	9.00	61.83	87.85
Sandstone	less suitability	5.00	8.55	12.15
TOTAL			70.38	100.00

from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 12 above out of 70.38 km^2, 87.85% of the area is highly suitable and 12.15% of the area is less suitable for future urban development.

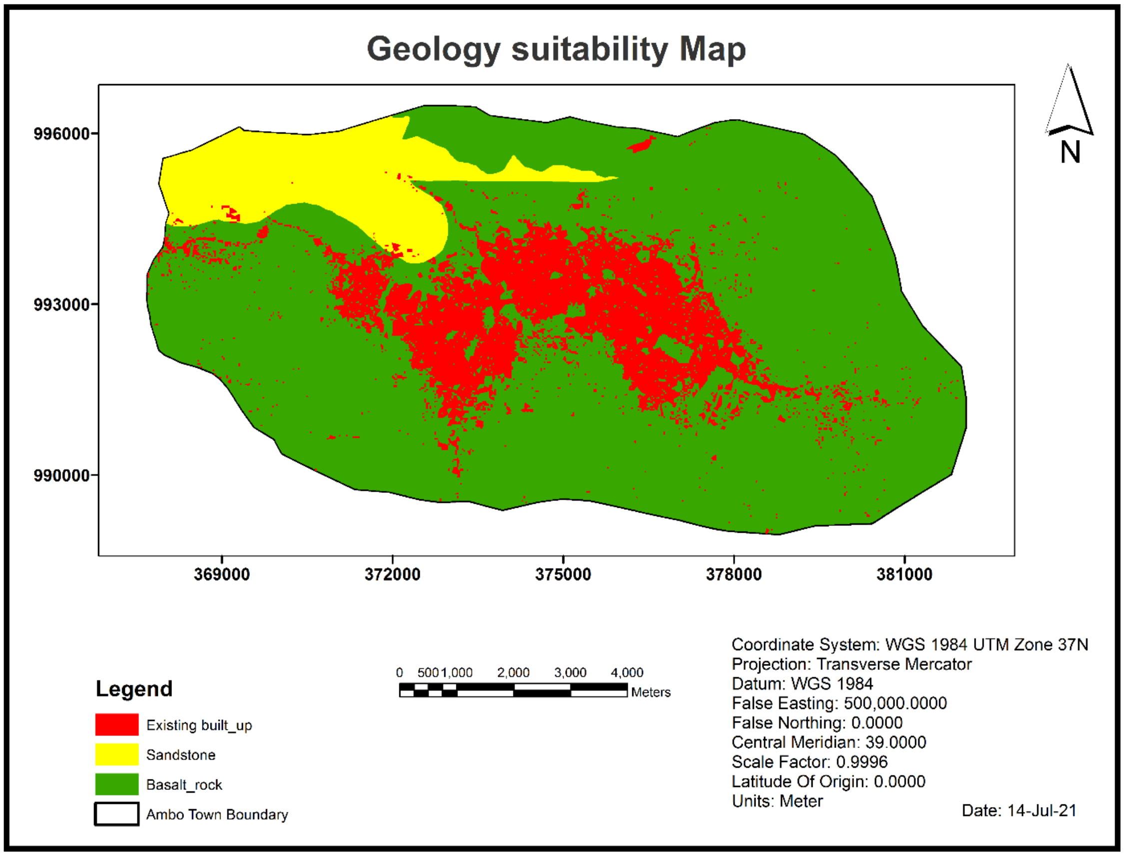

Figure 19: Geology Suitability map

4.3 Calculating the Weights of parameters

A weight can be defined as a value assigned to an evaluation criterion which indicates its importance relative to other criteria under consideration (Sener et al., 2005). One of the components of GIS-Based Multi Criteria Decision Analysis (MCDA) methodology is assigning criteria weights for each factor maps. Assigning weights of importance to evaluation criteria accounts for the changes in the range of variation for each evaluation criterion and the different degrees of importance being attached to these ranges of variation (Malczewski, 1999). The purpose of weighting in urban development site selection process is to express the importance or preference of each factor relative to other factor effect on urban development site analysis. A number of parameter-weighting procedures based on the judgments of decision makers have been proposed in the multi-criteria decision literature. Accordingly, one of the most promising is pair-wise comparison developed in context of a decision-making process is known as the AHP.

AHP is a decision-making technique utilized for solving complex problems, with many parameters of interrelated objectives or concerned criteria. The importance level of each parameter is not equal; some parameters are dominant over others. Different weights can generate difference in the level of suitability (Andi et al., 2017). In Ranking Method, every criterion under consideration is ranked as per decision maker's preference. To generate criterion values for each evaluation unit, each parameter was weighted according to the estimated significance for determining urban development site. The factors and their resulting weights were used as input for the MCDA module for weighted linear combination of overlay analysis. The larger the weight, indicates the more important is the parameter in the overall utility of site and small weight indicates the less important is the parameter in the overall utility of site. The ranking of parameter is related to their relative importance as listed in Table 13 of Scale for pairwise comparison below. The relative importance ranges from 1 to 9; 1 means an equal contribution of the pairwise parameter and 9 means extreme important parameter (Saaty, 2008).

Table 13: Scale for pairwise comparison of Parameters (Saaty, 1980)

Intensity of importance	**Definition**
1	Equal importance
2	Equal to moderately 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

The weight of each parameter was derived by taking the principal eigenvector of a square reciprocal matrix of pair-wise comparisons of the relative importance of factors to the suitability using IDRISI selva 17. These pair wise comparison was then analyzed to produce of weights that sum to 1 and the total weight should be added up to 100% in order for the output map to be meaningful and consistent (Saaty, 2008; as cited by Lamessa kenate, 2017 and Getahun Kafe, 2020). The AHP weight derivation interface to derive the weights for each parameter, with its consistency ratio, for urban development site selection was shown by figure 20 below.

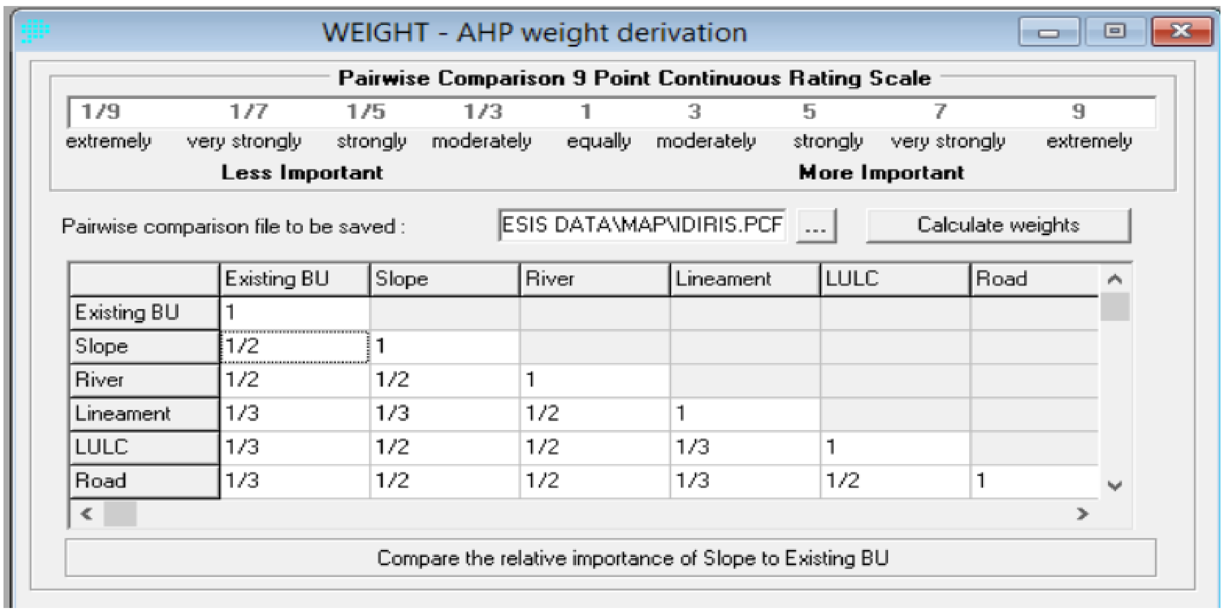

Figure 20: AHP weight derivation method of PWC Point Continuous Scale (Author, 2021)

4.3.1 Ranking parameters by AHP

The main use of AHP is ranking and prioritization of parameters. Priority framework quality affects the effectiveness of available sources which are the essential judgment from the decision maker (Andi et al., 2017). Furthermore, the experts usually use their experiential judgment when making the decision. Each of the expert participants determined the weight to the design factors and gave the weights depend on the Table 14 parameters of the factors. The responses of the experts, professionals and researchers on related area were shown in Table 14 below:

The computation of weights for parameters using Analytical Hierarchical Process (AHP) involves three main steps. The steps followed to calculate the weight of parameters used in this study are detailed as below.

The first step is the summation of the values in each column of the matrix (see table 14 last row).

Table 14: Pair-Wise Comparison Matrix

	EXTING	SLOPE	RIVER	LINEAMENT	LULC	ROAD	SOIL	GEOLOGY	SCHOOL
EXTING	1	2	2	3	3	3	3	4	5
SLOPE	1/2	1	2	3	2	2	2	3	4
RIVER	1/2	1/2	1	2	2	2	2	3	3
LINEAMENT	1/3	1/2	1/2	1	3	3	2	3	2
LULC	1/3	1/2	1/2	1/3	1	2	2	2	2
ROAD	1/3	1/2	1/2	1/3	1/2	1	2	2	2
SOIL	1/3	1/2	1/2	1/2	1/2	1/2	1	2	3
GEOLOGY	1/4	1/3	1/3	1/3	1/2	1/2	1/2	1	2
SCHOOL	1/5	1/4	1/3	1/2	1/2	1/2	1/3	1/2	1
SUM	3.78	5.917	7.67	11	13	14.50	14.83	20.50	24

Second, each element in the matrix should be divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix).

Table 15: Normalized Pair-Wise Comparison Matrix

	EXTING	SLOPE	RIVER	LINEAMENT	LULC	ROAD	SOIL	GEOLOGY	SCHOOL
EXTING	0.26	0.34	0.26	0.27	0.23	0.21	0.20	0.20	0.21
SLOPE	0.13	0.17	0.26	0.27	0.15	0.14	0.13	0.15	0.17
RIVER	0.13	0.08	0.13	0.18	0.15	0.14	0.13	0.15	0.13
LINEAMENT	0.09	0.06	0.07	0.09	0.23	0.21	0.13	0.15	0.08
LULC	0.09	0.08	0.07	0.03	0.08	0.14	0.13	0.10	0.08
ROAD	0.09	0.08	0.07	0.03	0.04	0.07	0.13	0.10	0.08
SOIL	0.09	0.08	0.07	0.05	0.04	0.03	0.07	0.10	0.13
GEOLOGY	0.07	0.06	0.04	0.03	0.04	0.03	0.03	0.05	0.08
SCHOOL	0.05	0.04	0.04	0.05	0.04	0.03	0.02	0.02	0.04

Third, computation of the average of the elements in each row of the normalized matrix by dividing the sum of normalized scores for each row by the number of criteria.

Table 16: Eigen vector weight

	EXTING	SLOPE	RIVER	LINEAMENT	LULC	ROAD	SOIL	GEOLOGY	SCHOOL	Weight (%)
EXTING	0.26	0.34	0.26	0.27	0.23	0.21	0.20	0.20	0.21	24.21
SLOPE	0.13	0.17	0.26	0.27	0.15	0.14	0.13	0.15	0.17	17.49
RIVER	0.13	0.08	0.13	0.18	0.15	0.14	0.13	0.15	0.13	13.63
LINEAMENT	0.09	0.06	0.07	0.09	0.23	0.21	0.13	0.15	0.08	12.25
LULC	0.09	0.08	0.07	0.03	0.08	0.14	0.13	0.10	0.08	8.87
ROAD	0.09	0.08	0.07	0.03	0.04	0.07	0.13	0.10	0.08	7.68
SOIL	0.09	0.08	0.07	0.05	0.04	0.03	0.07	0.10	0.13	7.18
GEOLOGY	0.07	0.06	0.04	0.03	0.04	0.03	0.03	0.05	0.08	4.83
SCHOOL	0.05	0.04	0.04	0.05	0.04	0.03	0.02	0.02	0.04	3.84
TOTAL										**100.00**

The value obtained here were an estimate of the relative weights of the criteria being compared. As shown in table 16 above the last column indicates the weight of each parameter.

4.3.2 Estimation of the consistency ratio

The aim of estimating consistency ratio is to determine whether comparisons are consistent or not. Estimation of the consistency ratio involves the following operations:

1. Determine the weighted sum vector by multiplying the weight for the first criterion times the first column of the original pairwise comparison matrix, then multiply the second weight times the second column, the third criterion times the third column of the original matrix, finally sum of these values over the rows.

Table 17: weighted sum vector

	EXTING	SLOPE	RIVER	LINEAMENT	LULC	ROAD	SOIL	GEOLOGY	SCHOOL	weight sum
EXTING	0.24	0.35	0.27	0.37	0.27	0.23	0.22	0.19	0.19	2.33
SLOPE	0.12	0.17	0.27	0.37	0.18	0.15	0.14	0.14	0.15	1.71
RIVER	0.12	0.09	0.14	0.25	0.18	0.15	0.14	0.14	0.12	1.32
LINEAMENT	0.08	0.06	0.07	0.12	0.27	0.23	0.14	0.14	0.08	1.19
LULC	0.08	0.09	0.07	0.04	0.09	0.15	0.14	0.10	0.08	0.84
ROAD	0.08	0.09	0.07	0.04	0.04	0.08	0.14	0.10	0.08	0.72
SOIL	0.08	0.09	0.07	0.06	0.04	0.04	0.07	0.10	0.12	0.66
GEOLOGY	0.06	0.06	0.05	0.04	0.04	0.04	0.04	0.05	0.08	0.45
SCHOOL	0.05	0.04	0.05	0.06	0.04	0.04	0.02	0.02	0.04	0.37

2. Determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously.

Table 18: Consistency vector

weight sum	Criteria weight	Consistency Vector (WS/CW)
2.33	0.24	9.62
1.71	0.17	9.77
1.32	0.14	9.72
1.19	0.12	9.73
0.84	0.09	9.43
0.72	0.08	9.31
0.66	0.07	9.25
0.45	0.05	9.29
0.37	0.04	9.59

3. Compute lambda max (λmax) which is the average value of the consistency vector and compute Consistency Index (CI) which provides a measure of departure from consistency by using 3.2 formula:

$$CI = \frac{\lambda\,\mathrm{max} - n}{\mathrm{n-1}} \text{---} 3.2$$

λmax = (9.62 + 9.77 + 9.72 + 9.73 + 9.43 + 9.31 + 9.25 + 9.29 + 9.59) / 9 = 9.523

CI = (9.523 – 9) / 9 - 1

CI = 0.523 / 8

CI = 0.065

4. Calculation of the consistency ratio (CR) by using 3.3 formula:

$$CR = \frac{\mathrm{CI}}{\mathrm{RI}} \text{--} 3.3$$

Where **RI** is the random index and depends on the number of parameters being compared and detailed in table 19 below:

Table 19: Random Index

Order Matrix	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The number of parameters used in this study were nine (9). RI value for nine parameters is 1.45, using this value consistency ratio was calculated as shown below.

CR = CI / RI

CR = 0.065 / 1.45

CR = 0.045

The consistency ratio of this study indicated that 0.045 which is less than 0.1. thus, consistent matrix was formed which was acceptable in order to combine all the layers to process overlay analysis. Accordingly, the determined factor weights were accepted to use in the fourth step, which is synthesis using weighted linear combination.

4.4 Weighted linear combination (WLC)

WLC is the most prevalently used multi-criteria evaluation analysis method in GIS (Siefi et al., 2017; Malczewski, 2000). Land-use suitability analysis using weighted overlay method leads to more rational urban planning decision-making. In this method, manipulation of the overlay process is allowed by assigning different weights for each input layers, so the factors that play a more critical role will have a more significant impact on shaping the outcome of the overlay analysis. This is the advantage of weighted overlay over other methods such as fuzzy overlay, binary overlay, or ranking overlay (Malczewski, 2006). However, this method is highly dependent on determination of factor weights, where highly favored factors will result in higher values in the final output raster. This issue is critical, so experts' opinion is crucial in the defining scales applied to input layers and weights given to factors in the AHP process.

To be able to combine the attribute of layers and perform calculations on them, before executing the weighted overlay, all vector criteria layers were converted to raster format. Since the WLC method requires all values which are included in different attribute layers to be transformed to a comparable unit, all the criteria layers had already been normalized in the scale of 1 to 5 (see Figure 10 - 18 and table 4 - 12). Table 16 shows the influence weight of factors which were determined based on the literature review, experts' opinion, and AHP method. In this study the new urban should connected to the existing urban area and proximity to existing urban area is extremely important in urban planning; thus, proximity to existing urban area factor was given primary weight (24.21%) in the analysis. Secondary weighting (17.49%) was given to the slope factor due to the significance of topography in urban planning. The remaining weights are 13.63%, 12.25%, 8.87%, 7.68%, 7.18%, 4.83% and 3.84% were given to River, Lineament, LULC, Road, Soil, Geology and school & health care center respectively. The sum of the criteria weights must be equal to 100 (see Table 16). Finally, the overall weighted linear combination was performed using equation 3.4.

$$\mathrm{S} = \sum_{i=0}^{n} wi\ xi\ * \Pi\ cj \text{ -- } 3.4$$

where **s** is the composite suitability score, w_i is weights of factor, x_i is factor scores (normalized cell values), c_j is constraints (built-up and protected area), and Π is the product of constraints.

4.5 Final urban development site suitability Analysis

After all parameters were prepared in raster format the overlay analysis was performed using weighted overlay tool in GIS spatial analysis extension by considering weight of parameters and buffer zones as shown in table 20.

Table 20: weight of parameters and rank of buffer zones determined using AHP method

Planning parameters	Buffer zone /class	Suitability class	rank	Weight of parameter
Proximity to Existing urban	<500m	highly suitable	9	24.21
	500-1000m	moderately suitable	7	
	1000-2000m	Less suitable	5	
	2000-3000m	very less suitable	3	
	>3000m	unsuitable	1	
Slope in degree	<5	highly suitable	9	17.49
	5-10	moderately suitable	7	
	10-15	Less suitable	3	
	15-20	very less suitable	1	
	>20	unsuitable	Restricted	
Proximity to River	<100m	unsuitable	1	13.63
	100-250m	very less suitable	3	
	250-500m	less suitable	5	
	500-750m	moderately suitable	7	
	>750m	highly suitable	9	
Lineament	<100	unsuitable	1	12.25
	100-200m	very less suitable	3	
	200-300m	less suitable	5	
	300-400m	moderately suitable	7	
	>400m	highly suitable	9	
LULC	Bare land	highly suitable	9	8.87
	Shrubs and bushes	moderately suitable	7	
	Agricultural land	Less suitable	3	
	Closed forest	very less suitable	1	
	built-up Area	unsuitable	Restricted	

Proximity to major Road	<500m	highly suitable	9	7.68
	500-1000m	moderately suitable	7	
	1000-1500m	Less suitable	5	
	1500-2000m	very less suitable	3	
	>2000m	unsuitable	1	
Soil	Eutric Nitosols	highly suitable	9	7.18
	Pellic Vertisols	Less suitable	5	
Geology	Basalt rock	highly suitable	9	4.83
	sandstone	Less suitable	5	
Proximity to School and health care center	<1000	highly suitable	9	3.84
	1000-2000m	moderately suitable	7	
	2000-3000m	Less suitable	5	
	3000-4000m	very less suitable	3	
	>4000m	unsuitable	1	

Finally, the result map was reclassified According to FAO (1976) suitability classification standard. The standard establishes five suitability ratings whether the area is suitable or not suitable. In this case study five of land suitability ratings were used to generate the final urban development site suitability map. The five ratings are highly suitable, moderately suitable, less suitable, very less suitable and unsuitable. Accordingly, the findings of this study shows that from 83.91km^2 total area of Ambo town, 13.35 km^2 of total area was occupied by existing built-up and not considered for this analysis. As shown in table 21 below out of 70.38 km^2, 36.13% of the area were highly suitable, 31.59% of the area were moderately suitable, 9.80% of the area were less suitable, 2.63% of the area were very less suitable and 3.74% of the area were unsuitable for urban development (see figure 21 and table 21 below). These results call attention to the need for proper and sustainable urban planning in order to save Ambos's and surrounding area's ecosystem in the long term by using the highly suitable area primary for urban development site.

Table 21: Final suitable Site for Urban Development

Suitability class	Rank	Area (km^2)	By %
highly suitable	5	30.32	36.13
moderately suitable	4	26.51	31.59
less suitability	3	8.22	9.80
very less suitability	2	2.20	2.63
unsuitable	1	3.14	3.74
Existing built-up	Not considered	13.53	16.13
TOTAL		83.92	100.00

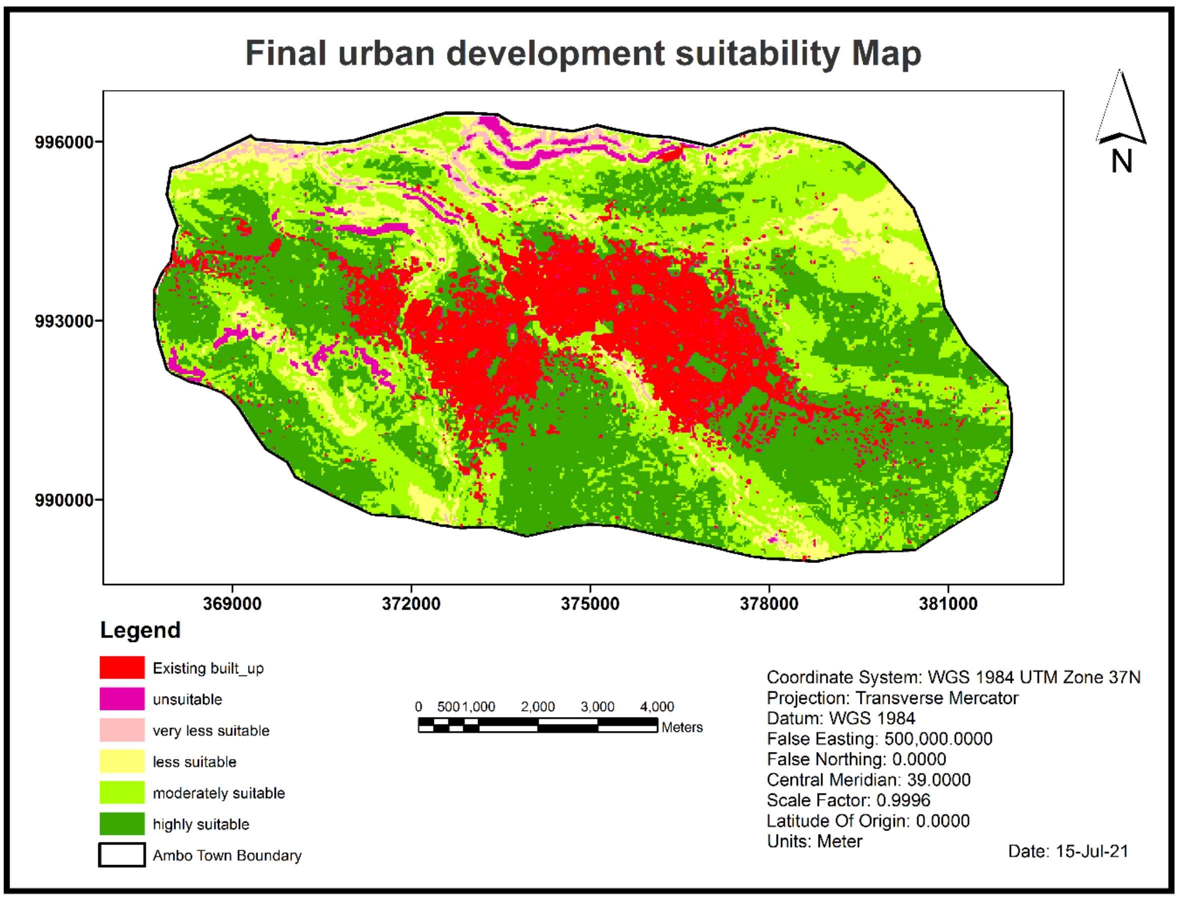

Figure 21: Final Urban Development suitability map

4.6 Discussion

Although AHP and WLC have been extensively used in developing lands suitability maps in a number of diverse situations, there is no commonly accepted method for assigning the relative weights to the criterion maps (Malczewski, 2004). As a result, different weighting schemes can produce different outcomes (Chen Y. et al., 2010; Vander Merwe, 1997). For instance, Heywood et al. (1995), reveals different multi-criteria evaluation rules result in different suitability pattern.

Therefore, this study used nine site selection criteria (proximity to lineament, proximity to main road, proximity to river, land use land cover, proximity to school and health care center, slope, soil, geology and proximity to existing built-up area) to select and evaluate potential urban development site. The final suitability map has shown that, five suitability classes (unsuitable, very less suitable, less suitable, moderate suitable and highly suitable) from all surface of study area and seven highly suitable candidate sites (see figure 22).

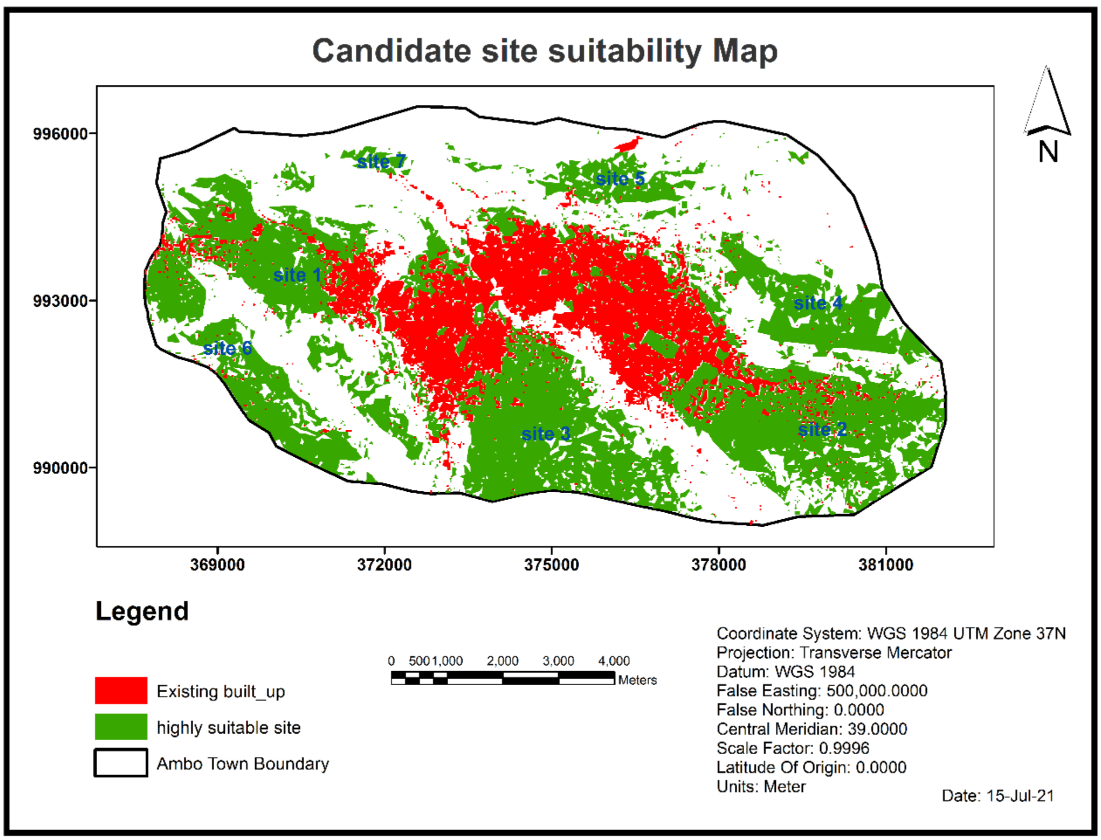

Figure 22: Candidate site suitability map

The class selected as highly suitable sites can be used for future urban development. But to compare each selected site with existing literatures, standards and international practices highly suitable sites are classified to seven candidate sites. Those candidate sites are located in western, southern, eastern, northern and south eastern part of the town area (see figure 22).

According to C Santosh et al. (2018), more settlement develops near the road because of the transportation facilities and very easy access to the nearby places and city centers. R. Z. Liu et al. (2014), discussed in their study Buffer zone falling under 500m distances from road is highly suitable for urban development. The urban development sites are not be located on an area where the average surface slope is steeper, it must be 100m away from drainage to prevent flood vulnerability, it must 100m away from lineaments (Culshaw and Price, 2011; Akbulut et al., 2018; Mesfin Girma, 2019; Kamal jain & Y. Venkata subbaiay, 2007; Ishaq & Hakan, 2019; C Santosh et al., 2018).

However, the analyzed result of this study showed that, candidate Site 1, 2 and 3 are about 500m close to the roads, enough faraway from river and lineaments, they are not lay on protected area, they are located on gentle slope less than 5^0 and stable geologic formation. So, candidate Site 1, 2 and 3 are acceptable for first face urban development and growth; because those sites meet the minimum required criteria set out to urban development site selection when evaluated in terms of proximity to road, proximity from river, slope and proximity from lineament.

According to Chen S. (2016), to take advantage of existing resources, such as infrastructure and facilities, to prevent scatter settlement the future urban area should be in reasonable near to the existing built-up areas to consolidate the urban zone and reduce the impacts of urban sprawl. Accordingly, Site 1, 2 and 3 are directly connected to existing built-up area. But site 4, 5, 6 and 7 are not connected to existing built-up because of rive and lineament constraint. Thus site 1, 2 and 3 can be used for first face urban development. Therefore, the newly proposed urban development sites are at safer proximity from river, lineament, protected area and located on area of stable geologic formation, flat slope, allowable LULC, reasonably close to road, existing urban area, existing school and health care center. Thus, appropriate urban development location of Ambo Town was generated with considering physical, environmental, economic and socially acceptable.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this study, a GIS-based land suitability analysis based on critical factors was conducted to find the most suitable areas for sustainable urban development in Ambo Town province. Urban development site analysis is a complex procedure which involves evaluating numerous physical, environmental and socio-economic factors. A GIS is a good tool to help in finding of suitable sites for urban development purposes. The use of GIS for evaluation of urban development sites saves the time and resource needed for evaluation of suitable site.

In this study nine criteria were considered (proximity to lineament, proximity to main road, proximity to river, land use land cover, proximity to school and health care center, slope, soil, geology and proximity to existing built-up area) for proper urban development site selection in Ambo Town and prepared as input map layers. To achieve the aim of this study, selected parameters were analyzed Using AHP with WLC in a GIS and spatial pattern of future land uses for urban development was reclassified to five classes and mapped out.

The result of this analysis revealed that for the selected parameters out of the total area of 83.91Km^2 found in study area, 16.13% (13.35km^2) of area was occupied by existing built-up and not considered for this study. From the rest of 70.38 km^2 area, 36.13% (30.32Km^2) area is highly suitable for urban development, 31.59% (26.51Km^2) area is moderately suitable for urban development, 9.80% (8.22Km^2) area is less suitable for urban development, 2.63% (2.20Km^2) area is very less suitable for urban development and 3.74% (3.14Km^2) area is unsuitable for urban development. Most of the sites selected as highly suitable for urban development are far away from river and lineaments, located on gentle slope less than 5^0, baren land, shrubs, bushes and stable geologic formation, connected to existing built-up area and follow the existing road. Those highly suitable sites are located in western, southern, eastern and south eastern part of the town. Therefore, this study presented that the advantages of integrated AHP with WLC in GIS for land suitability analysis and simplifies such complicated decisions.

5.2. Recommendations

Based on the findings of this study the following Recommendations are drawn:

- The combination of GIS with MCDA is powerful tool for land suitability analysis for urban development. The method requires only computer skills within a GIS environment. Therefore, GIS-based MCDA for land suitability has proven to facilitate efficiency as compared to the traditional methods.
- The outcome of this study will help the local people as well as urban planners to formulate and implement suitable master plan for development of Ambo Town and surrounding. Further field verifications will be needed before the final decision is made using the result of this study.
- Areas identified as very less suitable, less suitable and unsuitable in this study which are located near river, near lineament and on steeper slope. Thus, those area will be used for urban greenery and planting tree (if not occupied by other urban infrastructures).
- The land use land cover and existing built-up maps used in this study were mapped from Landsat 8 image of 30m resolution. Therefore, further study should be recommended to use high resolution image for generating LULC and existing built-up.
- Further studies are necessary about the planning and design of future urban development to identify suitability of identified sites for specific purposes (residential, commercial, industrial and other purposes).
- Some factors such as ground water table depth and community preferences were not incorporated as evaluation criteria; because of expensiveness of remotely sensed data and population density also not incorporated because of absence of updated population data and kebele boundary to calculate density for each kebele in study area. Hence, further study should fill this research gap by including these layers as evaluating criteria.

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APPENDICES

Appendix 1: World total population and Urban Population 1950-2020

year	World pop	Yearly change	Net change	Urban pop	Urban Pop %
2020	7,794,798,739	1.05%	81,330,639	4,378,993,944	56%
2019	7,713,468,100	1.08%	82,377,060	4,299,438,618	56%
2018	7,631,091,040	1.10%	83,232,115	4,219,817,318	55%
2017	7,547,858,925	1.12%	83,836,876	4,140,188,594	55%
2016	7,464,022,049	1.14%	84,224,910	4,060,652,683	54%
2015	7,379,797,139	1.16%	84,506,374	3,981,497,663	54%
2014	7,295,290,765	1.17%	84,708,789	3,902,831,934	53%
2013	7,210,581,976	1.19%	84,753,917	3,824,990,329	53%
2012	7,125,828,059	1.20%	84,633,758	3,747,842,586	53%
2011	7,041,194,301	1.21%	84,370,698	3,671,423,872	52%
2010	6,956,823,603	1.22%	84,056,510	3,594,868,146	52%
2009	6,872,767,093	1.23%	83,678,407	3,516,830,263	51%
2008	6,789,088,686	1.24%	83,142,076	3,439,719,128	51%
2007	6,705,946,610	1.24%	82,428,777	3,363,609,560	50%
2006	6,623,517,833	1.25%	81,610,806	3,289,446,226	50%
2005	6,541,907,027	1.25%	80,747,638	3,215,905,863	49%
2004	6,461,159,389	1.25%	79,974,275	3,143,044,892	49%
2003	6,381,185,114	1.26%	79,411,926	3,071,743,997	48%
2002	6,301,773,188	1.27%	79,146,582	3,001,808,223	48%
2001	6,222,626,606	1.29%	79,132,783	2,933,078,510	47%
2000	6,143,493,823	1.31%	79,254,768	2,868,307,513	47%
1999	6,064,239,055	1.33%	79,445,113	2,808,231,655	46%
1998	5,984,793,942	1.35%	79,748,154	2,749,213,598	46%
1997	5,905,045,788	1.38%	80,153,837	2,690,813,541	46%
1996	5,824,891,951	1.40%	80,678,972	2,632,941,583	45%
1995	5,744,212,979	1.43%	81,062,552	2,575,505,235	45%
1994	5,663,150,427	1.46%	81,552,881	2,518,254,111	44%
1993	5,581,597,546	1.50%	82,677,737	2,461,223,528	44%
1992	5,498,919,809	1.56%	84,630,365	2,404,337,297	44%
1991	5,414,289,444	1.63%	87,058,383	2,347,462,336	43%
1990	5,327,231,061	1.71%	89,789,503	2,290,228,096	43%
1989	5,237,441,558	1.79%	92,015,550	2,233,140,502	43%
1988	5,145,426,008	1.84%	92,903,861	2,176,126,537	42%
1987	5,052,522,147	1.85%	91,954,235	2,118,882,551	42%

1986	4,960,567,912	1.84%	89,646,172	2,062,604,394	42%
1985	4,870,921,740	1.82%	86,910,119	2,007,939,063	41%
1984	4,784,011,621	1.80%	84,442,317	1,955,106,433	41%
1983	4,699,569,304	1.78%	82,182,762	1,903,822,436	41%
1982	4,617,386,542	1.77%	80,389,780	1,854,134,229	40%
1981	4,536,996,762	1.77%	78,993,248	1,804,215,203	40%
1980	4,458,003,514	1.77%	77,497,414	1,754,201,029	39%
1979	4,380,506,100	1.76%	75,972,599	1,706,021,638	39%
1978	4,304,533,501	1.77%	75,027,441	1,659,306,117	39%
1977	4,229,506,060	1.80%	74,839,196	1,616,419,308	38%
1976	4,154,666,864	1.84%	75,186,258	1,577,376,141	38%
1975	4,079,480,606	1.89%	75,686,434	1,538,624,994	38%
1974	4,003,794,172	1.94%	76,013,934	1,501,134,655	37%
1973	3,927,780,238	1.98%	76,129,993	1,462,178,370	37%
1972	3,851,650,245	2.01%	75,890,628	1,424,734,781	37%
1971	3,775,759,617	2.04%	75,322,571	1,388,834,099	37%
1970	3,700,437,046	2.06%	74,756,419	1,354,215,496	37%
1969	3,625,680,627	2.09%	74,081,500	1,319,833,474	36%
1968	3,551,599,127	2.09%	72,829,165	1,285,933,432	36%
1967	3,478,769,962	2.08%	70,847,332	1,252,566,565	36%
1966	3,407,922,630	2.05%	68,339,033	1,219,993,032	36%
1965	3,339,583,597	2.00%	65,605,259	1,188,469,224	36%
1964	3,273,978,338	1.96%	62,977,329	1,157,813,355	35%
1963	3,211,001,009	1.92%	60,580,214	1,122,561,940	35%
1962	3,150,420,795	1.89%	58,577,288	1,088,376,703	35%
1961	3,091,843,507	1.87%	56,893,759	1,055,435,648	34%
1960	3,034,949,748	1.86%	55,373,563	1,023,845,517	34%
1959	2,979,576,185	1.84%	53,889,480	992,820,546	33%
1958	2,925,686,705	1.82%	52,380,615	962,537,113	33%
1957	2,873,306,090	1.80%	50,862,808	933,113,168	32%
1956	2,822,443,282	1.78%	49,423,346	904,685,164	32%
1955	2,773,019,936	1.77%	48,173,195	877,008,842	32%
1954	2,724,846,741	1.76%	47,237,781	850,179,106	31%
1953	2,677,608,960	1.78%	46,747,398	824,289,989	31%
1952	2,630,861,562	1.81%	46,827,301	799,282,533	30%
1951	2,584,034,261	1.88%	47,603,112	775,067,697	30%
1950	2,556,000,053	1.09%	28,034,208	766800015.9	30%

Appendix 2: African countries 2020 total population and Urban Population

	Country	Pop of 2020	Yearly Change	Net Change	Density (P/Km²)	Land Area (Km²)	Urban Pop %
1	Nigeria	206,139,589	2.58%	5,175,990	226	910,770	52%
2	Ethiopia	114,963,588	2.57%	2,884,858	115	1,000,000	21%
3	Egypt	102,334,404	1.94%	1,946,331	103	995,450	43%
4	DR Congo	89,561,403	3.19%	2,770,836	40	2,267,050	46%
5	South Africa	59,308,690	1.28%	750,420	49	1,213,090	67%
6	Tanzania	59,734,218	2.98%	1,728,755	67	885,800	37%
7	Kenya	53,771,296	2.28%	1,197,323	94	569,140	28%
8	Uganda	45,741,007	3.32%	1,471,413	229	199,810	26%
9	Algeria	43,851,044	1.85%	797,990	18	2,381,740	73%
10	Sudan	43,849,260	2.42%	1,036,022	25	1,765,048	35%
11	Morocco	36,910,560	1.20%	438,791	83	446,300	64%
12	Angola	32,866,272	3.27%	1,040,977	26	1,246,700	67%
13	Ghana	31,072,940	2.15%	655,084	137	227,540	57%
14	Mozambique	31,255,435	2.93%	889,399	40	786,380	38%
15	Madagascar	27,691,018	2.68%	721,711	48	581,795	39%
16	Cameroon	26,545,863	2.59%	669,483	56	472,710	56%
17	Côte d'Ivoire	26,378,274	2.57%	661,730	83	318,000	51%
18	Niger	24,206,644	3.84%	895,929	19	1,266,700	17%
19	Burkina Faso	20,903,273	2.86%	581,895	76	273,600	31%
20	Mali	20,250,833	3.02%	592,802	17	1,220,190	44%
21	Malawi	19,129,952	2.69%	501,205	203	94,280	18%
22	Zambia	18,383,955	2.93%	522,925	25	743,390	45%
23	Senegal	16,743,927	2.75%	447,563	87	192,530	49%
24	Chad	16,425,864	3.00%	478,988	13	1,259,200	23%
25	Somalia	15,893,222	2.92%	450,317	25	627,340	47%
26	Zimbabwe	14,862,924	1.48%	217,456	38	386,850	38%
27	Guinea	13,132,795	2.83%	361,549	53	245,720	39%
28	Rwanda	12,952,218	2.58%	325,268	525	24,670	18%
29	Benin	12,123,200	2.73%	322,049	108	112,760	48%
30	Tunisia	11,818,619	1.06%	123,900	76	155,360	70%

31	Burundi	11,890,784	3.12%	360,204	463	25,680	14%
32	South Sudan	11,193,725	1.19%	131,612	18	610,952	25%
33	Togo	8,278,724	2.43%	196,358	152	54,390	43%
34	Sierra Leone	7,976,983	2.10%	163,768	111	72,180	43%
35	Libya	6,871,292	1.38%	93,840	4	1,759,540	78%
36	Congo	5,518,087	2.56%	137,579	16	341,500	70%
37	Liberia	5,057,681	2.44%	120,307	53	96,320	53%
38	Central African Republic	4,829,767	1.78%	84,582	8	622,980	43%
39	Mauritania	4,649,658	2.74%	123,962	5	1,030,700	57%
40	Eritrea	3,546,421	1.41%	49,304	35	101,000	63%
41	Namibia	2,540,905	1.86%	46,375	3	823,290	55%
42	Gambia	2,416,668	2.94%	68,962	239	10,120	59%
43	Botswana	2,351,627	2.08%	47,930	4	566,730	73%
44	Gabon	2,225,734	2.45%	53,155	9	257,670	87%
45	Lesotho	2,142,249	0.80%	16,981	71	30,360	31%
46	Guinea-Bissau	1,968,001	2.45%	47,079	70	28,120	45%
47	Equatorial Guinea	1,402,985	3.47%	46,999	50	28,050	73%
48	Mauritius	1,271,768	0.17%	2,100	626	2,030	41%
49	Eswatini	1,160,164	1.05%	12,034	67	17,200	30%
50	Djibouti	988,000	1.48%	14,440	43	23,180	79%
51	Réunion	895,312	0.72%	6,385	358	2,500	100%
52	Comoros	869,601	2.20%	18,715	467	1,861	29%
53	Western Sahara	597,339	2.55%	14,876	2	266,000	87%
54	Cabo Verde	555,987	1.10%	6,052	138	4,030	68%
55	Mayotte	272,815	2.50%	6,665	728	375	46%
56	Sao Tome & Principe	219,159	1.91%	4,103	228	960	74%
57	Seychelles	98,347	0.62%	608	214	460	56%
58	Saint Helena	6,077	0.30%	18	16	390	27%

Appendix 3: Ethiopia Urban Population 1960-2020

Date	Urban Population	% Of Total	Annual % Change
12/31/1960	1424992	6.433	
12/31/1961	1507634	6.650	5.6375
12/31/1962	1596238	6.874	5.7108
12/31/1963	1690640	7.104	5.7458
12/31/1964	1791229	7.342	5.7795
12/31/1965	1897784	7.587	5.7785
12/31/1966	2010258	7.840	5.7576
12/31/1967	2128691	8.100	5.7244
12/31/1968	2225607	8.260	4.4522
12/31/1969	2328911	8.422	4.5371
12/31/1970	2440287	8.588	4.6715
12/31/1971	2561011	8.756	4.8286
12/31/1972	2690971	8.928	4.95
12/31/1973	2824957	9.102	4.8591
12/31/1974	2956415	9.279	4.5484
12/31/1975	3080824	9.460	4.122
12/31/1976	3194879	9.644	3.6352
12/31/1977	3300643	9.830	3.2568
12/31/1978	3406129	10.020	3.1459
12/31/1979	3522584	10.214	3.3618
12/31/1980	3658252	10.410	3.7791
12/31/1981	3817958	10.610	4.273
12/31/1982	4000296	10.813	4.6653
12/31/1983	4203323	11.020	4.9507
12/31/1984	4422527	11.232	5.0836
12/31/1985	4655890	11.453	5.1422
12/31/1986	4901173	11.679	5.1341
12/31/1987	5160078	11.909	5.1477
12/31/1988	5434867	12.143	5.1883

12/31/1989	5728511	12.380	5.2621
12/31/1990	6043927	12.621	5.3598
12/31/1991	6383315	12.867	5.4634
12/31/1992	6744717	13.116	5.5072
12/31/1993	7125617	13.370	5.4937
12/31/1994	7519515	13.627	5.3805
12/31/1995	7888014	13.827	4.7843
12/31/1996	8247227	14.006	4.4533
12/31/1997	8610539	14.186	4.311
12/31/1998	8981735	14.369	4.2206
12/31/1999	9363839	14.553	4.1662
12/31/2000	9761536	14.740	4.1594
12/31/2001	10174157	14.927	4.1401
12/31/2002	10604081	15.118	4.1388
12/31/2003	11049316	15.310	4.113
12/31/2004	11510093	15.504	4.0856
12/31/2005	11986371	15.700	4.0546
12/31/2006	12478999	15.899	4.0277
12/31/2007	13001478	16.116	4.1016
12/31/2008	13689470	16.510	5.1564
12/31/2009	14413055	16.910	5.1507
12/31/2010	15178365	17.319	5.1737
12/31/2011	15986316	17.735	5.1862
12/31/2012	16839218	18.160	5.1977
12/31/2013	17717910	18.575	5.0865
12/31/2014	18635946	18.998	5.0516
12/31/2015	19590313	19.428	4.9943
12/31/2016	20581872	19.866	4.9375
12/31/2017	21609845	20.310	4.8738
12/31/2018	22678295	20.763	4.8259
12/31/2019	23788710	21.225	4.7803
12/31/2020	24947099	21.700	4.8694

Appendix 4: List of school and health care center in Ambo Town

NO	Name of school (health care center)	X	Y
1	Liban macha elementary school	373426.36	994107.23
2	Ambo 2nd and prep school	375223.77	992907.09
3	Chari elementary school	374866.30	993507.23
4	Homacho 2nd school	374657.70	993573.29
5	Betakinat school	374382.17	992933.05
6	Adis keteme elementary school	372959.93	992412.08
7	Ambo high school	372465.15	992716.08
8	Sankale KG	371415.12	993827.67
9	Awaro elementary school	376505.46	992596.80
10	Awaro 2nd school	376391.32	993846.31
11	Karchale elementary and 2nd school	373458.51	993416.37
12	Adis keteme health care center	372485.85	992962.42
13	Ambo referal hospital	372085.24	993890.18
14	Ambo hospital	373578.33	993170.16
15	Awaro health care center	377400.78	992241.86