

**SPATIAL EVALUATION OF THE ACCESSIBILITY AND  
SUITABILITY OF URBAN AMENITIES: A CASE OF SECONDARY  
SCHOOLS IN ADAMA CITY, ETHIOPIA**



Bisrat Welegebrial

A Thesis Submitted to The department of Geomatics Engineering

School of Civil Engineering and Architecture

Presented In Partial Fulfillment of the Requirement for the Degree of

Master's in Geo-Informatics

Office of Graduate studies

Adama science and Technology University

September, 2022

Adama, Ethiopia

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## APPROVAL SHEET

I, the advisor of the thesis entitled “Spatial Evaluation of the Accessibility and Suitability of Urban Amenities: A Case of Secondary Schools in Adama City, Ethiopia” and developed by Bisrat Welegebrial, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Bisrat Welegebrial have read and evaluated the thesis entitled “Spatial Evaluation of the Accessibility and Suitability of Urban Amenities: A Case of Secondary Schools in Adama City, Ethiopia” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in GeoInformatics Engineering.

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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).

Head of Department	Signature	Date

School Dean	Signature	Date

Office of Postgraduate Studies, Dean	Signature	Date

## **DECLARATION**

I, hereby declare that this Master Thesis entitled “Spatial Evaluation of the Accessibility and Suitability of Urban Amenities: A Case of Secondary Schools in Adama City, Ethiopia ” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Bisrat Welegebrial

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Name of the student

Signature

Date

## **RECOMMENDATION**

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled “Spatial Evaluation of the Accessibility and Suitability of Urban Amenities: A Case of Secondary Schools in Adama City, Ethiopia” Prepared under our guidance by Bisrat Welegebrial submitted in partial fulfillment of the requirements for the degree of Master’s of Science in Geo-Informatics. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dejene Tesema (PhD)

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Advisor

Signature

Date

## **ACKNOWLEDGMENT**

First and foremost, I would like to thank Almighty God, the Lord of everything, who gives me health and who makes everything possible for me in my entire life. I would like to express my deepest thank and gratitude to my advisor Dr. Dejene Tesema for his supervision, guidance, support and constructive comments throughout the compilation of this thesis work. I never forget to thank my uncle Dr. Amanual who facilitated, supported everything to start my study. I wish him may God give long age and health. Thanks to my mother Roman wedaj and my father for unpaid safeguarding, care, blessings and best wishes from my childhood until now. Great thanks to my aunt teacher Alemnesh, my brothers Tesfay, Nati, my sisters, my family, my friends, my classmates for your care, support and motivation. Finally, I am thankful to Adama Science and Technology University (ASTU) for its sponsorship and Mr. Gemechu Keba (M.Sc.), who is Head of the Department of Geomatics Engineering, for his patience and experience he shared information.

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## LIST OF ABBREVIATION

AHP	Analytical Hierarchy Process
ASTE	Advanced Space borne Thermal Emission and Reflection Radiometer
CSA	Central Statistical Agency
DEM	Digital Elevation model
DTM	Digital Terrain Model
DEO	District Education Office
ERDAS	Earth Resource Data Analysis System
EMA	Ethiopian Mapping Agency
GCP	Ground Control Point
GIS	Geographical Information System
GPS	Globally positioning system
LCM	Land Change Modeler
LULC	Land Use land Cover change
MCDM	Multi- Criteria decision making
MCDA	Multi-Criteria Decision Analysis
RS	Remote Sensing
USGS	United State of Geological Survey
SED	State Education Department
TIFF	Tagged Image File Format
WLC	Weighted Linear Combination

## ABSTRACT

*The achievement of equity in the distribution of urban public amenities is a main goal of paramount importance to urban planning. The allocation of schools in Ethiopian urban areas is mostly based on the population index, with little thought given to spatial accessibility and distribution patterns, which have an important implication for equitable service provision. There is a greater need for more schools as the population expands. Given the expense and challenges for both the initial implementation and any necessary future revisions, choosing the optimum site for a new school location is a difficult decision. This study aims to analyze the spatial distribution and accessibility of existing secondary schools in Adama City as of 2022 and to identify suitable sites for new secondary school development. The locations of secondary schools in the study area were spatially mapped. Location quotient and nearest neighbor analysis (NNA) were used to analyze the spatial concentration and spatial distribution pattern of the schools, respectively. The level of accessibility was assessed using the service area, which was calculated using the city's population density and road network distance. Through a literature study and expert interview, physical, environmental, and socioeconomic criteria for secondary school placement were identified. The suitability of the factors was standardized based on suitability rankings. An Analytical Hierarchy Process (AHP) was employed to determine the relative importance of each factor. Suitable sites were identified through weighted spatial overlay analysis in a GIS environment. The findings show that there is inequality of service provision between neighboring parts of the city, and the overall spatial distribution of the schools is found to be uneven and exhibits a clustered pattern. In addition 6.5% of the population is expected to travel more distances than the standard set to access secondary schools. Moreover, the results reveal that 3% and 17% of the study area are identified as highly suitable and moderately suitable for secondary school development, respectively. The study would support the planning of service provision, and it would also assist in formulating effective policies for the context. It would also give planners and stakeholders vital information regarding appropriate sites for the development of new secondary schools in the future in Adama City.*

**Keywords:** Adama city AHP MCDA Geospatial technology spatial accessibility spatial distribution secondary school

# CHAPTER ONE: INTRODUCTION

## 1.1 Background of Study

Urbanization is a worldwide phenomenon that emphasizes the process physical expansion of urban areas (Ibido, 2020). It is mainly the process by which towns and cities are formed and become larger gradually as more people begin living and working in cities (Satterthwaite et.al. 2015). Urbanization is a global phenomenon that manifests rapidly increasing population.

The world has experienced tremendous urbanization and population growth. According to United Nations report (United Nations, 2019), the world's population is expected to increase by 2 billion persons in the next 28 years, from 7.7 billion currently to 9.7 billion in 2050. In recent decades cities around the world including in developing countries have been facing rapid urbanization and expansion of cities (UNDESA, 2015). Sub-Saharan Africa will account for most of the growth of the world's population over the coming decades (World Population Prospects, 2019).

Ethiopia is the second most populous country in Africa with 107 million inhabitants (United Nations, 2017). According to the National Report on Housing & Sustainable Urban Development, Ethiopia is one of the least urbanized countries in Sub-Saharan Africa. Currently, 20 percent of the total population lives in urban areas (MoUDC, 2014). However, the country has one of the highest rates of urbanization even by the standards of developing countries, which is estimated at 4.1 percent (MoUDC, 2014).

Urbanization results from the fast increase of people moving from rural to urban. The increase urban population creates changes into different social, economic, and environmental such as unplanned sprawl, inadequate housing facilities, and lack of public utility service ((Liu, Yang and Chen, 2020). This implies that, when the urban population rapidly increased, the demand of the community for social services also increased. They mainly include education, health care, water supply and a variety of cultural and recreational services. In particular, education plays an important role in the life of every citizen and the nation at large (Burtch, 2006) referred to it as a major force in economic, intellectual, social and cultural empowerment. However, the performance of schools in particular area depends on the availability of service, the number of population it serves, the location distribution of the services, socio-economic characteristics etc (Chukwuemeka, 2013;Naidoo et al., 2014). For instance, poor service availability makes it

difficult for users to access the facility. Sometimes even a facility's level of service decreases due to the overwhelming number of people it must serve. This subpar performance could have an impact on the resident's quality of life. One of the elements that can be included in Ethiopia's urban planning tools is the establishment of schools. According to the urban planning and implementation manual (MUDEC, 2012), schools should be located based on the population index and the maximum travel distance (catchment area radius).

However, due to limited effectiveness of plan implementation, urban development in the case of Ethiopia urban centers is rarely meeting this standard. Moreover, developers of private schools in particular, in Adama city are mainly market-oriented and focus on an area where they can attract relatively residents with better income. This can affect spatial distribution of schools in the city that leads to unbalanced service provision between neighboring areas such as Kebeles and expectation for equal distributions of educational infrastructure is a major challenge (Adebola, 2011). Apparently, residents in the urban periphery have low level of accessibility to educational facilities. In order to balance services in the long term urban social service (school) planning, assessing the level of existing school services provision and accessibility is a useful approach to select suitable site for future school development.

Schools site selection is an essential process which needs knowledge of different fields. The process involves scientific justification, judgment and a finding of suitable land, which consider financial, social, ecological and political perspectives, that limit conflicts and supports agreement among the decision makers. Lack of scientific analysis may negatively impact on the economy, health, and safety of the public. One of the factors that ensure a good quality in education is a systematic plan developed and well equipped school site. This factor has proven to be an important indicator in students' achievement (Bukhari et al., 2010). Planners and decision makers need to consider many factors such as size, access/traffic, utilities, shape, security/safety, costs, locations, noise levels, topography/drainage and soil conditions/plant life (Alaska Department of Education, 1997; Public Schools of North Carolina, 1998).

Today, with the advancement of geospatial technology, site selection and land suitability become an uncomplicated assignment for planners. Land Suitability Analysis refers to a procedure or tool used for the identification of the most spatially appropriate pattern for locating current and future specific land uses (Collins et al., 2001). Therefore, LSA is a

function of specific requirements, preferences, or predictors of a defined activity (Malczewski, 2006). Land suitability analysis is a GIS-based process applied to determine the suitability of a specific area for considered use, i.e., it reveals the suitability of an area regarding its intrinsic characteristics /suitable or unsuitable(Jafari and Zaredar, 2010). This analysis involved considering wide ranges of criteria including accessibility, environmental, physical, and socio-economic factors. Thus, suitability analysis is the process to determine whether the land resource is suitable for some specific uses and determine its suitability level.

Land Suitability Analysis (LSA) is vital in school planning as it gives room for choosing the most suitable site from among various alternatives (Sahabo and Mohammed, 2016). Multi-criteria analysis (MCA) approach that is integrated with the Geographical Information System (GIS) has been increasingly used for suitable site selection (Jayaweera, 2014) .

Geographic Information System and Remote Sensing are now providing new tools for advanced ecosystem management. It is noted, that there have been wide studies carried out on the land suitability analysis using the GIS-based multi-criteria analysis (MCA) procedures for land development. Analytic Hierarchy Process (AHP) has been widely used as a multi-criteria analysis process (Saaty, 1987; Saaty, 2003) and MCA is also one of the most viable methods addressed in many studies on the land suitability analysis through GIS(Youssef, Pradhan and Tarabees, 2011).According to (Mohit, Mohammad Abdul and Ali, 2006) GIS-based land suitability analysis techniques are useful for decision makers, engineers and planners to provide a framework for land development.

The method MCA approach that is integrated with the GIS can be used to solve large-scale geographic issues such as land use suitability, site selection, and resource evaluation. It can usually provide limitless possibilities for land use planning and management problems(‘Dadfar’, 2014.; Daneshvar et al., 2017; Muskut, Mshelia and Jerry, 2015) .In order to specifically analyze the characteristics of school site and possible suitable sites for schools in developed countries, studies were conducted (Rezayee, 2020;sohel rana *et al.*, 2019; Murad, Dalhat and Naji, 2020; Carolina, 2017; Jain and Subbaiah, 2007;Ababa, 2014; Sarath, Saran and Ramana, 2018;Shemsu D., 2018;Ali, 2014; KENATE, 2017;Zhou and Wu, 2012).

In Ethiopia, there were some studies conducted on school site selection using GIS and RS (Getachew, 2019; Ayele, 2018; Firomsa Mengistu, 2021). However, these studies conducted directly to site suitability analysis did not give attention to existing schools. Besides, there were no studies conducted in the study area related site suitability analysis. Therefore, this study aimed to fill the existing research gap by using geospatial technology and applying GIS-based multicriteria analysis method to examine spatial distribution, identify accessibility level of existing secondary school and identify suitable sites for secondary school in Adama city.

## **1.2 Statement of the Problem**

Access to education at all levels aids in giving people the potential to overcome development restraining factors. Inequality in service delivery across adjacent communities worsens inhabitants' lack of physical access to educational institutions, which has an impact on their quality of life. So understanding the distribution and accessibility of the amenities at the current level is crucial to solving the issue.

Numerous case studies have been conducted to assess the distribution and accessibility of urban public facilities, such as health centers (Wendweson, 2018; Dejen, Soni and Semaw, 2019) and urban infrastructures, including green areas (Hopkins and Knaap, 2019; Yrgalem, 2021). However, evaluating the distribution and accessibility of educational services in Ethiopia urban centers is uncommon, although there is an example to the contrary (Bulti et al., 2018). The extent of the spatial distribution and accessibility of the secondary schools to residents, particularly in Adama, is yet unclear. The uneven distribution and inaccessibility of schools could have an impact on the delivery of services, which would have an impact on educational performance and national development. Moreover, decision for locating new secondary school requires information through systematic analysis of various criteria. Addressing these issues will have practical benefits for Adama City in developing effective strategies to mitigate the impacts. Moreover, it contributes to understanding of the level of services delivery, as well as potentially informs future policy objectives.

The location of a number of secondary schools in Adama city is around the city center. This shows lack of geographical distribution of schools. This means the large number of population at the corner of the city is not found the school service near to their residence.

Therefore, the city need additional schools to satisfy future population demands for educational access and to meet the national standard for minimum pupil section ratios in order to increase educational excellence (CGAAEB, 2018).These necessitate the need for suitability analysis for secondary school using geospatial technology.

### **1.3 Objectives of the Study**

#### **1.3.1 General objective**

To analyze the spatial distribution and accessibility of existing secondary schools in Adama City and to identify suitable site for new secondary school development based on AHP-MCDA.

#### **1.3.2 Specific objective**

This paper has the following type of specific objectives:

- To determine spatial concentration of the secondary schools in the study area
- To examine distribution pattern of the secondary schools in the study area
- To analyze the spatial accessibility level of the secondary schools to the residents
- To identify suitability map of the main determinant factors for secondary school development in study area
- To determine suitable sites for locating new secondary schools in the study area

### **1.4 Research Question**

The conducted research attempted to answer the following questions.

1. What is the level of concentration of existing secondary schools in the city?
2. How could the existing spatial pattern of the secondary school be determined?
3. To what extent those secondary schools in adama city are accessibility?
4. How to prepare suitability map of the main identified factors for secondary school development in study area?
5. Which sites are more suitable for the development of secondary schools in study area?

### **1.5 Significance of the Study**

The main significance of this study will be to show the level of educational service provision in Adama City, and more specifically, the spatial distribution and accessibility of secondary schools, as well as to choose suitable location for the future development of

secondary schools. This can increase awareness about the delivery of social services in the context of sustainable urban development. It can also help planners in identifying service differences that could have a negative impact on municipal citizens. Moreover, it serves as a monitoring tool to direct the demand for the services, to change course in response to new information, or to plan a new course before negative impacts become irreversible. A deeper understanding of the key elements influencing the distribution and accessibility of services in Adama City specifically is also provided by the study, which could also be an example for other urban areas across the country.

The government can design sustainable spatial policies and the direction of spatial development with respect to sustainable socio-economic demands and reduce disparities in accessibility of services by understanding why imbalanced developments happen in unexpected locations. Most importantly, adaptive approach and techniques used in this study provide a basis for monitoring, evaluation and suitable site selection of other all school in other urban centers in the region and country as well. Finally, it can launch additional investigations into problems related to the delivery of sustainable urban services in Adama City and the nation.

## **1.6 Scope of the Study**

The spatial scope of this study was limited to Oromia Regional State, Adama city Administration. Whereas, the contextual scope was to evaluate the spatial distribution, accessibility existing school and suitability analysis for secondary school site development using geospatial technology.

## **1.7 Limitation of the Study**

The researcher has been met different obstructing problems that faced when collecting data and visiting sites. Some schools have no access road for the vehicle. One of the primary limitations was the difficult to obtain high-resolution satellite images for accurate and precise mapping and classification of LULC maps in the study area. Landsat imageries were used for LULC analysis, Landsat imageries were of 10 m resolution which are not high resolution and incurred some LULC classification errors that were indicated in error matrixes of accuracy assessment. Another limitation was that parameters or criterion of secondary school development were set by analyzing different literature and prior knowledge of the research area instead of common standards.

## **1.8 Organization of the Thesis**

This thesis is organized into five chapters. The first chapter is the introduction part, which includes background of the study, statement of the problem, objectives of the study, research questions, and significance of the study, scope of the study and limitations of the study. The second chapter highlights a review of literature that consists of both research related review literature and conceptual review literature. The third chapter gives a description of the study area and methodology of the study. The fourth chapter talks about data analysis, results and discussion of the study. The final part presents the conclusion and recommendations.

## CHAPTER TWO: LITERATURE REVIEW

This study focuses on determining the best location for a secondary school and how existing secondary schools are distributed throughout the city. The purpose of this literature review is to present past studies on the issue to serve as the foundation for the study's arguments and assertions. Following a thorough and in-depth search by the researchers, this section presents the associated literature and studies. Various perspectives on the subject from past researchers are offered and discussed. The theoretical and conceptual framework was built based on the aims and statement of problem presented in chapter one in this chapter.

### 2.1 Theoretical Reviews

#### 2.1.1 Spatial Location of Urban Facilities

Urban public facilities are crucial resources that enhance all-round development of man and his environs. Especially, educational infrastructure is an important aspect of infrastructures that needs to be earnestly developed in the society. Education is an important part of public facilities since it provides services to the people and also impacts on individuals who do not have access to its use in the area. The selection of the location of each service depends on the specific nature and characteristic of service; the catchments area for which the service is provided; the location area of the users /served population; the availability of appropriate area of land/site (topography, area). In Ethiopia, locational standards (table 1) for urban infrastructure provision have been set in Urban Planning and Implementation Manual to guide planning process.

Table 2.1: level, requirement and location of educational service (source: UPIM, 2012)

<b>Level of education</b>	<b>Space requirement*</b>	<b>Radius of Catchment area</b>	<b>Served population</b>
Secondary Education	2.5-6 ha	3-5km	10,000- 15,000

#### 2.1.2 Spatial concentration of urban facilities

The concept of spatial concentration is used to measure the extent to which the public facilities in different parts of urban areas are in balance (Jahan & Oda, 2005). It takes population distribution in to consideration and computed value of location quotient LQ ratio. The location quotient is a device for comparing a percentage share of a particular

facility within a part of the City with its percentage share of the total population. It helps to quantify and benchmark the degree of relative concentration of an activity in the analysis of area localization. The values of the result of spatial concentration can be categorized into above average, average, and below average. This concept has been used in different studies. For instance, in spatial analysis of urban amenities to evaluate distribution of public facilities as a tool for measuring progress towards sustainable neighborhood environments (Karol & Brunner, 2009).

### **2.1.3 Spatial accessibility of urban facilities**

#### **Concept of accessibility**

Accessibility is a concept that has taken variety of meanings in different fields of study. It is an “explanatory factor” used to support formulation, or to increase understanding on the performance of policy instruments in these fields. In transportation, for example (Litman, 2003) defined accessibility as an ease of reaching the opportunities (goods, services, activities and facilities) in a given destination. Also (Baradaran & Ramjerdi 2001) defined accessibility as “a state of connectivity”. In the field of geography and urban economics, accessibility refers to the relative ease of reaching a particular location or area. In social planning, accessibility refers to people’s satisfactions and behaviors. Moreover, it is concerned with the local societies’ attitude and focuses on psychological points of view. Accessibility, also, refers to people’s ability to use services and opportunities (Litman, 2007). Accessibility can be interpreted as the amount of effort for a person to reach a destination or the number of activities which can be reached from a certain location (K.T. Geurs & J.R. Ritsema Van Eck, 2001). These all demonstrate that the concept of accessibility varies depending on its aims and the scientific field that it comes from. However, in general term, a particular location can be defined, as accessible if the effort it takes to get there is acceptable to the target group. So, the concept of accessibility incorporates not only the transport link between origin and destination and the ability for travelling by the target group, but also characteristics of the destination and the objective of the trip. Despite the fact that accessibility has disparate differences in its operational formulation and theoretical basis, its concept has played an important role in spatial analysis of the urban environment. Spatial accessibility to social infrastructure broadly refers to the ease with which residents of a given location can reach social infrastructure. Its role includes helping understanding of the complex urban system of land value, household location choice, population density, land-use patterns, social exclusion, urban

growth, and intensity of economic and social development. Therefore, accessibility can show the potential of sustainability and a dimension of the quality of life.

### **Accessibility measures**

Accessibility indicators give different values that rank accessibility to facilities from high accessibility to inaccessibility. They can also be used to classify facilities in term of their peripherally and centrality locations (Schurmann & Talaat, 2002). As there is no agreement about the concept of accessibility, measuring accessibility differs from study to another depending on its aims and the nature of factors that are used to measure accessibility, which might be quantitative or qualitative factors. These factors can be time or distance of travel, available transport modes, people characteristics, activities characteristics, etc. As a result of this disparity in the causes of measurement of accessibility, a number of accessibility measures have been appeared in the different disciplines. For this reason (Geurs & Ritsema van Eck, 2001) has categorized accessibility measures into three groups: infrastructure-based accessibility measures, utility-based accessibility measures, and activity-based accessibility measures. Infrastructure-based accessibility usually used in transport studies and infrastructure planning, such as analyzing the performance of transport infrastructure such as travel speed, journey time and congestion. This category does not concern the spatial or land use components; therefore, it considers traffic or transportation measures. Utility-based accessibility measures analyze the benefits individual derive from the land use-transport system. It measures based on the random utility theory. This measure represents evaluation for accessibility by the persons. Therefore, it is based on the assumption that persons choose activity that gives them high value of utilization compared to other valuable activities (Marki & Flokesson 1999). This measure is often used in economic studies, especially, for cost-benefit analysis. Activity-based accessibility measures take in account land-use components as well as people, transport and activities and are used to analyze the range of available opportunities with respect to their distribution in space and travel impedance between origins and destinations. Hence, Activity based accessibility measure is best suited to this study as it deals with people's access to reach the social facilities from their origin and spatial distribution of the services. From this perspective, four interdependent components determining accessibility can be identified. They are transport component, land use component, temporal component and individual component. Transport component reflects the travel time, cost and effort to travel between origin and destination location. Land use

component reflects the spatial distribution of activities at destinations (e.g. jobs, schools, shops) and the demand for those activities (e.g. workers, pupils, inhabitants). Temporal component reflects the time restrictions of individual and availability of activities at different times of the day. Individual component reflects the needs, abilities and opportunities of individuals. This argument demonstrates that accessibility can illustrate the spatial relationship between the people's demand of social infrastructures and the availability of activities, in this case schools. Activity-based accessibility measurement is best suited to this study as it deals with people's access to reach the social facilities from their origin and spatial distribution of the services.

### **Measuring spatial accessibility**

Activity-based accessibility considers cumulative opportunities measures, gravity models or potential measures, person based accessibility measures, and distance measures. All these measures have their own limitations. For instance, potential measures neglect the spatial behavior of persons; person-based measure determines the accessibility of each person, so it needs large amount of data to measure accessibility, it is difficult to use this measure at the higher level and often used at small areas. The contour measure (also called a proximity count, proximity distance, cumulative opportunities, isochronic measure) indicates the total number of destinations reachable within a given travel time or distance. This measure emphasizes the number of potential destinations or opportunities rather than their distance. In cumulative opportunity measure the cut-off value is determined arbitrarily to define the accessibility to opportunities, which leads to biased results. Distance measures are relatively simple to calculate and interpret; requires small amount of data; used as average distance, weighted area distance or distance to the closest activity using road network distance measurement. On top of this, they assume all persons have equal access to activities. Hence, it is best suited for this study. For the distance measures, it calculates straight line distances. This cannot give an accurate description of the reality. However, if the distance calculated is network distance, this can represent travel path of people in reality. For the contour measures, the choice of a cut-off travel distance (or time) is very crucial. The result of analysis, in terms of accessibility levels, can be highly sensitive to this cut-off value. But the measures do not incorporate an impedance function to weigh opportunities according to their travel time or cost. For composite measures, a parameter value for the travel impedance function must be selected or estimated using recent empirical data of spatial travel behavior in the study area, and the

measures are based on aggregate travel patterns. Actually, a contour measure is a specific form of the gravity-based measure, with the impedance function equal to one if the opportunity is within the travel time limit, and zero otherwise. These measures have their own benefits and shortage in terms of analytical capability and the data requirement. The choice of the most suitable measure to be used in the study depends upon the objective of research, data availability and time available to conduct the research (Parry et. al, 2013).

#### **2.1.4 Suitability analysis**

Suitability analysis, or site selection, is a GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of suitability analysis is that each aspect of the landscape has intrinsic characteristics that are in some degree either suitable or unsuitable for the activities being planned. Suitability is determined through systematic, multi-factor analysis of the different aspect of the terrain. Suitability analysis can be performed using either vector or raster data, but is often performed using the latter. Different data layers are created which correlate to various physical, cultural, or economic factors that would be important for site selection analysis. The results are often displayed on a map that is used to highlight areas from high to low suitability (*Hofstee and brussel, 2019*).

#### **Site Selection process**

Site selection requires consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for a defined land use. The selection of school sites involves a complex array of critical factors drawing from physical, demographical, economic, policies and environmental disciplines. The current spatial decision making could benefit from more systematic methods for handling multi criteria problems while considering the physical suitability conditions. Traditional decision support techniques like the ability to simultaneously take into account these aspects. The process of school site selection begins with the recognition of an existing or projected need. This recognition triggers a series of actions that starts with the identification of geographical areas of interest. In the past, site selection was based on almost purely on economic and technical criteria. Today, a higher degree of sophisticated is expected. Selection criteria must also satisfy a number of physical, social and environmental requirements, which are enforced by legislations and government regulations(Moussa, mostafa and Elwafa, 2017).

### **2.1.5 Suitable Site Selection Analysis Importance**

Site selection has a vital role in human activities. It is a key factor associated with capital expenditure, resources management and development plan (Zhou and Wu, 2012). Locating a suitable site for facilities need to consider various criteria that have to be evaluated relative to their importance, to prevent considerable environmental impact and concerning accessibility and fair distribution of the available resource for the society (Abazari et al., 2012; Elsheikh, 2017). One major issue in early (Mokarram and Aminzadeh, 2010) research, describe land assessment is performed to evaluate the land property for specific purposes to maximise benefit and minimise the loss in the environment, such as a suitable site for farmlands, new schools, hospitals, hotels, and waste disposals. Thus, the land planners and developers used the assessed land as preliminary input for their projects (Beskese et al., 2015). Many research studies reveal that unscientific and poor site selection approach leads to failure on the development of the project and cause challenges related to transportation access, heavy traffic, and high travelling cost in most cities (Bukhari et al., 2010; Jayaweera, 2014). In (Ebistu and Minale, 2013) the author examined that an inappropriate place for waste disposal sites manifested a cause for soil contamination, water, and air pollution.(Jayaweera 2016) Described educational facilities accessibility for the public is the crucial component on a country's development, socio-economic and lifestyle. ( Unesco, 2021)This study identified a decreasing trend in students' enrollment over the years due to accessibility issues and parents forced to admit their children on a limited number of schools with excellent services. (Muskut et al., 2015) Demonstrate that school locations should be appropriate and serve uniformly for the community. Overpopulated in the classroom, poor academic result, long walking distance, expose for a contaminated area and serve only for the specific group are the major problem on school locations. Another research paper (Bukhari et al., 2010) highlighted that one of the measurement scales for quality education is a well-structured plan and assessable schools facilities. The process of school site selection passes several levels and associate with different departments. Hence, this multi-step process led to the selection process to delay and caused to allocate the school sites in contaminated places. Therefore the selection of school location is a vital process which needs careful planning using socio-economic and geographical data for the right decision to assuring student's academic achievement and sustainable development.

### **2.1.6 School Facility Site Selection and Development**

The school is an integral and inseparable part of a neighborhood or community. The selection and development of an appropriate school site should first consider local education agency (LEA) population projections and potential school growth scenarios, then proceed with coordination efforts between the LEA and the local municipality and/or county, the local health department, the Utah Department of Transportation, and local utility providers such as Rocky Mountain Power, Questar Gas, and Century Link (Document, 2012). Other site considerations should include complete geologic hazards and soils report, as well as a Level One Environmental Impact Statement for potential sites [U.S. Environmental Protection Agency; Utah Department of Environmental Quality; Utah Geological Survey]. A properly located and developed school site can be an aesthetic, functional asset to a community for a great number of years. The purpose of this section is to stimulate the best possible selection of school sites in view of present and future LEA needs(UTAH state office of education,2013).

#### **A.Long-Term Planning**

As the population of the state continues to grow, the need for educational services and facilities generally also increases in proportion. Some LEAs in Utah are experiencing accelerated growth spurts, others have regular steady growth, and a few are experiencing a slight decline. Three basic problems are sometimes accentuated in areas of high growth: (1) the competition for acquisition of undeveloped land increases; (2) capital outlay for new service facilities may cause an increase in capital outlay, voted capital and/or debt service property tax rates for school districts; and (3) the initial costs to open and operate new schools for the first one to three years can strain a school district or charter school's maintenance and operations budget. These three problems provide an incentive for proper long-term planning that involves the school district or charter school, municipal, county, utility and transportation planners of school sites, facilities and services.

#### **B.Size and Location**

Although increasing rapidly in cost, land is still one of the least expensive education resources provided for schools. The quantity of land needed for a school facility will vary according to specific local needs, such as the number and ages of pupils, the type of building to be constructed, and the multiple uses of the site for such things as community recreational functions. The size of a school site also depends on the shape, contour, general suitability, and availability of land in the area where the building is to be located. If

transportation is readily available, the size of a site is more important than location. Inadequate site size is a major factor in the obsolescence of educational facilities. The State Office of Education suggests the following site sizes for the various grade levels shown: • K-6 school—10 acres plus one acre for each 100 students • Middle school—20 acres plus one acre for each 100 students • Junior high school—20 acres plus one acre for each 100 students • Senior high school—30 acres plus one acre for each 100 students • Combined 7-12 high school—30 acres plus one acre for each 100 students.

### **C. General Soil Conditions**

Geodetic and soil survey maps are available from county offices and the State Geological Survey to determine such things as seismic conditions and ratings, land contours, drainage, and other soil conditions and ratings. The topography of the site should permit the drainage of surface waters from the grounds without creating a nuisance during inclement weather, thawing periods, lawn sprinkling, or irrigation. The school site must not be located in an area where there is a history or high possibility of flooding, high ground water, or snow or earth slides, or directly on an earthquake fault, or an area that was a repository for hazardous substances. Test pits should be dug to determine the general characteristics of the soil table and drainage of a potential school site before it is purchased by the school district or charter school. The subsoil must be a type that will provide a proper base for building foundations. Surface soils should be the kind that will make play field preparation and maintenance economical and efficient.

### **D. Site and Surroundings**

Maps and aerial photographs should be used to gain a better understanding of the relationship of the sites being considered to the surrounding environments. Aerial photographs may show, for example, that a potential school site is safely accessible to children. The school district or charter school may also consider investing in a Level One Environmental Impact Statement, which provides decision-makers with a comprehensive report regarding the prior uses of the land and surrounding areas. Municipal and county planning officials must be consulted to review their recommendations for school site locations which best match municipal and county land use, planning and zoning ordinances, as well as enhance community recreation facilities and services. A school site which is developed in close cooperation with community officials can be an excellent asset for multiple uses. Development of a community park center in conjunction with a school plant is one of the most economical means of accomplishing such a task. These types of

developments can range from limited use by neighboring children to large athletic centers and park facilities.

### **E. Hazards**

Hazardous conditions and installations in the vicinity of, or as part of, school sites must be avoided. Dangerous physical hazards exist in many forms, including junkyards, ponds, sewer plants, canals, railroads, freeways, and highways, as well as electric or natural gas substations. Potentially dangerous conditions like these naturally attract children because of their curiosity. Airfields, fire stations, stores, taverns, sexually oriented businesses, mills, factories and other industrial areas sometimes become undesirable distractions or serious menaces to the safety and well-being of children. Dangerous highway conditions, such as high traffic density, high vehicle speed, oversize or large vehicles, poor visibility of pedestrians by drivers or poor visibility of vehicles by pedestrians, steep topography, and poor access to the roadway and high pedestrian traffic should be considered very carefully when site selection is in process.

### **F. Health and Safety**

The potential school site should be located where safe and healthful conditions exist for the building occupants. It is best to avoid sites that are subject to sources of odors, dust, disturbing noise, and other types of air and sound pollution. The water supply must be of adequate volume and pressure and of a safe, sanitary quality and must comply with the requirements of the state Safe Drinking Water Act and Administrative Rules. Municipal water and sewage connections are the most desirable for a school. Where on-site water supplies or sewage disposal systems are used, health and environmental codes must be strictly followed. Plans and specifications for such water systems must meet state safe drinking water standards and must be submitted to and approved by the State Department of Environmental Quality prior to construction. All newly installed or modified existing on-site sewage disposal systems must submit plans to the local health officer having jurisdiction for review and approval prior to construction or modification.

#### **2.1.7 GIS-based Multicriteria Decision Analysis**

Multicriteria decision analysis (MCDA) is a group of techniques for structuring and evaluating decision alternatives based on multiple attributes and objectives (Voogd, 1983). MCDA approaches have capability to integrate numerous notions of decision problems. They enhance communication and expedite the process reaching concurrence and

determining the most suitable options (Boroushaki and Malczewski, 2006). Geographic information systems (GIS) furnish various potent tools for the decision-makers to capture, manipulate, analyze, and manage spatial information. GIS are applied to determine suitable areas for land development. Two decades ago, the functionality of GIS was essentially limited to utilizing (overlying) existing digital map data to define areas which may concurrently meet the requirements of the determined criteria. Overlays are an adequately suitable tool when dealing with suitably defined siting criteria but may pose limitations when dealing with information that is not deterministic (Carver, 2015).

The integration of multicriteria decision analysis techniques with GIS is a procedure which transforms and combines geographical data and value judgments (the decision-maker's preferences) to evaluate a set of alternatives with respect to relevant criteria (Malczewski, 1999). This method combines all important spatial criteria, and illustrates the most suitable location for a certain land use on a map. It has been argued that GIS-based multicriteria decision analysis can potentially increase collaboration among stakeholders in the decision-making process by providing flexibility that may be used for analysis, comprehension and reevaluation of a decision problem (Boroushaki and Malczewski, 2011).

### **Classification of Multi Criteria Decision Making Problem (MCDM)**

Multi Criteria Decision Making (MCDM) problems are classified based on character of the alternatives; either discrete or constant (Liou and Tzeng, 2012; Mulliner et al., 2016).

1. Discrete: - which contain defined attribute and alternative, those are Multi Attribute Decision Making (MADM).
2. Continuous: - which consist of an infinite number of alternatives, this is Multi-Objective Decision Making (MODM).

In MADM problems contain a finite number of alternatives, apparently known in the start of the solution procedure, and used for taking care of issues which require selection from a defined set of alternatives (Zavadskas et al., 2014., Montis *et al.*, 2001).

In Multi-Objective Decision Making (MODM) the alternatives are not known and can be found by resolving a mathematical model. The quantity of alternatives is either infinite or not countable (Antucheviciene et al., 2011; De Montis et al., 2000; Majumder, 2015; Pohekar and Ramachandran, 2004; Zavadskas and Turskis, 2011; Zavadskas et al., 2014).

One of the primary functions of MODM is to evaluate planning and design problems with various objectives and criteria (Liou and Tzeng, 2012)

### **2.1.8 Application of geographical system (GIS) for site suitability**

Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. The data type in GIS can be classified into two major groups as spatial and non-spatial data. The spatial data are the data that have location value and that non-spatial data are data, which describe more the spatial data in the form of a table. According to (Burrough, 1990) data in GIS is composed of three dimensions that mean spatial (geographic), time and attribute. Some people believe that a geographic information system is the system of hardware and software, which contributes to analyzing applications or information processing (Redmond, 2005). Geographic information system is not only a digital store of spatial objectives (areas, points and lines) but also capable of spatial analysis based on the relation between these objects, including the relationship between objects defined by their location and geometry. According to (Foresman, 2001), the combination of computer technology and cartography in the 1960s paved the way for the possibility of using techniques of superimposing and overlaying maps in fields other than cartography. GIS is a digital database management system designed to manage large volumes of spatially distributed data from a variety of sources (Mandal *et al.*, 2021). It is ideal for preliminary site selection studies because it efficiently stores, retrieves, analyzes and displays information according to user defined specifications. Once a GIS database is developed it can provide an efficient and cost-effective means of analyzing potential green space site attributes.

### **2.1.9 Analytic Hierarchy Process (AHP)**

Analytic Hierarchy Process (AHP) was introduced by Thomas (Saaty, 1987). AHP has been used as an effective tool for dealing with the complex decision-making process and aids the decision makers to set priorities to make better decisions through reducing the complex decision to series of pairwise comparison and then producing the results. Though AHP is a conventional land suitability analysis technique and that provides the right decision-making use extensively for site selection process. In a parallel way, AHP has integrated with GIS for land suitability modeling (Malczewski, 2006).

AHP helps to capture a mutually subjective and objective aspect of the decision and also for checking the consistency of the decision maker's evaluations, consequently reducing

the bias in the decision-making method (Saaty, 1980; Malczewski, 2006). This study describes the integration of GIS, MCDA and AHP methods that are based on scientific and author judgment to determine the land suitability analysis for urban green space development in Adama city.

### **2.1.10 Weighting Methods for Multi-Criteria Decision Making Technique**

#### **The point allocation method**

This is one of the simplest methods used to determine criteria weights according to the priority of criteria; a decision-maker allocates a certain number of points to each criterion. The more points a criterion receives, the greater its relative importance (Golaszewski et al., 2012). In this scenario, the decision maker is asked to allocate 100 points across the criteria under consideration. The total of all criterion weights must sum up to 100. This method is easy to normalize. However, the weights obtained from the use of point allocation method are not very precise, and the method becomes more difficult as the number of criteria increases to 6 or more.

#### **The direct Rating method**

The direct rating method is a type of approach in which the decision maker first ranks all the criteria according to their importance. The rating does not constrain the decision maker's responses as the fixed point scoring methods does. It is possible to alter the importance of one criterion without adjusting the weight of another (Last, 2021, Arbel, 1989).

#### **Pairwise Comparison Method**

The pairwise comparison method established by (Satty ,1980) for determining factor weights in the Analytic Hierarchy Process (AHP). This method involves pairwise comparison to create a ratio matrix. It takes the pairwise comparisons as an input and produces the relative weights as output. The weights are determined by normalizing the eigenvector correlated with the maximum eigenvalue of the reciprocal ratio matrix (Malczewski 1999). The pairwise comparison method involves the three following steps:

1): Development of a pairwise comparison matrix

The method uses a scale with values range from 1-9 to rate the relative

References for two criteria (Table 2).

Source: Saaty (2003)

Table 2.2: Scale for Pairwise Comparison

Degree of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderately more important	Experience and judgment slightly favor one activity over another
5	Strongly more important	Experience and judgment strongly favor one activity over another
7	Very important	An activity is strongly favored and its importance demonstrated in practice
9	Very strongly more important	The evidence favoring one activity over another is of the highest possible order of affirmation

2): Computation of the criterion weights

The computation of weights involves three operations, first sum the values in each column of the matrix, then each element in the matrix should be divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix). Afterwards, computation of the average of the elements in each row of the normalized matrix should be made which includes dividing the sum of normalized scores for each row by the number of criteria. These averages provide an estimate of the relative weights of the criteria being compared.

3): Estimation of the consistency ratio

Estimating the consistency ratio helps determine if the comparisons are consistent or not. The process uses a several step process. First, 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 these values over the rows. Second, determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously. Third, compute lambda ( $\lambda$ ) which is the average value of the consistency vector and Consistency Index (CI) which provides a measure of departure from consistency and has the formula below:

$$CI = \frac{\lambda - n}{n - 1}$$

Finally, calculation of the consistency ratio (CR) which is defined as follows:

$$CR = \frac{CI}{RI}$$

### **Ranking method**

This is one of the simplest approaches to assign criteria weights. The criteria are usually ranked from best to worst importance. There are three approaches to calculate weights using the ranking method. They include rank sum, the rank exponent and rank reciprocal. In the rank sum, the weights are computed from the individual ranks normalized by dividing the sum of the ranks. The formula for rank sum determination can be expressed as (Odu, 2019;Raszkowska, 2013).

#### **2.1.11 Criteria for suitability analysis of school site**

##### **Proximity to the existing high school**

Proximity to the existing high school is the most important criterion in site selection for the new high school. In accordance with rational resource allocation, the new high school location should be at a suitable distance from the existing high school. Since the current high school covers the all part of the city.

##### **Population density**

Schools should be conveniently located for the student populations they serve; therefore the population distribution is an important criterion. Since it is essential that the new campus serve a specific target demographic, it should be closer to the residential areas with a higher population.

##### **Land Use**

It is very important to identify how to coordinate the site selection for the new high school with the city land use planning. Current and projected zoning and land use should be compatible with the use of the site for a school. Land parcels should be available at an affordable cost. The most favorable situation is one in which the intended parcel is public land and is made available at no cost to the district or donated by a private entity.

### **Proximity to major roads**

Another important factor in site selection is access to roads. The site shall not be adjacent to a road or freeway that any site-related traffic and sound level studies have determined will have safety problems or sound levels which adversely affect the educational program." However, we should not overlook the fact that the school should be located in an area that would minimize the commute time to the school for parents and students. Thus, access to a road of sufficient capacity is important.

### **Slope**

The overall slope of a site should be flat enough to allow for ease of construction, and yet be steep enough for proper site drainage. A flat terrain is the easiest and least expensive to build on. On the contrary, a rolling or sloping terrain is more difficult and more expensive for construction. By using the natural slope of the ground, the drainage and sewage disposal systems can be designed to result in lower construction and maintenance cost. As a rule, slopes of 0-10% are desirable and easy to build on (Albuquerque Public Schools, 2014, Of et al., 2016).

## **2.2 Review of Empirical Studies**

Different researchers were attempted to analyze school site selection development due to urban change and increase population index in both nationally and internationally in the previous years. These studies conducted that the low performance of analyze school site selection system in the analyzed areas is mainly related to lack of good understanding and poor site selection and roads integration.

(Bukhari, 2010) studied about Spatial multi-criteria decision analysis for public school site selection based on geographic information system (GIS) and multi-criteria evaluation model. One of the factors that ensure a good quality in education is a systematic plan developed and well equipped school site. A set of criteria was used to design a number of potential sites using a spatial analysis model. Mukim Batu which is located in Federal

Territory of Kuala Lumpur (WPKL) has been selected as the study area. The methodology that was developed and applied in this study has combined multi-criteria evaluation technique with GIS in supporting a school site selection problem. The final suitability model outputs were compared with field verification data and found to be reliable.

(Abera yared,2018) studied was designed to determine the optimal site for new schools construction in Addis Ababa using GIS integrated MCDA with Air pollution model input. Site selection is one of the interdisciplinary and indispensable choices in the start-up step; the procedure is a specific finding of advantageous land for the actual position and predetermined number of possible locales for a particular reason. The importance of this research is highly substantial because of the city's population growth and the need for additional schools. Most of the desirable area placed on the eastern part of the city, where there are no existing schools, and it is adjacent to residential places. In this research study, air pollution modeling was conducted using Landsat 8 satellite image to identify optimal school sites and considering a permissible PM10 value as per the standard. The result of air pollution modeling illustrates that even if most of the area PM10 concentration value is below  $50 \mu\text{g}/\text{m}^3$ , conversely, the most remainder area which is a nearby road network, airport, and industrial places are above  $100 \mu\text{g}/\text{m}^3$ . According to the United States Environmental Protection Agency, the values above  $100 \mu\text{g}/\text{m}^3$  are categorized as unhealthy for sensitive groups. Thus, proximity to roads, airports and industrial sites are essential criteria for school selection process to ensure pupil's health and comfort. Air pollution model integrated with GIS was useful to describe improved weight, unlike pre-decided values. In this study the use of MCDA, GIS, and remote sensing techniques with air pollution model input was successfully demonstrated for the site selection process.

(Ayel *et al.*, 2018) Studied about GIS Based Suitable Site Selection and Road-map Preparation for Equitable Distribution of Secondary Schools of Amhara Region, Ethiopia. The school site selection analysis is done by Multi-Criteria Analysis Method (MCAM) using Arc GIS software and GIS models. Three models: Restriction Model, Suitability Model and Integrated Suitable Sites Model were developed. First, Restriction Model was developed to identify areas excluded from suitability site analysis. Constraints or restrictions considered in this study includes: the area covered by roads, 150-meter noise level buffer along roads, 5-kilometer radius area around existing high schools, ecologically sensitive areas (parks and conservation areas), lakes and dams, and gorges of major rivers. Having Restriction Model results, Suitability Model was developed to identify suitable

areas for high school construction. The major criteria used were: number of students in each school and their spatial distribution, slope, access to road, power access, drinking water access and telecommunication access. Finally, the integrated suitable sites model was developed to combine the restricted areas and suitable areas. The combination gives the final suitable sites for construction of new high schools. The finding of high school suitability sites of Amhara Region indicated that 235,903.67ha (2.1%), 2,551,599.57ha (22.3%), 7,518,477.63ha (65.8), 1,127,206.72ha (9.9%) of the areas of the Region were least suitable, marginally suitable, moderately suitable and highly suitable respectively.

### **2.2.1 Research and knowledge gaps**

There were some studies conducted on school site using GIS and RS and these studies have focused on the Suitability Analysis for safe school site selection (Amir Jamal,2016; Bukhari,2010;shaker,2019),(Getachew, 2019; Narguess Akbary Dadfar2014; Firomsa Mengistu,2021),(Abdul-Nasir,2011),(Ayele, 2018;mustfa,2021). However, these studies conducted directly to site suitability analysis did not give attention to existing schools and they did not used up-to-date data from geospatial technology (such as Google earth) most of them used out-of-date data from municipality of respective city. Besides, there were no studies conducted in the study area related site suitability analysis. Therefore, this study aimed to fill the existing research gap by using geospatial technology and applying GIS-based multicriteria analysis method to examine spatial distribution, identify accessibility level of existing secondary school and identify suitable sites for future secondary school development in Adama city.

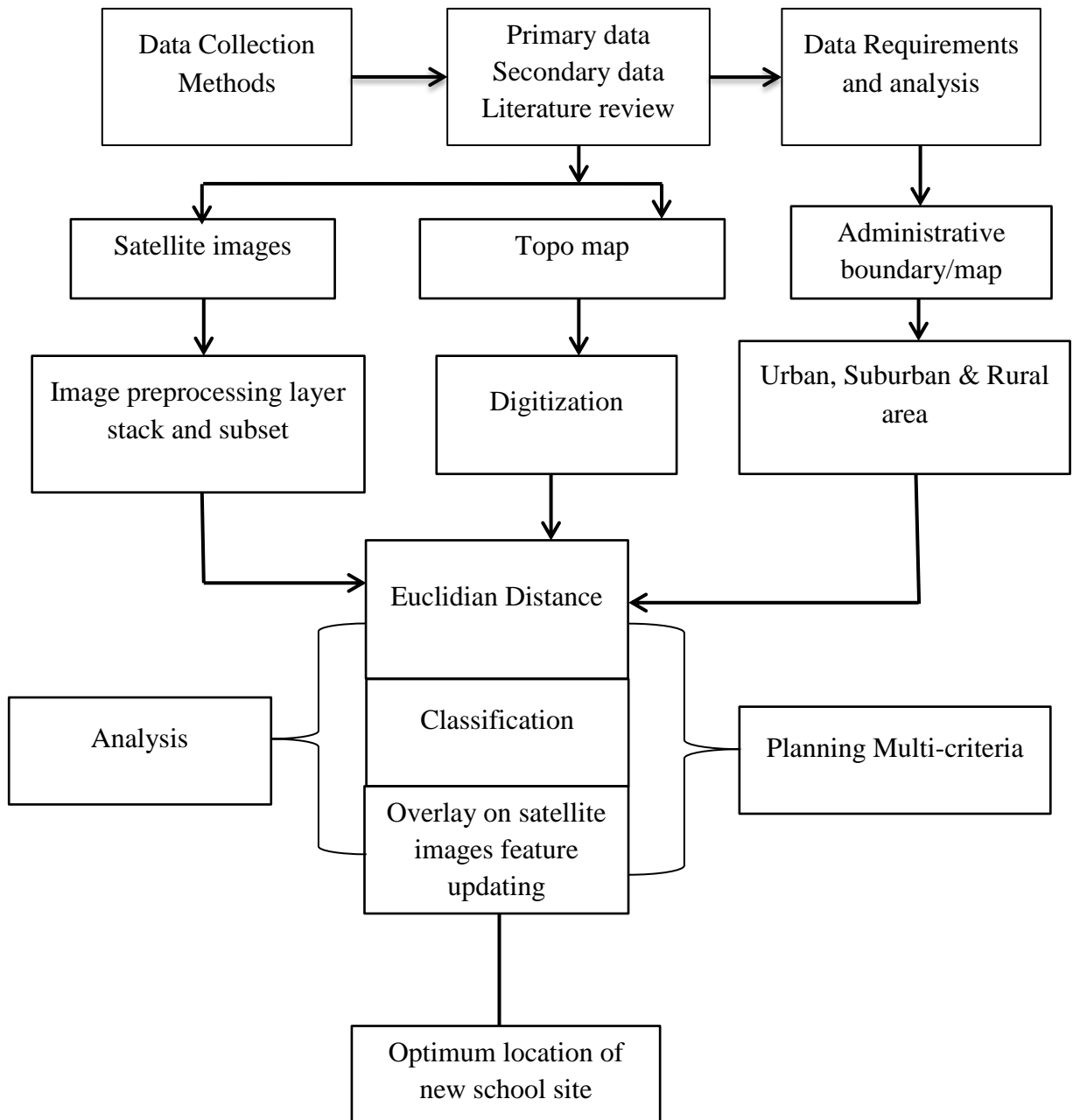


Figure 2.1: Conceptual frameworks Diagram From literature and by the Author

## CHAPTER THREE: MATERIALS AND METHODS

The chapter discusses the way the research is conducted from how literatures are reviewed to the final data discussion stage. The research design, data, description of study area, and research methods are the four primary issues covered in depth in this chapter. Brief image of the research design is presented through which the structural flow of the research can be understood. Data types used in the research and their sources, methods through which they are collected are clearly described. Finally the geospatial analysis methodology and techniques, which include optimal location analysis, service area analysis, and spatial analysis, on how to evaluate existing school sites and locate new secondary school sites.

### 3.1 Description of Study Area

#### 3.1.1 Location description

Geographically adama city is located in Oromia, Ethiopia, its geographical coordinates are lies between 33°35'N to 36°46'N latitude and 39° 11'57'E to 39° 21'15'E longitude covering an area extent of new proposed boundary about 3` 13.04 km<sup>2</sup> with an average altitude of 1620m above mean sea level.

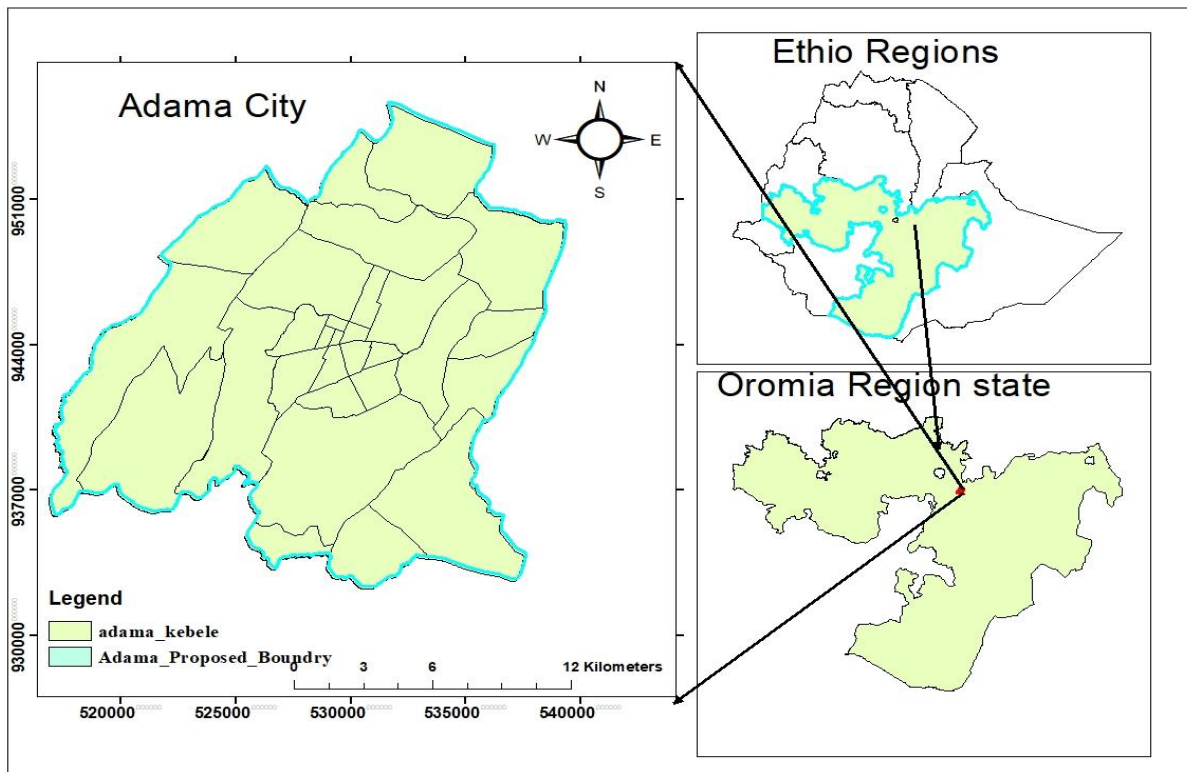


Figure 3.1: Location map of Study area

The city is located about 99 km along old road and 75 km along new road southeast of Addis Ababa. Adama lies in the great Ethiopian rift valley on a nodal location along the main national and regional transport lines from the capital city, Addis Ababa, to other important cities and towns like DireDawa, Harar, Semara, Jigjiga and to Djibouti. It is also situated close to natural recreational sites such as Sodare and Boku hot springs (Socio-economic profile of Adama, 2021).

### 3.1.2. Topography

The topography of an area like slope and elevation has an important contribution in selecting suitable sites for public secondary school site selection development. The topography of this area is characterized by flat land that is surrounded by ridges. The study area is particularly flat with slopes varying between 0 and 159% (Figure 3.2). According to the extracted elevation of the study area from DEM, the study area is located along an elevation range from 1443m -2055m (Figure3.2).

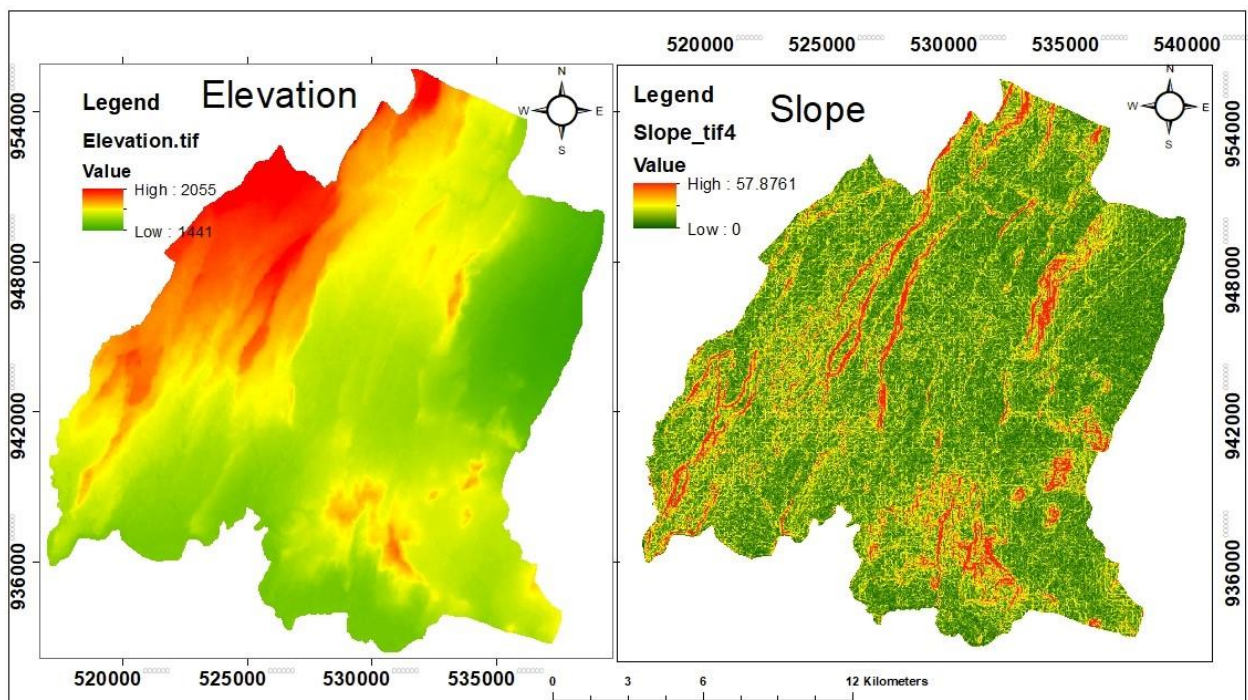


Figure 3.2: Elevation and Slope map of the study area

### 3.1.3 Climatic

The city enjoys favorable climatic conditions due to its geographical locations surrounded by plateaus that experiences moderate temperature and rainfall which is favorable for life. Rainfall mostly occurs in the summer season. It receives abundant and heavy rainfall every year during this season.

Table 3.1: Rain fall and temperature data of Adama (2005-2009 E.C)

Year	Cl. type	Months												Annual data
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2005	T RF (mm)	22	0	10.4	17.6	68.7	54.8	215	155.8	192.1	0	0	0	736.5
	M Max (°C)	27.3	29.4	31	31.2	31.2	30.4	26.1	26.3	27.99	28.1	27.5	26.4	28.6
	M Min (°C)	14.3	15.1	17.3	17.4	18.3	18.2	15.6	16.7	15.88	14.8	14.2	11.9	15.8
2006	T RF (mm)	4.4	0.2	69.2	35.1	36	38.9	443	105.2	132.8	34	5.2	0	904.2
	M Max (°C)	28.1	29.5	29.8	30.7	31.4	31.6	28.3	26.7	27.3	26.9	27.5	26.2	28.7
	M Min (°C)	13.9	16.4	16.7	17.4	17.3	18.1	17.1	16.5	16	14.7	15	13.3	16
2007	T RF (mm)	0	4.8	123	7.1	62.3	7.7	212	180	150.6	91.7	8.9	0	847.8
	M Max (°C)	27	30.5	31.3	31.5	30.7	30.5	29.5	27.9	28.9	29.9	28	26.9	29.4
	M Min (°C)	12.6	15.8	17.1	16.4	17.2	18.1	17.4	16.6	16.3	17.1	15.9	15.5	16.3
2008	TRF (mm)	0	0	11	3.6	180	74.9	131	207.9	78.6	2.3	47	1.5	738.5
	M Max (°C)	28.8	29.8	27.9	26.8	28	29.3	32.7	30.3	29.7	29.5	26.9	27	28.9
	M Min (°C)	16.3	17	15.8	15.5	15.6	15	18.9	17.7	17.3	17.4	16.5	16.9	16.6
2009	T RF (mm)	135	0.9	33.2	0	0	54.1	29.4	7.6	166.4	31.9	250	226	934.8
	M Max (°C)	28.3	29.4	27.9	26.6	27.9	28.8	31.5	30.2	28.97	31.6	27.5	26.7	28.79
	M Min (°C)	15.6	15.5	14.8	12.7	12	14.5	16.9	17.5	16.96	28.7	25.5	16.4	17.25

NB. Cl. Type=climate type, M Max= Monthly maximum temperature, M Min= Monthly minimum temperature, TRF= Monthly total Rainfall Source: (Socio-economic profile of Adama, 2021)

The above table reveals the trends of rainfall and temperature during the consecutive past five years. As can be observed from table 3 during the past five consecutive years the maximum average and minimum average annual temperature was 29.4o c and 15.8o c in the year 2014/15 and 2012/13 (2007 and 2005 E.C) respectively. Similarly, the maximum annual total and minimum annual total rainfall was 934.8 mm and 736.5 mm in the year 2016/17 and 2012/13(2009 and 2005 E.C) correspondingly (Socio-economic profile of Adama, 2021).

### 3.1.4. Population

According to the last three consecutive censuses conducted in the country, Adama city showed a large increase in population. In the first Ethiopian population and housing census, which was held in May 1984, Adama had a population of 77,237. The second population and housing census conducted in 1994 reported that Adama had a total population of 127,842 of whom 61,965 were males and 65,877 were females. According to the third Ethiopian population and housing census which was conducted in 2007 (the most recent year for which data are available), 220,212 people of whom 108,872 males and 111,341 females were inhabited in Adama. Based on this the projected population of Adama city including four subs urban Ganda's under the city administration in 2018/19 (2011 E.C) was 433,046 of whom male 216,046 and female 217,000 (Socio-economic profile of Adama, 2021).

Table 3.2: Population of Adama Town from 1984 to 2018/19(CSA, 2018/19)

Year	1984	1994	2007	2018/19 (projected)
Population	77,237	127,842	220,212	433,046
Increase	-	50,605	92,370	21,834

### Distribution of Population and Population Density

Adama is inhabited by 433,046 populations in 2011, according to population projection made based on the result of 2007 housing and population census. Naturally, in urban areas a huge number of populations live on small portions of the earth with uneven distribution across them. The distributions of population in the city are uneven as elsewhere in the country. The pattern of spatial distribution of population shows difference among different quarters of the city. The density of population varies from area to area. The central parts of the city have high population density in comparison with the urban expansion areas. The urban Ganda with the biggest population is irreecha (09), whereas, the urban Ganda with the least population is Boku shenan. Badhatu (07) and Gurmu (06) are the first and the second dense gada respectively.

Table 3.3: Projected Population by kebele in 2021 by sex, sex ratio and Population density

Ganda	Male	Female	Total	Ratio to total pop	Total area in hectare	population density/ hectare	sex ratio (F:M)
Goro(01)	17,397	17,227	34,624	7.99	1571.410	22	0.99
Migira(02)	12,041	11,994	24,035	5.55	338.328	71	0.996
Gara lugo(03)	17,649	17,384	35,033	8.09	334.799	104	0.985
Dhadachar(04)	17,046	18,677	18,677	8.25	256.039	139	1.096
Dagaga(05)	17,594	16,140	33,734	7.79	351.136	96	0.917
Gurmu(06)	6,128	6,408	12,536	2.89	30.942	405	1.046
Badhatu(07)	10,652	9,922	20,574	4.75	49.429	416	0.931
Oda (08)	10,036	9,399	19,435	4.49	54.921	353	0.937
rrecha(09)	19,188	19,643	38,831	8.96	482.042	80	1.024
Biqa(10)	15,215	16,260	31,475	7.27	192.887	163	1.069
Barecha(11)	16,245	16,817	33,062	7.63	161.905	204	1.035
Gada(12)	8,979	10,003	18,982	4.38	85.150	222	1.114
Chafe (13)	9,771	9,514	19,285	4.45	127.326	151	0.974
Angatu (14)	18,585	18,206	36,791	8.49	1016.460	36	0.98
Boku shenan	2,640	2,610	5,250	1.21	3466.932	2	0.989
Deka adi	7,650	7,523	15,173	3.5	1683.566	9	0.83
Dabe soloke	5,705	5,619	11,324	2.61	1098.165	10	0.985
Melka Adama	3,525	3,654	7,179	1.66	1910.636	3	1.037
Total	216,046	217,000	433,046		13,212.073		

Source: (Socio-economic profile of Adama, 2021)

### Sex Ratio

The majority of the residents of the city are women as the existing data portrays. As the projection of population made on the bases of 2007 G.C housing and population census results indicates the shares of males and females dwelling in Adama was 193,899 and 197,606 respectively. Table 2 shows the name of kebeles, size of population, total area and population density of Adama city. It also points out the name given for kebeles, before 2017 the name of 14 kebeles (which listed in table below 1-14) designated in number, later

2017 the name which were called by after number renovated by historical name of the place (Socio-economic profile of Adama, 2021).

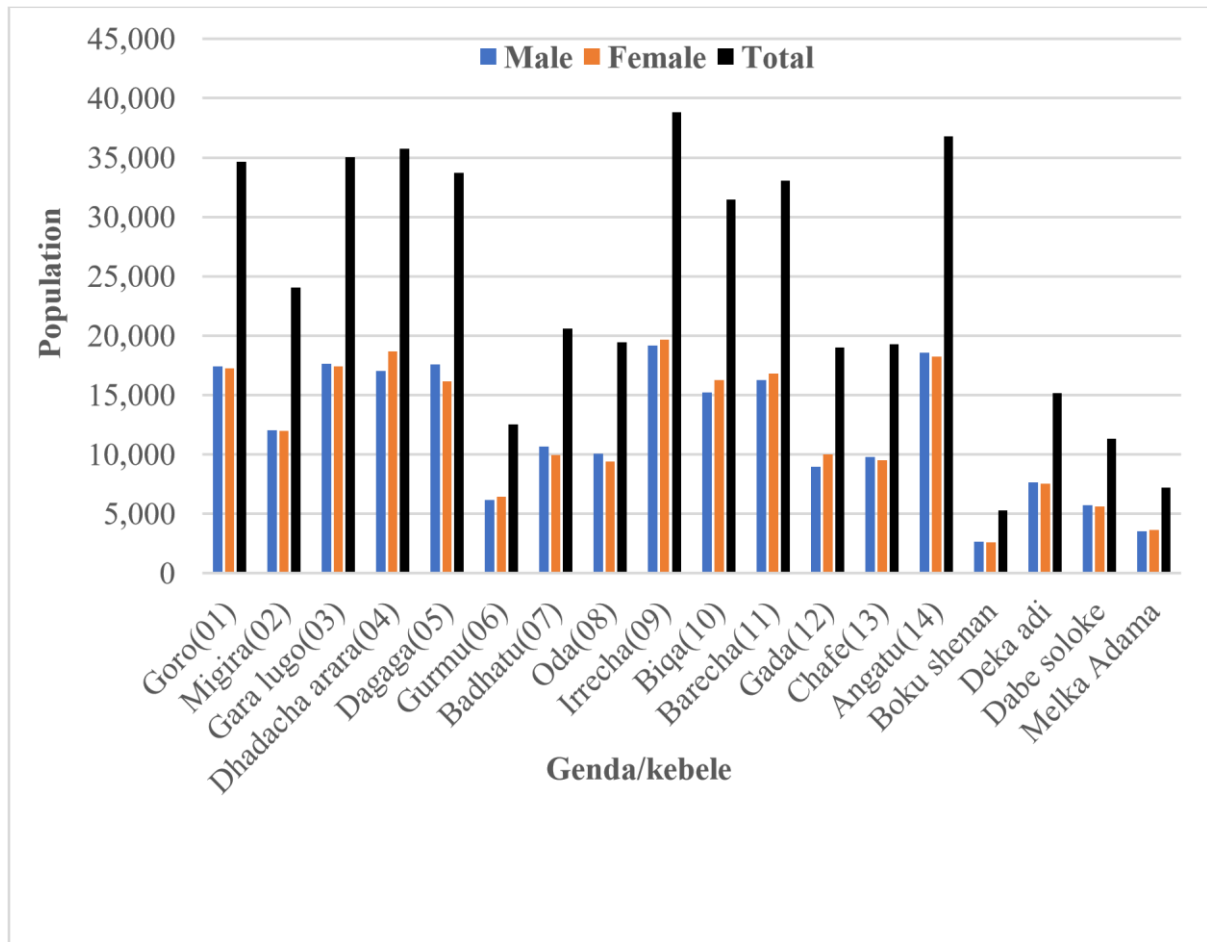


Figure 3.3: Population of Adama cities at kebele level (CSA, 2018/19)

### 3.2 Materials and Software Used

The software and materials used in this study were selected based on their capability to solve existing problems in achieving the predetermined objectives. In order to achieve the objective of the study different software and materials were used. As a result, image processing and classification activities on satellite pictures were performed using software such as ERDAS IMAGINE 2015. Google Earth was used to digitize a road and a river, as well as to check the accuracy of the land use/land cover class. The ArcGIS 10.8 software package was also used to do rasterization, intersection, reclassification, weight overlay, and factor map development.

Table 3.4: Software/Material used

S/N	Software name	Version/sources	Purposes
1	ArcGIS	10.8//ESRI	Data store, process and Map preparation
2	Erdas Imagine	v 2015/	Image Processing
3	Global Mapper	v20.2	processing DEM(generating contour)
4	Google Earth	v 7.3	Verification of timely updates image and generate coordinate points for the images
5	Idrisi Selva	V 17.02/open sources	AHP weighted rank/compute pair wise comparison
7	Ms-Office	2016	Writing paper and reporting results
8	BM SPSS	22	For tabulations and graphical representations

### 3.3. Data used and Source

This study used data from both primary and secondary sources, including both spatial and non-spatial data from actual fieldwork and secondary (ancillary) data. The table below describes data required, types of data used in the study, formats and where the data were gathered from (Table3.5).

Table 3.5: Data Type and Data Source

NO	Data	Source	Data type	Resolution	software process
1	satellite image(TM)	Sentinel-2 USGS,2022	TIFF	10m	Erdas Imagine v2015
2	DEM	ASTER DEM	GRID	20m	Global Mapper 2022
3	Topographic map	Adama city administration urban land sectors office	TIFF	1metr	ArcGIS
4	Population	CSA	secondary data	-	Excel &ArcGIS
5	Existing school	GPS field survey	Primary data	1:50,000	point data
6	Road Stream	Adama master plan	Shape file	-	ArcGIS
7	Adama Proposed Structural Plan	Adama city administration urban land sectors office	Shape file	-	ArcGIS
	Materials		Accuracy		
8	GPS (Garmin)	Collected from field	Coordinate (XYZ)	2m	Excel &ArcGIS

### 3.4 Data Processing

#### 3.4.1 Methods of data collection

Methods of data collection involve primary data collection and secondary data collection. In order to obtain all documents for the study, numerous strategies are used formally and informally in the data gathering procedure. There are two types of data collection procedures used: primary and secondary data collection.

**Primary data collection:** Field data obtained by conducting direct surveys to the field such as the school coordinate point collecting; this can be done with the use of handheld (Garmin GPS) with accuracy of 2m to obtain the coordinates of Base Transceivers Stations

(BTS) in the study area. Another method of data collection used in this study was Interview with Organizations: The interview method was used to collect primary data.

**Secondary data Collection:** One of the most noticeable advantages of using secondary data analysis is its cost effectiveness. Because someone else has already collected the data, the researcher does not need to invest any money, time, or effort into the data collection stages of his or her study. But need to check correctness of data and its legal sources. Data obtained from other sources such as Topo graphic/digital map usage, population data, existing school and new suitable school in adama city. The ancillary data will be used in this study are Administration boundary, road data, satellite imagery Sentinel-2 of 10m resolution.

### **3.4.2 Land Use Classes of Adama city**

A land use classification is a classification providing information on land cover, and the types of human activity involved in land use. It may also facilitate the assessment of environmental impacts on, and potential or alternative uses of land. There is several land use types are recognized in irregularly mixed appearance with one another through the whole study area.

According to information from Adama city Administrative, there are about much class number of land use types identified in city such built up, force land, agricultural land, water body, open space.

### **3.4.3 Image Classification**

Image classification is important to convert image data to thematic data. According to Author (Li *et al.*, 2014), the overall objective of image classification procedures is to automatically categorize all pixels in an image into land-use/land-cover classes. The image data was preprocessed in ERDAS imagine 2015 and standard image processing techniques such as image extraction, rectification, atmospheric correction, radiometric correction and classification was used for analysis of satellite imageries. Image classification was performed by the maximum likelihood algorithm methodology for the extraction of land use of the study area. Finally, major land use types were identified by using the satellite images of sentinel 2 in specified year. In ERDAS Imagine software, the signature editor also created for defining classes.

### 3.4.4 Accuracy Assessment of land use land cover classification

The term accuracy is typically used to express the degree of correctness of a map or classification in thematic mapping from remotely sensed data. The increased usage of remote sensing data and techniques has made geospatial analysis faster and more powerful; however, the increased complexity also creates increased possibilities for errors (Dagistanli et al., 2018). Therefore, the assessment of the accuracy of mapping generated from remote sensing data is a critical and essential step in the classification process (Dagistanli et al., 2018). The error matrix is the most common tool in terms of determining the accuracy of the classification results (Fan et al., 2007). User accuracy, producer accuracy, overall accuracy and Kappa statistics were then derived from the error matrices for LULC classes. According to (Moller-Jensen, 1997), Kappa analysis is a discrete multivariate technique used in accuracy assessments. In other words, Kappa analysis is a standard component of accuracy assessment and is considered as a required component of most image analyses (Dagistanli et al., 2018).

**Producer’s Accuracy (Errors of omission):** Producer’s Accuracy measures the percentage of correctly classified pixels from a sample data or indirectly indicates errors of omission for a particular class. Producer’s accuracy was calculated 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). It is calculated as:

$$\text{Producer's Accuracy} = \left(\frac{C_i}{C_t}\right) * 100 \dots\dots\dots (1)$$

Where,  $C_i$  = correctly classified sample locations of the reference data or column and

$C_t$  = total number of sample locations of the column.

**User’s Accuracy (Commission error):** 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). This result is a measure of commission error. It is calculated as:

$$\text{User's Accuracy} = \left(\frac{R_i}{R_t}\right) * 100 \dots\dots\dots (2)$$

Where,  $R_i$  = correctly classified samples in the row and  $R_t$  = total number of samples in the row.

**Overall Accuracy:** Overall accuracy was computed by dividing the total diagonal (i.e., the sum of the correctly classified sample units) by the total number of sample units in the error matrix. This value is the most commonly stated accuracy assessment statistic.

$$\text{Overall Accuracy} = \left(\frac{\text{Sd}}{n}\right) * 100 \dots\dots\dots (3)$$

Where, Sd = sum of values along diagonal and, n = total number of samples.

**Kappa Coefficient:** Kappa coefficient can be used as another measure of agreement or accuracy. Kappa was used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data as indicated by the major diagonals and the chance agreement. This was indicated by the row and column totals. Kappa values can range from +1 to -1. But, as there should be a positive correlation between the remotely sensed classification and the reference data, positive values were expected. Landis and Koch (1977) taken the possible ranges for kappa into three groups: a value greater than 0.80 (i.e., 80% and above) represent strong agreement; a value between 0.40 and 0.80 (i.e., 40%–80%) represents moderate agreement; and a value 0.40 (i.e., 40% and below) represents poor agreement.

$$K^{\wedge} = \frac{\sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \cdot x_{+i})} \dots\dots\dots (4)$$

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

### 3.4.5 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 were converted to raster format in ArcMap 10.8 for further analysis.

### 3.4.6 Reclassification

Reclassification is the process of classifying something (map) again and again. In this regard the parameters considered in this study were slope, topo map, industrial area, commercial, existing school, LULC, Road and new school. Finally Based on (FAO, 2007) 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.

Table 3.6: Raster dataset reclassification

Reclassified raster cell value score	Reclassified raster cell value score
1	Unsuitable
2	Very less suitable
3	Less Suitable
4	Moderately suitable
5	highly suitable

### 3.5. Methods of Data analysis

School site selection requires effective criteria assessment according to the governmental legislations, policy and existing relevant literatures. In this study, by taking into account these criteria the overlaying method of influencing parameters was used to analyze suitable school 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 32 and ERDAS Imagine 2015 (see table 3.5).

#### 3.5.1 Analysis of spatial concentration of the schools

An idea about the extent of concentration of public facilities between neighbors; in this case Kebeles of the city was analyzed by taking distribution of population into consideration. In this context the use of location quotient method by (Jahan and Oda, 2005) was adopted. It was used to measure the extent of public facilities in different parts of the city. The location quotient (LQ) ratio was computed to quantify and benchmark the degree of relative concentration of an activity in the analysis of area localization. For calculating the location quotient for a particular facility ‘i’ in a particular Kebele, the following formula was used.

Where

$$LQ = \frac{n_i/p}{N/P} \dots\dots\dots (5)$$

$n_i$ = number of school in particular kebele

N= number of school in the city

p= number of population in particular kebele

P= number of population in the city

$LQ < 1$ , suggests that the concentration of a particular facility in a particular Kebele is less than that of the Town as a whole

$LQ = 1$  or close to 1, indicates self-sufficiency means a particular facility in a given Kebele is exactly sufficient to meet the local demand.

$LQ > 1$ , concentration is indicated since the per capita availability of that facility in a particular Kebele exceeds that of the Town as a whole.

### 3.5.2. Analysis of distribution of the schools

The spatial distribution of schools was examined using standard distance measure in spatial statistic in GIS environment. It measures the degree to which features are clustered or dispersed around their geographic mean center. The spatial pattern was examined using Average Nearest Neighbor (ANN) analysis. ANN calculates a nearest neighbor index based on the average distance from each feature to its nearest neighboring feature (leta', 2018),(Ecofog and Guiana, no date),(State, Study and Local, 2019). It was conducted using the distance between each feature geometric center and that of its nearest neighbor's location. Then, distances were averaged. The average nearest neighbor index (ANNI) was calculated as the ratio of observed average distance (Do) and the expected average distance (DE) (with expected average distance being based on a hypothetical random distribution with the same number of features covering the same total area).

Where,

$$ANNI = \frac{\bar{D}_o}{\bar{D}_E}$$

$$\text{and } \bar{D}_o = \frac{\sum_{i=1}^n d_i}{n} \bar{D}_E = \frac{0.5}{\sqrt{n/A}} \dots\dots\dots (6)$$

$d_i$  equals the distance between feature and its nearest neighboring feature.

$n$  corresponds to the total number of features

$A$  the spatial extent of the expected area

In this regard, the distribution of the features being analyzed is considered as:

Clustered if ANNI < 1

Dispersed if ANNI >1

The z-score and p-value results will be used to measure statistical significance to determine whether or not to reject the null hypothesis. Because it indicates that rather than a random pattern, the features (or the values associated with the features) exhibit statistically significant clustering or dispersion. For the Average Nearest Neighbor statistic, the null hypothesis states that features are randomly distributed.

Z-score of indicates that maximum probability that the distribution likelihood could be the result of random chance. It was calculated as:

$$z = \frac{\bar{D}_0 - \bar{D}_E}{SE}$$

Where,  $SE = \frac{0.26135}{\sqrt{n^2/A}}$ ..... (7)

The p-value is a probability that the observed spatial pattern is created by some random process. When the p-value is very small, it means it is very unlikely (small probability) that the observed spatial pattern is the result of random processes, so null hypothesis can be rejected. But how small enough? To answer this question, the table below shows the critical p-values and z score’s for different confidence levels used in this study.

Table 3.7: p-value and z-score for different confidence level

z-score (Standard Deviations)	p-value (Probability)	Confidence level
< -1.65 or > +1.65	< 0.10	90%
< -1.96 or > +1.96	< 0.05	95%
< -2.58 or > +2.58	< 0.01	99%

### 3.5.3 Analysis of spatial accessibility of the schools

Actual accessibility is composed of three components: people, transport and activities. The size and composition of the population affect the accessibility, because it determines the scale of the demand for social infrastructures. The transport link reflects the travel time, costs and effort to travel between origin and destination. The activities reflect the spatial distribution of services at destinations and demand for those services. This concept fits the objective of this study and the components can be easily represented in GIS environment.

Moreover, location-based accessibility measurement is best suited to this study as it deals with people's access to reach the social facilities from their origin and spatial distribution of the services('The Spatial Distribution of the Basic Education Schools in Lattakia City ( Syria ) Kinda Wazzan ( PhD )', 2017);(Assessment *et al.*, 2009).

Further, distance based measurement technique was used to analyze the spatial accessibility measure of residents. Because, distance measures are simple to calculate and interpret, requires small amount of data, used as average distance or weighted area distance or distance to the closest activity using road network distance measurement. In this case, the spatial accessibility was analyzed using road network based service area analysis which answers the question "what is the likely service area of a facilities based on actual travel distance?" In this regard an area was considered accessible if it is enclosed by a polygon generated by specified travel distance from a facility along a road network.

Then, number of served population was determined from the product of spatial extent inside service area and population density. Similarly, inaccessible population was computed from spatial extent outside the service area and population density of the area.

$$\text{Serviced or unserved population} = \sum_{i=1}^{14} a_i * p_{di} \dots \dots \dots (8)$$

Where

$a_i$  is total serviced or unserved area in  $i$ th Kebele

$p_{di}$  is population density of  $i$ th Kebele

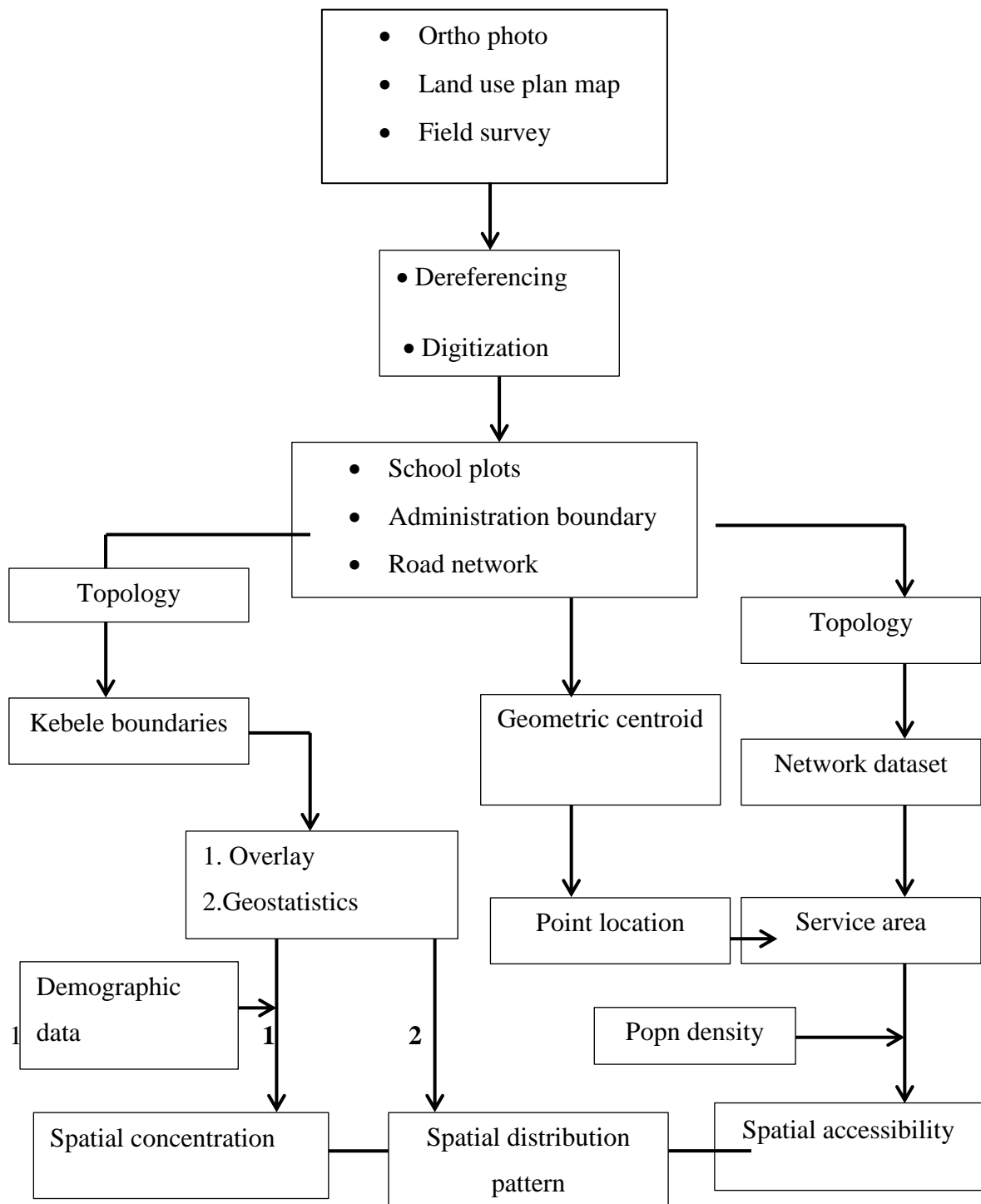


Figure 3.4: Methodology Workflow for Spatial concentration, distribution and accessibility

### **3.5.4 Selection of suitability factors and standardization**

In this study, to select a suitable site for secondary school using GIS-based multi-criteria analysis the following five main steps were used (Estoque, 2011).

1. Determine the criterion (factors/constraints)
2. Standardize the factors/criterion scores
3. Weight assignment of the site suitability factors
4. Integrate the criteria
5. validate/verify the result

#### **1. Determine the criterion (factors)**

There were many criteria/factors for secondary school site selection. Different literature suggests a variety of factors that may influence school site. According to the researchers (Yared 2018, Bukhari and Noordin 2010; (Engel, 2014); Narguess Akbary Dadfar, 2014; Aftab hussian, 2014; Pokhrel, 2019; Kuldeep, 2019; Talami and Ngig 2015) distance from the existing secondary school, land use land cover, road, residential, population density and slope were often used for secondary school site suitability. Based on the existing situation and availability of data for Adama city, land suitability analysis for selection of suitable site for secondary school was carried out based on the following factors distance from the existing school, road, land use, residential, population density, slope, sites. Though air quality, industrial, commercial and religious, climate, distance from the park, distance from noisy influences, historic and cultural sites, are the other factors influence school suitability as well, but they were not included in this analysis, because there is not much variety in the study area in terms of climate; and regarding air quality. Also, Park, historic and cultural sites are not found in the study area.

#### **2. Standardize the factors/criterion scores**

It's essential to standardize the data in GIS-based multi-criteria decision-making analysis, in order to integrate the data measured in different units and mapped in scale of measurement such as ordinal, interval, nominal and ratio scales (Kaźmierski, 2008). Even though there are different methods that can be used to standardize criterion, linear scale transformation is the most frequently used technique (Malczewski, 2003). In this study for factors standardization, all the vector maps of the factors were converted to raster data formats. Then using the Spatial Analyst tool in Arc Map, the raster maps were reclassified.

According to (FAO, 1981), land suitability classification, the datasets were reclassified from highly suitable (S1) to permanently unsuitable (N2); where S1, S2, S3, N1 and N2 represents the highly suitable, moderately suitable, less suitable, not suitable and permanently unsuitable conditions for secondary school site suitable respectively. This method enables all measurements to have an equivalent value before any weights are applied.

### **3.5.5 Identification of Potential Sites for School Development**

#### **3. Weight assignment of the site suitability factors**

Assigning criteria weights for each factor is an important component of GIS-Based multi-criteria decision-making analysis. The purpose of weighing is to express the importance or preference of each factor relative to one another factor effect on secondary school site selection. There are several methods available to determine the weight like Analytical Hierarchy Process (AHP), rating and ranking. For this study the Analytical Hierarchy Process (AHP) method using pairwise comparison matrices was adopted to assign weight for each factor.

##### **Analytical hierarchy process (AHP)**

AHP is first developed by (Saaty, 2003) who combines qualitative and quantitative analysis of complex problems of land management with the best alternatives (Kordi and Brandt, 2012). Analytical hierarchy process (AHP) methodology has been widely used for multi-criteria decision-making regarding land suitability analysis of different land uses. The AHP method determines the weight of importance of different factors influencing land suitability based on pairwise comparisons of the factors considering their relative significance (Kordi and Brandt, 2012). Weighting is an important component of land suitability analysis as it affects the output and is complicated as the considered factors interact with each other.

In this study, to select a suitable site for secondary school development the AHP was carried out in the following three steps:

##### **A. Pair-wise comparison of criteria**

Pair-wise comparison of criteria was performed first and results were put into a comparison matrix. A Pair-wise comparison matrix was constructed, where each criterion

was compared with the other criteria, relative to its importance, on a scale from 1 to 9 which is suggested by (Saaty ,2005) (Table 3.8).

According to (Saaty ,2005), the values in the matrix need to be consistent, which means that if x is compared to y, it receives a score of 9 (extreme significance), y to x should score 1/9 (less significance) and something compared to itself gets the score of 1 (equal significance).In this study the pairwise comparison matrices were developed by taking into account the information Provided by various literatures (Abazari, F. Babalhaveaji and Jahangirifard, 2012;Yared 2018; Bukhari and Noordin 2010;Firomisa 2021;Narguess Akbary Dadfar, May 2014,Aftab hussian, 2014,et al Pokhrel, 2019; Kuldeep, 2019; Mohai and Kweon, 2020;Murad, Dalhat and Naji, 2020;Mustaffa *et al.*, 2021;Jamal, 2016,Mustaffa *et al.*, 2021;Ali, 2018;yrgalem, 2021;Said, 2021;Ibrahim and Shouman, 2012).

Table 3.8: AHP Scale of Relative Importance

Intensity of relative importance	Definition	Explanation
1	Equal Importance	Two activities combine equally to the objective.
3	Moderate importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another.
7	Demonstrated importance	An Activity is strongly favoured and its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed.
Reciprocals of above non zero numbers.	If an activity has one of the above numbers (e.g.,3) Compared with a second activity, then the second activity has the reciprocal value (i.e., 1/3) when compared to the first.	

Source: (Saaty, 2003)

### B. Calculating criterion weights

The weight of all factors is calculated by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix.

Manually the computation of the criterion weights involves the following operations: (a) summing the values in each column of the pairwise comparison matrix; (b) dividing each element in the matrix by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix and (c) computing the average of the elements in each row of the normalized matrix that is, dividing the sum of normalized scores for each row by the number of criteria. In this study the computation of the criterion weights was calculated by using IDRISI Selva software.

### C. Calculating consistency ratio (CR)

After the pair-wise comparison was filled and the weight of the factors was determined, a consistency ratio (CR) was calculated to identify inconsistencies and develop the best-fit weights in the complete pair-wise comparison matrix. Consistency ratio of 0.1 or less is acceptable to continue the AHP analysis (Saaty, 2008). But if a consistency ratio is greater than 0.1, then there are inconsistencies in the evaluation process and the AHP method may not yield a meaningful result (Saaty, 2007). A consistency ratio was calculated for the matrix to verify the degree of credibility of the relative weights, by using the following formula:

$$CR = \frac{CI}{RI} \dots\dots\dots (9)$$

where CR=Consistency ratio, CI = referred to as consistency index, RI = is the random consistency index whose value depends on the number (n) of factors being compared; as illustrated in table 3.9 (Saaty, 2005). The consistency index (CI) was calculated by the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1} \dots\dots\dots (10)$$

Where  $\lambda_{max}$  is the principal Eigen value; n is the number of factors.  $\lambda_{max} = \Sigma$  of the products between each element of the priority vector and column totals.

Table 3.9: Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty (2003)

#### 4. Integrate the criteria

Step four was to integrate the criteria using weighted linear combination (WLC) and apply it in the ArcGIS raster calculator.

##### Weighted overlay spatial analysis

After the criteria maps and weights have been developed and established, a decision rule of multi-criteria analysis was used. There are three common decision rules in multi-criteria analysis namely weighted linear overlay, Boolean overlay and ordered averaging (Jiang and Eastman, 2000; Malczewski, 2003). In this study the weighted linear combination (WLC) technique was applied to aggregate the standardized layers. In this technique, factors or parameters ( $X_i$ ) are multiplied by weight of the parameters ( $W_i$ ) to get composited weights and then summed. WLC technique is a straight forward linear method calculating composite weights. WLC multiplies and sums up the layers to produce suitability maps for public secondary school. This can be done by using the following formula to derive the intended map (i.e. Secondary school site suitability map for Adama city).

$$S = \sum_{i=1}^n (W_i X_i) \dots\dots\dots (11)$$

Where  $S$  = Suitability,  $W_i$  = relative importance or weight of factors / parameters  $i$ ,

$X_i$  = parameters  $i$ , and  $n$  = total number of parameters related to the study.

#### 5. Validate/verify the result

Validating or verifying the result was the final step and it helps to assess the reliability of the output and usually assessed by ground truth verification and sensitivity analysis. According to (Abebe and Megento, 2017) sensitivity analysis was performed by changing the weight of criteria and field surveys were conducted for ground truth verification.

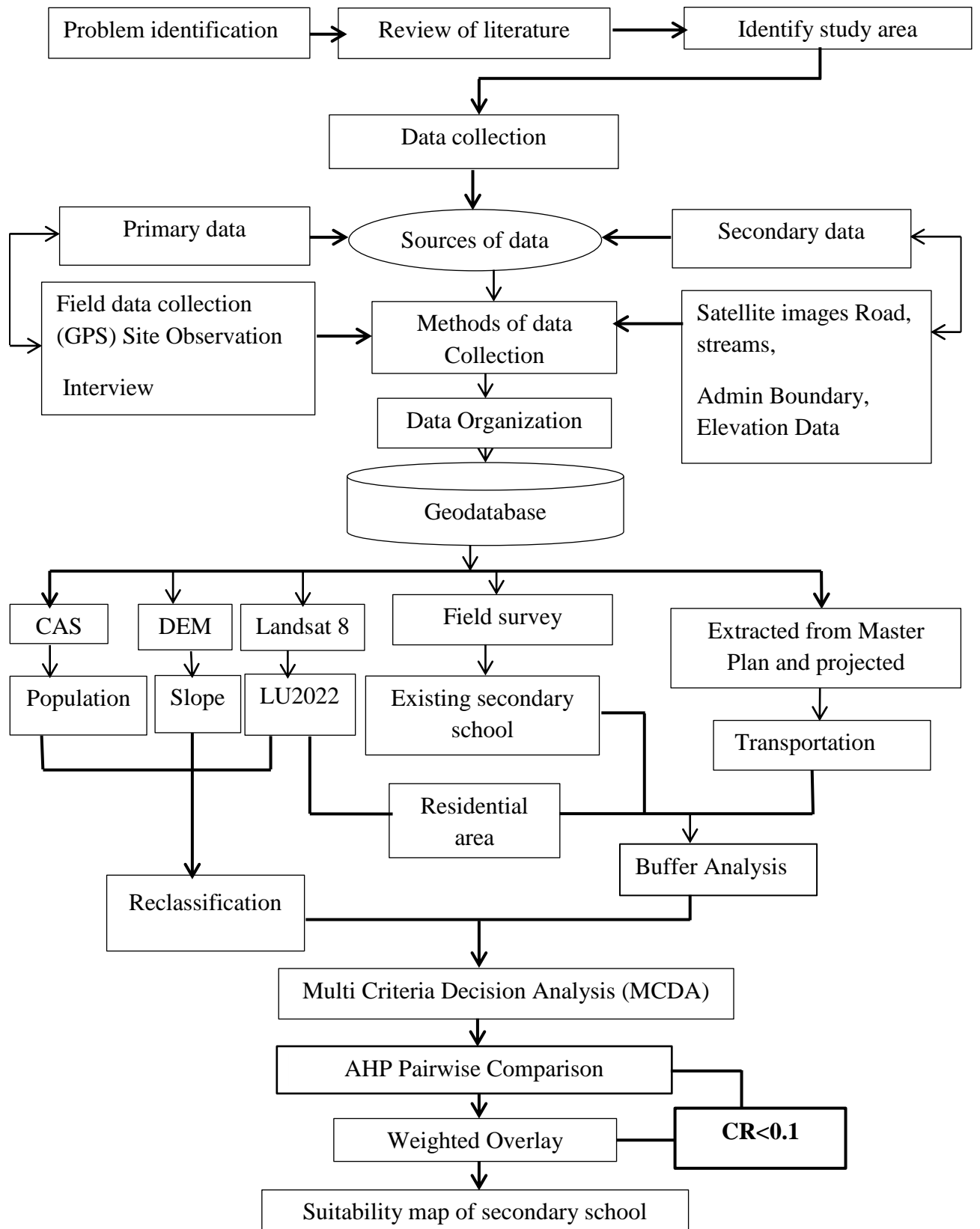


Figure 3.5: Methodological workflow

## **CHAPTER FOUR: RESULTS AND DISCUSSION**

This chapter attempted to deal with the data in order to answer the previously stated research questions starting from estimated assumptions up to the most reliable solutions that even Stakeholders can apply to action. Relevant data analyses are performed using a predefined methodology and sequential spatial analysis approaches. Descriptions of the discussed results in the form of information are briefly arranged. Discussions are provided to meet the purpose of study and objectives set briefly at the beginning of the study. Finally the intentioned and refined greatest output of the research that is the secondary school sites are distinguished as a candidate sites.

### **4.1 Land Use Classes of Adama city**

A land use classification is a classification providing information on land cover, and the types of human activity involved in land use. It may also facilitate the assessment of environmental impacts on, and potential or alternative uses of land. There is several land use types are recognized in irregularly mixed appearance with one another through the whole study area. According to information from Adama city Administrative, there are about much class number of land use types identified in city such built up, force land, agricultural land, water body, open space.

#### **4.1.1 Accuracy assessment of land use land covers classification**

Accuracy assessment is the final step in the analysis of remote sensing data which help us to verify how accurate our results are. It is carried out once the interpretation/classification has been completed. The confusion matrix/error matrix has numbers as the quantity of sample. Any particular quantity arranged in rows and columns i.e. square matrix, where columns represent the referencing data while row represents the classification data. The overall accuracy for the LULC image is defined as the total correct pixels (major diagonal's sum) divided by the total number of pixels in the provided matrix which is 91.9047 % ( table 11). In addition, the overall kappa coefficient for the image was = 0.887816 i.e. 88.7816% better agreement than by chance alone respectively. Kappa values are characterized as < 0 as indicative of no agreements and 0 to 0.2 as slight, 0.2 to 0.41 as fair, 0.41to 0.60 as moderate, 0.60 to 0.80 as substantial and 0.81–1.0 as almost 39 perfect agreement. Therefore, the overall classification accuracy of the image yielded a Kappa statistic of 88.7816% (Table 4.1) for the 2022 image. This implies that the image classification accuracy was almost perfect agreement.

Table 4.1: Accuracy Assessment and Error Confusion matrix of lulc map 2022

Reference Map							
Classified map	Classified Data	Forest/shrub land	Water body	Built up	Open space	Agricultural land	User Accuracy (100%)
	Forest/shrub land	24	0	1	1	6	31
	Water body		10	0	0	0	10
	Built up	0	0	31	1	0	32
	Open space	0	0	0	47	5	52
	Agricultural land	2	0	2	1	80	85
	Producer Accuracy (100%)	26	10	34	49	91	210
	Overall Accuracy = $193 / 210 = 0.919047$ Overall Accuracy percentage = $0.919047 * 100 = 91.9047\%$ Kappa Statistics $K^{\wedge} = 0.887816 * 100 = 88.7816\%$						
User Accuracy (Row)				Produce Accuracy (Diagonal)			
Forest/shrub Land = $(24/31) * 100 = 77.419\%$				Forest / shrub land = $(24/26)*100 = 92.3076\%$			
Water body = $(10/10)*100 = 100\%$				Water Body = $(10/10)*100 = 100\%$			
Built up = $(31/32)*100 = 96.875\%$				Built Up = $(31/34)*100 = 91.1764\%$			
Open Space = $(47/52)*100 = 90.3846\%$				Open Space = $(47/49) * 100 = 95.918\%$			
Agricultural Land = $(80/81) * 100 = 94.1176\%$				Agricultural Land = $(80 / 91) * 100 = 87.91208\%$			

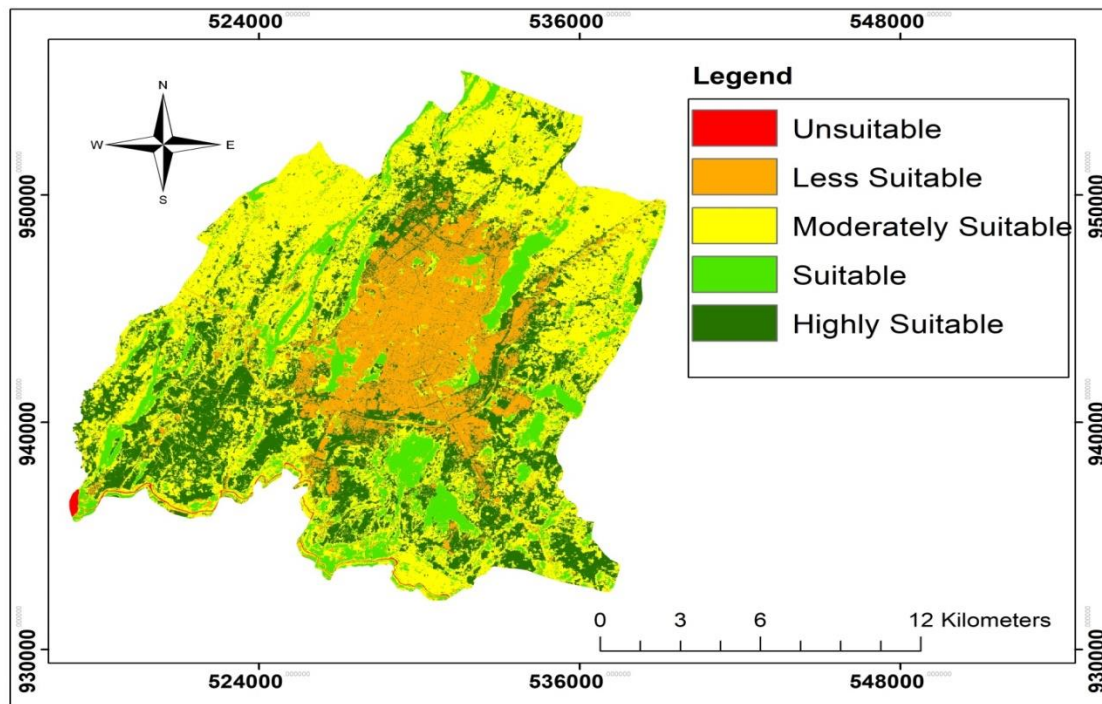


Figure 4.1: LULC map of study area in 2022

Table 4.2: land use land cover types and their respective area coverage

Land use type	Area in	
	(Ha.)	(%)
Open space/bare land	8385.948	26.79
Forest/shrub land	3693.026	11.79
Agriculture land	13696.825	43.75
Built up	5452.820	17.42
Water body	72.884	0.23

## 4.2 Spatial concentration of the schools

The number of secondary schools, population number in each kebele as of 2022 along with computed value of spatial concentration measure (location quotient) is indicated in the (table 4.13). In adama city 11GOSS and 22 POSS secondary schools are identified. Most of these secondary schools are distributed in the center part of the city. The information in the table 13 reveals that the allocation of secondary schools in adama city is inadequacy and inequality in the allocation of secondary schools among the various kebeles in the study area. Some areas are very well served while some are poorly served. It is clear from the table 13 that 5 kebeles out of 18 kebeles have absence of secondary school. Kebele

wise, the value of location quotient shows that maximum concentration of secondary schools (2.5) is associated with kebele Boku shenan. The analysis indicates that the level of concentration of schools varies quite significantly across kebeles in the adama city and this leads to believe that considerable disparity exists among the kebeles in terms of secondary school facilities. Spatial concentration –Reflects the inequality of services among kebeles with respect to their population.

Table 4.3: number and spatial concentration of scondary schools in adama city of 2022

Kebele Name	Total Number of Population	Number of School in that Kebele	Location Quotient(LQ)
Deka adi	15,173	0	0
Boku shenan	5,250	1	2.5
Goro	34,624	6	2.27
Dhadacha arara	35,723	6	2.20
Badhatu	20,574	0	0
Gada	18,982	1	0.69
Oda	19,435	0	0
Gurmu	12,536	0	0
Barecha	33,062	5	1.98
Biqa	31,475	4	1.67
Melka Adama	7,179	1	1.83
Dagaga	33,734	2	0.79
Gara lugo	35,033	1	0.37
Irrecha	38,831	2	0.68
Chafe	19,285	1	0.68
Migira	24,035	0	0
Dabe soloke	11,324	1	1.16
Angatu	36,791	1	0.36

The numbers of private owned secondary schools are two times that of government owned secondary schools indicating the large share of private sectors in contributing to middle level education in the city as compared to government.

The shortage of infrastructures and availability of land for development might have contributed to less attraction of the private sectors. Because; secondary school by its nature requires better facilities and large spatial extent than primary level. This can be evident that almost all of privately owned secondary schools in the city are within the same compound with primary schools. On the other hand, purchasing power of the community for secondary schools might be another potential factor affecting provision of private secondary schools. In such circumstances the focuses of government towards establishment of secondary schools in the city become the primary important. However, less attention is paid to the sector by Government.

### 4.3 distribution Pattern of the schools

Spatial distribution of secondary schools in adama city is depicted in figure 4.2. Alongside to inadequate number of provision, the secondary schools in adama are located in the central urban area. This indicates that there is uneven spatial distribution of middle level educational facilities. Most of the facilities are located close to main Streets passing through the city. Relatively other services such as electricity are better provided in this area. This underpins the level of infrastructure in urban areas can influence the establishment of secondary schools. Moreover, existence of such infrastructures can highly attract private developers.

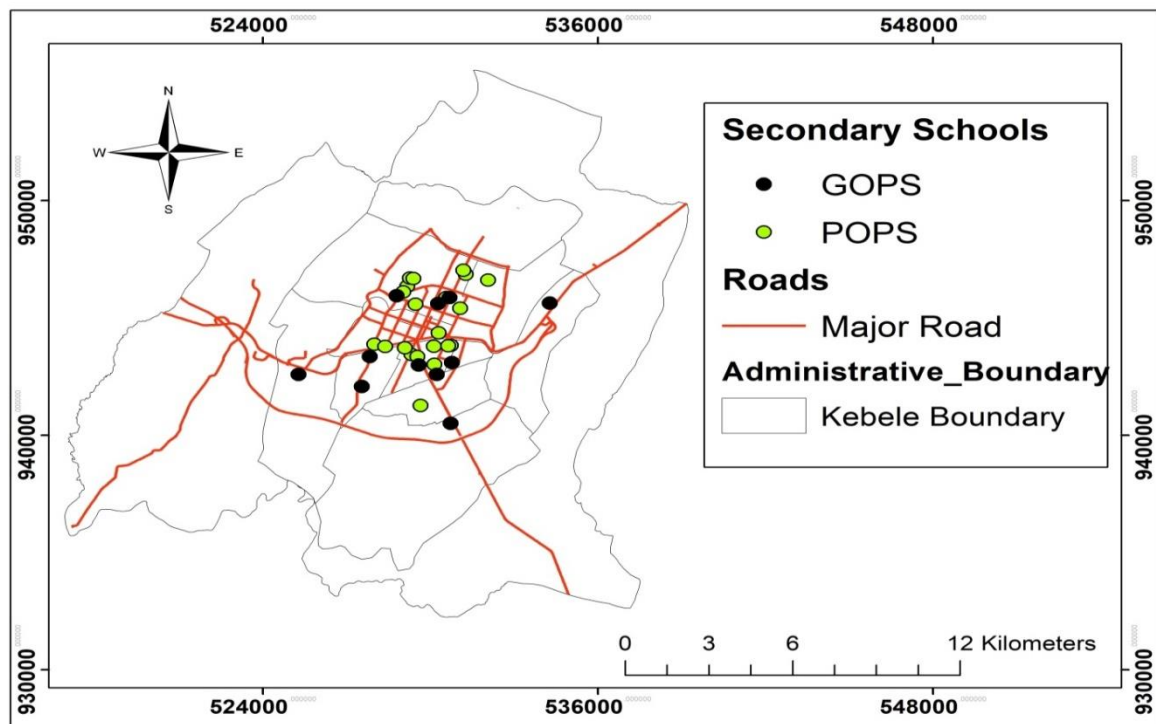


Figure 4.2: Spatial location of secondary schools in adama city as of 2022

However, the values of the result of nearest neighbor analysis of spatial distribution of secondary schools in the city (figure 4.3) shows NNR (0.353174) which is less than 1 indicating clustering pattern.

Further, values of Z-score (-7.108452) is less than the critical value, -2.58, and P-value (0.000) which is less than 0.01, reveal that the observed distribution pattern is dispersed at 99% confidence level.

The output shows that the spatial distribution of schools is clustered mainly in the center of the city. Also as the p value the clustered nature of the spatial distribution of the schools is not random but rather it a clustered pattern distribution.

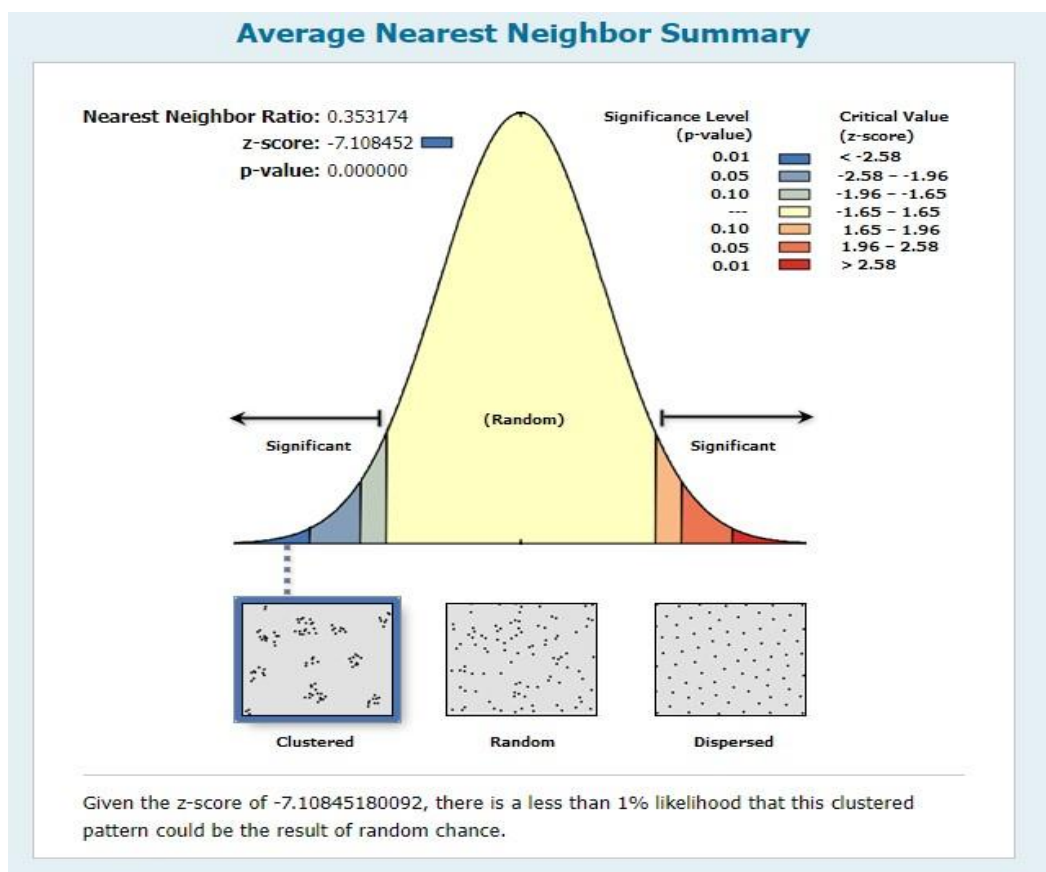


Figure 4.3: Distribution pattern of secondary schools in adama city in 2022

#### 4.4 Spatial Accessibility of the schools

Spatial Accessibility with respect to existing Road networks was used to determine the accessibility of existing secondary schools in Adama city. The Accessibility was computed

using distances 1 Km, 2 Km, 3 Km, 4 Km, 5 Km and greater than 5 km by using Existing secondary schools and available road network with in the mentioned spectrums.

Figure 12 and tables 14 demonstrate the result of spatial accessibility analysis of secondary schools in adama city as of 2022. Overall, residents in gada kebele followed by barcha kebeles and dhaducha arara are well served within the maximum travel distance set by standard (5km) while boku shenane kebele is not accessible to secondary schools when compared in terms of standard. In addition, some residents in boku shenane.dehaka adil,goro and melka adama kebele are expected to travel more than 5 or 6km to access the secondary schools.

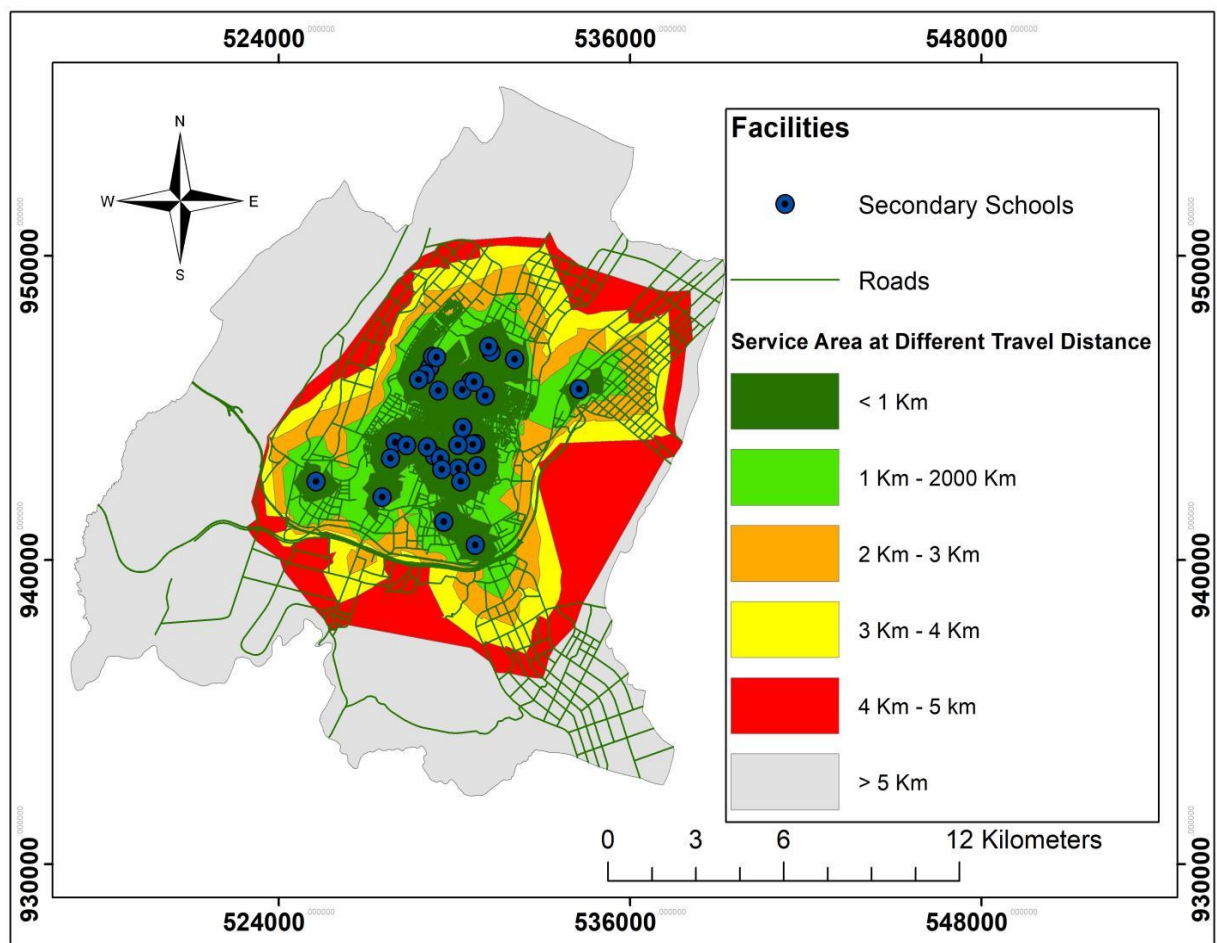


Figure 4.4: spatial accessibility level of secondary schools in adama city 2022

The findings indicate that secondary schools in adama city are accessible unevenly by residents. This might be due to lack of timely evaluation and monitoring. In addition, lack of road network development and fast increasing population density might have influenced the resulted distribution. This is done using Network data set by computing available Road

networks and Existing schools as service area with respect distance towards facility in arc map.

Table 4.4: spatial accessibility of secondary schools in adama city as of 2022

Number of served population and Unserved Population							
Kebele	0 – 1 Km	1 – 2 Km	2 – 3 Km	3 – 4 Km	4 – 5 Km	>5 Km (Unserved )	Total
Boku shenane (2 = PD)	156 (3%)	463 (9%)	896 (17%)	931 (18%)	1059 (20%)	1745 (33%)	5,250
Dehaka (=9 PD) Adil	172 (1%)	1432 (9. %)	3475 (23%)	4636 (31%)	3529 (23%)	1929 (13%)	15,173
Goro (=22 PD)	8678 (25%)	5950 (17%)	3288 (9%)	3398 (10%)	7886 (23%)	5424 (16%)	34,624
Dhadachaarara (139= PD)	35762 (99.8%)	61 (0.2%)	0 (0%)	0(0%)	0(0%)	0(0%)	35,823
Badhatu (416 = PD)	19652 (95.5%)	922 (4.5%)	0(0%)	0(0%)	0(0%)	0(0%)	20,574
Gada (222 = PD)	18965 (99.9%)	15 (0.1%)	0	0	0	0(0%)	18,980
Oda (=353)	13078 (67.3%)	6356 (32.7%)	0	0	0	0(0%)	19,434
Gurmu (405 = PD)	6977 (55.65%)	5559 (44.35%)	0(0%)	0(0%)	0(0%)	0(0%)	12536
Barecha (=204 PD)	33062 (100 %)		0(0%)	0(0%)	0(0%)	0(0%)	33,062
Biqa (163 = PD)	22389 (71.1%)	9006 (28.6%)	80 (0.3%)	0(0%)	0(0%)	0(0%)	31,475
melka Adama (3 = PD)	489 (7%)	1684 (24%)	1451(20% )	1181 (16%)	1711 (24%)	663(9%)	7,179
Dagaga (96 = PD)	15203 (45%)	18375 (54.5%)	156 (0.5%)	0(0%)	0(0%)		33,734
Gara lugo (104 = PD)	16420 (47%)	14747 (42%)	3866 (11%)		0(0%)	0(0%)	35,033
Irrecha (80 = PD)	20302 (52.3%)	17887 (46.1%)	419 (1.1%)	161 (0.5%)	62 (0.15966 %)		38,831
Chafe (151 = PD)	12135 (63%)	6681 (35%)	469 (2%)	0(0%)	0(0%)	0(0%)	19,285
Migira (71 =PD)	8461 (35%)	13505 (56%)	2069 (9%)	0(%)	0(0%)	0(0%)	24,035
DabeSoloke (10 = PD)	981 (9%)	2352 (21%)	2609 (23%)	1785 (16%)	3599 (31%)		11,326
Angatu (36 = PD)	9631 (26%)	15423 (42%)	9125 (25%)	2428 (6.5%)	184 (0.5%)		36,791
Total	242,513	120,418	27,903	14,520	18,030	9,761	433,145

Total population (433,145) distribution in different kebeles of adama city might be important reason for resulted distribution of the schools.

Population (6.5%) is forced to travel more than 5 km from all Kebeles with the greater share from Boku shenane 1745 (33%).

#### **4.5. Standardized suitable site selection factors**

In Ethiopia, as mentioned above developed standards and used for schools site selection have weaknesses which mean not deliver enough and detailed information for each parameter standard. Because only two parameters, slop, and road are defined in detail. For example, their standards were developed and used by the Oromiya State Educational Office in the year of 2012 G.C stated that schools must be away from factories but no detailed information about how long school sites should be away from it. This is why researcher the national current standards implemented across the country is not enough. So that, for this thesis the standards used by a researcher for each parameter are taken from various previously conducted researches by different scholars for suitable site selection for school.

Now a day different developed country had own well-developed school site selection guideline and parameters to select a suitable site for school. For example, the School site guideline of the United State of America (School Siting Guidelines , 2007) and New School Site Selection, Processes and Criteria (Albuquerque Public Schools, 2014), and School Sites Selection and Development 44 (Kansa State Department of Public Instruction, 2013). School site standards, site selection, and site development, New York the State of the education department, 2018. For this study, six parameters were identified to map suitable sites for secondary school. These criteria are proximity to existing secondary school, population density, transportation rout, residential, land use, and slope. All parameters are supported by a known source. Because the selected parameters enable the researcher to develop a suitability map.

Thematic map of all parameters illustrated above each Euclidean distance calculated for six criteria's dataset. Then after Euclidean distance has been done the reclassification for each parameter was computed. The result of reclassified; Land use, proximity distance to Existing schools, Roads, Slope, residential, Population Density, developed in scientific method and standards. Each reclassified suitability map of parameters is ordered from the

most suitable to unsuitable by depending upon criteria that have been mentioned in the methodology part of this research.

#### 4.5.1 Land use

Land use is a significant factor for suitability analysis. It gives information and occupation of the natural land resource. During suitable site selection for anything related to location, the primary task understands the existing land use of the study area. This assists the researcher to choose a safe and suitable site with the help of geospatial techniques/technology. Based on the previous research studies information the land use map reclassified from suitable to unsuitable. Based on knowledge obtained from the analysis of literature, open space/bare land and Shrub land/forest were considered to be highly suitable and moderately suitable for secondary school development respectively. Additionally, in this study Agricultural land, Built-up area and water body were considered as less suitable, very less suitable and permanently unsuitable conditions for school site development respectively (Table 4.5; Figure 4.5).

Table 4.5: Reclassified LU and area coverage of suitability levels

Land use	Standardization Score/Value	Level of suitability	Area in	
			(Ha.)	(%)
Open space/bare land	5	highly suitable)	8385.948	26.79
Forest/shrub land	4	moderately suitable	3693.026	11.79
Agriculture land	3	less suitable	13696.825	43.75
Built up	2	very less suit	5452.820	1
Water body	1	Unsuitable	72.884	0.23

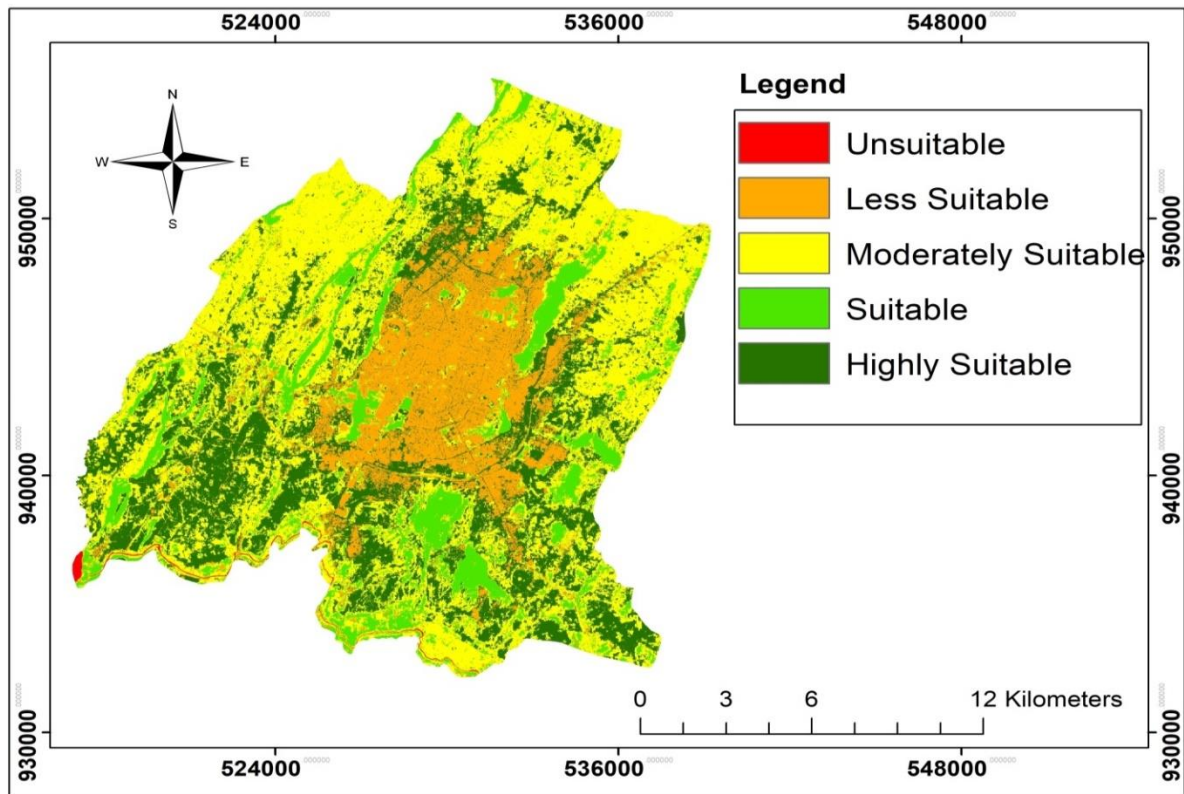


Figure 4.5: LULC map of study area in 2022

#### 4.5.2 Proximity to existing school

Proximity distance from existing school has great influence regarding utilizing the available resource. New school should be placed apart from the existing school to accommodate extensive service to the community. Keeping the proximity distance from other existing schools as well as anticipating impact from each other, it is not only relevant to rational resource allocation but also matters fair distribution of school among the community. So that, the new secondary school site is not near to the existing secondary schools. This is why the Proximity distance of the existing secondary school is chosen as an influencing parameter by the researcher. Hence, in this study, the new secondary schools are also wished to keep a distance of 2,000m the further away is better. This is based on how far a pupil should walk to reach schools. The buffer distance used for this factor was identical to the research done by (Talam & Ngigi, 2015; Abera, 2018, Jamal, 2016). And also, in determining optimum buffer distances from schools, the School Siting Guidelines (the United States Environmental Protection Agency, 2011) were consulted.

Table 4.6: Reclassified school and area coverage of suitability levels

Distance from existing school	Standardization Score/Value	Level of suitability	Area In	
			(Ha.)	(%)
>2000	5	highly suitable	24031.673	76.76
1600-2000	4	moderately suitable	1734.715	5.54
1350-1600	3	less suitable	1105.497	3.53
1000-1350	2	very less suitable	1667.249	5.32
<1000	1	Unsuitable	2767.347	8.83

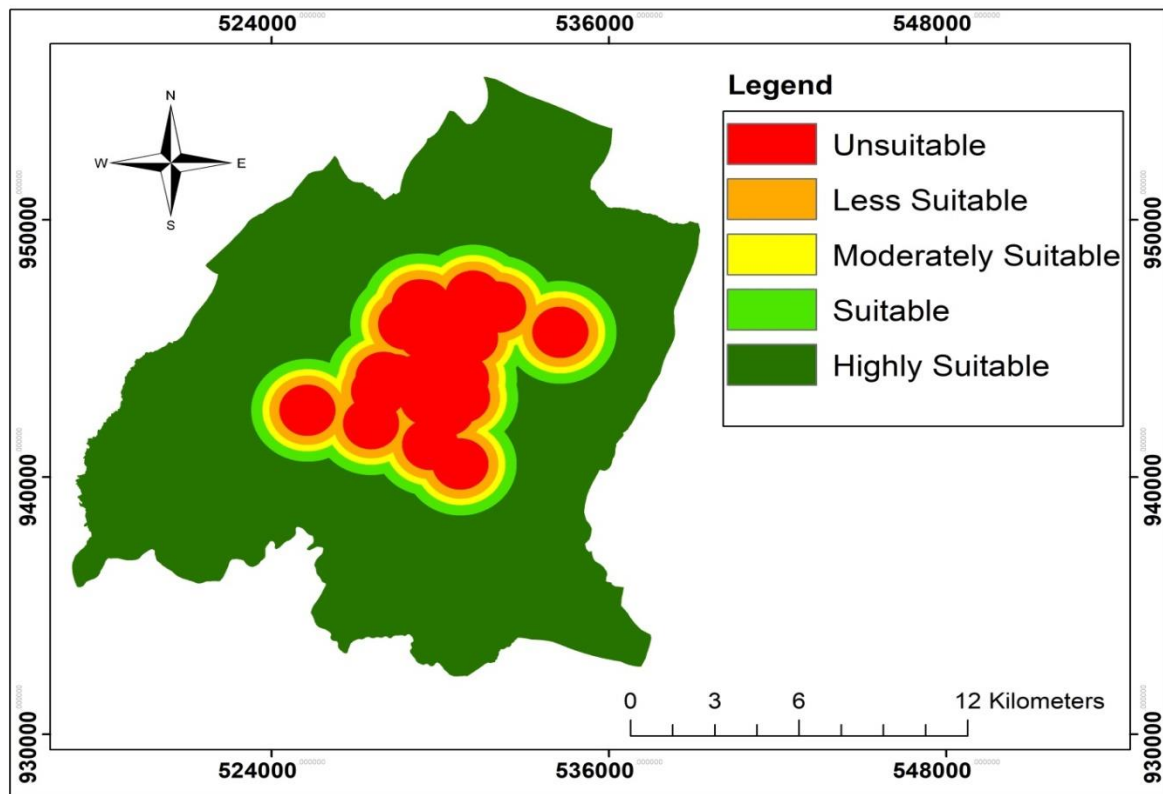


Figure 4.6: Reclassified proximity to existing public secondary school suitability map

The guidelines outlined that the maximum acceptable walking/biking distance for high school children in the US are 1.5 miles or approximately up to 2,400 m. The standard used for this parameter is taken from these above sources.

### 4.5.3 Suitability of distance from major transportation/road

The optimum distance to road infrastructures is vital for schools; being close for road networks will avoid long walking distance, and bring a convenient transportation system for pupils. In contrast, roads are the primary source of air and sound pollution, and it may affect the educational programs. Hence the schools should not be far and close to the main transportation/road network (Jamal, 2016; Jayaweera, 2016). The optimum distance adopted from different research studies, and 50 meters assigned as minimum proximity and 300 meters considered as the maximum distance. In this study, by making buffer analysis, areas within the 50m- 100m, 100-150m, 150-200, 200-300 and >300m radius of the road have been considered as highly suitable, moderately suitable, less suitable, very less suitable and unsuitable respectively (Table 4.7; Figure 4.7).

Table 4.7: Reclassified major transportation route and area coverage of suitability levels

Distance from transportation route (m)	Standardization Score/Value	Level of suitability	Area in	
			(Ha.)	(%)
50-100	5	highly suitable	1419.663	4.78
100-150	4	moderately suitable	1230.142	4.14
150-200	3	less suitable	1107.081	3.73
200-300	2	very less suitable	1860.718	6.27
>300	1	Unsuitable	24034.875	81.05

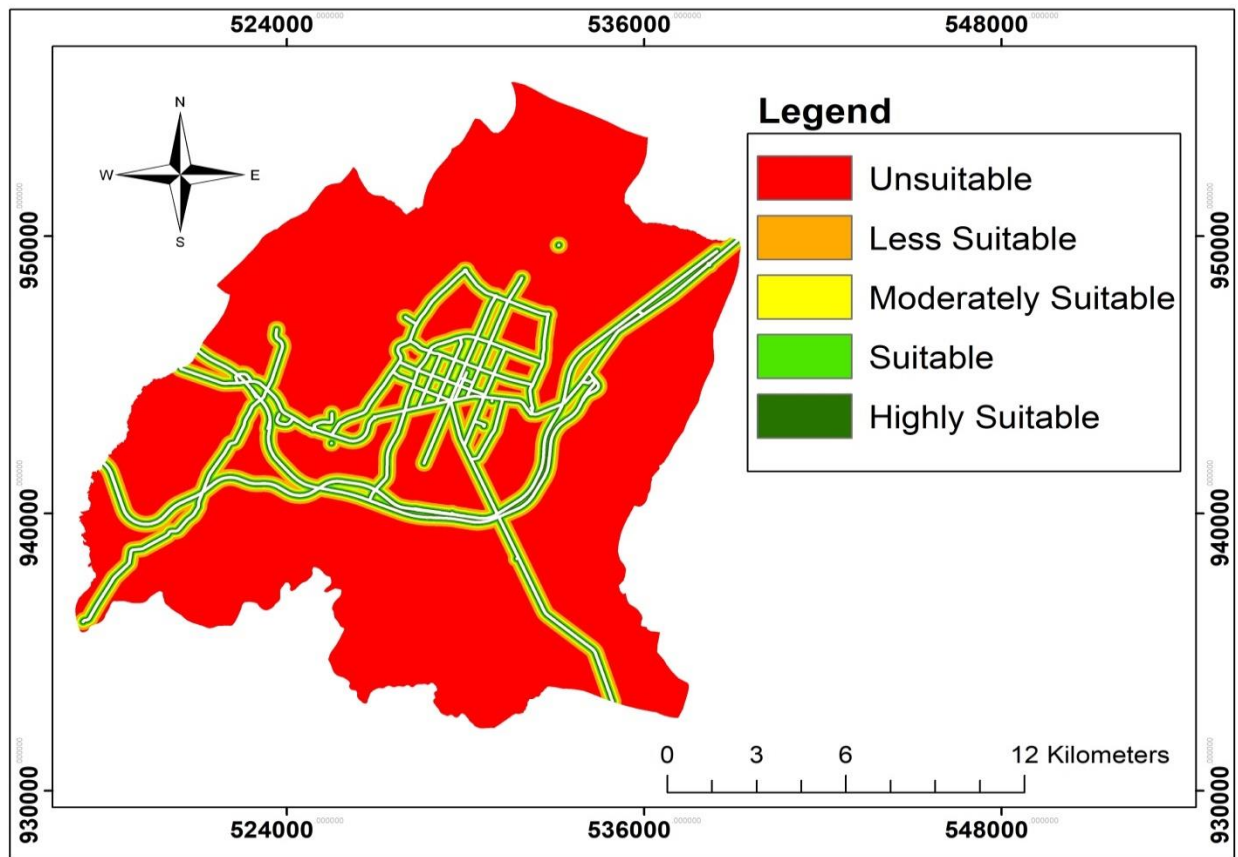


Figure 4.7: Reclassified distance from transportation route (road) map

#### 4.5.4. Suitability of slope

Slope is one of the aspects of school site selection; it should not be low or steep. Steep slopes expose for natural disasters such as landslides, snow slip, and rock-fall, besides school construction on a steep area is not cost-effective. Thus the site should be reasonably level to have sufficient playing space for pupils. Many research studies show that slope value less than 10 % is convenient for school construction (Bukhari et al., 2010; Dadfar, 2014; Jamal, 2016; Jayaweera, 2016; Talam and Ngigi, 2015). Based on previous studies, the slope map has been reclassified from suitable to unsuitable according to slope value. The slope less from 10% considered as highly suitable in this study for secondary school development. Slope value 10 to 15 %, 15 to 20 % 20 to 25% and greater 25% is called sloping (moderately suitable, less suitable, very less suitable and unsuitable) respectively (Table 4.8; Figure 4.8).

Table 4.8: Reclassified slope and area coverage of suitability levels

Slope%	Standardization Score/Value	Level of suitability	Area in	
			(Ha.)	(%)
<10	5	highly suitable	18078.348	58.82
10-15	4	moderately suitable	5421.48	17.64
15-20	3	less suitable	3036.887	9.88
20-25	2	very less suitable	1486.702	4.83
>25	1	Unsuitable	2707.325	8.40

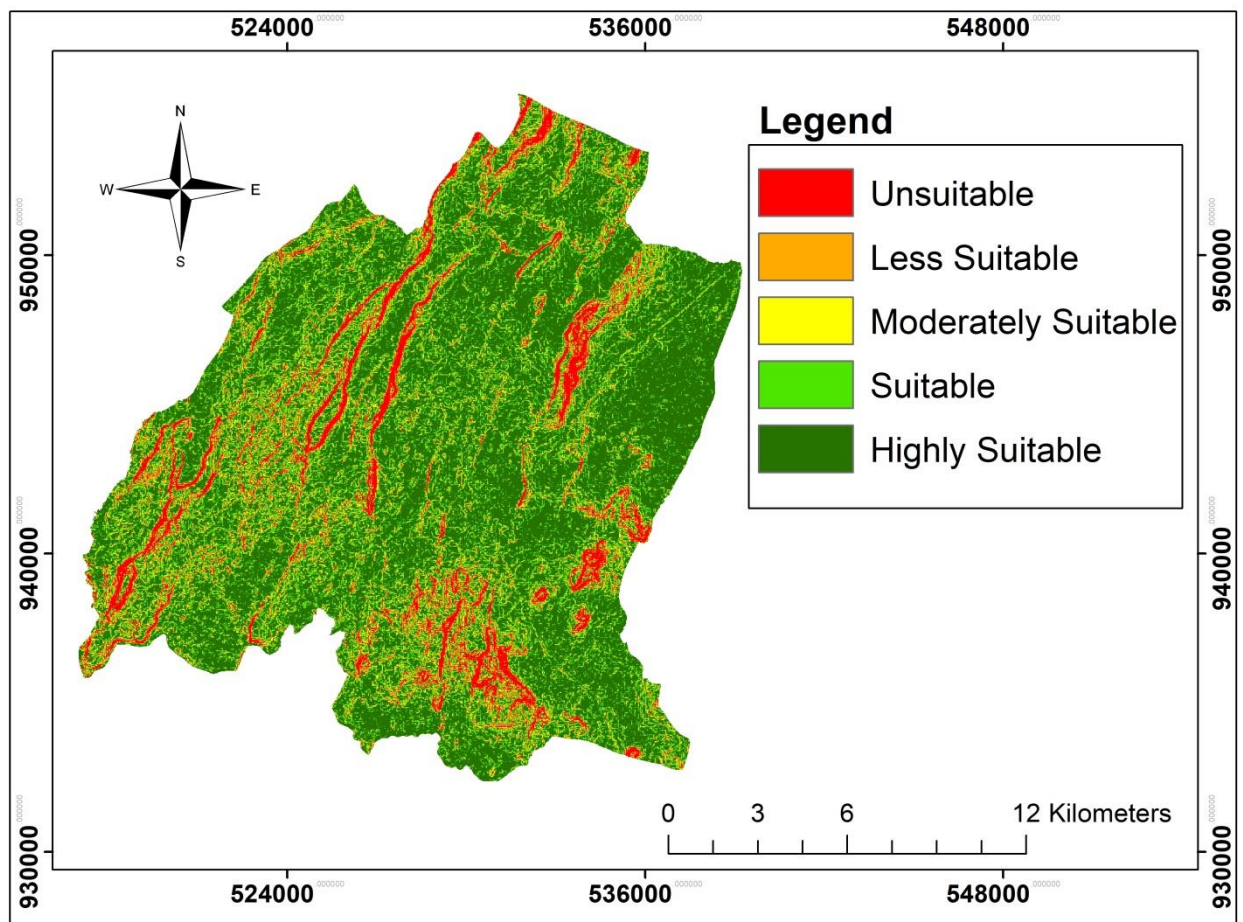


Figure 4.8: Reclassified slope map

#### 4.5.5. Population density

School should be located in a residential area with high population density (Dadfar, 2014). And also, Suitable sites and existing Population density have a positive influence to select suitable site selection for schools. Some researches (Wondwossen and Bedasa ,2019)

recommend that areas that have high population density are highly suitable for selecting suitable school site. On the basis of this claim, the study area is densely populated in the central parts of the city and it is considered as highly suitable for the development of secondary school. Therefore the population of the study area living greater than 49 pop/ha considered as highly suitability. Population density (pop/ha) from 44-49 pop/ha, 21-44pop/ha, 12-21pop/ha and less than 12pop/ha is calling population density (moderately suitable, less suitable, very less suitability and unsuitability) respectively (Table 4.9; Figure 4.9).

Table 4.9: Reclassified population density and area coverage of suitability level

Population density (pop/ha)	Standardization Score/Value	Level of suitability	Area in	
			(Ha.)	(%)
>49	5	highly suitable	135.273	0.43
44-49	4	moderately suitable	823.247	2.62
21-44	3	less suitable	1506.053	4.81
12-21	2	very less suitable	2587.610	8.26
<12	1	Unsuitable	26254.682	83.86

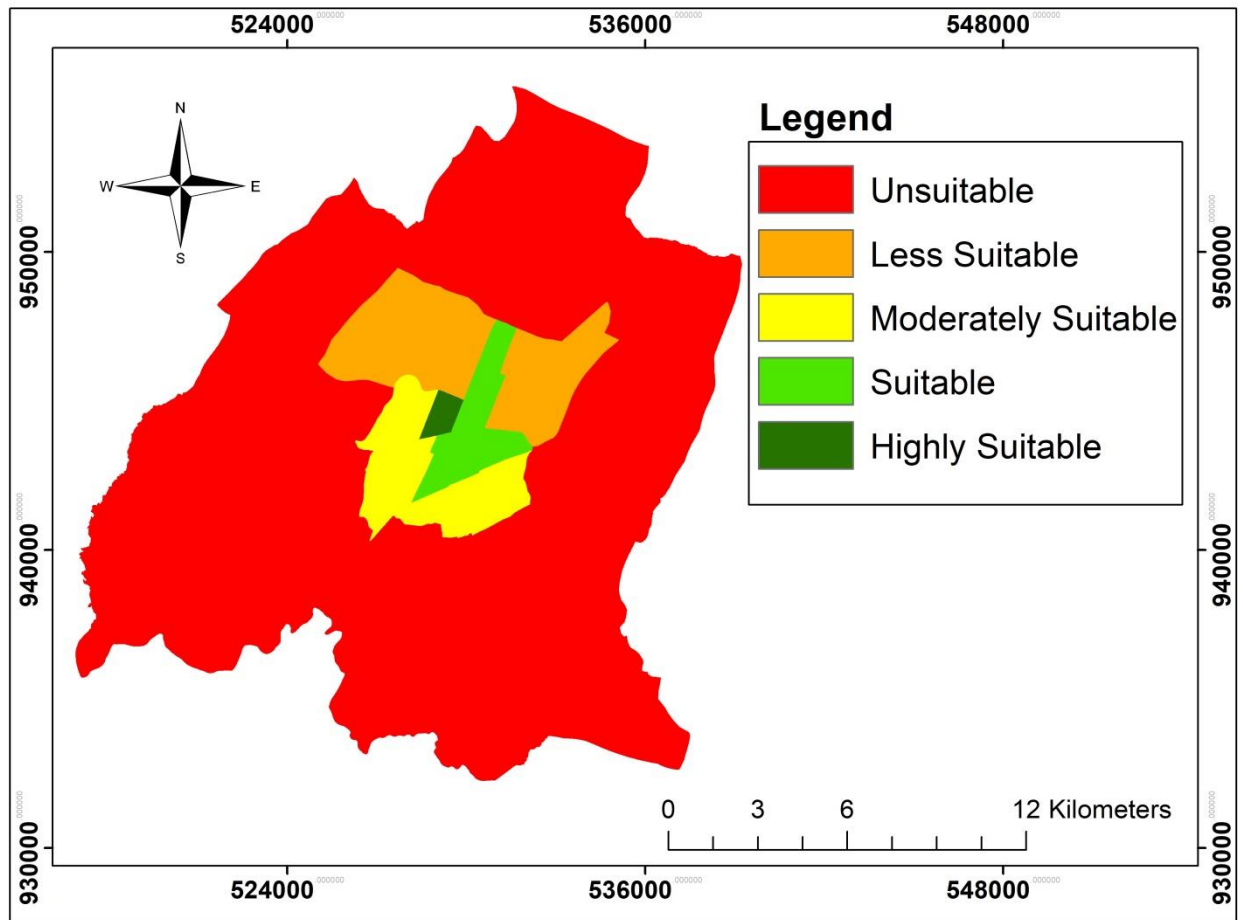


Figure 4.9: Reclassified population density map

#### 4.5.6. Suitability of distance from residential area

The distance to the student from residence to school is one of the most important factors determining the location of the school, the longer the distance, the more negative it will affect this criterion? The residential area in a way that means the resident population, so the nearer from the residential area, the better for the student safety and more accessibility (Ministry of urban and Development, 2012). For this study, areas within 0m to 100m, 100 to 200 and 200m to 350 m, distances from residential area have been considered as highly suitable, moderately suitable and less suitable respectively (Table 4.10; Figure 4.10).

Table 4.10: Reclassified residential and area coverage of suitability level

Distance from Residential (m)	Standardization Score/Value	Level of suitability	Area in	
			(Ha.)	(%)
0-100	5	highly suitable	8587.038	27.43
100-200	4	moderately suitable	3650.954	11.66
200-350	3	less suitable	4766.380	15.23
350-450	2	very less suitable	2608.541	8.33
>450	1	Unsuitable	11693.504	37.35

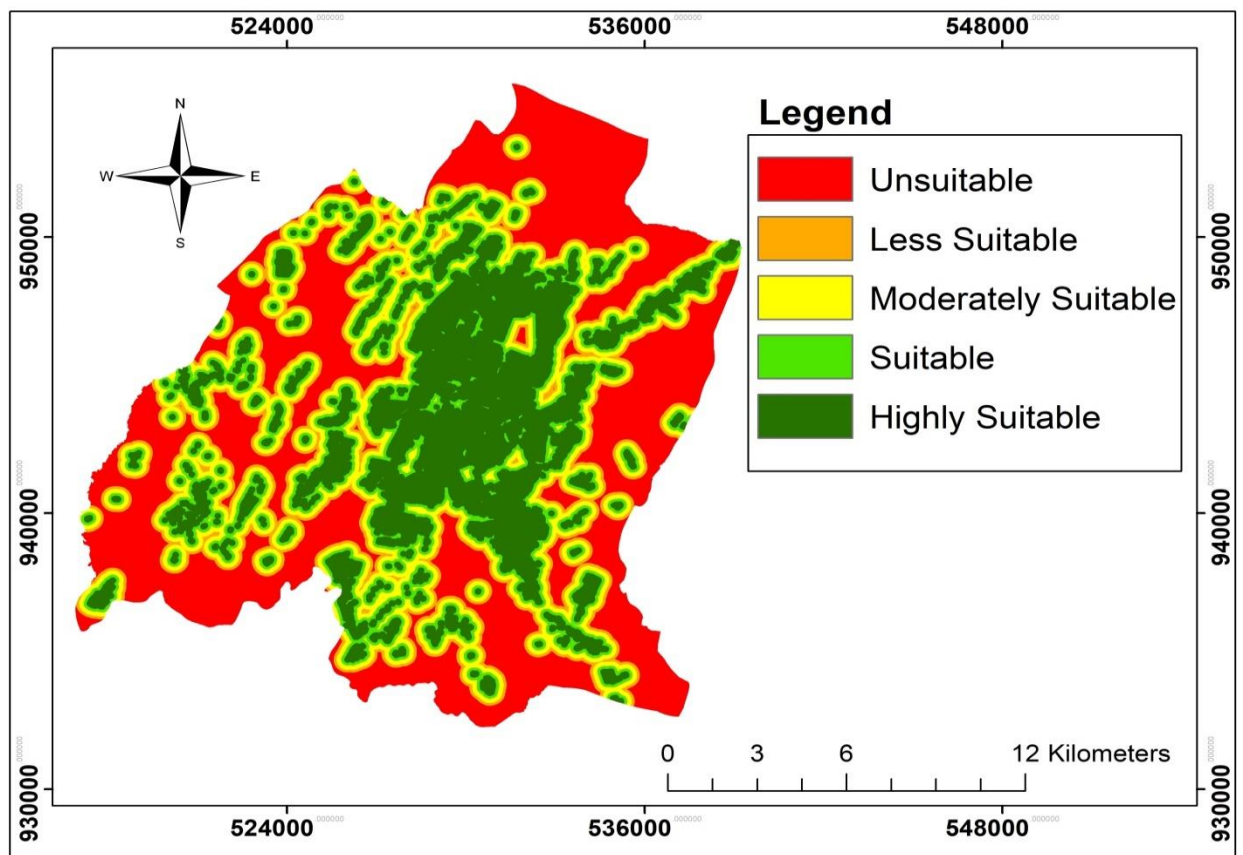


Figure 4.10: Reclassified residential area map

## 4.6 Suitable sites for new school location

### 4.6.1. Ranking, scaling and Weighting Factor Maps

This thesis' consisted of different steps: analysis of spatial distribution and accessibility, site selection constrains and suitability factors, rating and ranking the suitability factors,

weighing the factors chosen, and finally performing the suitability model. The remaining procedures are described below: scaling, ranking, and weighting.

**Ranking:** The raster layers were reclassified after the Euclidian distance calculation was completed. Reclassification is the process of putting relevant values (ranks) in their orderly sequence. During the reclassification procedure, this was done simultaneously. The arrangement of entities and their attributes is not arbitrary made. During the field work, document analysis, expert comments and suggestions were used to rank and describe the suitability class values. Suitability classes are categorized into five categories: high suitable, moderate suitable, less suitable, very less suitable, and not suitable locations. Suitability class 5, 4, 3, 2 and 1 are listed as high suitable, moderate suitable, less suitable, very less suitable, and not suitable respectively.

**Scaling Value:** After the suitability classes are ranked in order, the next step was to numerically value a given factor based on extent of strengthen or weakness of influencing a given variable in comparison with the others. Rating is refers to an evaluation, usually expressed in numerical terms, of how suitable a site is supporting a specific land use. Numeric scores to a total of five (one as least and five as most suitable) are assigned to each factor attribute class. Comparisons between classes were based on their level of suitability with respect to the choice of optimal location selection for secondary school. Since environmental factors for each specific study areas are different with others, there is no uniform standard for rating factors. For this thesis however, factors are rated based on the situation of study area, review of literatures and suggestion from experts.

#### **4.6.2. AHP Weight Derivation**

Analytical Hierarchy Process (AHP) pairwise comparison matrix was created and criteria weights were calculated for each factor by comparing factors on a scale from 1 to 9. The reclassified input datasets were assigned a weight value to express the importance or preference of each criterion to the other criteria for suitable site selection for secondary school (Table 4.12).

The computation of weights for parameters using Analytical Hierarchical Process (AHP) involves the following 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 4.12 last row).

Table 4.12: Pairwise comparison matrix

	LULC	Residential	Road	Population	Existing _school	Slope
LULC	1					
Residential	0.5	1				
Road	0.5	1.5	1			
Population	0.5	1.5	0.9	1		
Existing _school	0.77	0.83	0.91	1	1	
Slope	0.77	0.83	0.91	1.1	1.2	1

In AHP method using the data which have collected by the GPS/ interview from different organization and Analytic Hierarchy Process (AHP) technique, weight matrix was formed for land use ,distance from residential, distance from road, population, distance from existing school, slope, as Main criteria's. In AHP technique each every criterion's are compared with every other criterion's with user define scale values. Each Main criterion's pair wise comparison the collected data is averaged and results are used to create single Pair-wise Matrix by AHP technique. (Table 4.12) is representing Pair-wise Matrix of main criteria's. Description factors to be compare for Pair-wise Matrix in Idirisi Selva software (AHP technique).

Second, 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 4.13: Eigen vector of the pair wise comparison matrix

<b>The Eigen vector of weights is</b>	
LULC	0.2523
Residential	0.1364
Road	0.1621
Population	0.1496
Existing_ school	0.1441
Slope	0.1555
Consistency ratio=0.02 Consistency is acceptable	

The above AHP result shows that the derived factors have a different degree of influence on school. As it is evident from the weight assigned to the factors reveals the relative importance of each parameter in exposing an area to secondary school evaluation. As a result, shows land use/land cover with the weight of 25 has the highest priority, 14, 16, 16, 14, and 15 was obtained as a weight value for the distance from residential area, distance from roads/transportation, distance from suitability of slope, distance from Existing school, and distance from population density respectively with 0.02 of consistency ratio (Table 4.13). Consistency ratio of 0.1 or less is acceptable to continue the AHP analysis (Saaty, 2008). In this study, consistency ratio (CR) of conducted AHP comparisons has obtained 0.02, which is smaller than 0.1 therefore the comparisons can be acceptable. Based on the result of this study, AHP is a highly effective instrument for determining factor weights and is more helpful than alternative approaches since the inconsistency of the factor weight's pair-wise comparison matrix can be calculated and controlled by the Consistency Ratio (CR).

Table 4.14: Priority weighted matrix for main criteria's

Factors	Weighted factors	weighted percentages
Land use	0.2523	25%
Residential	0.1364	14%
Road	0.1621	16%
Population	0.1496	15%
Existing school	0.144	14%
Slope	0.1555	16%

Table above show weighed factors calculated in idirisi selva software based on a given data we entered in rows and column Consistency ratio = 0.02 Consistency is acceptable.

#### 4.6.3. Weighted Overlay Analysis

After reclassifying the parameters in terms of relative importance and suitability index, all of the reclassified parameters were overlaid in order to select suitable secondary school sites using the weighted overlay tool or a raster calculator in ArcGIS, and a final secondary school suitability map was prepared (Figure 4.11).

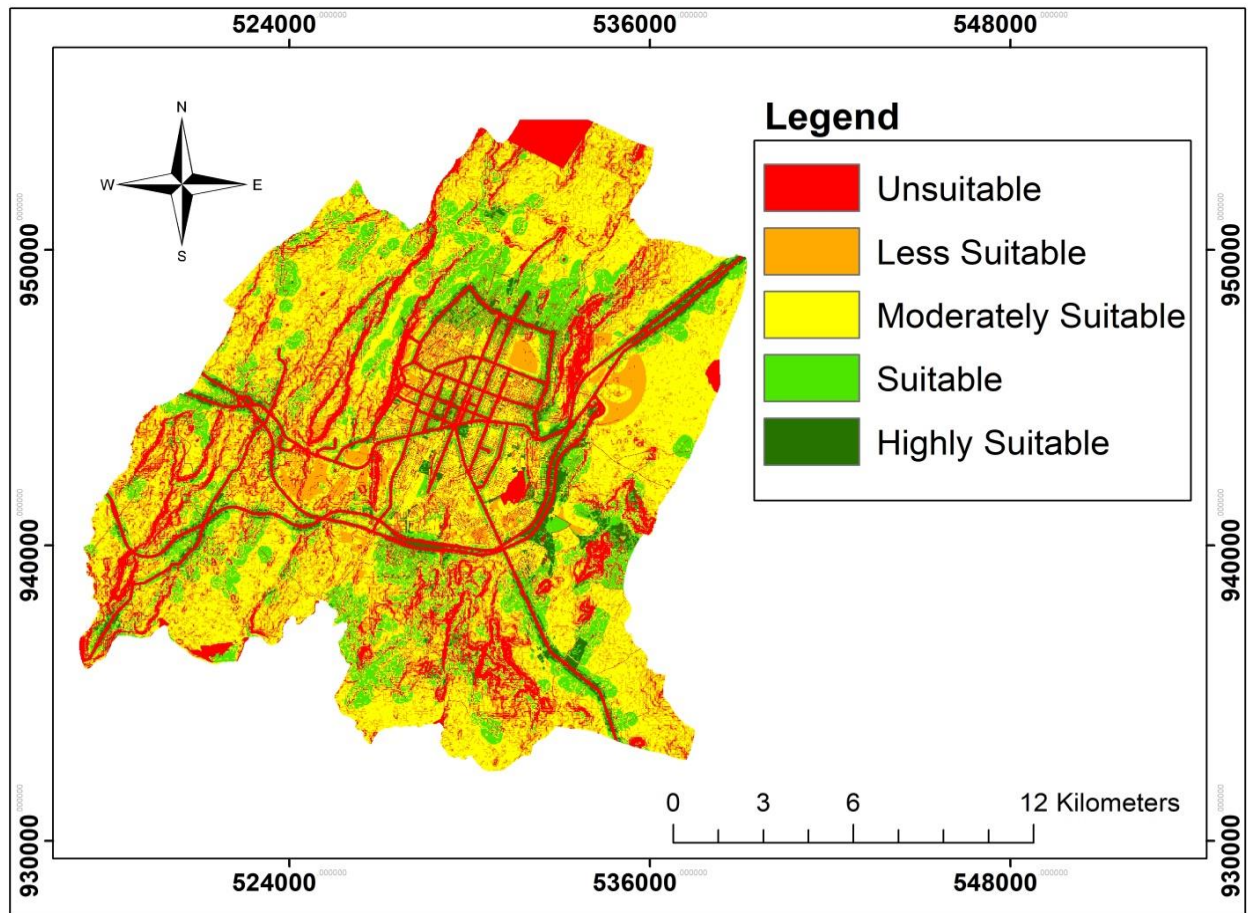


Figure 4.11: Weighted overlay suitability map of secondary school

According to GIS-based multi-criteria analysis, the result obtained from the overall suitability map shows 765 and 4449 hectares are highly suitable and moderately suitable for secondary school development. The large area is less suitable for secondary school development in the existing situation which covers 44% (11565ha) of the area. The remaining 14% and 22% are very less suitable suitable and permanently unsuitable for secondary school development respectively (Table 4.16). In the land use plan, the selected areas are mostly categorized as open space/Shrub land, forest/ bare land.

Table 4.15: Final suitability area and percent of total area coverage

Level of Suitability	Area (Hectares)	Percentage of Total Area (%)
highly suitable	765	3.02
moderately suitable	4449	17.011
less suitable	11565	44.00
very less suitable	3660	14.04
Unsuitable	5828	22.02

Total Area in Hectares = 25401

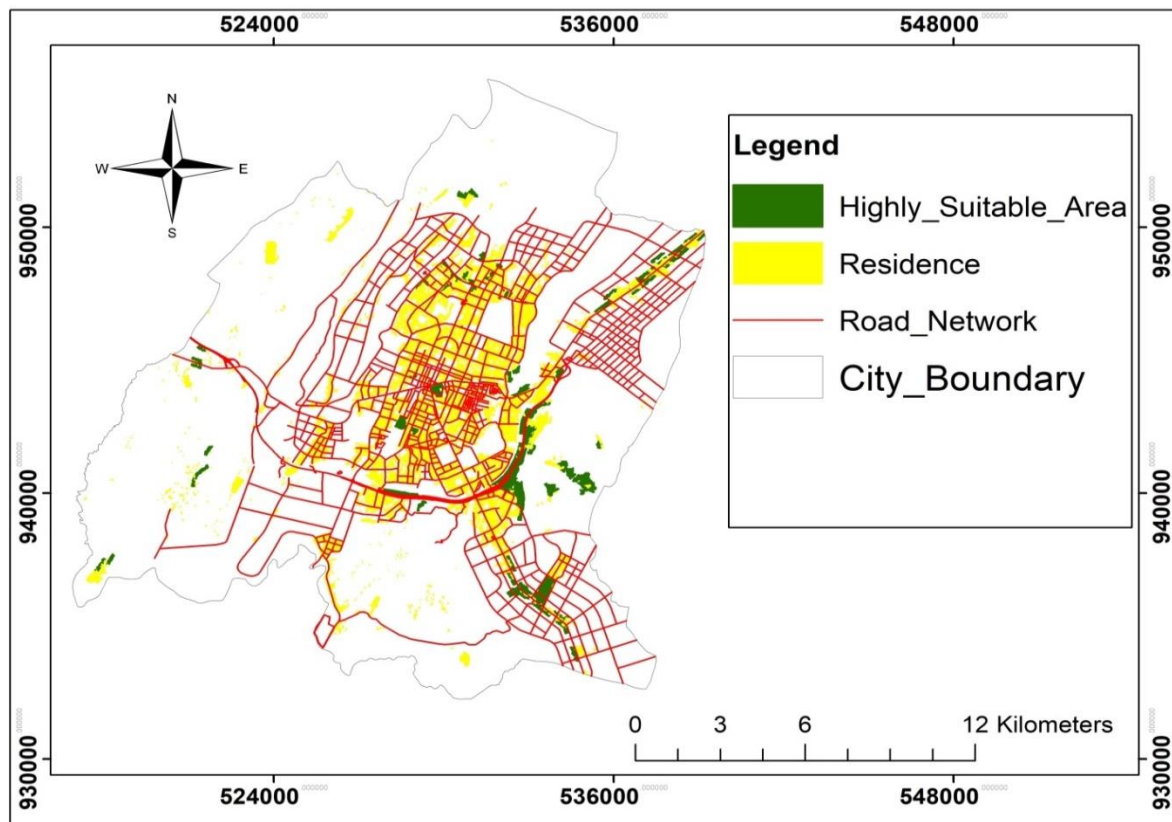


Figure 4.12: highly suitable areas map

As indicated the map is the highly (most) suitable sites and are the best preferable sites of secondary school construction. These sites are those which most satisfy the standards of the criteria used in the suitability model. Therefore, secondary schools are preferred to be constructed on these sites.

#### 4.6.4. Validation of the result

It is essential that the results should be validated; this was done with field verification. Validation helps to assess the reliability of the output and is usually assessed by ground truth verification (Abebe and Megento, 2017).

#### Verification Images

Visiting the location and comparing the results to your observations is known as field verification. Remote Sensing often calls this process —ground-trothingl. Using GIS-MCA methodologies, field verification was performed to assess the ground reality of the suitable area with reference to the below image are among the best suitable sites for secondary school development.



Figure 4.13: Selected suitable areas for secondary school

The LULC of the selected areas are mostly categorized under Open space/bare land and some part of Forest/shrub land are relatively suitable for selecting school site. With respect to the distance from residential area, transportations, transformer, stream, slope, facility locations, and population, the selected areas are identified as suitable sites for selecting in school site (Figure 4.13).

## 4.7 Discussion

In this study, spatial distribution and accessibility of secondary schools in Adama city are examined in a GIS environment. By spatial mapping of the location of secondary schools, the level of concentration and spatial distribution pattern of the service are evaluated at Kebele level as well as the city. Likewise, the spatial accessibility of each school was measured using a road network distance. The results show that the number of secondary schools offered at the local level is acceptable when compared to the benchmark set for population index. This serves as proof of the government's efforts to meet the needs of the town's residents who require secondary education facilities. However, a significant number of Kebeles have been shown to be connected to a lack of service when the lower administrative unit is taken into account. This inconsistency shows that the service's generalizability is limited.

Further, the computed value of NNR (0.353174) shows the general pattern of the service distribution in the city exhibits a clustered pattern. Result of NNR analysis at lower scale in the present study indicates a dispersed pattern in some of the urban Kebeles at 99% confidence level. The findings also reveal that the secondary schools in the city are inaccessible when we compared to the standard distance. Some of the population is expected to travel more than twice of the standard to access the services. The result of this study is pertaining to analyzed secondary schools and applicable to analyze spatial distribution and accessibility of secondary school provision in Adama city.

In general, based on this evidence, it is enough to conclude that spatial distribution and accessibility of secondary schools in city has a limitation in the provision of balanced service between Kebeles. Based on that, we conducted a location suitability analysis for a secondary school in Adama city.

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, 2016). For instance, Heywood et al. (2008), reveals different multi-criteria evaluation rules result in different suitability pattern.

Therefore, this study used six site selection criteria (proximity to existing school, proximity to road, proximity residential, land use land cover, slope and population) to select suitable

site for secondary school. The final suitability map has shown that, five suitability classes (unsuitable, very less suitable, less suitable, moderate suitable and highly suitable).

The class selected as highly suitable sites can be used for future secondary school development. The result indicated using GIS-based multi-criteria analysis, the result obtained from the overall suitability map shows 765(3%) and 4449 (17) hectares are highly suitable and moderately suitable for secondary school development. The selected area are Mostly categorized as open space/bare land and Shrub land/forest were considered to be highly suitable and moderately suitable for constricting new secondary school development respectively.

The final map shown that, 3%, 17%, and 44% of the study area has been identified as highly suitable, moderately suitable, and less suitable for secondary school development respectively(see figure ). Accordingly, selected and identifying suitable sites for secondary school development, requires accurate use of geospatial technology in order to assist an effective planning process of suitable school in a sustainable way.

## **CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS**

### **5.1. Conclusions**

Conclusion part discusses the results presented in previous chapters, General concepts and procedures for a comprehensive location analysis context, and states the contributions of this study. It also suggests future research that may extend the concept and implementation of the integrated location analysis framework. The results we obtained from spatial analysis and additional analysis to reach at the goals and objectives of the research based on which the following conclusions and recommendations are developed.

This study analyzes spatial distribution, accessibility and suitable site selection development of secondary schools in Adama City as of 2022. The results indicate that secondary schools in adama city are distributed unevenly throughout all Kebeles, implying unequal service provision between neighbors. The spatial distribution of Secondary school shows a clustered pattern distribution. The planners and the government can define future service spatial development directions to ensure sustainable development with the help of this uneven spatial distribution. the result of spatial accessibility of schools indicates that a significant percentage of the population has poor access to secondary education. This leads to the conclusion that there are not enough secondary schools in Adama City.

In addition, GIS-based land suitability analysis using critical factors was conducted in order to identify the best locations for secondary school development. Secondary school development site study is a challenging process that requires assessing a wide range of socioeconomic, environmental, and physical aspects. A GIS is a good tool for help in the selection of suitable locations for school development. The use of GIS for evaluation of secondary school development sites saves the time and resource needed for selection of suitable site.

In this study six criteria were considered (land use land cover, proximity to roads (transportation), existing school, slope, population density, and residential) sites are essential criteria for school selection process to ensure pupil's health and comfort. To achieve the goal of this study, selected parameters were analyzed using AHP and WLC in a GIS for Secondary school 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 25401, found in the study area 3% (762ha) highly suitable, and 17% (4449ha) moderately

suitable of the city is suitable for secondary school development. The remaining 44% (11565ha), 14 % (3660ha) and 22% (5828) are very less suitable and permanently unsuitable for secondary school development respectively. The majority of the locations chosen as being highly suitable for secondary school development are on flat area with a slope of 10 or less, open space, shrub land, and forest, as well as bare land that is connected to an existing built-up area or populated area, and they also follow the existing road. Those highly suitable sites are located in all part of the city. Therefore, this study simplify such complex decisions, demonstrated the benefits of integrating AHP and WLC in GIS for land suitability analysis.

## **5.2. Recommendation**

The findings of this particular study have shown that Geospatial technologies and GIS-based multi-criteria analysis (MCA) are important tools for studies of analysis spatial distribution, accessibility and suitability site selection for secondary school development.

- In this study, only one urban center is considered which by itself is not sufficient. It is recommended that in more urban centers in the country should be examined, as comparative analysis would provide an increased understanding of the effectiveness of school planning.
- The correlation between actual services and performance of schools and distribution of the facilities should be examined.
- Federal and State Government through the Ministry of Education ought to give due consideration to those areas poorly in their future plans.
- Ethiopian ministry of education has not pointed out criterions regarding school site selection. Therefore, this research study gives insight for the decision makers and planners to incorporate such scientific analysis for site selection process to ensure sustainable land planning and management.
- GIS and MCDA are a powerful tool for land suitability analysis for school site selection. The method needs only computer skills within a GIS environment. Therefore, it has been demonstrated that GIS-based MCDA for land suitability facilitates efficiency.
- For future researchers to select suitable site for school they should first evaluate the existing schools location and accessibility using geospatial technology.

## REFERENCE

- Ababa, a. (2014) ‘An Integrated Application Of Ahp And Gis For Environmental Suitability Analysis For Villagization Site Selection : The Case Of Homosha Woreda , Western Ethiopia A Thesis Submitted To The School Of Graduate Studies Of Addis Ababa University , In Partial Fu’, (June).
- Abazari, Z., F. Babalhaveaji and Jahangirifard, B. (2012) ‘GIS - based evaluation of Public Libraries locations for more sustainable building site selection ( An Iranian experience )’, *78th IFLA general conference and assembly*, (June), pp. 1–16.
- Abebe, M.T. and Megento, T.L. (2017) ‘Urban green space development using GIS-based multi-criteria analysis in Addis Ababa metropolis’ (November). doi:10.1007/s12518-017-0198-7.
- Ali, K.A. (2018) ‘Multi-Criteria Decision Analysis for Primary School Site Selection in Al-Mahaweel district Using GIS Technique 16(1).
- Ali, N. (2014) ‘Analytic Network Process based evaluation and analysis of railway station site selection in Ethiopia By Analytic Network Process based evaluation and analysis of railway station site selection in Ethiopia’, (September).
- Assessment, A. *et al.* (2009) ‘The Information Manager Vol.9 (1)2009’, 9(1), pp. 1–9.
- Ayele, L.G. (2018) ‘GIS Based Suitable Site Selection and Road-map Preparation for Equitable Distribution of Secondary Schools of Amhara Region ’, 8(1), pp. 100–113.
- Bulti, D.T., Bedada, T.B. and Diriba, L.G. (2019) ‘Analyzing spatial distribution and accessibility of primary schools in Bishoftu Town, Ethiopia’, *Spatial Information Research*, 27(2), pp. 227–236. doi:10.1007/s41324-018-0227-6.
- Carver, S. (2015) ‘International Journal of Geographical Information Integrating multi-criteria evaluation with geographical information systems’, 5(July 1991), pp. 321–339. doi:10.1080/02693799108927858.
- Dejen, A., Soni, S. and Semaw, F. (2019) ‘Spatial accessibility analysis of healthcare service centers in Gamo Gofa Zone, Ethiopia through Geospatial technique’, *Remote Sensing Applications: Society and Environment*, 13(December 2017), pp. 466–473. doi:10.1016/j.rsase.2019.01.004.
- Document, T.G. (2012) ‘Technical Guidance Document Identification and Suitability Assessment of Sites for Primary Schools’, (057).

- Dorling, D. (2021). World population prospects at the UN: our numbers are not our problem?. In *The Struggle for Social Sustainability* (pp. 129-154). Policy Press.
- Ecofog, U.M.R. and Guiana, F. (no date) '4 . Spatial distribution of points'.
- Engel (2014) 'No Title No Title No Title', *Paper Knowledge . Toward a Media History of Documents* [Preprint].
- Estoque, R.C. (2011) 'GIS-based Multi-Criteria Decision Analysis'.
- FAO (2007) 'THE FAO GUIDELINES FOR LAND EVALUATION W.Verheye', *Land Use, Land Cover and Soil Sciences*, II. Available at: <https://www.eolss.net/Sample-Chapters/C12/E1-05-02-03.pdf>.
- Fritz, S., See, L., Carlson, T., Haklay, M. M., Oliver, J. L., Fraisl, D., ... & West, S. (2019). Citizen science and the United Nations sustainable development goals. *Nature Sustainability*, 2(10), 922-930.
- Foresman, T.W. (1998) 'The History of geographic information systems: perspectives from the pioneers', *Choice Reviews Online*, 36(04), pp. 36-2183-36-2183. doi:10.5860/choice.36-2183.
- Fuad, N.M. *et al.* (2017) 'Improving junior high schools' critical thinking skills based on test three different models of learning', *International Journal of Instruction*, 10(1), pp. 101-116. doi:10.12973/iji.2017.1017a.
- Getachew, Y. (2019) 'Use of Multi-Criteria Decision Analysis Integrated with GIS and Air Pollution Model Inputs for schools site Selection', (March).
- Hopkins, L.D. and Knaap, G.J. (2019) 'The "Illinois school" of thinking about plans', *Journal of Urban Management*, 8(1), pp. 5-11. doi:10.1016/j.jum.2019.02.001.
- Ibrahim, M. and Shouman, M.A. (2012) 'Hospital Site Selection in Benghazi City in Libya', pp. 399-409.
- Jafari, S. and Zaredar, N. (2010) 'Land Suitability Analysis using Multi Attribute', *International Journal of Environmental Science and Development*, 1(5), pp. 441-445.
- Jahan, S. and Oda, T. (1994) 'Distribution of Public Facilities in Dhaka , Bangladesh : A Spatial Analysis'.
- Jain, K. and Subbaiah, Y.V. (2007) 'Site suitability analysis for urban development using GIS',

- Journal of Applied Sciences*, 7(18), pp. 2576–2583. doi:10.3923/jas.2007.2576.2583.
- Jamal, I.A. (2016) ‘Multi-Criteria GIS Analysis for School Site Selection in Gorno-Badakhshan Autonomous Oblast , Tajikistan’, (55).
- Jayaweera, K.D.N. (2014) ‘Application of Geographic Information Systems for Government School Sites Selection’, p. 130.
- Journal, D. (2010) ‘Spatial multi-criteria decision analysis for safe school site selection’, 1(2), pp. 1–14.
- Kazmierski, A. (2008) ‘Description of two new species of tydeinae (Acari: Actinedida: Tydeidae) from Spain with the remarks about the iberian species of subfamily’, *Annales Zoologici*, 58(2), pp. 357–363. doi:10.3161/000345408X326672.
- KENATE, L. (2017) ‘Suitability Analysis of Solid Waste Disposal Site using GIS Techniques for Sululta Town : Oromia Special Zone Surrounding Finfinne , Oromia , Ethiopia BY LAMESSA KENATE A Project Submitted to the Department of Geography and Environmental Studies Presented’, (June).
- Last, L. (2021) ‘Elsevier cookie notice’, (July), pp. 2–4. Available at: <https://www.elsevier.com/legal/cookie-notice>.
- Li, M. *et al.* (2014) ‘A review of remote sensing image classification techniques: The role of Spatio-contextual information’, *European Journal of Remote Sensing*, 47(1), pp. 389–411. doi:10.5721/EuJRS20144723.
- Malczewski, J. (2006) ‘GIS-based multicriteria decision analysis: A survey of the literature’, *International Journal of Geographical Information Science*, 20(7), pp. 703–726. doi:10.1080/13658810600661508.
- Mandal, P. *et al.* (2021) ‘Delineation of groundwater potential zones using the integration of geospatial and MIF techniques: A case study on Rarh region of West Bengal, India’, *Environmental Challenges*, 5(November), p. 100396. doi:10.1016/j.envc.2021.100396.
- Mohai, P. and Kweon, B.-S. (2020) ‘Michigan School Siting Guidelines Taking the Environment into Account Principal Investigators’, pp. 1–126.
- Mohit, Mohammad Abdul and Ali, M.M. (2006) ‘Integrating GIS and AHP for land suitability analysis for urban development in a secondary city of Bangladesh’, *Jurnal Alam Bina*, pp.

1–20. Available at: <http://irep.iium.edu.my/id/eprint/33724>.

- Muvhali, P. T., Bonato, M., Malecki, I. A., Du Plessis, L., Soley, J. T., & Cloete, S. W. P. (2020). Ostrich ejaculate characteristics and male libido around equinox and solstice dates. *Tropical Animal Health and Production*, 52(5), 2609-2619.
- De Montis, A. *et al.* (2004) 'Assessing the quality of different MCDA methods', *Alternatives for Environmental Valuation*, pp. 99–133. doi:10.4324/9780203412879-14.
- Moussa, M., mostafa, Y. and Elwafa, A.A. (2017) 'School Site Selection Process', *Procedia Environmental Sciences*, 37, pp. 282–293. doi:10.1016/j.proenv.2017.03.059.
- Murad, A.A., Dalhat, A.I. and Naji, A.A. (2020) 'Using Geographical Information System for Mapping Public Schools Distribution in Jeddah City', 11(5), pp. 82–90.
- Muskut, G.B., Mshelia, A.D. and Jerry, S.H. (2015) 'Site Suitability Selection for Future Establishment of Secondary Schools in Mubi North Local Government Area of Adamawa State , Nigeria : the Geographic Information System Approach .', 6(3), pp. 34–42.
- Mustaffa, A.A. *et al.* (2021) 'GIS and Multi-criteria Analysis for School Site Selection ( Study Case : Malacca Historical City )', 4, pp. 234–241.
- Nurul hidayah Liew, J.A. & Suhaizal H. (2004) '1, 2 1 1.', *Peranan Sosiologi dalam pendidikan alam sekitar satu cabaran*, 98, pp. 65–70.
- Odu, G.O. (2019) 'Weighting methods for multi-criteria decision making technique', *Journal of Applied Sciences and Environmental Management*, 23(8), p. 1449. doi:10.4314/jasem.v23i8.7.
- Of, D. *et al.* (2016) 'BofA Merrill Lynch', 2016045511(September), pp. 104–124.
- Of, M. and Development, U. (2012) 'Ministry Of Urban Development And Construction Revised Standards for Structure Plan Preparation and Implementation'.
- Redmond, T. (2005) 'A Brief History of Exchange', *Tony Redmond's Microsoft Exchange Server 2003 with SP1*, pp. 1–34. doi:10.1016/b978-155558330-9/50003-9.
- Rezayee, M. (2020) 'Hospital Site Selection in Iskandar Malaysia using GIS-Multi Criteria Analysis', (10), pp. 8–15. doi:10.35940/ijbsac.K0159.0221020.
- Rikalovic, A., Cosic, I. and Lazarevic, D. (2014) 'GIS based multi-criteria analysis for industrial site selection', *Procedia Engineering*, 69, pp. 1054–1063.

doi:10.1016/j.proeng.2014.03.090.

Saaty, R.W. (1987) 'The analytic hierarchy process-what it is and how it is used', *Mathematical Modelling*, 9(3–5), pp. 161–176. doi:10.1016/0270-0255(87)90473-8.

Said, R.A. (2021) 'July, 2021 adama, ethiopia'.

Sarath, M., Saran, S. and Ramana, K. V. (2018) 'Site suitability analysis for industries using GIS and multi criteria decision making', *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 4(5), pp. 447–454. doi:10.5194/isprs-annals-IV-5-447-2018.

Science, A. (2018) 'Adama Science and Technology University', (January), pp. 1–2.

Services, H. (2007) 'Siting Guidelines School Siting Guidelines', (December), pp. 1–12.

Shemsu D. (2018) 'Addis Ababa Institute of Technology, School of Civil and Environmental Engineering', p. 6206. Available at:  
<https://nadre.ethernet.edu.et/record/5184/files/TesfaAklilu.pdf>.

State, O., Study, C. and Local, S. (2019) 'Spatial Distribution and Accessibility to Post Primary Educational Institution in Spatial Distribution and Accessibility to Post Primary Educational Institution in Ogun State , Southwestern Nigeria : Case Study of Yewa South Local Government Area , Nigeri', (January 2015). doi:10.9734/JSRR/2015/12328.

Tacoli, C., McGranahan, G., & Satterthwaite, D. (2015). *Urbanisation, rural-urban migration and urban poverty*. London, UK: Human Settlements Group, International Institute for Environment and Development.

'The Spatial Distribution of the Basic Education Schools in Lattakia City ( Syria ) Kinda Wazzan ( PhD )' (2017), 7(1), pp. 71–79. doi:10.5901/jesr.2017.v7n1p71.

UNDESA, U., & UNECLAC, U. (2015). Water for a sustainable World. *World Water Development*.

World Health Organization and Unesco (2021) *WHO guideline on school health services*.

Youssef, A.M., Pradhan, B. and Tarabees, E. (2011) 'Integrated evaluation of urban development suitability based on remote sensing and GIS techniques: Contribution from the analytic hierarchy process', *Arabian Journal of Geosciences*, 4(3–4), pp. 463–473.  
doi:10.1007/s12517-009-0118-1.

Zhou, L. and Wu, J. (2012) 'GIS-Based Multi-Criteria Analysis for Hospital Site Selection in Haidian District of Beijing'.

## APPENDICES

### Appendix I: Coordinates of factory locations

<b>Name of Factories</b>	<b>Easting</b>	<b>Northing</b>
Tyre Process	520164.364	938995.743
National Cement Factory	520267.993	939519.751
Steel Factory	520856.326	940080.342
Mixing Plant	524981.718	942735.904
Adama Roof Factory	527182.377	940506.7
Adama Roof Factory	526964.756	940673.057
Adama Roof Factory	527106.728	940867.57
Ayinarge Flour Factory	526958.164	940947.574
ACOS Ethiopia	527044.947	941099.842
T.M Food Complex	527147.937	941205.08
Industrial Park	533494.362	940934.8
Beza Mar	530450.795	941960.687
Family Flour Factory	530781.256	942489.643
Oxygen, Nitrogen gas Plant	528374.839	943561.099
BEKAS Chemical Manufacturing	527345.019	944369.291
Tractor Factory	527922.275	944392.133
Turkey Textile Industry	528068.484	945740.082

Appendix II: Coordinates of health facility locations

<b>Name of health facilities</b>	<b>Easting</b>	<b>Northing</b>
Sire Robi Healthy Center	518,139.01	937,384.55
Mary Stop Clinic	521,171.47	940,240.13
Health Center	527,632.54	941,453.07
Health Center	531,585.51	939,640.64
NGO/Mary Stops Hospital/	528,358.50	943,443.89
Health Center	531,515.14	943,255.90
Rifty Valley Hospital	529,731.14	944,168.75
Gada Health Center	528,705.16	944,746.32
Noah Hospital	530,306.38	944,532.21
Iyor Clinic	530,273.02	944,633.12
Health Center	530,439.22	944,640.64
Adama Hospital	530,299.25	944,901.72
Health Association	529,858.68	945,129.91
Family Association Clinic	529,594.92	945,266.25
Medhanialem Hospital	530,041.14	945,523.29
Chilalo Health Center	528,866.88	945,980.08
Adama General Hospital	531,125.11	946,255.65
Health Center	529,946.77	947,764.46

Appendix III: Coordinates of school locations

Aandaaluus	<b>527983</b>	<b>943868</b>
Ababaa Lafiree	<b>529464</b>	<b>946891</b>
Abdii Adaamaa	<b>529429</b>	<b>942182</b>
Abdii Boruu 01	<b>529170</b>	<b>946335</b>
Abdiiboruu	<b>529170</b>	<b>946335</b>
Abidi Adaamaa	<b>529147</b>	<b>945194</b>
Abunagorgoriyoos	<b>531177</b>	<b>947021</b>
Abune Goorgooriyoos	<b>531175</b>	<b>947027</b>
Adaamaa Abdii Booruu	<b>529147</b>	<b>945194</b>
Adaamaa Adveeentistii	<b>528786</b>	<b>944198</b>
Adaamaa boossat Sad.2FFAA	<b>529575</b>	<b>942991</b>
Adaamaa Bosat	<b>529570</b>	<b>943061</b>
Adaamaa Faanaa	<b>530270</b>	<b>944790</b>
Adaamaa Lakk.5	<b>530723</b>	<b>945306</b>
Adaamaa Lakk-6	<b>530154</b>	<b>946058</b>
Adaamaa SAd.2ffaa	<b>530771</b>	<b>943092</b>
Adaamaa Yuuz Akkaadami sad-2ff	<b>529262</b>	<b>946687</b>
Adama Lakk 3	<b>528579</b>	<b>944765</b>
Adama Lakk 4	<b>530665</b>	<b>943958</b>
Adama Yuuz Akaadamii	<b>529262</b>	<b>946687</b>
Adamaa LAkk.2	<b>530139</b>	<b>945729</b>
Adamaa Lkk.3	<b>528579</b>	<b>944765</b>

Adamaa Yuuz Akaadamii	<b>529262</b>	<b>946687</b>
Adamaa.Lakk.1	<b>529323</b>	<b>944387</b>
Akaadaamii Ekseel Lakk-2	<b>530558</b>	<b>944070</b>
Akbaar Akkadamiik	<b>532120</b>	<b>943462</b>
Akbar Akadaamii	<b>532120</b>	<b>943462</b>
Almaaz Sadarkaa 1ffaa	<b>529911</b>	<b>945872</b>
Andiluus	<b>528429</b>	<b>943507</b>
Aresema Yooth Akadame	<b>529593</b>	<b>942072</b>
Arseemaayuuz Akkaadamii	<b>529593</b>	<b>942072</b>
Awaash Sad. 2ffaa	<b>531061</b>	<b>945403</b>
Awaash Sad.1ffaa	<b>531061</b>	<b>945403</b>
Bariitee	<b>527603</b>	<b>942556</b>
Beeteel Akadami	<b>530815</b>	<b>943650</b>
Beeteel Moodeel Lakk-2	<b>530815</b>	<b>943650</b>
Betel Model Akadami	<b>530833</b>	<b>943652</b>
Biftuu Adamaa	<b>530910</b>	<b>944816</b>
Biiftuu Adaamaa	<b>530907</b>	<b>944855</b>
Biiftuu Adaamaa	<b>530907</b>	<b>944855</b>
Birraa	<b>530705</b>	<b>940880</b>
Biruutaayit sad. 1ffaa	<b>531540</b>	<b>947317</b>
Bokkuu Kurabboo	<b>526315</b>	<b>934971</b>
Brihaan Akaadaamii	<b>530705</b>	<b>940880</b>
Burqaa Bokkuu	<b>530718</b>	<b>940505</b>

Burqaa Bokkuu	<b>530718</b>	<b>940505</b>
Chiroonta Giriinhiil	<b>531864</b>	<b>944844</b>
Cilaaloo	<b>528258</b>	<b>943297</b>
Cilaloo	<b>528258</b>	<b>943297</b>
COQONU	<b>527356</b>	<b>946747</b>
Daabee Qacee	<b>533090</b>	<b>941842</b>
Dambalaa sad 2ffaa	<b>527821</b>	<b>943349</b>
DANA	<b>529277</b>	<b>942734</b>
Deeystaar Intarnaashinaal Akka	<b>531131</b>	<b>946012</b>
Deeystaar Intarnaashinaal Akka	<b>532177</b>	<b>945140</b>
Desaangaam	<b>527318</b>	<b>943760</b>
Dessangam	<b>527983</b>	<b>943868</b>
Dhakaa Adii	<b>531458</b>	<b>948385</b>
Dhakaa Adii	<b>532573</b>	<b>948802</b>
Eebba	<b>531201</b>	<b>946006</b>
Eebba	<b>531188</b>	<b>945996</b>
Ekosalans Yasmiin	<b>532024</b>	<b>943857</b>
Ekseel Akaadaamii	<b>530731</b>	<b>943827</b>
Ekseel Akaadaamii	<b>529981</b>	<b>943240</b>
Ekseel akaadaamii lall-1	<b>530758</b>	<b>947829</b>
Falaga Xibab	<b>530161</b>	<b>944034</b>
Falaga Xibab	<b>530146</b>	<b>944814</b>
Fiqiir	<b>530932</b>	<b>942283</b>

Fiqir Akkaadaami	<b>530932</b>	<b>942283</b>
Gadaaliyaa	<b>528330</b>	<b>944188</b>
Gadaaliyaa	<b>528634</b>	<b>940900</b>
Galiilaa Akaadaamii	<b>528139</b>	<b>943739</b>
Ganda-02	<b>530649</b>	<b>942196</b>
Get-Akaadaamii	<b>528917</b>	<b>942879</b>
Get-Akaadaamii Ganda-10	<b>528917</b>	<b>942879</b>
Get-Akkaadaamii Ganda-11	<b>530244</b>	<b>943613</b>
Giriin Aveenu Intaarnashinaal	<b>530336</b>	<b>944118</b>
Goroo Sad.2ffaa	<b>528788</b>	<b>945937</b>
Goyaas sad. 1ffaa	<b>529030</b>	<b>943087</b>
Goyaas Sad.2FFAA	<b>529643</b>	<b>941265</b>
GRIIN AVEENUU	<b>531864</b>	<b>944844</b>
Guddaa Mijuu	<b>531362</b>	<b>948009</b>
Hayligii	<b>529323</b>	<b>943434</b>
Hiddaasee Sad.1FFAA	<b>529111</b>	<b>944848</b>
Hohita Xibab	<b>530882</b>	<b>943155</b>
Holii Enjils Ganda 09	<b>528416</b>	<b>943407</b>
Holii seviyer Adaamaa	<b>529598</b>	<b>946385</b>
Holii Seviyyar Adaama	<b>529598</b>	<b>946385</b>
Hoolii Eenjilisi	<b>529390</b>	<b>946675</b>
Hoolii Enjjils	<b>529390</b>	<b>946675</b>
Ingilishi Alive Akadaami Lakk-	<b>528428</b>	<b>943506</b>

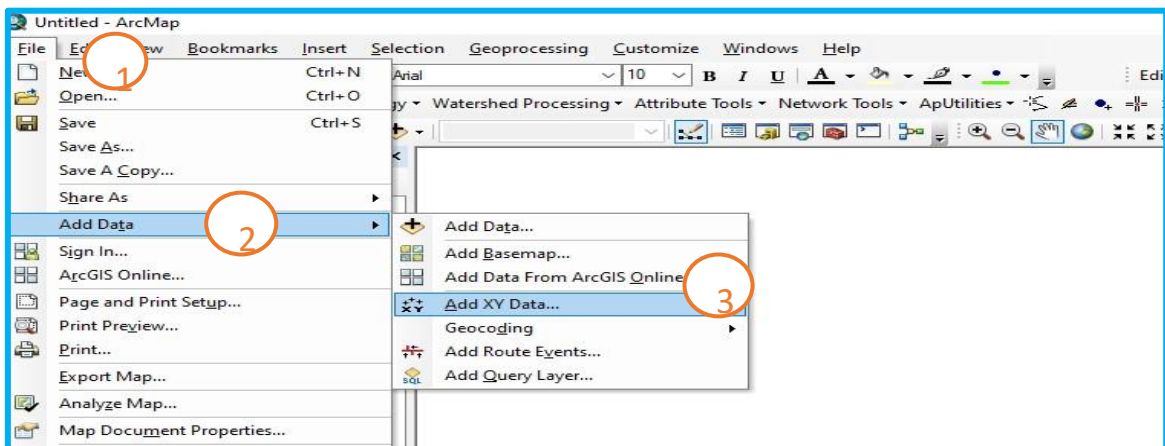
Inglish Alaayiv Akkaadaamii	<b>527348</b>	<b>943533</b>
Inglish Aliave Lakk-2	<b>527348</b>	<b>943533</b>
Istaar Akkaadamii	<b>529461</b>	<b>945575</b>
Kaamaraa Lakk 2	<b>532565</b>	<b>946408</b>
Kaamaraa Lakk-2	<b>532562</b>	<b>946464</b>
Kamaaraa	<b>530994</b>	<b>944612</b>
Kidaana Mihirat Kaatoolik	<b>531741</b>	<b>945729</b>
Kiyyaa Intarnaashinaal	<b>531069</b>	<b>945967</b>
Kulaafaa Urrashiidiin	<b>530410</b>	<b>943952</b>
Kulafaa'urraashidiin	<b>530630</b>	<b>943807</b>
Kulafaa'urraashidiin	<b>530400</b>	<b>943999</b>
L/K/Dajanee Simee	<b>527727</b>	<b>943423</b>
Luugoo Sad Iffaa	<b>528702</b>	<b>941741</b>
Luusii	<b>528923</b>	<b>946306</b>
Luusii Sad.1FFAA	<b>528926</b>	<b>946310</b>
M/B.Bultii Addaa WMO	<b>527540</b>	<b>942073</b>
M/B/M/Sir/Go/Sha/Bahaa	<b>530065</b>	<b>945421</b>
Madaahanalam	<b>530613</b>	<b>946650</b>
Madaahanalam .Kaatedraal	<b>530613</b>	<b>946650</b>
Makko Billi	<b>529044</b>	<b>946061</b>
Makkoo Billii	<b>529021</b>	<b>946103</b>
Malkaa Hidda	<b>525747</b>	<b>938197</b>
MALKAA HIDDAA	<b>526079</b>	<b>937958</b>

Masarata Kiristoos	<b>530612</b>	<b>945258</b>
Midlaandii Koominity	<b>530569</b>	<b>945867</b>
Miidiand Koominiitii	<b>530569</b>	<b>945882</b>
Miidlaand Koomiinitii	<b>530569</b>	<b>945867</b>
Modeela ganda-07	<b>529785</b>	<b>945240</b>
Modela O'dhimo 05	<b>529770</b>	<b>945237</b>
Muhaajir	<b>530193</b>	<b>943671</b>
Muhaajir	<b>530410</b>	<b>943110</b>
Mula'ata Haaraa	<b>527264</b>	<b>941852</b>
Mul'ata Haaraa	<b>527267</b>	<b>941831</b>
Naafiyaad Lakk-2	<b>531337</b>	<b>946900</b>
Naafiyaad 1	<b>529082</b>	<b>943717</b>
Naafiyaad Lakk 2	<b>531264</b>	<b>946650</b>
Naanatii	<b>531701</b>	<b>945051</b>
Naawzeer	<b>529621</b>	<b>946902</b>
Naawzeer Sad 1ffaa	<b>528628</b>	<b>946208</b>
Nafiyaad Lakk.1	<b>529082</b>	<b>943717</b>
Nafiyaad Lakk.2	<b>531264</b>	<b>946855</b>
Najashi Sad.1ffaa	<b>530101</b>	<b>943777</b>
Najjaashii Sadarkaa 2ffaa	<b>530125</b>	<b>943785</b>
Namabee	<b>532376</b>	<b>942583</b>
Neeros	<b>527319</b>	<b>943779</b>
Niiw Laayif	<b>528924</b>	<b>946305</b>

Niiwuu Moodeel	<b>527116</b>	<b>943737</b>
Odaa	<b>530930</b>	<b>947811</b>
Progreesii	<b>530778</b>	<b>942449</b>
Qiddist Kilaaraa	<b>529498</b>	<b>943757</b>
Qiddist Marriyaam Katademaal	<b>530294</b>	<b>944362</b>
Qiddus Quraan	<b>528967</b>	<b>944081</b>
Qiddus Yoseef	<b>529530</b>	<b>943345</b>
Qiddus Yoseef	<b>529530</b>	<b>943670</b>
Qiddus Yoseef	<b>529530</b>	<b>943670</b>
Qidduus Anxooniyooos	<b>529506</b>	<b>942677</b>
Qidista.Mariyaam Kaateedral	<b>530294</b>	<b>944362</b>
QidistiKilaaraa	<b>529498</b>	<b>943757</b>
Qophaa'ina Goroo	<b>528566</b>	<b>945961</b>
Qophaaina Hawaas	<b>531592</b>	<b>939600</b>
Qudduus Qur'aan	<b>528911</b>	<b>944898</b>
R.P.C/remeber the purest commu	<b>529142</b>	<b>944516</b>
Rehobot	<b>530573</b>	<b>943368</b>
Rehoobot Int	<b>530560</b>	<b>943364</b>
RPC Lakk-2	<b>529249</b>	<b>944221</b>
Salamoon Akaadaami Lakk-1	<b>531049</b>	<b>943904</b>
Salamoon Akaadaamii Lakk-2	<b>531865</b>	<b>943794</b>
Salamoon Akkaadaamii Lakk 2	<b>531890</b>	<b>943837</b>
Saqaqalloo	<b>530873</b>	<b>949695</b>

Shaaloom Akaadaamii	<b>528208</b>	<b>942510</b>
SOAF Adama TRC	<b>531132</b>	<b>946011</b>
SOAFAdaamaa TRC	<b>531132</b>	<b>946025</b>
Solloqqee kurfaa Sad 1ffa	<b>533739</b>	<b>943982</b>
Spaark	<b>531658</b>	<b>944493</b>
Tiwaab Adaamaa	<b>530429</b>	<b>943096</b>
Tiwwaab Adaamaa	<b>530410</b>	<b>943110</b>
Tiwwaab Adaamaa Lakk-1	<b>530169</b>	<b>943009</b>
Tiwwab Adamaa	<b>530141</b>	<b>943012</b>
Tsehay.Tigist.yodit/T.T/Y/	<b>530087</b>	<b>946271</b>
Veera 09	<b>528374</b>	<b>943779</b>
Veera 09	<b>528374</b>	<b>943779</b>
Veera Ganda 10	<b>528628</b>	<b>946208</b>
Veeraa Boolee	<b>530664</b>	<b>945882</b>
Veeraa Boolee /04/	<b>530680</b>	<b>945867</b>
Veeraa Sad.1FFAA	<b>529170</b>	<b>946335</b>
Wandar Laand Akkaadamii	<b>527716</b>	<b>943454</b>
Ya'elshaadaay Akaadaamii	<b>528050</b>	<b>941427</b>
Ya'elshaadaay Acadamy	<b>528050</b>	<b>941427</b>
Dabee	<b>534272</b>	<b>941427</b>
Siree Abba Bunaa	<b>525275</b>	<b>942591</b>
Ifaborusaqaqalloo	<b>530227</b>	<b>949774</b>

## Appendix IV: Adding and Displaying Downloaded Data in ArcMap



## Appendix V: Field book data collection format

Table. Data collection format

<i>Manual Data Collection Gps Field Book</i>						
Point No	Name Of Site	Site No	Northing	Easting	Elevation	Remark

Manually collecting data when device cannot store data/when memory full. In another way is to save data in different format and store, data during collecting from field use also hardcopy materials are recommended.

## Appendix VI Distribution of Schools in adama city

The spatial distribution of schools in adama city as of 2022 is depicted in figure. in adama city there are two hundred eight private and public schools including Kindergarten, primary schools, secondary schools. There is no public kindergarten school in the study area.

Table: Distribution of schools in adama city

No.of school in adama city			
kindergarten	113	No. Public secondary schools	11
public Primary schools	92	No. private secondary schools	22
Private Primary schools	28	Private & public secondary school	33
Total	-	-	266

In adama city there are one hundred thirteen kindergarten, two hundred twenty public and private primary schools and thirty three Private and public secondary schools are there. Most of these schools are in the center of the city.

## Appendix VII Distribution of public secondary Schools in adama city

Name of public secondary school	kebele	x-coordinat	y-coordinate
Gooroo sad.2ffaa	Ganda-01	528788	945937
M/B.Bultii Addaa WMO	ganda-09	527540	942073
Hawaas		530276	945605
Boolee	Genda 04	530680	945867
Dabee	Dabee	534272	945621
Dambalaa	Adama 09	527821	943349
AdaamaaBosat	Ganda-10	529575	942991
Siree Abba Bunaa	Melka adama	525275	942591
Burqaa	bukku Shanan	530718	940505
Adaamaa SAd.2ffaa	Adama 13	530771	943092
Ifaborusaqaqalloo	Leka hadi	530227	942591

