LAND SUITABILITY ANALYSIS FOR INDUSTRIAL AREA USING INTEGRATED GEOSPATIAL TOOLS: A CASE OF ADAMA CITY, ETHIOPIA

Jemal Abibeker Abdi

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 Science in Geo-informatics Engineering

Office of Graduate Studies
Adama Science and Technology University

October, 2022
Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "Land Suitability Analysis for Industrial Area Using Integrated Geospatial Tools: A Case of 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

Jemal Abibeker Abdi	_______________	___________________
Name of student	Signature	Date

RECOMMENDATION OF ADVISORS

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Land Suitability Analysis for Industrial Area Using Integrated Geospatial Tools: A Case of Adama City, Ethiopia". Prepared by Jemal Abibeker Abdi submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Geo-Informatics.

Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Tilahun Erduno (PhD)	______________________	________________
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APPROVAL PAGE

I the advisor of the thesis entitled "Land Suitability Analysis for Industrial Area Using Integrated Geospatial Tools: A Case of Adama City, Ethiopia" and developed by Jemal Abibeker, here by certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Tilahun Erduno (PhD)	____________________	________________
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We, the undersigned, members of the Board of Examiners of the thesis by Jemal Abibeker Abdi have read and evaluated the thesis entitled " Land Suitability Analysis for Industrial Area Using Integrated Geospatial Tools: A Case of 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 Geo-Informatics.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATMO…Adama Town Municipality Office.

AHP…Analytical Hierarchy Process

CSA…...Central Statistics Agency

DEM...Digital Elevation Model

EIA... Existing Industrial Areas.

ERDAS...Earth Resource Data Analysis System.

GDP ...Gross Domestic Product.

GIS...Geographic Information System.

GPS...Global Positioning System.

GST…....Geospatial Technology.

IPDC ...Industrial Park Development Corporation.

LULC...Land Use Land Cover.

MADM ...Multi Attribute Decision Making.

MCDM ...Multi Criteria Decision Making.

MODM ...Multi Objective Decision Making.

MRF...Multiplicative Reflectance Factor.

NAVSTAR…Navigation System with Timing and Ranging.

PLC...Private Limited Company.

RS…......Remote Sensing.

SRTM ...Shuttle Radar Topographic Mission.

SSDS...Site Selection Decision System.

UNID ...United Nation Industrial Development.

USGS...United State Geological Survey.

WHO...World Health Organization.

WLC ...Weighted Linear Combination

ABSTRACT

Industrial site selection is the process of choosing the most suitable location(s) that meets the desired requirements set by the selection criteria and segregation of incompatible land uses for future development. According to various reports, industrial areas are the second most important factor contributing to the global increase in releasing noise disturbance and toxic pollution problems. As a result, it is critical to plan and select appropriate sites in order to minimize the negative effects on people and the environment. However, industrial land suitability analysis, by its nature is a complex process and involves considerations of multi-criteria evaluation, which considers not only physical conditions but also environmental, social, and economic factors. Hence, this study is to analyze land Suitability for industrial area using integration of geospatial tools in Adama City. Twenty factors were identified are criteria for assessment. The thematic maps of these criteria were prepared and standardized using pair wise comparison matrix known as Analytical Hierarchy Process (AHP). A weight for each criterion was given by comparing them with each other according to their importance, the consistence of comparing matrix were checked by calculating the consistence ratio (CR). The consistency ratio of this study indicated that 0.068 which is less than 0.1. Thus, consistent matrix was formed which was acceptable in order to combine all the layers. Finally using the weights of all maps layer were integrated and overlaid to generate final site suitability map. The final suitability map classified the whole Adama city into four-suitability classes, restricted, less suitable, moderately suitable and suitable zones. Surprisingly unsuitable and highly suitable zone was not detected in the study area. Thus, the second alternative, which is a suitable zone accounts for 63.10km^2 of the study area while about 176.01km^2 of the area was restricted for medium and heavy industrial activity. The other less suitable and moderately suitable class index covers 73.94 km^2 of the study area collectively. Assessment map statistics confirmed that around 48.10 % existing industrial areas and proposed industrial area are clustered in a restricted class index. To validate compatibility map Assessment of statistics confirmed that 9.61 km^2 (28.17%) is incompatible for residential area in Heavy industry where as 14.16 km^2 (41.53%) are compatible for residential area in restricted area for industry. Result of the study reveals strong reverse relationship. Therefore, the study would improve the efficiency of using limited land resources by minimize the negative effects of Industrial development in the city on people and the environment.

Keywords: Geospatial Tools, MCE, AHP, Land suitability, weighted overlay analysis.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Land suitability analysis is a systematic procedure for examining combined effects of a related set of factors that an analyst assumes to be the important determinants of locational suitability (Eastman et al., 1995). According to (Al-shalabi et al., 2006), suitability analysis and site selection require consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for defined land use. In other words, it is the process to determine whether the land resource is compatible or incompatible for some specific land uses and to determine the suitability level.

Land use planning creates the prerequisites required to achieve a type of land use, which is sustainable, socially and environmentally compatible, socially desirable and economically sound. As (Adhikari and Li., 2013) cited in (Abedin, 2015) noted, land use planning is a field of science which tends to order and regulate different land uses in urban areas in an efficient situation. It deals with organizing, arranging and planning of land uses with the aim of achieving a conducive and aesthetically pleasing environment. It requires a critical study, analysis and investigation of land structures and arrangement to determine suitability and compatibility of land uses. In all, land use planning can be defined as the arrangement of land uses in a spatial structure and separating conflicting land uses to achieve a harmonious environment with a pleasant environmental landscape. In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully, done with the aim of directing growth to the most appropriate sites.

Compatibility of land use is a prerequisite for an aesthetic environment. An environment with incompatible land uses is set to produce a chaotic urban landscape with different conflict of interest among the various land uses. Compatibility of land use is determined to ascertain the close link or relationship between two or more land uses. The characteristics of each land use are analyzed to determine whether it is compatible or not. For two land uses that the compatibility is set to determined, the characteristics of each land use is known while the analysis is done so as to arrive at a conclusion if the two are compatible or not. Therefore, determination of compatibility land uses is a friendly analysis of the characteristics of land use to determine their level of correspondence (Abedin et. al., 2015). According to (Taleai et al., 2007) the co-habitation of different activities of different scales may cause positive or negative effects on urban space. Those effects may vary from one space to another, depending on the existing activities in the urban area. For example, cohabitation of residential and industrial activities in the same urban space may cause negative impact like congestion, air pollution that makes urban life more difficult.

Preliminary observations indicate that industrial area development can considerably boost Ethiopia's attractiveness for investment and business, as demonstrated by intense interest to take up space in one of the parks that are under construction (UNIDO, 2018a). As indicated in the urban planning and implementation manual of Ethiopia (MUDC, 2012) the location of the industrial area should be in terms of certain predetermined factors such as physical, economic, social and environmental conditions, which influence the suitability of the site. A proper location must attend to a wide range of factors to coordinate socio-economic benefits and environmental sustainability.

Successful formulation of policies for land usage requires analysis of land usage details to make sure that site selected for certain purpose is appropriate. Land use planning consists of identification, suitability analysis, with the rapid industrial development, using integration of geospatial methods have been widely used to analysis the land utilization. The significant impact of industrial area development in the national economy, environment and the effectiveness of geospatial technology in site suitability analysis were the motivation of the present study. These specialized information systems should adapt standardized modern technical and technological solutions arising from the operational requirements of their functionality. Integrated approach of geospatial technologies such as E-cognition developer, GIS, Auto CAD, GPS data, remote sensing imagery, aerial photographs and Google earth is valuable in the development of modern Geo-spatial to Problem solving, improving accuracy, extracting new information, analyzing information, to fill gaps of one’s technology, to secure data and to update data.

Finding suitable locations for industrial activity is a complex problem whose solution involves the analysis of multiple factors. The most widely used approach is to decompose the problem into simple component parts or hierarchies referred to as the Analytic Hierarchy Process. AHP was a choice method for this study because of the possibility of incorporating both technical knowledge and subjective judgments in the decision making process. This approach also supports both quantitative and qualitative data analysis (Rahman & Sahaty, 2008).In this research study, expert interviews was conducted to identify the most important factors influencing location decisions for not only large scale industrial area as previous conducted but also including light and medium scale industrial areas in the Adama City.

The AHP methods were used to compare and measure the subjective judgments of business officials using Thomas Saaty’s ratio scale. Spatial data based on subjective judgments were gathered and entered into a GIS-based multi-criteria evaluation to rank areas in the town according to their levels of industrial suitability.

To date there are little previous study that has used Geospatial technology tools to investigate industrial location in the Adama City. The present study therefore demonstrates how the integrated Geospatial technology based multi-criteria evaluation and human judgments can be implemented for all scale industrial location suitability in the Adama City.

1.2 Statement of the Problem

The rapid development of the industrial field resulted in equally rapid diffusion of industries. However, most investors confront high transaction costs due to a lack of infrastructure and weak institutions on the one hand, and people and environment influenced in various fields by the industrial pollution on the other. Industrial pollution affects people and the environment in a variety of ways. Furthermore, according to various reports, industrial areas are the second most important factor contributing to the global increase in releasing noise disturbance and toxic pollution problems. As a result, it is critical to plan and select appropriate sites in order to minimize the negative effects on people and the environment. Unfortunately, in many low and middle-income countries, industrial zones have little attention paid on the environmental and social impacts because their industries are often located in very populated areas (Fernando et al., 2015).

Adama City is one of the selected cities for sub-sector industrial planting, according to the Ministry of Industry (2015). Industrial areas are comprised of groups of industries clustered together in a given geographical area because of collective benefits such as industrial linkages as well as access to infrastructure services and raw material. According to Adama City newly developed structural plan, the majority of the earlier planned industries are clustered around the residential and social service area. As a result, the firm may be able to release noise disturbance and environmental contamination or incompatibility problems. Incompatibility problems are characterize because of lack of best site selection, this is lead our environment to create conflict in community by disturbance, high levels of pollution, high Road traffic problems, noise, emissions, waste water, decreases access to public services like health and educational centers. For corrected planning through a sustainable land management, so it is necessary to find out the potential site for industrial development in the city in sustainable manners to reduce the problem raised by Incompatibility.

On the other hand, the main problem is that geospatial data (specifically, vector and image data) obtained from various data sources may have different projections, different accuracy levels, and different inconsistencies. This difference in scales call for a modeling approach that provides a basis to combine multiple information from different sources and scales as well as technical knowledge into an aggregated model output.

In response to the scale problem arising from the complex interactions between location factors as outlined above, this research utilized an integrated GIS based multi-criteria evaluation and the AHP method to assess the suitability of industrial areas in the Adama city with respect to Physical, social, economic and environmental factors.

An integrated approach to the suitability analysis may enhance Land management and planners' understanding of how location-based factors determine prime industrial areas in the Adama city. Furthermore, the model fills an academic research gap as it contributes to empirical research on all scale industrial location suitability within Additional factors.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this study is to analyze land suitability for industrial area using integrated geospatial tools: A Case of Adama City, Ethiopia.

1.3.2 The Specific objectives of the study are to:

i. Identify the criteria responsible for industrial site selection.
ii. Examine the existing industrial areas based on the produced suitability map.
iii. Identifying suitable site using MCE approach for industrial development in the Adama City.
iv. Determine the prime locations for industrial development in the municipality.

1.4 Research questions

1. What are the criteria responsible for industrial site selection?

2. What are the existing industrial areas in Adama City?
3. How to identify the location of industry by integration geospatial tools?
4. Which areas in the Adama City are prime locations for industrial development?

1.5 Significance of the Study

The primary aim of this thesis research is to determine a suitable site selection for the all kind of industrial area in Adama City. Thus, it is important to proper planning, accurate timely and monitors the industrial process in a systematic manner. Hence, the paper is useful for planners, policy-makers, developers, and land managers. Moreover, it helps Adama city planners and developers to recognize that where is optimal land for future industrial development to keep urban sustainable development while utilizing the land properly. Secondly, the study was illustrate the effectiveness of integration geospatial technology such as GIS, RS, Google Earth, ECD and the (AHP) method for suitability site selection industrial area mapping, monitoring and management for future continue development. Organizations working on environmental issues and researchers also used as a baseline study for further studies and Thirdly, if the decision-makers use the result of this study then the community may be benefit because, this study was consider physical, environmental, economic, Social and population factors for industrial area location. The community may be benefit in sustainable land, clean environment within minimum industrial pollution and the customer may profit by the location of industry near to infrastructure by reducing the cost spent on transportation of raw materials.

1.6 Research Scope

This study was conducted in Adama City administration boundary; Research on Industrial suitability site selection requires a complex process that involves not only technical requirement, but also physical, economic, social and environmental requirements that is a wide scale study in all cities of the country. Nevertheless, with the available time and resource in order to make the study more manageable manner and due to the difficulties of each Industrial area site selection, the scope of the study has delimited to Adama City administration boundary.

1.7 Limitation of the Study

Because of the problem of data availability, the number of map inputs for the suitability analysis was limited to twenty. Additional data inputs could have been the "fire-protection, availability of fiber optic line, income of the community, and availability of workforce".

These factors could improve the suitability model further by creating the opportunity to evaluate candidate locations based on the combined effects for all specific industrial type location factors.

1.8 Organization of the Paper

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

CHAPTER TWO: LITERATURE REVIEW

In this chapter, information related to the study that was-studied before by other researcher was taken as stepping-stone to compare gaps. The researcher also tries to put the theoretical frame works that are relevant for this study and conceptualizing those terms on his account.

2.1 Concepts Related With Industrial Site Selection

2.1.1 Site selection

Site selection is one of the basic vital decisions in the start-up process, expansion or relocation of businesses of all kinds. Construction of a new industrial system is a major long-term investment, and in this sense, determining the location is critical point on the road to success or failure of industrial system (Alek sander et al, 2013). According to (Alek sander et al, 2013), one of the main objectives in industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. Most of the data used by managers and decision makers in industrial site selection are geographical which means that industrial site selection process is spatial decision problem. Such studies are becoming more and more common, due to the availability of the Geographic Information Systems (GIS) with user-friendly interfaces. Geographic information systems (GIS) are powerful tool for spatial analysis which provides functionality to capture, store, query, analyze, display and output geographic information. Geographic Information Systems used in conjunction with other systems and methods such as systems for decision-making and the method for multi-criteria decision-making (MCDM).

2.1.2 Site selection process

In the past, site selection was based almost purely on economic and technical criteria. Today, a higher degree of sophistication is expected. Selection criteria must also satisfy a number of physical, economic, social and environmental requirements, which are enforced by legislations and government regulations. The process selection of industrial site means complex multi-criteria analysis, which includes a complex array of factors involving economic, social, technical, environmental and political issues that may result in conflicting objectives (Masood, 2007). Nowadays, in the post-industrial society and knowledge-based society, people become the most important resource. Proximity to universities and scientific institutions, number of innovation per citizen can be one of the key factors for decision makers. All so risk management is an indispensable analysis in site selection process. Managing the risks involved in selecting a new industrial location is one of the most critical factors in determining the ultimate success or failure of a business. To keep risks at a minimum, investors should first be familiar with the stages of the site selection process and what are the key risks that need to be considered and managed during each of these stages (Florida, 2002). One of the most important and far-reaching decisions faced by operations managers is deciding where to locate new industrial facilities. This is a strategic decision involving irreversible allocation of the firm's capital, and often has a crucial impact on key measures of the firm's supply chain performance such as lead-time, inventory, and responsiveness to demand variability, flexibility, and quality (Bhatnagar, 2005). Collection of information allows the generation of a potential industrial sites that can grouped, while the use of certain term criteria, through several iterations, gradually narrowing to a choice (Fig. 1). In such way, the total number of available sites, the customer is aware of a certain number of them. Of these, only a certain number of locations meet the selection criteria of the decision maker, so that makes group of sites for consideration. By collecting information on these sites, it remains just making a group of sites that are included in the shortlist. Out of this group, based on the criteria used by the decision maker (investor) chooses one location.

According to land use planning rules, the arrangement of land use types in a location should be such that the unwanted and repulsion effects between neighboring land units are minimum(bakhtiarifar et al., 2011). Compatibility matrix examines how a land use is in neighborhood of one another; also, it investigates their positive and negative effects on each other. Land use compatibility matrix values are usually determined by experts and are representation of different levels of consistency among different land uses (bakhtiarifar et al., 2011). Land-use compatibility is defined as "the degree to which two or more land use types co-exists without significant negative impact" (Taleai, 2007).

2.2 Determining Factors for Industrial Site Selection

In the past, site selection was-based almost purely on economic and technical criteria. However, currently, a higher degree of sophistication is expected. Selection criteria must also satisfy a number of physical, social and environmental requirements. Those parameters affecting Industrial area suitability are; Availability of developable land, proximity to CBDs, Proximity to raw materials source, proximity to existing industry Proximity to health and Social facilities, proximity to Residential areas. Proximity to Sewerage system, Water Body, proximity to Highway Road, Railway Road, Major Road, Landfill Site, Availability of reliable electricity supply, Availability of ground water potential, land use land cover, slope,elevation, soil, geology and Most of parameters were obtained from secondary source and others were collected from primary source. (Source. MUDC 2012).

Selection of industrial site means complex multi-criteria analysis, which includes a complex array of factors involving economic, social, technical, environmental and political issues that may result in conflicting objectives (Reisi, 2011). Nowadays, in the post-industrial society and knowledge-based society, people become the most important resource. Managing the risks involved in selecting a new industrial location is one of the most critical factors in determining the ultimate success or failure of a business.

To keep risks at a minimum, investors should first be familiar with the stages of the site selection process and what are the key risks that need to considered and managed during each of the stages (Aleksandar et al, 2013).

2.3 Empirical Review of the Study

2.3.1 Industrial Location Theory

The early economists who made substantial contributions to the theory of industrial location identified industrial location factors. Von Thunen, "the father of location theorists" was the first economist to attempt to conceptualize the factors that influence the location of industries (Safari & Soufi, 2014). Other theorists like Wilhelm Launhardt further advanced the ideas of the Thunen model (Puşcaciu, 2014), however, the German geographer, Alfred Weber was the first to add a scientific explanation to the theory of industrial location (Jirásková, 2002). Weber's theory identified primary and secondary factors that caused industries to move from one geographic area to the other. He referred to Primary causes as transport and labor costs and the secondary causes he described as agglomerative and deglomerative factors (Weber, 1929). However, his model attracted many early criticisms from many authors. For instance, according to (Predöhl, 1928).

Weber's theory was more selective than deductive. He posits that the primary and secondary causes of industrial location in the theory are not realistic nor logical and that other factors like "capital costs" and management costs affect the choice of location for industries thus the factors are not limited to transportation and labor costs. In addition, Predöhl (1928) explains that Weber failed to analyses the technical factors behind agglomeration. He asserts that agglomeration factors such as access to power, water, consumers and specialized machinery are too heterogeneous and that the model fails to identify how much cost can be reduce by agglomeration.

Irrespective of the criticisms of Alfred Weber’s theory, an analysis by Djwa (1960) points to the fact that several early publications recognized the importance of transportation, raw material source, markets, and lab our as the most important factors influencing the location of industries. Advancements on Weber’s agglomeration forces did not expire with the outdating of the earlier economists. Hoover (1937) classified agglomeration into large-scale economies, localization economies and urbanization economies. Isard (1956) gave a detailed explanation to Hoover's classification; he posited that localization economies occurred when similar firms in the same industry converged at a particular location to benefit from a common resource pool, or common facilities and infrastructure. He further referred to urbanization economies to occur when different firms concentrated in a particular location; that is when firms are “spatially juxtaposed” (Isard, 1960; Palacios, 2005).

A practical approach to solving this problem is to model industrial location suitability by assessing location factors based on empirical judgments instead of theoretical data. This approach eliminates the likelihood of including factors, which do not necessarily describe the region in question. The approach also assumes a scientific nature, which makes it transparent, and repeatable (Rauber, Miksa, Mayer, & Proell, 2015).

One of the most powerful methods for assessing industrial location suitability based on empirical information is the spatial multi-criteria evaluation. Spatial multi-criteria evaluation “can be thought of as a process that combines and transforms a number of geographical data (input) into a resultant decision (output)” (Drobne & Lisec, 2009). The main aim of the method is to determine areas suitable for a specific objective based on several criteria or conditions that the area should satisfy (Eastman, 2005).

2.3.2 Global Experience in Industrial Site Selection

The industrial revolution, which occurred in the last part of the nineteenth century, caused the dramatic economic growth of cities in developed countries. The population in cities such as Manchester, England increased exponentially due to the rapid industrial expansion and technological improvements in the manufacturing of consumer goods (Douglas, Hodgson, & Lawson, 2002). Modern day cities have become models of the industrial revolution where still economic prosperity is link to manufacturing and rapid urbanization.

The high population densities in contemporary cities provide support for the production of goods and services. They attract talents and skilled lab our, which enhances specialization (UN-HABITAT, 2011). In many developing countries, cities are also the places where most of a country's public infrastructure, which promote business productivity including highways, telecommunication systems and water treatment, is concentrated (Eberts & McMillen, 1999).

Identifying an optimal site for industrial areas is an extremely difficult and complicated process because it requires data from diverse social and environmental fields and a number of conflicting qualitative and quantitative criteria existed for evaluation/selection (Mehdi et al., 2015). (Sarath et al., 2018) had presented the combination of a Geographic information system (GIS) and multi criteria decision-making (MCDM) to identify distinctly the suitable zone for industries. Six criteria that were used by the researchers for analysis of land suitability for industrial sites are LULC, flood, geology, road, DEM and slope. To develop the importance level of criteria for industry location they implemented AHP based pairwise comparison. The high and lower weights were assigned to geology and road respectively. For criteria standardization, they used simple linear transformation by allocating a score value of 1,2,3,4, and 5 for the consecutive influence from unsuitable to highly suitable. Finally, for aggregation of these criteria, they used weighted linear combination methods.

Fernando et al., 2015 had produced a GIS-based model to screen the most suitable location for industrial zone in Kesbewa Divisional Secretarial Division of Colombia District Srilanka. As a methodology, initially they used seven sets of site selection criteria that were identified through literature review and consultation of experts. Land use, water, soil type, wildlife archeological site, roads and power line were the selection criteria. For deriving the weight for the criteria, they used AHP methods. The set minimum requirement for the industrial zone was 25 acres and they developed a 100m buffer zone (green belt) for the final suitable zone to minimize the pollution of industry.

The principles of liberalization, globalization, and privatization and the relative changes at the global economy have been very important for the industrial zones development. Most of the countries use this tool for the development of industrial field with minimizing its negative impacts on people and the environment. This has been very important as a better environmental management tool, which can use for sustainable development of the industrial sector. The best location for the industrial zone is the key factor of the accomplishment of its main objectives, which are the requirement of all facilities and the minimum of social and environmental negative impacts (Fernando et al., 2015).

2.3.3 Dimensions of industrial location in Africa's urban areas

The goal of the recent Agenda 2063 of the African union is to achieve a sustainable socio-economic transformation of the continent through industrialization and infrastructural development to eradicate poverty, create employment, increase productivity and improve the quality of life of all citizens (African Union Commission, 2015). The agenda is particularly targete at achieving among other SDG goals, goal 9 and integrates various aspects of this SDG such as increased access to transportation, water, sanitation and ICT infrastructure to promote economic growth especially through manufacturing. Deichmann, Lall, Redding, and Venables (2008) note that in order to achieve equity in the economic development of both urban and rural areas of a country, industrial location decisions that draw on the specific natural resource endowments and comparative advantages of different areas is a necessary requirement. Exploring the dimensions of the location of industrial activities in Africa as a whole would lead to a better understanding of the phenomenon in Adama City.

The 2017 United Nations Economic Report on Africa indicated that the current increasing consumption of the middle class population was a good opportunity for industrialization in Africa. There is a growing demand for manufactured and processed goods in Africa's urban areas. The report argued that spatial targeting would ensure that industrial location strategies were tailor to meet the requirements of different firms.

Africa's Industrial development has remained stagnated since the beginning of the structural transformations in the 1970s through to the 1990s and 2000s (Enache, Ghani, & O'Connell, 2016) mainly because of the overreliance on extractive industries (oil, gas, and mining) (UNECA, 2013) and the poor management of urbanization and urban form (UNECA, 2017). In addition, the colonial legacy of restrictive zoning which is used to segregate land uses does not allow industries to connect with the urban system of metropolitan areas and further deprives manufacturing firms from benefitting from transportation infrastructure and the lab our markets.

2.3.4 Dimensions of industrial location in Ethiopia

Industrialization is the driving force behind a country's socio-economic change. It were chose for producing economic dynamism, creating job opportunities, and creating a competitive advantage. Ethiopia, like all other countries, has been working to change the structure of its economy since the late nineteenth century. Modern manufacturing plants first appeared in the country in the 1920s (about 25 were established by 1927, primarily by foreigners), but it was not until the 1950s that a concentrated attempt was made to develop a modern industrial sector. In addition, since then, the industry has gained momentum and a comprehensive plan to promote industrialization and economic development has been implemented (Mulu, 2013 as cited in Fenta, 2014). According to UNIDO (2018a), as stated in the introductory part, Ethiopia's economy has grown at a phenomenal rate of 11% per year during the last 12 years, with agriculture and service industries expanding. The contribution of industry to GDP, on the other hand, has remained below 14 percent, which is less than half of the sub-Saharan. Therefore, the phrase industrial park is now a very commonly used term under Ethiopian Economic Policies that it is vital to concentrate multiple resources into one single location to see a good impact on effective resource usage, infrastructures, and boost employment rate and productivity (Gebeyehu, 2014).

The proper utilization of natural resources is now an important component of economic development. Although land is one of the most valuable natural resources, it also contains several resources (Efe et al., 2015). Industrial manufacture is important for economic development and employment opportunities. However, it can also cause health problems and long-term environmental impact. A considerable number of people live too close to industrial plants are, directly affected by the pollutants emitted. They are also more at risk for accidental releases and fires.

Ethiopia has comprehensive legislation to safeguard environmental protection, notably the 2002 Environmental Pollution Control Proclamation. and the 2008 Prevention of Industrial Pollution Regulation, but the federal ministry of Environmental, Forestry, Climate Change and Regional Environmental Protection Agencies have limited capacity to manage and regulate the environmental threats posed by the fast growing industrial sector, and there is little systematic monitoring and inspection. Coordination between the industrial and other sectors is currently too weak to manage the impacts of the envisaged developments. The capacity of city-level Environmental Protection Offices is even more constrained. They are tasked with enforcing standards, but need appropriate guidelines, standards, and enforcement measures. City leaders currently give very little attention to managing and mitigating potential pollution impacts of existing and new industries (Heymans et al., 2017).

2.4 Integration of Geospatial Technology (IGST)

Geographical Information Systems (GIS), Global Positioning Systems (GPS), Remote Sensing (RS), Google Earth, and other new technologies that aid the user in the collecting, processing, and interpretation of spatial data are all examples of geospatial technology (U.S. Department of Labor, 2005 as cited in Jaglan et al., 2018).

Geospatial information technologies are the key to planning, management and administration of land. Remote sensing and GIS can contribute substantially in a more supplementary fashion to some of the interactive operations that should become an asset for assessing, understandings, mapping utility and solving complex urban environmental issues like industrial suitable site selection (Akanbi et al., 2013). Generally, combination of the GIS and Remote Sensing systems provide multi-spectral, multi-temporal and multi-scales (spatial resolution), which can be adopted according to the degree of details needed.

Modelling industrial location suitability involves the consideration of complex interactions between multiple technical, social, economic and environmental factors (Badri, 2007; Batista e Silva, Koomen, Diogo, & Lavalle, 2014). The complexity of the interactions arises from the manner that different factors operate to determine industrial location at different temporal and spatial scales. For instance, while general industrial location factors (Badri, 2007) may be appropriate for assessing industrial location suitability, location factors related to manufacturing, construction or hospitality industries are likely to vary.

2.4.1 Spatial Data Integration

The rapid changes in map-based technologies caused a complexity in spatial data and increased user demands and expectations from Geographic Information Systems (GIS). Considering this reality, Spatial Data Integration (SDI) needed to be taken into account by National Mapping Agencies and companies for developing strategies to have better data (complete, standard, robust and flexible) for a wide public use of GIS applications (Dawidowicz and Zróbek, 2014).

Multi-source data integration it would appear that the technologies (RS, GIS, and GPS) each provide the geomorphologist with distinctive but complementary tools for geomorphic research Despite, its various definitions, GIS distinguishes itself from the other two technologies in that it enables data from diverse sources to integrate analyzed, and even modeled owing to its powerful analytical functionality. These functions, however, cannot fully realized if the GIS database is incomplete, inaccurate, or obsolete.

By their nature, the data contained in a GIS database are either spatial (e.g., administrative boundaries and boundaries of land-cover parcels) or thematic (e.g., types of land cover). Traditionally, spatial data and some thematic data associated with them where digitized from existing topographic or land-use maps. Nevertheless, these maps are secondary in nature. They may not show all desired features because of map generalization. Second, topographic or land-use maps may be obsolete due to rapid changes on the ground. These limitations can overcome with the use of remote sensing and/or GPS. Aerial photographs and satellite images are original and are able to offer more current areal-based data than do topographic and thematic maps, while GPS is an efficient method of collecting data in a timely fashion (Dawidowicz and Zróbek, 2014).

Since site, selection and suitability process related to geospatial issues, geographical information system (GIS) allows using data related parameters for suitability modelling. One of the advantages of using GIS in site suitability analysis is the capability of GIS in development of alternative scenarios for urban development.

Suitability analysis in a GIS context is a geographic or GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of GIS suitability analysis is that each aspect of the landscape has intrinsic characteristics that are to some degree either suitable or unsuitable for the activities being planned. Suitability is determined through systematic, multi-factor analysis of the different aspects of the problem (Murphy, 2005).

2.4.2 Google Earth

Is a virtual globe, map and geographical information program that was originally called Earth Viewer 3D, and was created by Keyhole, Inc., a Central Intelligence Agency (CIA) funded company acquired by Google in 2004. It maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and GIS 3D globe. Google Earth uses digital elevation model (DEM) data collected by NASA's Shuttle Radar Topography Mission (SRTM). The internal coordinate system of Google Earth is geographic coordinates (latitude/longitude) on the World Geodetic System of 1984 (WGS84) datum i.e., the same datum that used by GPS. Google Earth shows the earth as it looks from an elevated platform such as an airplane or orbiting satellite. Most of the high-resolution imagery in Google Earth Maps is the Digital Globe Quick bird, which is roughly 65cm pan sharpened (65 cm panchromatic at nadir and 2.62 m multispectral at nadir). Google is actively replacing this base imagery with 2.5 m SPOT Image imagery and several higher resolution datasets (Mohammed et al., 2013). Due to the rising demand for spatial data, major advancements in the integration of remote sensing data and GIS are now taking place. Remote sensing and Geographic Information Systems (GIS) technologies complement one other in three ways: i) Remote sensing may be utilized to collect data sets for usage in GIS; ii) GIS datasets can be used as auxiliary information to improve remote sensing products; and iii) RS and GIS data can be combined in resource analysis and modeling (Abushnaf et al., 2015).

Topography information can be used to give important data for industrial planners and developers (Johar et al., 2013). Lastly, three main forms of geospatial technology, such as Geographic Information System (GIS), (RS), and GPS, will used to assist the site-selection decision system (SSDS) in this thesis for evaluating land use suitability for selection of industrial sites in Adama City.

2.5 GIS based multi-criteria evaluation for land suitability

GIS is often recognized as a Spatial Decision Support System (SDSS) because of its powerful capability of analysing relationships between both spatial and non-spatial data (Singh, 2015) and the unique functionality of displaying this data in an understandable form (Cutler & Vandemark, 2002). GIS provides planners with methods to simulate the effects of current urban development situations on future planning decisions. Even though many GIS usage in the real world confirm it as a powerful technology for collecting, manipulating and analyzing spatial data, many critics (Jankowski, 1995; Sheppard, 2001; Sieber, 2006; Thomson & Schmoldt, 2001) in recent times have contested the capability of GIS as a Spatial Decision Support System (Keenan, 2006; Sugumaran, V.,2007; Sugumaran, R., 2007). Sultani, Soliman and Al-hagla (2009) argue that one of the key components of a standard SDSS is the “what- if model” used to analyses future urban planning scenarios. Unfortunately, many GIS packages have a rather limited function in terms of modelling, as a result, Keena (2003) referred to Alter (1980) and described GIS as an Analysis Information System instead of a Decision Support System.

2.6 Multi-attribute evaluation methods for land suitability

Multi-attribute (multi-criteria) Decision Making Models offer a number of methods to evaluate alternative development solutions. The purpose of an evaluation method is to determine the most optimal solution or to rank the best alternatives for addressing a problem (Dodgson, Spackman, Pearman, & Phillips, 2009). Although all multi-criteria evaluation methods involve alternatives and preferences, approaches are very different and some methods are more useful in solving a given decision problem than others. Most often, land suitability analysis employs three most common MCE methods, that is, the Weighted Linear Combination method or Simple Additive Weighting (Corona, Salvati, Barbarti, & Chirici, 2008; Diouf et al., 2017) , Ordered Weighted Averaging or the Analytical Hierarchy Process (Bagheri, Sulaiman, & Vaghefi, 2012; Dang Khoi & Murayama, 2010; Mediaty Arief, Yazidun Nafi, Subiyanto, & Hermanto, 2018). Among the methods, the Weighted Linear Combination and Boolean overlay operations are the methods most often used for land suitability analysis (Beedasy & Whyatt, 1999; Jankowski, 1995; Malczewski, 2004). The industrial location problem in all its complex forms means that the process of selecting an MCE method should consider how efficient the method integrates with GIS and the capability of that method to combine a large number of attributes (Rikalovic, Cosic, & Lazarevic, 2014). It is against this background that the common methods namely; WLC, OWA and AHP are hereby discussed.

2.6.1 Weighted linear combination method

The WLC method is a type of multi - attribute decision rule for creating aggregated maps in a GIS environment (Malczewski, 2000). The method based on a weighted average concept wherein multiple criteria normalized to obtain a common numeric average (Eastman, 2006a). Attribute map layers ranked by assigning weights according to their levels of importance. The value of each weighted map is multiply by the normalized value of the alternative the map. The products of each attribute map and alternative summed up to obtain the total scores for all alternatives. The alternative with the highest score therefore selected.

The WLC approach is a preferred option for land suitability analysis because the procedure can easily be implement in GIS (Malczewski, 2004). It also supports the use of both raster and vector data models within the GIS (Eastman, 2006a) and is able to integrate a large number of alternatives (Dodgson et al., 2009). By way of examples, Al-Hanbali, Alsaaideh and Kondoh (2011) used raster and vector layers of constraints to develop alternative suitable locations for potential land fill sites in Mafraq, Jordan. The study reclassified the location constraints based on weights obtained through consultations with local experts and the use of the author’s local knowledge of the area. Jiang (2007) estimated the location – cost of suitable industrial locations in Panzhihua, China. Several map layers including green areas, water bodies, existing factories, highways and elevation were process using multiple buffers. The WLC method where used to rank suitable industrial areas by integrating with Boolean constraints. The results is the quotient of a standardized suitability map and location cost map.

As Malczewski (2004) points out "Once the GIS raster or vector database has been organized into a number of map layers of the same geometric framework, the land-use suitability procedure can be represented as a flowchart and executed using GIS operations". In this model, each cell of the city (case study area) will gain a value which shows the extent of its compatibility or incompatibility by using raster analysis and intermediate functions based on ASCII formats, focal neighborhood analysis (focal statistics) and finally applying and running the model in GIS. then these cells, which produced from the vector layers turned into a vector in a reversed matrix structure process and the compatibility extent of each land use (in comparison to its neighbors in different effect distances by applying a reversed proportion for the standard of distance) by allocating the average cellular values of each category of index in each extent.

2.6.2 Ordered weighted averaging

OWA refers to a set of approaches used to combine geographic data and the preferences of decision makers or stakeholders in an MCE (Malczewski, 2006b). It is an extension to the conventional methods used to combine maps in MCDM models (Jiang & Eastman, 2000). The difference between the OWA and the conventional methods is that with the OWA, decision-making regarded as an imprecise set problem that resembles the natural behavioral approach to the process (Dodgson et al., 2009; Drobne & Lisec, 2009). On the contrary, the conventional methods like the Boolean or WLC based on hard and crisp decision rules (Dodgson et al., 2009; Jiang & Eastman, 2000). Conventional methods are able to integrate a large number of finite alternatives however; land suitability problems known to involve series of infinite alternatives with complex interrelationships. As such, suitability under this condition is influence by some degree of natural language quantifiers such as "at least 4", "about 10", "most", "many", "a few". These quantifiers are difficult to implement with conventional methods (Malczewski, 2006b).

The OWA approach, involves two types of weights, the importance weights and order weights. An attribute is assign an importance weight (based on human judgements) which applies to all locations in the study area. These weights are also assigned with respect to the alternative that the attribute is associated with Order weights are assign to a location's attributes in a decreasing order not influenced by the values of any particular attribute (Eastman, 2006a). This weight is the central idea in the OWA methods; it determines whether an area satisfies at least one acceptable attribute value referred to as the degree of or ness or the degree of trade-off. Decreasing degrees of ORness automatically means a decreasing degree of trade-off or substitutability among attributes. This means that a large number of locations may become suitable with decreasing ORness or unsuitable with decreasing ORness depending on how order weights are define in terms of suitability (Malczewski, 2006b) adapted from Jiang and Eastman (2000).

OWA has many advantages in land suitability analysis. The method provides decision makers with a wide range of development strategies depending on the number of OWA combination rules applied. It is able to evaluate a large number of attributes with complex relationships (Malczewski, 2006b). Boroushaki and Malczewski (2008) undertook a study on the OWA approach and indicated that the combination procedure used in the OWA are similar to the Analytical Hierarchy Process (AHP), however, OWA ordered weights are determined by multiplying each attribute's importance weight by the ordered weight for different sets of attributes. Going by this procedure, a wide range of combination rules can be obtained including a full trade-off among attributes which is a condition associated with the WLC and Boolean overlay methodology illustrated in equation (4) that is, $S = \sum wj\ xi$.

2.6.3 Analytical Hierarchy Process (AHP).

There is no commonly accepted method for assigning the relative weights to the criterion maps (Malczewski, 2004). As a result, different weighting schemes can produce different outcomes (Chen Y. et al., 2010; Vander Merwe, 1997). For instance, (Heywood et al., 1995) reveals different multi-criteria evaluation rules result in different suitability pattern.

AHP is a Multi-attribute Evaluation method and a variant of the weighted linear combination methods. The method was developed by Saaty (1980) in response to his observation of a lack of a straightforward and easy to understand methodology for making complex decisions whilst directing research projects in the US Arms Control and Disarmament Agency (Saaty, 2004). Since then, AHP method has been widely applied in a large number of fields worldwide such as in healthcare, education, ecology, supply chain management, energy sector and manufacturing (Emrouznejad & Marra, 2017). In the process of analyzing location suitability, Banai-Kashani (1989) and Saaty (2004) recounted that many conventional models utilize expert judgements to determine the relative importance of attributes and preferences for several alternatives towards reaching a particular suitability objective. During this process, factors including zoning, land values and existing urban developments are also evaluated; however, none of the conventional suitability methods employed in Multi-criteria Decision Making includes a strategy to check for inconsistencies in human judgements or uncertainties in the evaluation of factors. As a result, errors introduced into suitability decision making and forecasting.

2.7 Conceptual Framework of the Study

Conceptual framework is summarized how all reviewed literature under this chapter is contextualized to the present study in order to formulate the framework for demarcating land for industrial site development. Demarcating optimal sites for industrial development is a complicated process it needs data from the diversified physical, social, economic and environmental fields. As indicated in the empirical review part, Several studies have been conducted in the field of industrial site selection and the criteria will be used for the site selection process for industrial area has been designated based on various literature and criteria will be categorized into the following major criteria such as physical criteria (Soil, Slope, Elevation, Geology). Economic criteria (Availability of developable land, Distance to CBDS, Availability /Proximity to raw materials source, Existing Industry, Proximity to Residential area, Proximity to health and Social facilities.) Environmental criteria (Sewerage system, Fire water body, Major Road, Railway Road, Highway Road, Landfill Site, Availability of reliable electricity supply, Availability of ground water potential). In addition, Social &Demographic criteria (LULC and Population density) are independent variable will identified for the current study to enhance the suitability of industrial sites (dependent variable) by harmonizing these factors based on integrated geospatial technology. Suitable industrial site selection is not only dependent on independent thematic map criteria but also it is dependent on different moderator variable, which includes spatial analysis, classification, bufferization, and geospatial technology and weight allocation. Suitable site selection for the industrial site is sensitive to the weight influence assigned for factors. Thus, in order to avoid vagueness in the decision-making process, the weight was critical and necessary established based on Analytical Hierarchy Process (AHP). According to empirical review, there is no integrated Geospatial technology based multi-criteria evaluation and human judgements that can implemented for all scale industrial location suitability in the Adama City. Finally, the weighted factors will integrated in a weighted linear algorithm to produce the expected result of the present study, which is a suitability map for industrial sites development. The overall summarized conceptual framework of all reviewed literature under this chapter is contextualize in the current study for selecting suitable land for industrial site development was shown in below (Figure1).

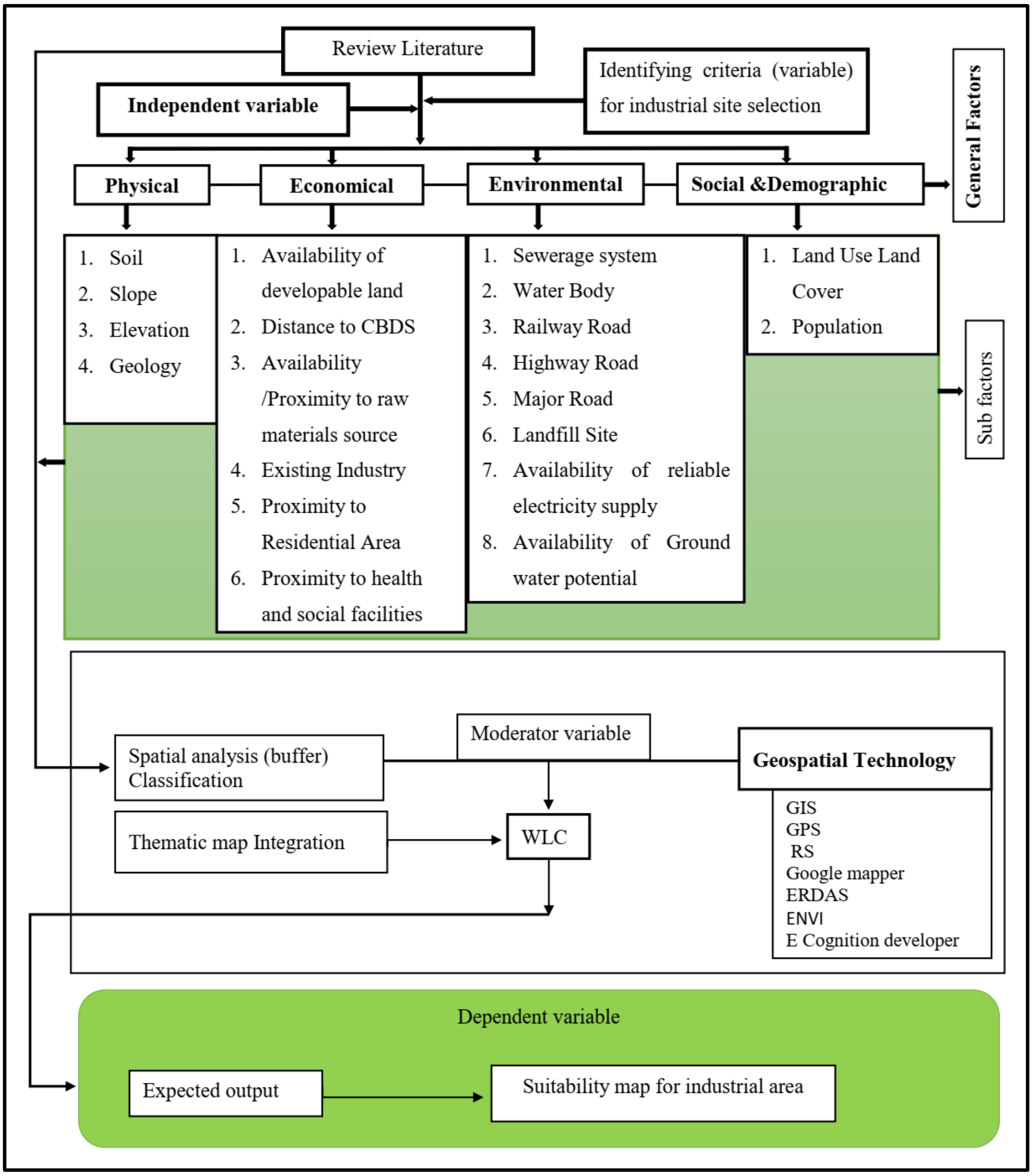

Figure 1: Conceptual framework of suitable analyze for industry

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location of Study Area

Adama is a City in central Oromia Region, Ethiopia. Adama city is located at nodal point along the railway line that stretched from Port of Djibouti to Finfinnee in the heart of Rift Valley with incomparable opportunities for tourism, conference, industrial and trade of development in the region. It is located at 8.54°N 39.27°E, at altitude of Adama varies from about 1500m to 1712meters above mean sea level, 99 km southeast of Finfinnee. The city sits between the base of an escarpment to the west, and the Great Rift Valley to the east. Adama city is a busy transportation centers and situated north of prominent Awash River that has been the most utilized river for irrigation in the country and the source of city's potable water (Adama Town Municipality Office [ATMO], 2018).

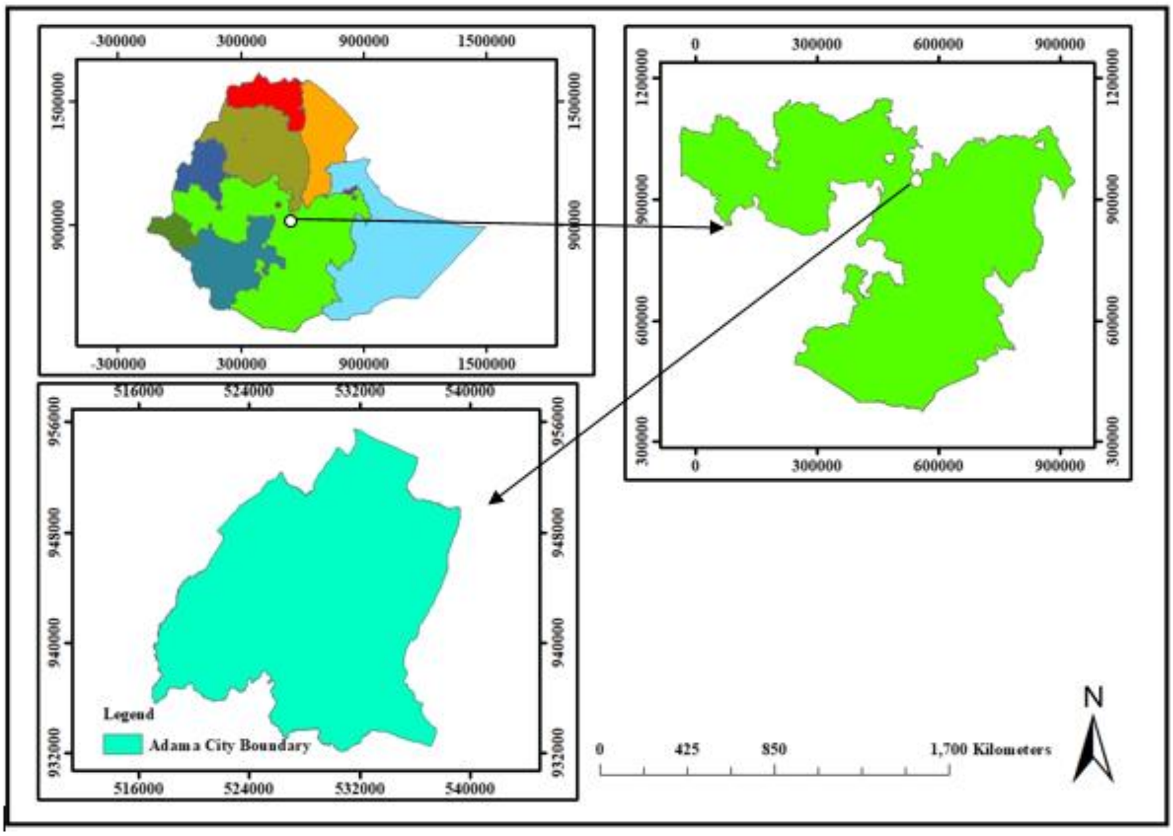

Figure 2: Location map of the study area

3.1.2 Demography /population

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), Adama City has a total population of 220,212, of whom 108,872 were men and 111,341 were women. The city has through recent years seen a robust annual growth rate and population counts as of 2020 are growing closer to 391,597 of whom male 193,992 and female 197,605 (Adama city Mayor Office report, 2021).The 1994 census reported this town had a total population of 127,842 of whom 61,965 were males and 65,877 were females. When compare the three reports the population of the town are highly increasing from time to time.

3.1.3 Climate

The mean annual temperature is 21°C. It can have classified as semi-humid to semi-arid climate, which characterizes the altitude range between 1300 to 1800m a.m. In Adama, the hottest month with the maximum mean temperature of 31°C is May. The monthly minimum mean temperature is Nov & Dec with the temperature of 11.5°C. The maximum temperature varies between 25.8°C and 31°C while the minimum monthly values vary between 11.5°C and 17°C. At Adama, the heavy truck movements could contribute to the increment of temperature due CO_2 input into the air (NMSA, 2022).

3.1.4 Rainfall

The rainfall recorded at Adama meteorological station for the past 49 years (1973- 2022) indicated that the average annual rainfall is about 866.25 mm. The maximum monthly average rainfall is about 200 mm. Most of the rain occurs in summer season (June to September). Rainfall intensity data is not available for Adama city. Thus, the data recorded at the nearby station of Bishoftu, Kulumsa and Metehara is adapted. Accordingly, the average of maximum intensity of rainfall in the three stations for the past 27 years (1995-2022) is about 39.7 mm/hr (NMSA, 2022).

3.1.5 Geological Characteristics

Adama is situated within the Wonji Fault Belt, in the main structural systems of the Ethiopian Rift Valley. Geological studies indicate that the present physiography of the area is the result of volcano-tectonic activities that occurred in the past and the resulting deposition of sediment largely of fluvial and lacustrine origin (ATMO, 2018).

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3.1.6 Soil conditions

Four main types of soils are mollic andosols, eutric fluvisols, haplic phaeozomes, and haplic luvisosols cover Adama City. These soils' physical and hydrological features are described as follows by the Food and Agricultural Organization (FAO, 2001):

Mollic andosols: - Andosols are a zonal soils found in all climates and at all altitudes. Consequently, they occur together with almost any other Reference Soil Group. Most Andosols have excellent internal drainage because of their high porosity and their occurrence in predominantly high terrain positions. The good aggregate stability of Andosols and their high permeability to water make these soils (relatively) resistant to water erosion (FAO, 2001).

Eutric fluvisols: - Most Fluvisols are wet in all or part of the profile due to stagnating groundwater and/or floodwater from rivers or tides. Their texture can vary from coarse sand in levee soils to heavy clays in basin areas (FAO, 2001).

Haplic phaeozomes: - Phaeozems are porous, well-aerated soils with moderate to strong, very stable, crumb to blocky structures. Phaeozems with clay accumulation have even better water storage properties than other Phaeozems but may still be short of water in the dry season (FAO, 2001).

Haplic luvisols: - Luvisols have favorable physical properties; they have granular or crumb surface soils that are porous and well aerated. They have a higher clay content in the sub soil than in the top soil, as a result of pedogenetic processes (especially clay migration) leading to an ArcGIS sub soil horizon (FAO, 2001).

3.2 Data Collection

In order to conduct this study, systematic methods was followed from data collection to analysis. First, preliminary studies of the literature were done, and parameters affecting the industrial area's suitability were identified. The primary data were obtained through field observation and field surveys conducted directly by the researcher and other surveyors at the time of data collection. Accordingly, location of existing industries, health and social facilities centers, and proximity to residential areas were collected from the field by GPS survey. On the other hand, secondary data, such as a geologic map, a river network, a road network, LULC, a slope map and a soil map, were obtained from their respective sources as mentioned in table 1. After all the data were collected from their respective sources, they were organized, manipulated, and analyzed using the software mentioned in Table 2 for further analysis. As mentioned in Table 1, some of the data are in TIFF, CAD, PNG, and GRID format. For example, the geological map was in PNG format, and to scan and cover the city map, Therefore, the two scenes were georeferenced, mosaicked, clipped, and digitized to convert the data to vector format. The road and river networks were digitized from Google Earth Pro in kml format. In addition, converted to vector format in ArcMap 10.8.

3.2.1 Data source

The availability of data is the most important thing to perform any kind of analysis. Therefore, in this research, spatial and non-spatial data has been used to extract data for the analysis of land suitability for industrial area. These spatial and non-spatial data are Adama city base map, master plan, topographic map, satellite imagery, population data, soil and geological map data. Additionally, Table 1 shows the list of data and their sources.

Table 1: List of data source used for the study

S.no	Data	Source	format	Resolution
1	Satellite image of 2nd February 2022	USGS	TIFF	30m
2	Road network & Railway network	Google earth pro + Export from New Structural plan	Vector	-
3	River network	Google earth pro + Export from New Structural plan	Vector	-
4	Elevation	Ethiopian GII	GRID	20m
5	Slope	Generate from DEM on Google Mapper	Raster	-
6	Soil map	FAO	Vector	-
7	Educational & Health centers	GPS data	Vector	-
8	Existing Industry	GPS data	Vector	
9	Geological map	EGS	PNG	-
10	Adama structural plan	Adama municipality	CAD	-
11	Population data	ECSA	Excel	-
12	Other	Ministry of Industry	interview	-

3.3 Materials Used

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

Table 1: Software used

S.no	Name of software	Purpose
1	ArcGIS 10.8	Data processing and thematic map preparation
2	E-cognition developer	Radiometric and atmospheric correction for classification of land use land cover (LULC) from land sat image.
3	ENVI	For processing and analyzing satellite Image, Accuracy assessment for LULC
4	IDRISI Selva 17	for weight module determination
5	GPS	To collect coordinate data from field
6	Google Earth Pro.	Use as a base map in visual image interpretation, and generate coordinate points for the images geo-referencing
7	Global mapper	To generate DEM and slope from DEM
8	Microsoft Word and Excel	Integrating attribute data and writing the report
9	SPSS 22	For making graphs and charts

3.4 Data preparation methods

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

3.4.1 Geo-referencing

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

3.4.2 Mosaicking

A mosaicking is the process of combining or merging two or more adjacent images and scanned map to make them single scene. The main objective of mosaicking is to merge more than one scene of image or scanned map that covers the study area (reference remote sensing).

3.4.3 Clipping

Clip is the process of cut the features in area of interest from image, scanned map, digital map and any GIS layers. To clip features in study area overlay a boundary of study area on target features were, clipped and perform GIS operation. In this study, most of data collected were, clipped in ArcMap 10.8 by using Adama City boundary. Accordingly, satellite image, soil map, geological map, road network, river network and elevation used in this study were clipped (reference remote sensing).

3.4.4 Digitization

Digitization simply defined as the process of converting analog data in to digital data. Geologic map and Soil map used in this study is in PNG format and digitized in ArcMap 10.8. Similarly, Highway Road, Railway Road, Major Road network and river network used in this study also digitized from google earth in kml format and converted to shape file in ArcMap 10.8 and to cross check exported from structural plan (reference remote sensing).

3.4.5 Image classification

Image classification is the process of categorizing and labeling groups of pixels or vectors within an image based on specific rules (Lu and Weng, 2004). It plays an important role in remote sensing images and is used for various applications such as environmental change, agriculture, land use/land planning, urban planning, geographic mapping, disaster control and object detection. Two general methods of classification are 'supervised' and 'unsupervised'. Supervised digital image classification method is the process of visually selecting samples (training data) within the image and assigning them to pre-selected categories (i.e., Settlement, water body, vegetation, agriculture, Forest, bare land etc.) in order to create statistical measures to be applied to the entire image. To use this method, the researcher, has to know the area and take correct training sample. Supervised digital image classification was used in this study to map the existing LULC of study area from Landsat image (figure 9).

3.4.6 Accuracy assessment

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

Table 2: Accuracy of classified LULC for Data Validation

		Reference Data					
		Settlements	Vegetation	Farm Land	Bare Land	Water Body	Row Total
Classified Data	Settlements	1942	8	0	1	3	1954
	Vegetation	37	190	43	0	0	270
	Farm Land	39	8	72	38	0	156
	Bare Land	0	0	0	89	0	89
	Water Body	0	0	0	0	22	22
	Column Total	2018	206	115	127	25	Total of Diagonal=2491

After creating the error matrix for each classification, user accuracy, producer accuracy, overall accuracy, and the Kappa coefficient were computed. According to Lillesand et al.

(2008), user accuracy is computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). The producer's accuracy results from dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training set pixels used for that category (the column total). The overall accuracy results from dividing the diagonal total by the sum of the row or column total. To check the accuracy of LULC used in this study, overall accuracy was computed from an error matrix.

Overall accuracy = (2315/2491) *100% = **92.9346%**

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

$$k\hat{}= \frac{n\sum_{i=0}^{r} Xii-\sum_{i=0}^{r}(Xii+\cdots x+i)}{N^2-\sum_{i=0}^{r}(Xii+\cdots x+1)} \text{---------------------------------} 1.00$$

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

3.5 Data analysis methods

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

3.5.1 Buffering

Buffering is a spatial analysis also called proximity analysis. It used to generate areas of a given distance around the specified criteria that has been used for Industrial development site selection. In this study, buffer zones were created around Highway Road, Railway Road, Major Roads, water body, Sewerage system, Landfill Site, electricity supply, proximity to CBDs, Proximity to raw materials and Existing Industry, proximity to Residential areas and health and Social facilities.

3.5.2 Rasterization

Rasterization can be defined as the process of converting information in vector format to raster format. As mentioned under data preparation section most of data used in this study were digitized from secondary sources. Those data in vector format (Highway Road, Railway Road, Major Roads, water body, Sewerage system, geology, Landfill Site, electricity supply, ground water potential, proximity to CBDs and Existing Industry, proximity to Residential areas and health and Social facilities) were converted to raster format in ArcMap 10.8 for further analysis.

3.5.3 Reclassification

Reclassification can be defined as the process of classifying something (a map) repeatedly. In this regard, the parameters considered in this study were slope, Elevation, soil map, geological map, LULC, availability of developable land, distance to CBDS, availability of and proximity to raw material sources, existing industry, proximity to residential areas, proximity to health and social facilities, sewerage system, water body, railway road, highway road, major road, landfill site, electricity supply, and ground water potential. Finally, based on FAO's (1976) classification, all those parameters were internally classified into five classes (highly suitable, suitable, moderately suitable, less suitable, and unsuitable), with values ranging from 5 to 1, where 5 denotes the highly suitable and 1 denotes the unsuitable for industrial factors and constraints considered.

3.5.4 GIS Based Multi Criteria Decision analysis

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

3.5.5 Analytic Hierarchy Processes (AHP)

The Analytic Hierarchy Process is a decision-making method for prioritizing alternatives when multiple criteria must considered. It offers a methodology to rank alternative courses of actions based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are, met by each of the alternatives (Nydick and Hill, 1992). AHP is a powerful and flexible decision-making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. AHP was used in this study to derive weights for each parameter (table 25).

3.5.6 Estimation of the consistency ratio

The aim of estimating the consistency ratio is to determine whether comparison matrices are consistent or not to use for overlay analysis. According to Lawal et al. (2011), if the consistency ratio is less than or equal to 0.1, it is a significantly acceptable reciprocal matrix. Thus, to check the consistence of the comparison matrices used in this study, the consistence ratio was calculated and discussed under the result and discussion part of this report. To calculate the consistency ratio: First determine the weighted sum vector, next determine the consistency vector, next compute lambda max (max) using 2 formulas, and finally calculate consistency ratio (CR) by using 3 formulas.

$$CI = \frac{\lambda max - n}{n-1} \text{---} 2$$

$$CR = \frac{CI}{RI} \text{---} 3$$

3.5.7 Weighted Linear Combination (WLC)

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

$$S = \sum_{i=0}^{n} wj\ xi. \text{---} 4$$

Where s is the composite suitability score, wj is weights assigned to each factor, xi is factor scores (normalized cell values.

The overall process performed to find suitable site area for future Industrial development in Adama City. Is illustrated by the below Technological Scheme of the thesis workflow (Figure 3). This workflow shows source of data, generated input data, and operation performed to Industrial suitability site analysis.

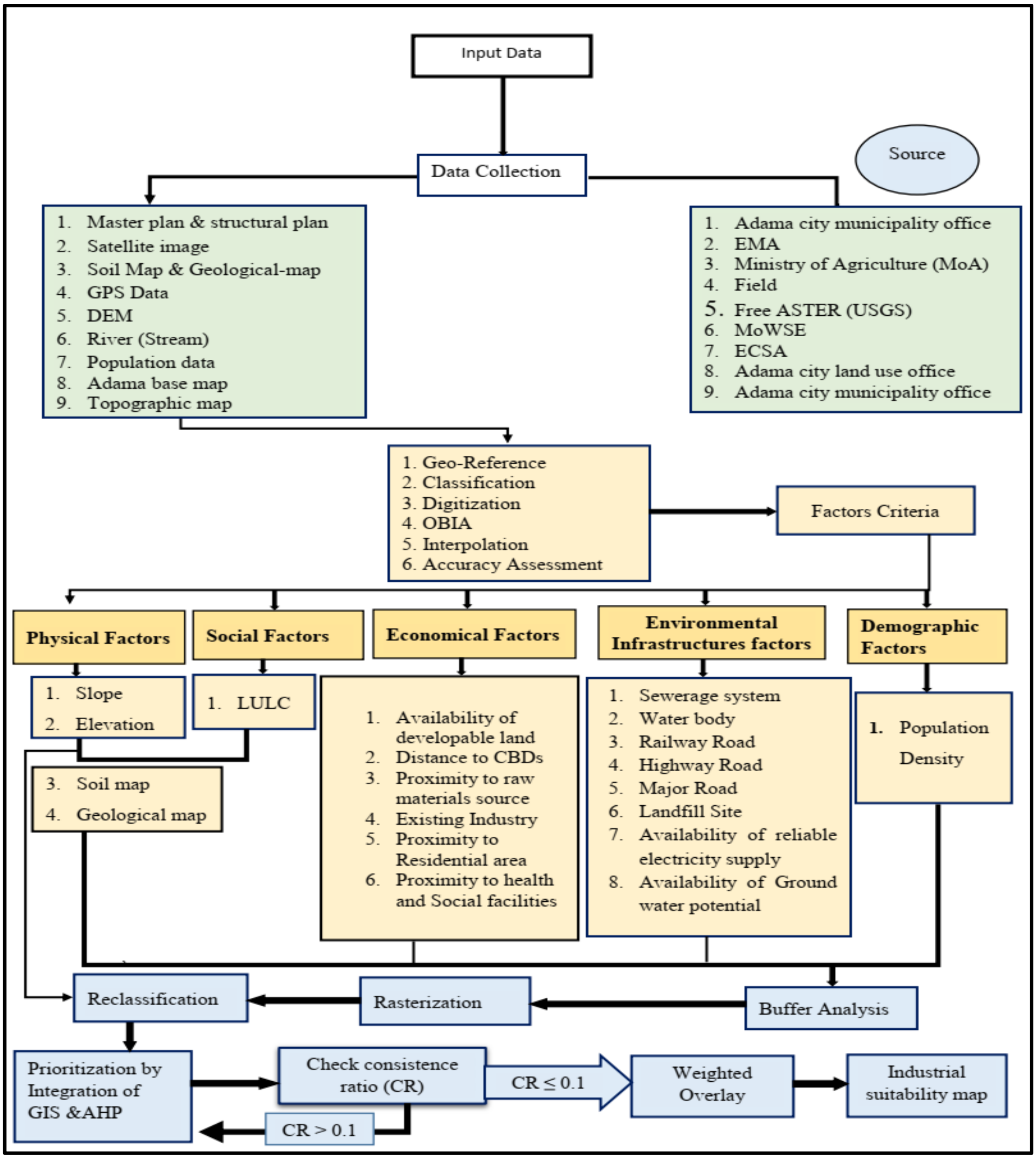

Figure 3: Technological Scheme of the thesis work

CHAPTER FOUR: RESULTS AND DISCUSSION

In this chapter, land suitability analysis for industrial areas using integrated geospatial tools was discussed for Adama City using the Analytic Hierarchy Processes (AHP) method. An industrial development site should be kept close to CBDs, railroads, highways, schools, and health care centers to take advantage of existing infrastructure. On the other hand, industrial development sites should be kept as far away as possible from residential areas. Rivers, volcanoes, water bodies, agricultural lands, gardens, forests, and sites with the highest slopes are not suitable for industrial construction (Reisi et al., 2011).

4.2 Industrial site Selection criteria and Maps Preparation

4.2.1 Slope

Slope gradient, usually expressed as percent slope or degree slope is used to represent the degree of variability in elevation. The sea level of an area is a very important factor during the identification of potential industrial sites. Areas with a gentle slope were chosen as more suitable, Suitable for the construction of large structures. The slope of the study area was generated from DEM data obtained from the Ethiopian Geospatial Information Institute with the help of ArcGIS 10.8. The slope of the study area ranges from 0 to 60 degrees, and it was classified into five classes based on suitability ranges obtained from different literatures and standards. Flat slopes are highly suitable for urban development, where steeper slopes are not. According to (Fataei et al., 2015; Ahmadipari et al., 2018, Jiang, 2007; Roy et al., 2019), a gently sloping slope is ideal for industrial site development.

Table 3: Reclassified slope and area coverage of suitability levels

Slope in degree	Suitability class	Score value	Rank	Area(km^2)	(%)
<5	highly suitable	S5	9	234.65	74.9%
5-10	suitable	S4	7	52.78	16.8%
10-15	moderately suitable	S3	5	15.41	4.92%
15-20	less suitable	S2	3	6.95	2.22%
>20	unsuitable	S1	1	3.25	1.04%
Total				313.042	100%

Figure 4 depicts the reclassified topographic slope distributions, suitability, and the indices used for the slope factor were unsuitable, less suitable, moderately suitable, suitable, and highly suitable. When we see the overall share of these suitability indices in area and As a percentage, industrial delineation accounts for about 3.25 km.^{2} (1.04%), 6.95 km^2 (2.22 %), 15.41 km^2 (4.92 %), 52.78 km^2(16.86 %) and 234.65 km^2 (74.96%) respectively. These results show that the study area was primarily highly suitable for industry establishment, with a slope ranging from 0 to 5 degrees. The maximum slope of the city, according to their classified portrayal, ranges from 30 to 60 degrees, while the minimum slope ranges from 0 to 5. Areas with higher slope values are not suitable for industry, whereas areas with a lower topographic slope rise are the right alternative for industrial sites. The smaller the slope amount, the more suitable it will be (Fataei et al., 2015).

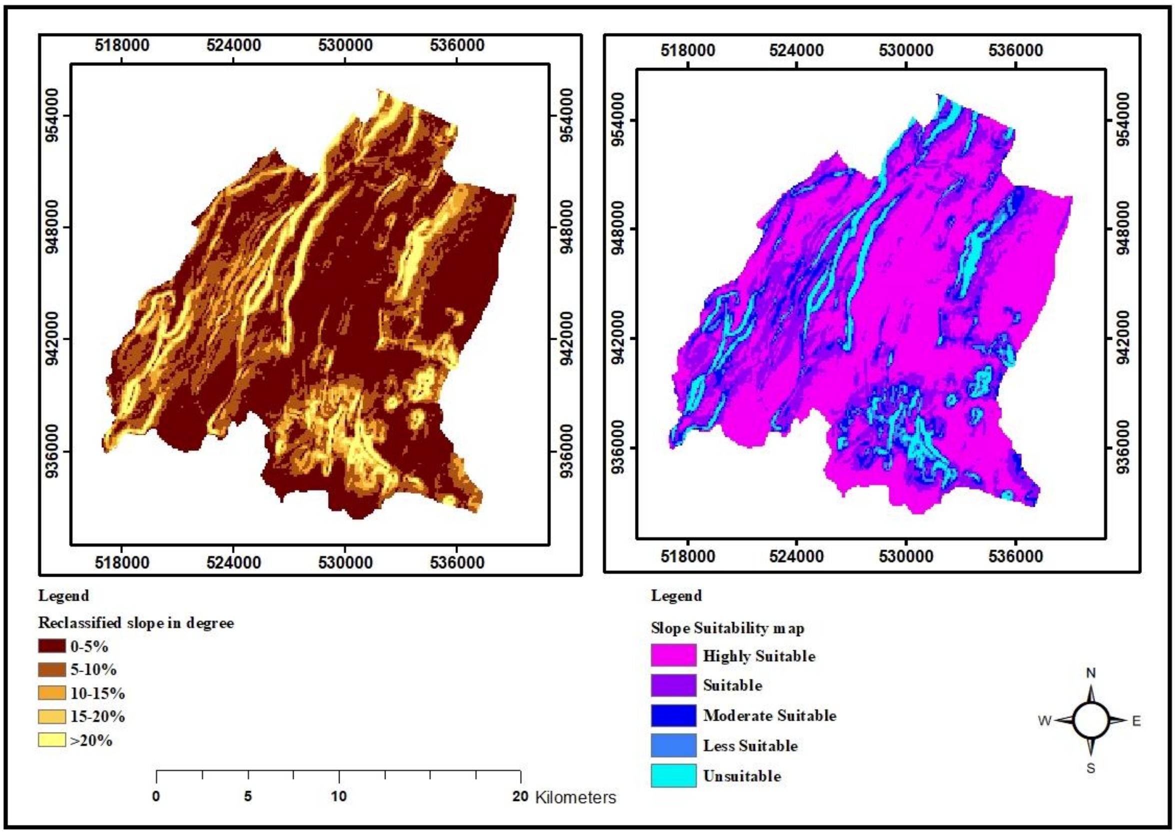

Figure 4: Slope Suitability map

4.2.2 Elevation

The sea level of an area is a very important factor during the identification of potential sites. Sites far above sea level increase the transportation cost and are considered unsuitable (Sarath et al., 2018). The elevation of the area where potential locations for industries are sited must be known for better decisions to be made. Shuttle Radar

Topographic Mission (SRTM) DEM with a spatial resolution of 30 m according to the study area was downloaded from the website www.Earth Explorer.com and classified based on the elevation present at that location. From the digital elevation model map, the maximum and minimum elevations of the study area are 1453 m and 2053 m, respectively, above mean sea level. The town's highest elevations are found in the northwest, west edge, and southeast directions. This means areas with higher elevations are not suitable for the optimal location of an industrial site due to physical factors. Based on this fact, the topographic elevation of the city was categorized under major physical criteria.

Table 4: Reclassified elevation and area coverage of suitability levels

Elevation	Suitability class	Score	Rank	Area (km2)	(%)
1453-1600	highly suitable	S5	9	79.165	25.28
1600-1700	suitable	S4	7	130.60	41.71
1700-1800	moderately suitable	S3	5	55.90	17.85
1800-1900	less suitable	S2	3	30.70	9.81
1900-2053	unsuitable	S1	1	16.73	5.34
Total		313.095			100%

According to Table 5, the study area's elevation was reclassified into five categories: unsuitable, less suitable, moderately suitable, suitable, and highly suitable, with elevation ranges of 1453–1600, 1600–1700, 1700–1800, 1800–1900, and 1900–2053 meters above sea level. From the reclassified map result statistics, the majority of the study area was highly suitable and suitable for zoning an industrial site, which covers 25.28 % and 41.71 % of the study area, respectively, while the least of the area was moderately suitable, less suitable ,and even unsuitable which covers 17.85%,9.81%, and 5.34 % of the study area collectively. For the current study' aim areas with a low elevation value were ranked as highly suitable for industrial sites.

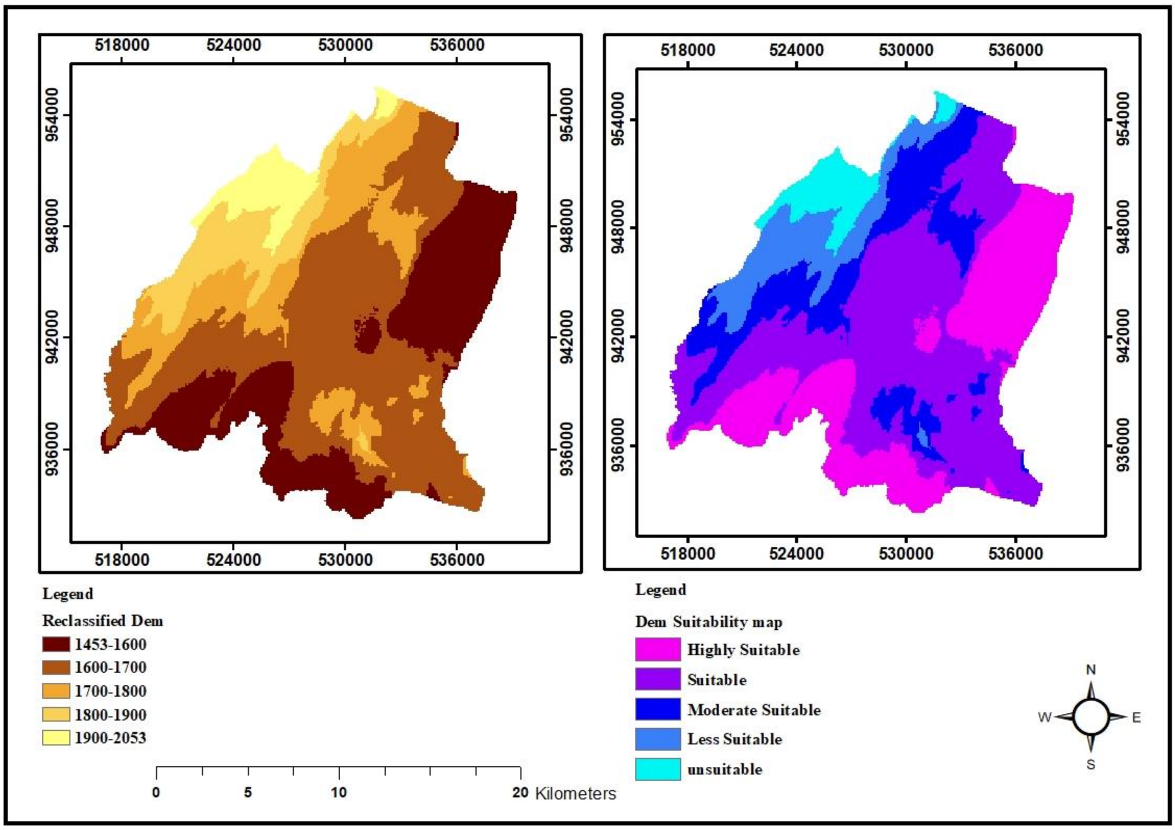

Figure 5: Elevation Suitability map

4.2.3 Soil

Soil is the most important parameter for determining an area's suitability for urban construction. Soil types that have high fertility, low nutrient deficiency, and high water holding capacity can be used for urban areas (Puntsag G., 2014).

Table 5: Soil type, texture and infiltration rate (source FAO, 2001)

S.no	Soil type	texture	Silt content	Clay content	Sand content	Infiltration rate(mm/h)
1	Mollic andosols	loam	39	22	39	10-20
2	haplic luvisols	loam	37	22	41	10-20
3	Haplic phaeozems	loam	39	21	40	10-20
4	Eutric fluvisols	Loam	12	8	80	20-30

In this study, soil type was measured to minimize the impact of industrial waste on groundwater contamination. Based on infiltration rate, soil type plays a great role in the movement of liquid waste into the ground. The soils with a high percentage of silt and clay particles have a higher water-holding capacity. Moreover, the size and spacing of soil particles determine how much water can flow in. Wide pore spacing at the soil surface increases the rate of water infiltration, thus coarse soils have a higher infiltration rate than fine soils (Ball, 2001, as cited in Gebriel, 2017).

For this study's purpose, the existing soil type of the study area digitized from the soil map of Ethiopia was reclassified into highly suitable, suitable, moderately suitable, less suitable, and unsuitable based on the amount of silt and clay content and infiltration rate as presented in Table 6. Mollic andosols have a high silt and clay content as well as a low infiltration rate. Therefore, it was grouped under "highly suitable classes." The soil with a high percentage of silt and clay particles has a high water-holding capacity and is less susceptible to erosion. The infiltration rate of haplic luvisols is similar to that of mollic andosols; however, their silt and clay amounts are lower. Thus, haplic luvisols were ranked as suitable. Haplic phaeozems and gleysols soil types were reclassified under the "moderately suitable" and "less suitable" classes, and eutric fluvisols were reclassified under the "unsuitable" category accordingly based on infiltration rate.

Table 6: Suitability map of soil type for industrial site selection

Soil type	Suitability class	Score	Rank	Area (km^2)	(%)
Eutric fluvisols	Unsuitable	S1	1	10.14	3.24%
Haplic phaeozems	moderate suitable	S3	5	24.25	7.75%
Haplic luvisols	suitable	S4	7	0.23	0.07%
Mollic andosols	highly suitable	S5	9	278.44	88.94%
Total				313.05	100%

As shown in the above table, the bulk of the study area was highly suitable for industrial site delineation in terms of the soil type spatial information layer, covering 278.44 square kilometers, while the second-smallest portion of the study area was suitable, accounting for 0.23 square kilometers. The remaining sections, with an area coverage of 24.25 and 10.14 square kilometers, were moderately suitable and unsuitable for zoning out of the overall study area.

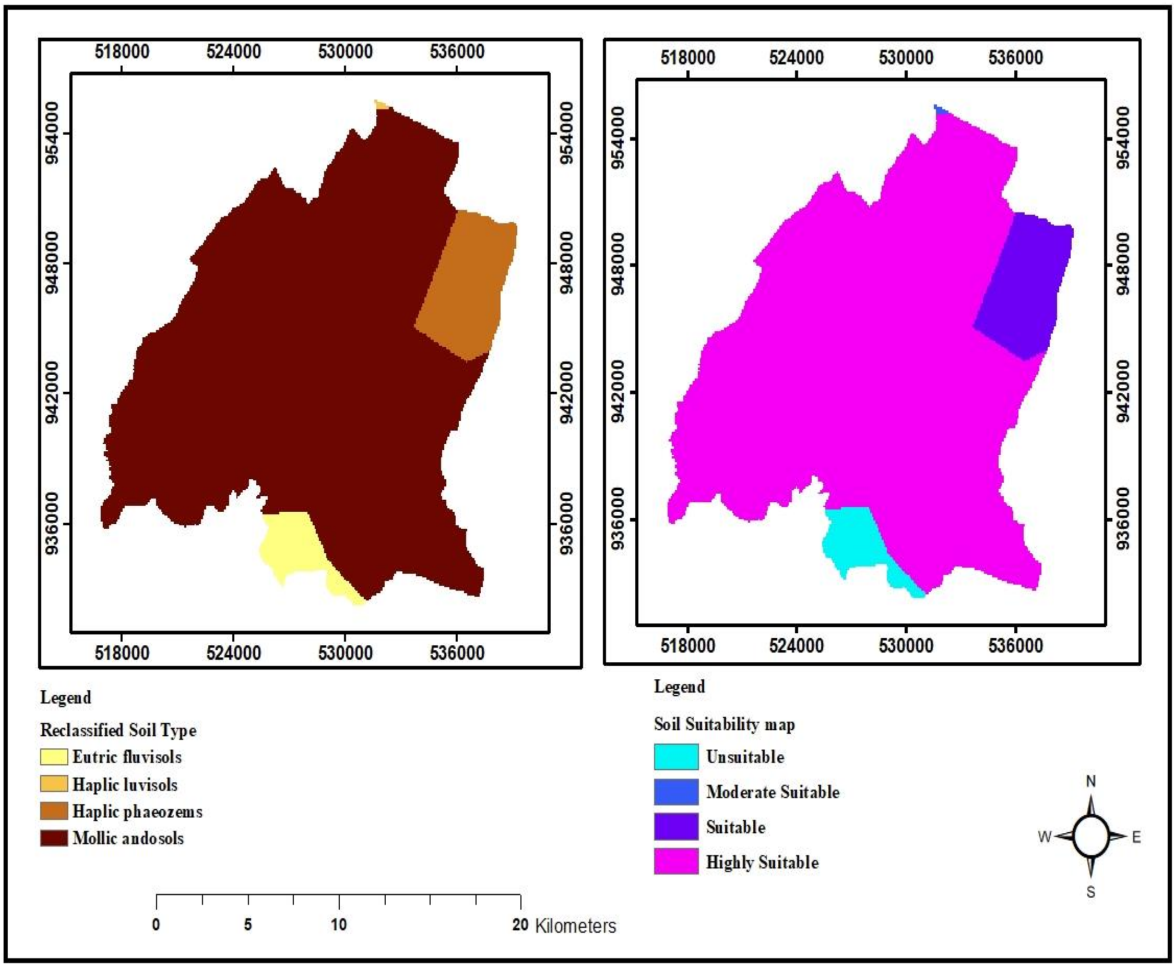

Figure 6: Soil type factor map (a) soil type and (b) Soil suitability map

4.2.4 Geological

Geological faults are one of the geological phenomena that cause problems for industrial construction, so they should be avoided in industrial sites (Reisi et al., 2013). Regarding the legal buffer from fault lines and avoiding industrial developments in such areas, these are considerable factors in industrial site selection (Fataei et al., 2015). As a result, one of the parameters in the current study was the geological fault line. According to Sarath et al. (2018) and Redwan Awel (2021), industrial site selection should be done carefully by watching out for fault lines and avoiding areas near them to ensure stable rock on which to build a structure. To determine the best land location for an industrial site, geological fault lines digitized from an Ethiopian geological map were reclassified by comparing and analyzing the fault distance categorization of other researchers, as shown in Figure 7.

Table 7: Suitability map of the reclassified geological Fault lines proximity distance (m)

proximity to Geological Fault lines (m)	Suitability class	Score	Rank	Area (km^2)	(%)
0-2500	Unsuitable	S1	1	182.50	58.30%
2500-4500	less suitable	S2	3	95.55	30.52%
4500-8000	Moderate suitable	S3	5	30.24	9.66%
8000-9000	suitable	S4	7	2.68	0.86%
9000-10374	highly suitable	S5	9	2.08	0.66%
Total				313.05	100%

According to the reclassified geological fault line factor map shown in Figure 7, Highly suitable, suitable, moderately suitable, less suitable, and unsuitable ranks were graded to the class intervals of 9000 to 10374, 8000 to 9000, 4500 to 8000, 2500 to 4500, and 0 to 2500, respectively. The statistical summaries of the reclassified fault line factor map are presented in Table 8. Illustrate that 182.50 km^2 (58.3 %) of the study area was unsuitable, 95.55 km^2 (30.52 %) of the study area was less suitable, 30.24 km^2 (9.66 %) of the study area was moderately suitable, 2.68 km^2 (0.86%) of the study area was suitable, and 2.08 km^2 (0.66 %) of the study area was highly suitable. For the present thesis research, according to suggestion of different scholars, the areas n to geological fault lines were assigned unsuitable whereas areas remote to fault lines were reclassified into highly suitable for the for delineation of industrial sites. In terms of fault lines suitability, the study area predominantly unsuitable for industrial site selection.

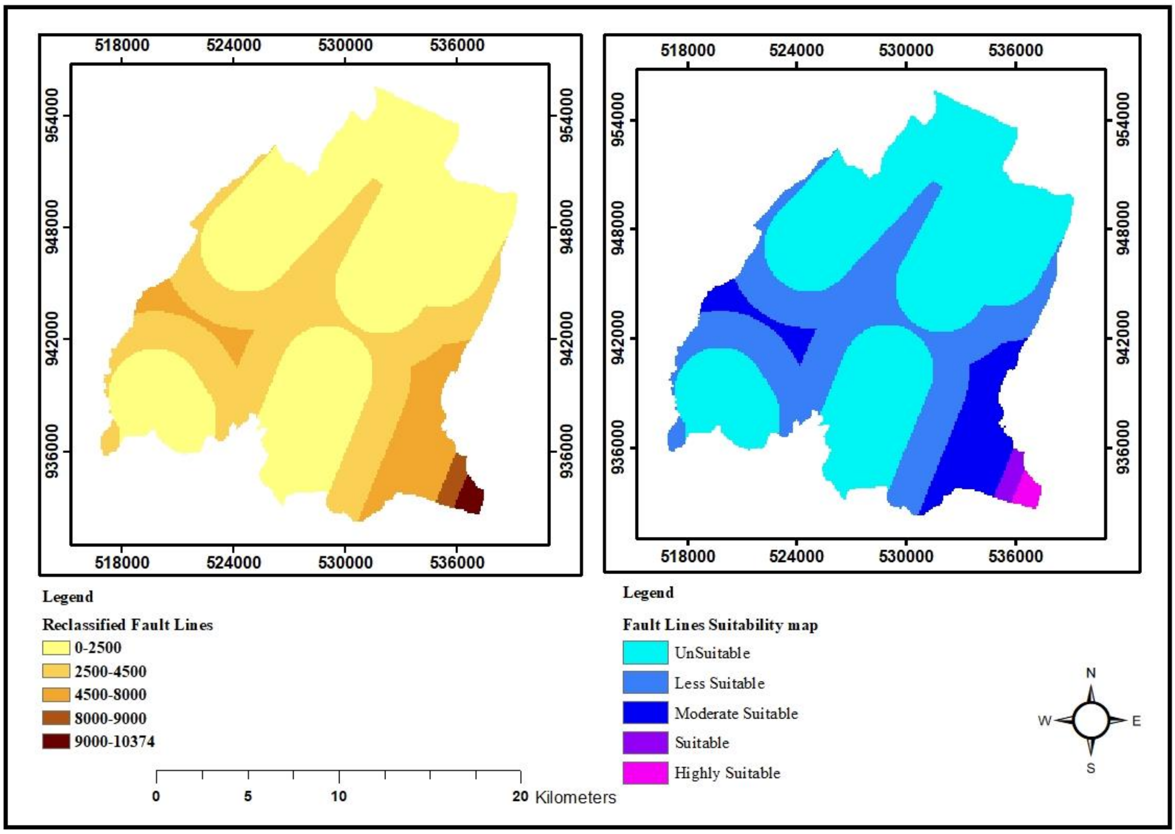

Figure 7: Geological Fault Line Suitability map

4.2.5 Land Use Land Cover (LULC) Factor

Land Use Land cover is the main basis for industrial land suitability analysis. A LULC map of the study area was prepared from a Landsat 8 image acquired on March 15, 2022, and supervised classification was employed using ENVI Classic 5.3. To check the accuracy of the classification, the error matrix was used, and the overall accuracy was 92.9346%. Since this value is greater than 85, it is acceptable. Five different classes of LULC were categorized (waterbody, vegetation, settlement, farmland, and bare land). To accomplish this, the study area's land use and land cover maps were reclassified, and ranked in order of suitability.

Due to the significant impact of these land cover classes on ecosystem balancing, delineating industrial sites from vegetation and water bodies is not suggested. Water bodies, wetlands, forest cover, and residential regions, according to Johar et al. (2013), are not ideal for industrial establishments. Open spaces, unoccupied lands, and rangelands are all good places to put an industrial site. Both water bodies and vegetative land cover were categorized as restricted for this study, as shown in Table 9 and Figure 8, whilst settlements, farmland, and bare land were allocated as unsuitable, suitable, and highly suitable, respectively. The overall contribution of each land cover class for industrial site selection in terms of area coverage was water bodies (0.14 km^2), vegetation (39.22 km2), settlement (73.52 km^2), farmland (188.11 km2), and bare land (12.05 km^2).

Table 8: Land use land cover class suitability for industrial site selection

LULC class	Suitability class	Score	Rank	Area (km^2)	(%)
Bare land	highly suitable	S5	9	12.05	3.85%
Farmland	suitable	S4	7	188.11	60.09%
Settlement	Unsuitable	S1	1	73.52	23.49%
Water body	Restricted	0	0	0.14	0.04%
Vegetation	Restricted	0	0	39.22	12.53%
Total				313.04	100%

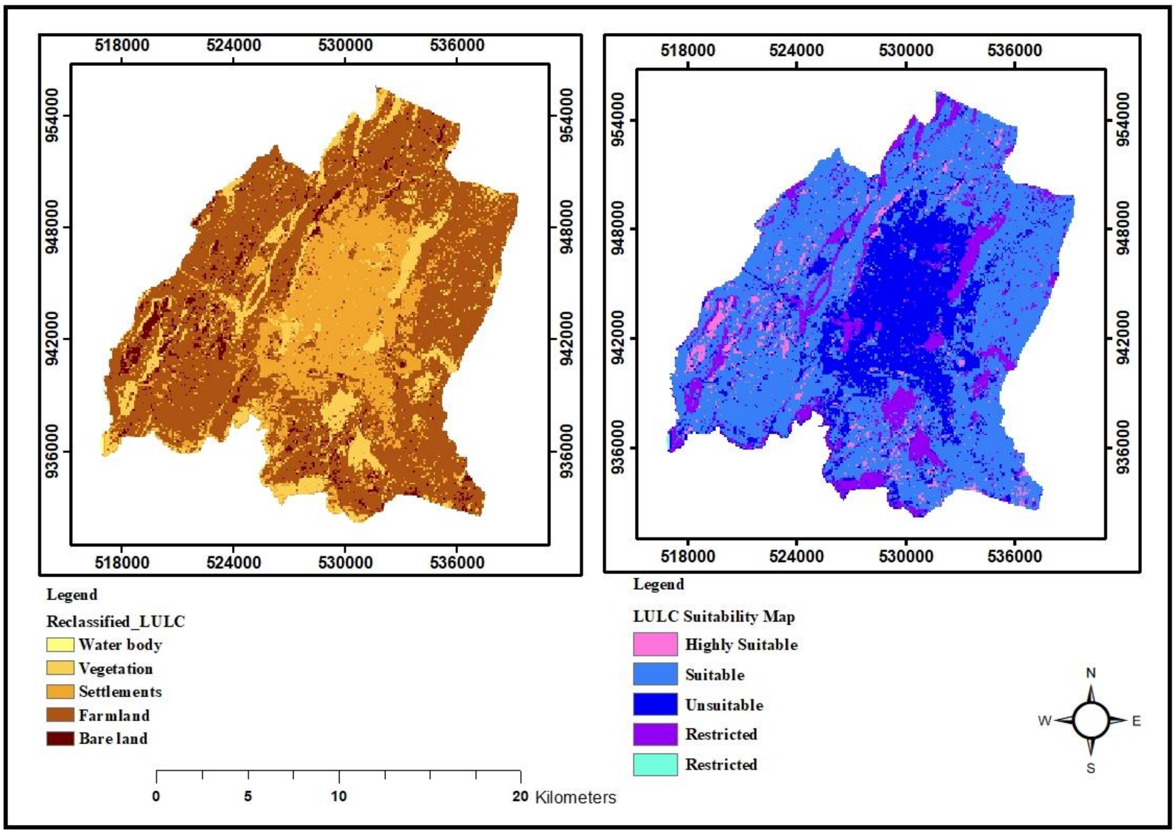

Figure 8: Land Use Land Cover Factor map (a) LULC classes (b) LULC suitability map

4.2.6 Availability of developable land

The availability of developable land had a significant influence on the pattern of suitable industrial locations in the municipality. This means that only areas that fell within the developable land area were assessed for suitability. After converting industrial land into commercial, residential, or agricultural parcels, it is nearly impossible to reclaim it, making industrial land vulnerable to disinvestment and displacement (Hoelzel and Leigh 2013). In addition to measuring the amount of priority developable industrial land, identifying one prime parcel within each community because of its key location, characteristics, and available developable industrial land helps further illustrate why these industrial parcels require protection and what characteristics to be aware of when searching for other priority locations. These sites are also larger than 10 acres and not adjacent to residential uses.

Finally, after suitability is measured, a more detailed analysis identifies the highest priority industrial parcels as those larger than 10 acres and not adjacent to residential parcels. Large contiguous acres are conducive to future investment because they allow a community to absorb industrial growth with the fewest restrictions. According to Holzel and Leigh (2013) and Mark Berube (2014), the developable industrial land factor map shown in Figure 9 has a high suitability class. Based on area in Arces Range, unsuitable, less suitable, moderately suitable, suitable, and highly suitable ranks were graded to the class intervals of 0 to 200, 200 to 300, 300 to 400, 400 to 600, and 600 to 5000, respectively.

Table 9: Suitability class of Developable Industrial Land

Suitability class of Developable Land	Score value	Rank	Area in (Acres)	Percentage (%)
highly suitable	S5	9	4491.82	77.47%
suitable	S4	7	532.11	9.18%
Moderate suitable	S3	5	311.33	5.37%
Less Suitable	S2	3	276.14	4.76%
un suitable	S1	1	186.94	3.22%
Total			5798.33	100%

The statistical summaries of the reclassified "suitability class" of the developable industrial land factor map are presented in Table 10. Illustrate that 186.94 acres (3.22 %) of the study area were unsuitable, 276.14acress (4.76 %) of the study area was less suitable, 311.3acreses (5.37 %) of the study area was moderately suitable, 532.acresres (9.18 %) of the study area was suitable, and 4491acrescres (77.47 %) of the study area was highly suitable.

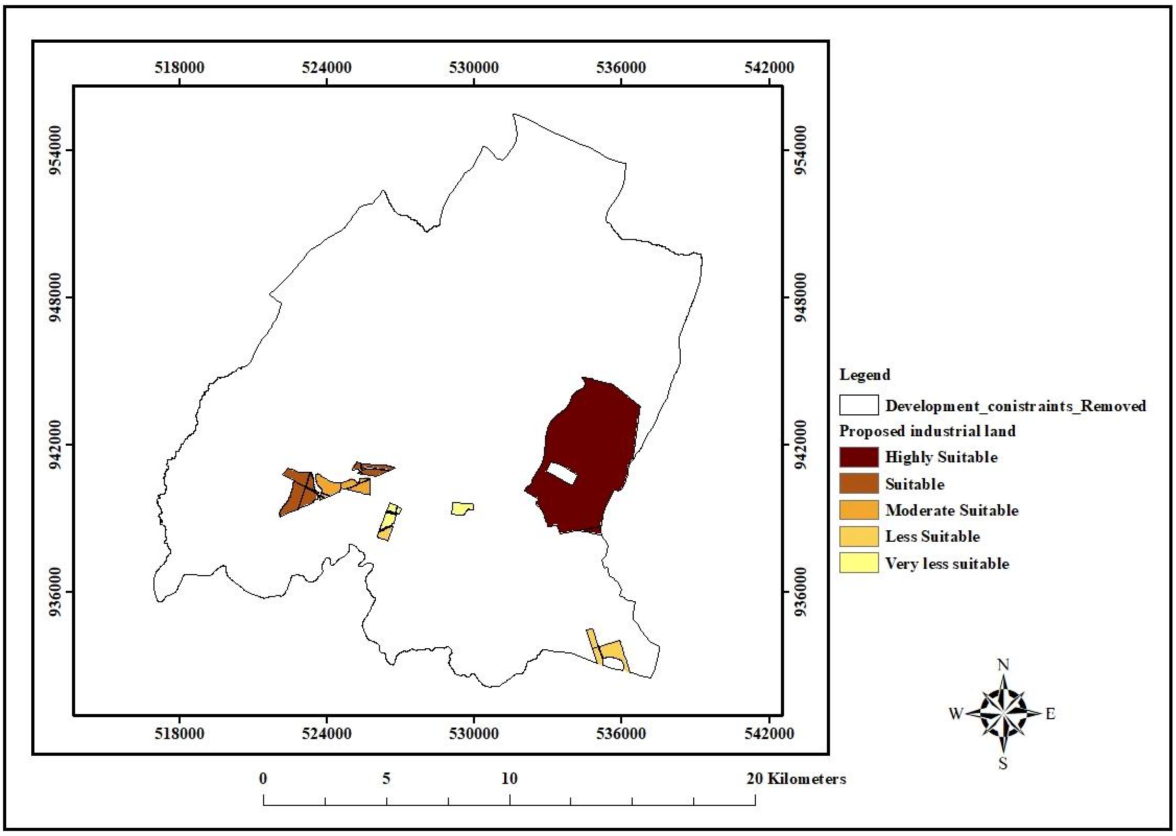

Figure 9: Developable Industrial Land

4.2.7 Distance to CBDS

An industrial site should be at a proximal distance from markets, which are often located in the CBDs. Proximity to CBDs ensures that customers can readily purchase a firm's products within a short distance from the main market location, thus reducing transportation and distribution costs (ASEAN, 2014). Figure 10 depicts a factor map based on the proximity of CBD's suitability. Highly suitable, suitable, moderately suitable, less suitable, and unsuitable ranks were graded to the class intervals of 0 to 2000, 2000 to 4000, 4000 to 6000, 6000 to 8000, and 8000 to 10000, respectively.

The statistical summaries of the reclassified proximity of CBD's suitability factor map presented in Table 11 illustrate this. That 20.21 km^2 (6.46 %), of the study area was very less suitable; that, 49.23 km^2 (15.72%), of the study area was less suitable; that, 54.61 km^2

(17.44%), of the study area was moderately suitable; that, 68.72 km^2 (21.9 %), of the study area suitable; that and 120.30 km^2 (38.3 %), of the study area was highly suitable.

Table 10: Proximity of CBDs Suitability map

Suitability Map of CBDs	Score	Rank	Area (km^2)	(%)
highly suitable	S5	9	120.30	38.43%
suitable	S4	7	68.72	21.95%
Moderate suitable	S3	5	54.61	17.44%
Less Suitable	S2	3	49.23	15.72%
Very Less Suitable	S1	1	20.21	6.46%
Total			313.05	100%

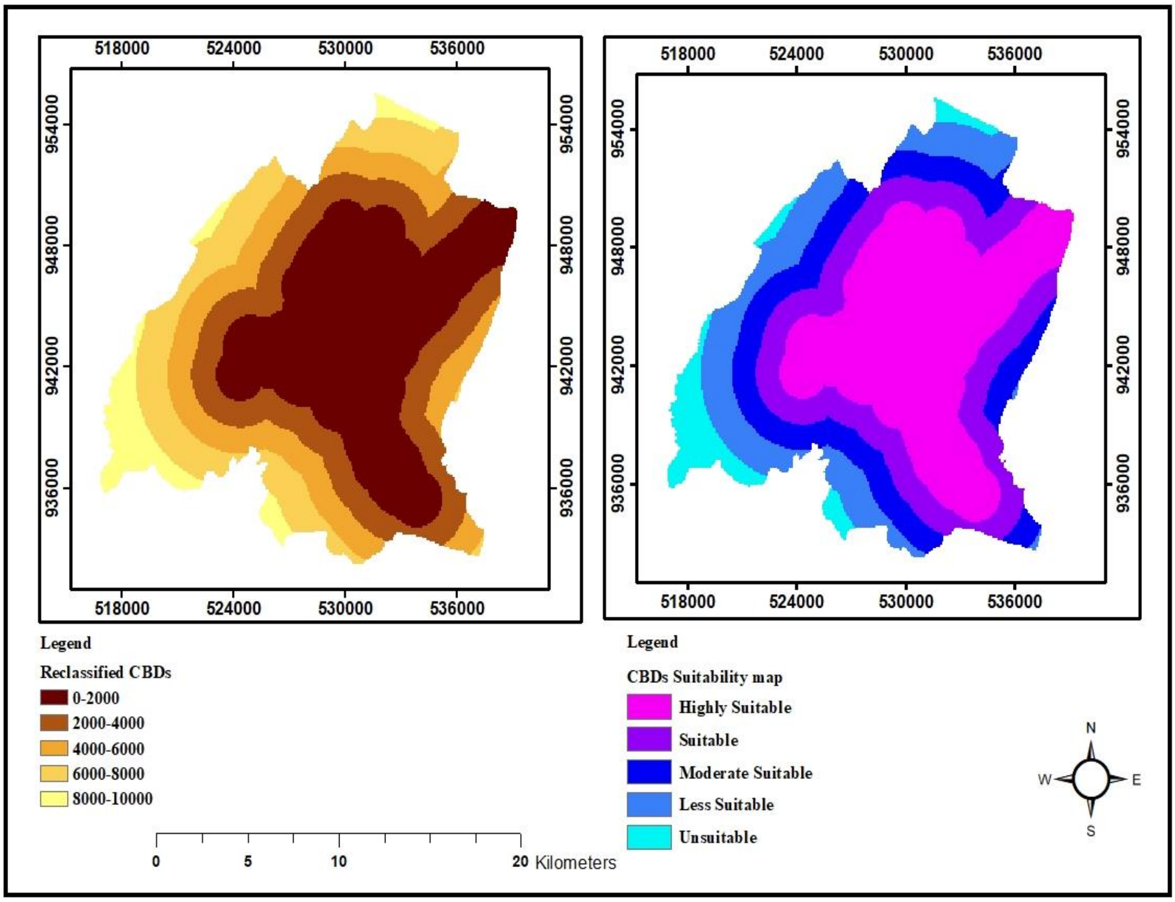

Figure 10: Proximity of CBDs Suitability map

4.2.8 Availability /Proximity to raw materials source

Urban industrial concentration provides close proximity to suppliers and customers, a network of skilled labor, and modern infrastructure for high-tech research and development activities, all of which are critical to the production process (Hoelzel and Leigh 2013). Therefore, protecting urban industrial activity facilitates efficient movement of goods between industries and communities, reducing transaction costs, and enhancing knowledge spillover within regional industry clusters. To begin with, the most common raw materials in the municipality, which had been the source of attraction for manufacturing firms, were (1) agricultural produce (2) groundwater (3) sandstone and limestone-rich soils. To analyze the "raw material source layer" (with a rank of (3), firstly, the point locations of 206 most notable food-producing firm areas were identified, using the point layer as the input source locations. The processing extent was set to the study area, and then the Euclidean distance tool was run. To ensure that the analysis was confined to the study area, the raster output was masked using the extract by mask tool. Lastly, the resulting raster data set was classified into four classes, with class four being the most suitable location in terms of distance to food-producing areas. Secondly, groundwater potential was treated as "raw material source" data using the symbology operations in ArcGIS, and the polygon layer was classified into five classes, with class five showing the best area with large amounts of groundwater in the aquifers (Kebede, 2013). A similar procedure was used for the geology map layer; the layer was classified from five to one; however, the classification was interpreted as meaning areas with the Voltaian sandstone formation were the most suitable (category 5) raw material sought by the concrete product-manufacturing firms. The next favorable formation was granite, then mixed quartzite and sandstone, which was developed by merging the three raw material sources.

According to the proximity of raw materials, the suitability factor map shown in Figure 12 shows the following: Highly suitable, suitable, moderately suitable, and less suitable ranks were graded according to the class intervals in meters from 0 to 600, 600 to 1600, 1600 to 2800, and 2800 to 4300, respectively. The statistical summaries of the reclassified proximity of raw material suitability factor map presented in Table 12 illustrate that 8.16 km2 (2.61 %) of the study area was less suitable, 72.47 km2 (23.15 %) of the study area was moderately suitable, 128.11 km2 (40.93 %) of the study area was suitable, and 104.26 km2 (33.31 %) of the study area was highly suitable.

Table 11: Proximity of Raw Materials Suitability Map

Proximity Suitability Map of Raw materials	Score value	Rank	Area (km^2)	By (%)
highly suitable	S5	9	104.26	33.31%
suitable	S4	7	128.11	40.93%
Moderate suitable	S3	5	72.47	23.15%
Less Suitable	S2	3	8.16	2.61%
Total			313.06	100%

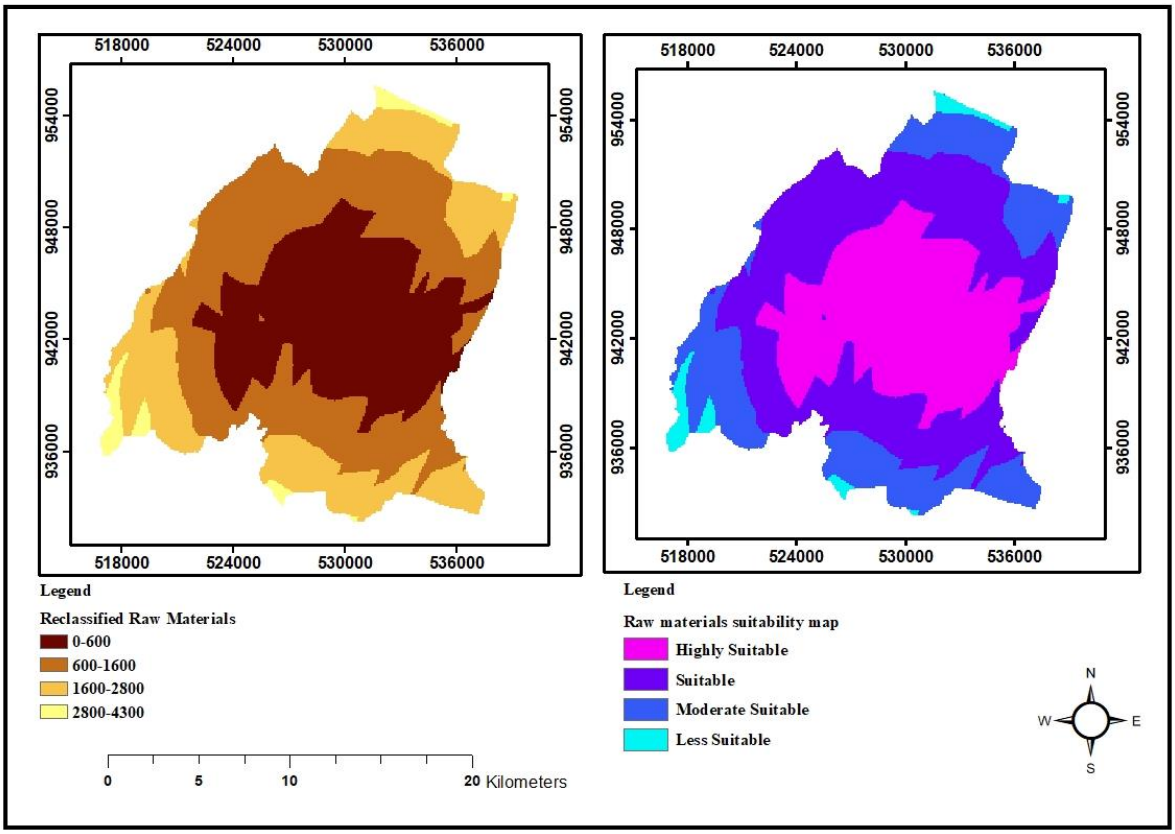

Figure 11: Proximity of Raw Materials Suitability Map

4.2.9 Existing Industrial and Manufacturing Site Factor

Industrial areas: to minimize the adverse impact of heavy industries due to their noise. disturbance and environmental contamination and create safer and more attractive health conditions, the location of residential areas is separated from the existing heavy industrial areas by creating buffer zones of restriction. (Rahim et al., 2014) suggested that residential area should be at least 500 meters away from heavy industry. In this study, the locations of existing heavy industries like national cement, warehouses, textile factories, and manufacturing plants were identified, and a buffer distance of 500 meters was created to exclude them from the analysis. According to Jiang (2007), centralized factories have a greater impact on each other than the far, dispersed factories. Therefore, if the new sites of plants are adjacent to the old factories they have more suitability. The existing industrial areas digitalized from the master plan of the study area were buffered and reclassified. As summarized in (Table13) the existing industrial and manufacturing sites proximity distance was graded into five suitability classes based on the suggestions of (Ahmadi pari et al., 2018) and (Jiang, 2007).

Table 12: Suitability index of the reclassified proximity distance in (m) used for the EIA

Proximity to Existing Industrial Area	Suitability class	Rank	Area (km^2)	By %
0-1000	Highly suitable	9	116.59	37.24%
1000-3000m	Suitable	7	114.06	36.43%
3000-4000m	Moderately suitable	5	39.08	12.48%
4000-5000m	Less suitability	3	29.03	9.27%
5000-7000m	unsuitable	1	14.32	4.58%
Total			313.06	100%

The suitability map utilized for the reclassified existing industrial zones was highly suitable, suitable, moderately suitable, less suitable, and unsuitable, as shown in Figure 12. Thus, the buffer distance interval used for the indexes in meters was 0-1000, 1000–3000, 3000–4000, 4000-5000, and 5000–7000, respectively. The statistical analysis result of the area and percentage for new industrial site selection based on the used EIA suitability factor was highly suitable at 116/59 km2 (37.24%). suitable 114.06 km2 (36.43%), moderately suitable 39.08 km2 (12.48%), less suitable 29.03 km2 (9.27%), and unsuitable 14.32 km2 (4.58%). These show that the majority of the study area was suitable for industrial sites, whereas the least amount of the study area was unsuitable.

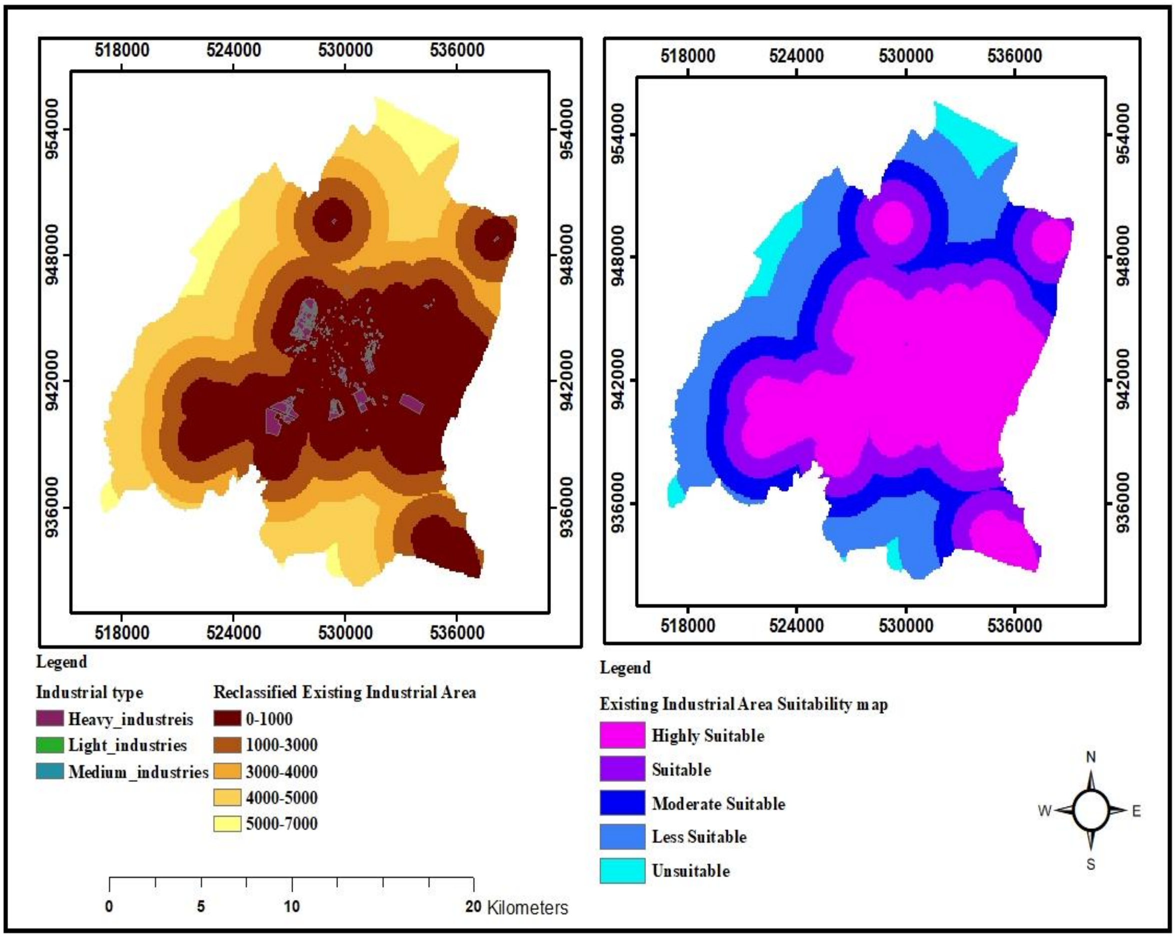

Figure 12: Existing industrial areas factor map (a) reclassified and (b) suitability map

4.2.10 Proximity to Residential Area

A "residential area" is a land use in which housing or residences predominate, as opposed to industrial and commercial areas. To minimize the adverse impact of heavy industries due to their noise disturbance and environmental contamination and create safer and more attractive health conditions, the location of residential areas is separated from the existing heavy, medium, and light industrial areas by creating buffer zones of restriction. The Department of Environment (2007) suggested that residential areas should be at least 500 meters away from heavy industry, at least 250 meters away from medium industry, and at least 50 meters away from light industry, with less than 50 meters to be considered a restricted industry zone.

In this study, the locations of existing residential areas were classified using buffer zones within residential areas. Heavy industries, medium industries, light industries, and micro level industries were identified, and buffer distances of >500, 500-250, and -50 meters were created, depending on the scale of their noise disturbance and environmental contamination potential, and distance between sensitive receptors to exclude from the analysis.

Table 13: Reclassified Residential area based on industrial type and suitability levels

Proximity to Residential area based on types of industries	Suitability class	Rank	Area (km^2)	By %
0-50 m	Suitable	7	35.914014	11.47
50-250 m for Light	Moderate suitable	5	40.649841	12.99
250-500 m for medium	Less suitable	3	38.437659	12.28
>500 m for Heavy	Unsuitable	1	198.146011	63.30
Total			313.07	100%

from 313.09 km^2 total area of Adama City, as shown in table 14 above 35.914 (11.47%) of the area is suitable, 12.99% of the area moderate suitable, 12.28% of the area is less suitable and 63.30% of the area is unsuitable for future Residential development.

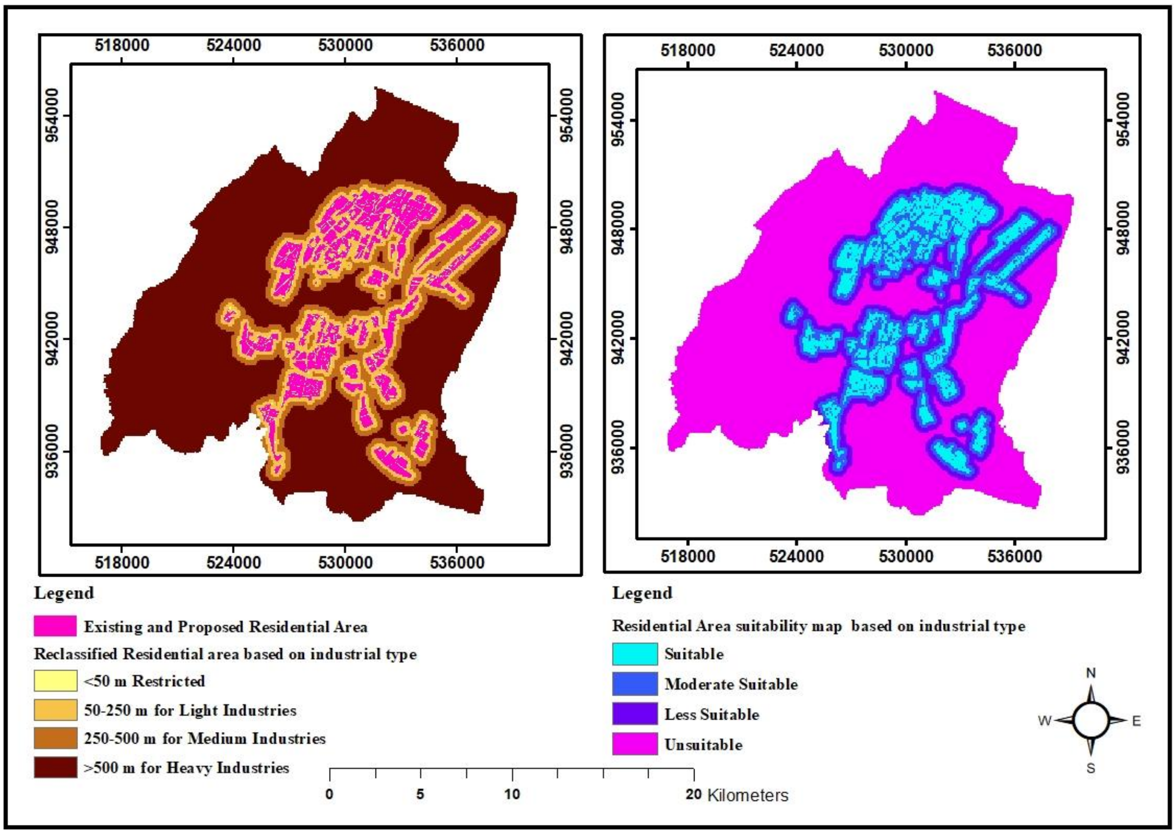

Figure 13: Reclassified Residential area based on industrial type and suitability levels

4.2.11 Proximity to health and Social facilities

The proximity to higher educational institutions was considered very important due to the advantage of a large population of customers created through the urbanization effects of universities and colleges. The industrial site selection process considered sites that were located at a proximal distance to health facilities to reduce the cost of transportation and the time employees spend accessing medical treatment. (ASEAN, 2014). To this end, maps of schools and health services were prepared from GPS data, and buffer zones were created in five classes. Areas with the closest distance to a school or health center were considered highly suitable for industrial development.

As shown in table 15, 64.81 km2 of Adama City's from total area of 313.06 km2 was occupied by existing built-up and was not considered for this analysis. As shown in the following table, 87.81 km2 (28.05 %) of the area is highly suitable, 28.11 % of the area is suitable23.70% is0 % moderately suitable, 14.16% of the area is less suitable, and 5.99 % of the area is unsuitable for future industrial development.

Table 14: Reclassified distance from School & health care and coverage of suitability levels

Proximity to school and health care center	Suitability class	Rank	Area (km^2)	By %
<1000	Highly suitable	9	87.81	28.05%
1000-2000m	Suitable	7	88.01	28.11%
2000-3000m	Moderately suitable	5	74.21	23.70%
3000-4000m	Less suitability	3	44.34	14.16%
>4000m	unsuitable	1	18.74	5.99%
Total			313.06	100%

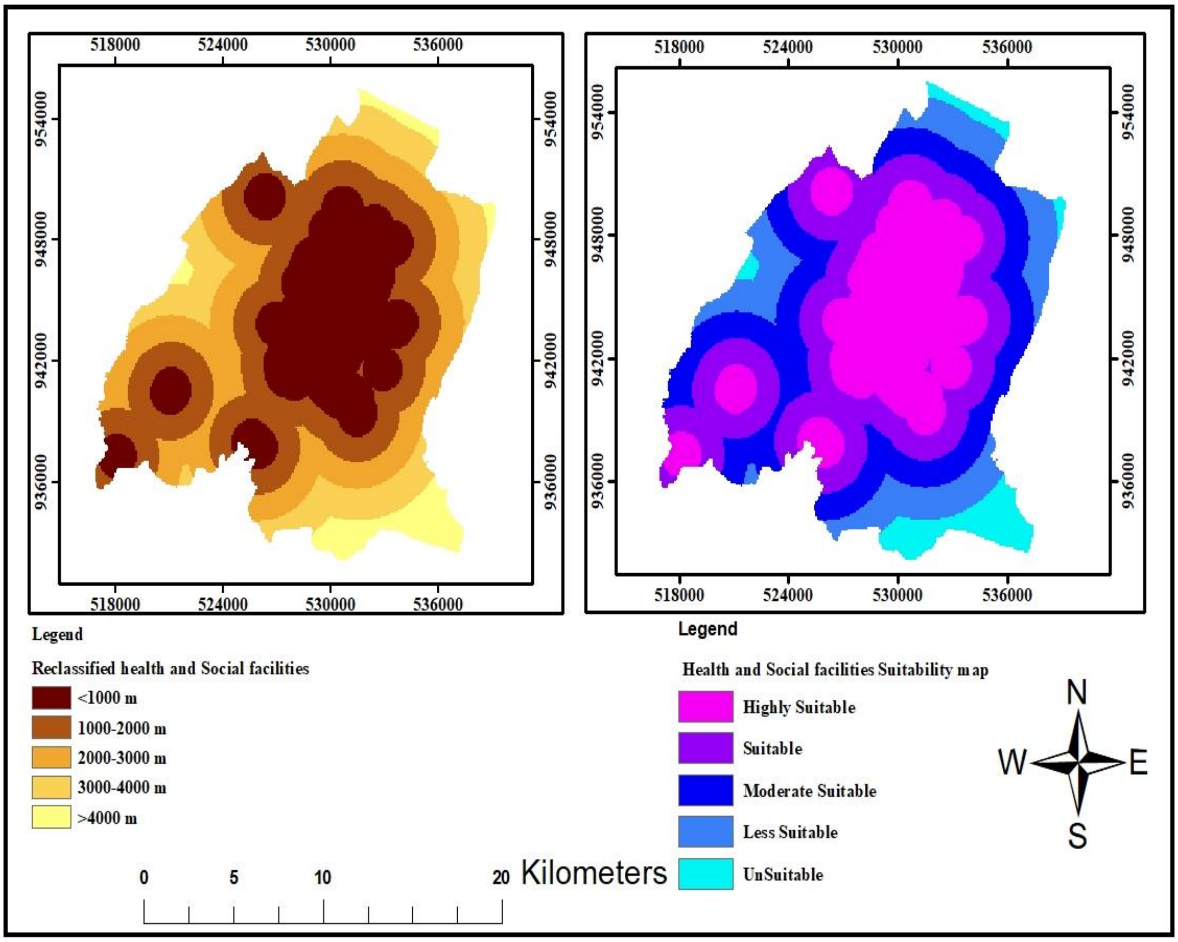

Figure 14: Proximity to health and Social facilities. (a) Reclassified and (b) Suitability map

4.2.12 Sewerage system

Industrial activities rely on available utilities and infrastructure. Wastewater management for manufacturing processes and day-to-day living standards, storm water infrastructure for precipitation runoff, and clean water for daily usage are standards for success and the ability to locate within a larger community (Steiner and Butler 2007, 244). Higher Drainage Density Low suitability for industrial locations due to flood inundation and the high investment required to realize a drainage system because such a site is very poor in terms of disposal system. According to Mark Berube (2014), Sewerage systems used in this study were based on drainage density determined by hydrological analysis from a digital elevation model of the city, and locations identified by the highest value (1) are located within the least unsuitable zone, while the lowest value (9) designates the most suitable zone.

Table 15: Reclassified Drainage density and area coverage of suitability levels

Classified Drainage density in value	Level of Suitability	Rank	Area (km^2)	By %
0-22	highly suitable	9	233.45	74.56%
22-64	suitability	7	59.97	19.15%
64-108	moderately suitable	5	14.24	4.55%
108-164	Less suitable	3	4.17	1.33%
>164	Unsuitable	1	1.24	0.40%
Total			313.05	100%

From the 313.05 km2 total area of Adama City, as shown in Table 16, out of 233.45 km2, 74.56% of the area is highly suitable, 19.15% of the area is suitable, 4.55% of the area is moderately suitable, 1.33% of the area is less suitable, and 0.40 of the area is unsuitable for future industrial development.

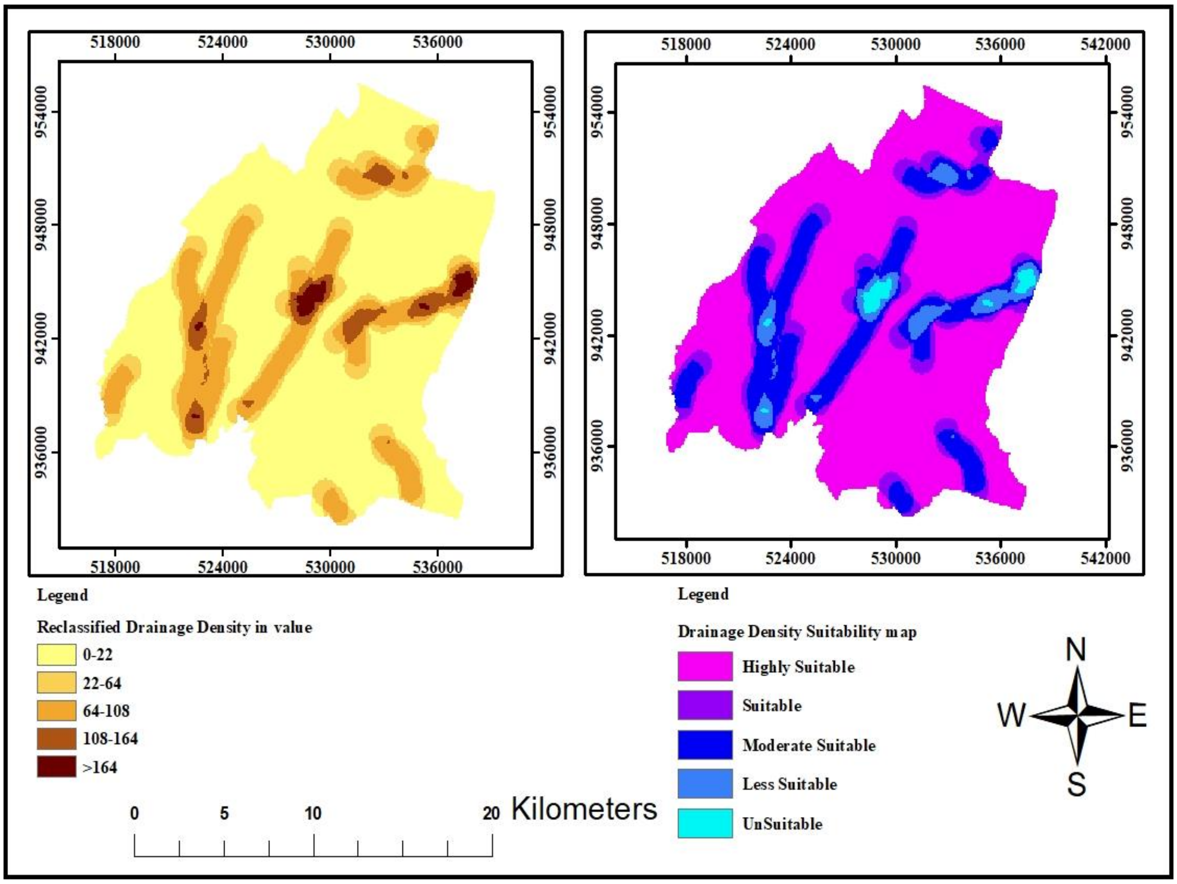

Figure 15: Drainage map (a) reclassified Drainage density in value and (b) suitability map.

4.2.13 Proximity to Rivers (streams)

The river (stream) network used in this study was digitized from Google Earth Pro in kml format. In addition, converted to a shape file in ArcMap 10.8, according to Ohri & Singh (2010) and EEPCo (2018). In addition, Gemeda (2018) mentions in their research that the area near the river is vulnerable to flooding. To avoid flood hazards and related problems caused by river and stream buffer zones, a stream map of the study area was created, and after the vector stream map was converted to raster, the map was reclassified into five classes and scored based on their suitability order. Areas 600 meters away from streams were deemed unsuitable due to their vulnerability to flooding. The ranking score increased as the distance from the river increased, with the highest score going to areas more than 5000 meters away from the river.

Table 16: Reclassified distance from river and area coverage of suitability levels

Proximity to Rivers (streams)	Level of Suitability	Rank	Area (km^2)	By %
<600m	unsuitable	1	122.59	39.16%
600-1600m	Less suitability	3	100.08	31.97%
1600-2800m	moderately suitable	5	52.85	16.88%
2800-5000m	suitable	7	31.48	10.06%
>5000m	highly suitable	9	6.10	1.95%
Total			313.08	100%

From the 313.1 km2 total area of Adama City, as shown in Table 17, out of 6.10 km2 (1.95%) of the area, 10.06% of the area is suitable, 16.88% of the area is moderately suitable, 100.08% of the area is less suitable, and 39.16 percent of the area is unsuitable for future industrial development.

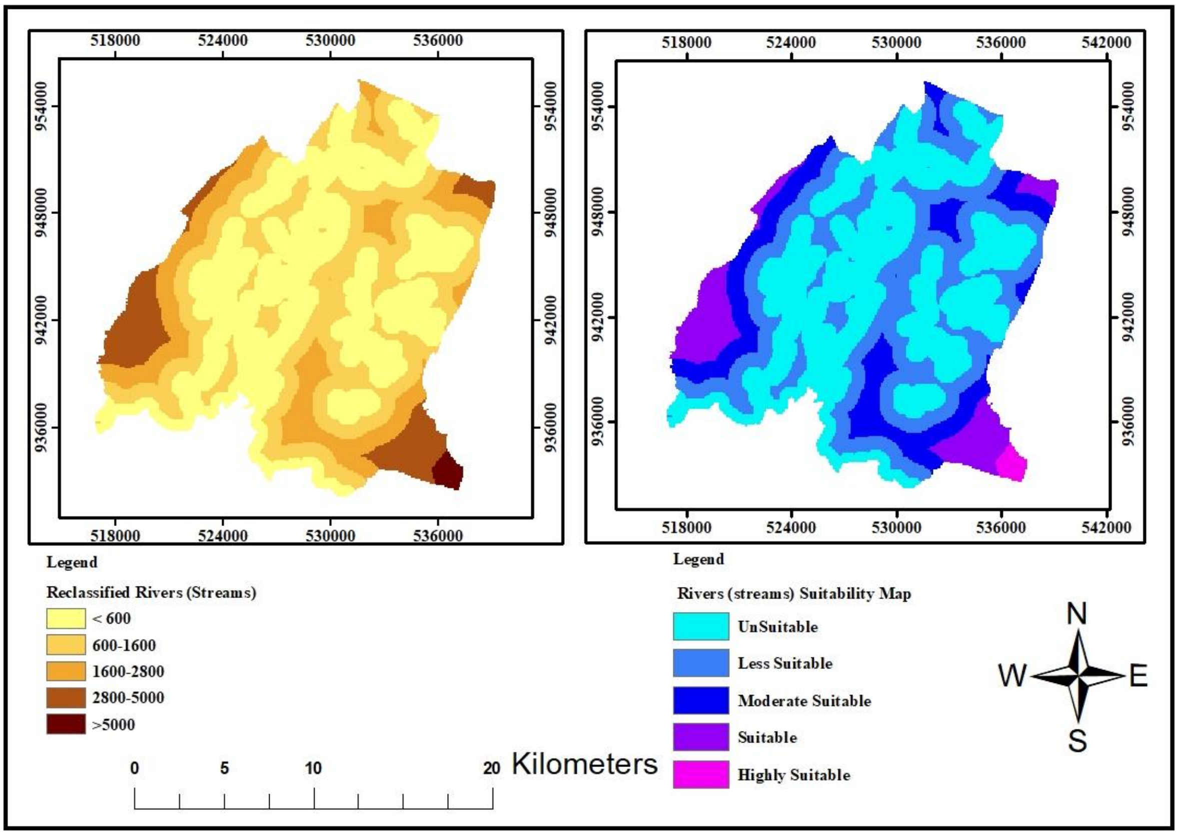

Figure 16: Rivers (streams) factor map (a) reclassified and (b) suitability map

4.2.14 Proximity to major Road Networks

Road is one of the criteria that should be considered in the site suitability analysis for industrial development. It plays an important role in urban planning and development as it connects different settlements and is important for conveying goods and services. The road networks used in this study were digitized from Google Earth Pro in kml format, digitized from the Adama City master plan. In addition, converted to shape files in ArcMap 10.8. According to suggestions of previous researchers for major road categorization (Ahmadipari et al., 2018, Jiang, 2007, Roy et al., 2019, Abushnaf et al., 2015), and Ohri & Singh (2010), the cost of raw material transportation, finished goods transportation, etc. is dependent on the proximity to a transportation facility. The transportation network bears the greatest importance in the site selection process. Therefore, the existing major road networks of Adama City were one of the transportation facilities that were considered for this study. As the distance from the road network increased, so did the suitability. This results in longer distances being less suitable as transportation costs increase (Reisi et al., 2011). As discussed in their study, buffer zones of less than 500 m are ideal for industrial development. The suitability decreases as the area is far away from the road, and areas >

2000 m away from major roads are considered unsuitable for industrial land development. Finally, the buffered zone was converted to raster, and the map was reclassified into five classes. They were also graded according to their suitability order.

Table 17: Reclassified distance from road and area coverage of suitability levels

Proximity to major Road	Level of Suitability	Rank	Area (km^2)	By %
<500m	highly suitable	9	101.51	32.43%
500-1500m	Suitable	7	79.42	25.37%
1500-3000m	moderately suitable	5	74.13	23.68%
3000-4500m	Less suitability	3	40.83	13.04%
>4500m	unsuitable	1	17.2	5.49%
Total			313.07	100%

From the 313.1 km2 total area of Adama City, as shown in Table 18, 32.43 percent of the area is highly suitable, 25.37 % of the area is suitable, 23.68 % of the area is moderately suitable, 13.04 % of the area is less suitable, and 5.49% of the area is unsuitable for future industrial development.

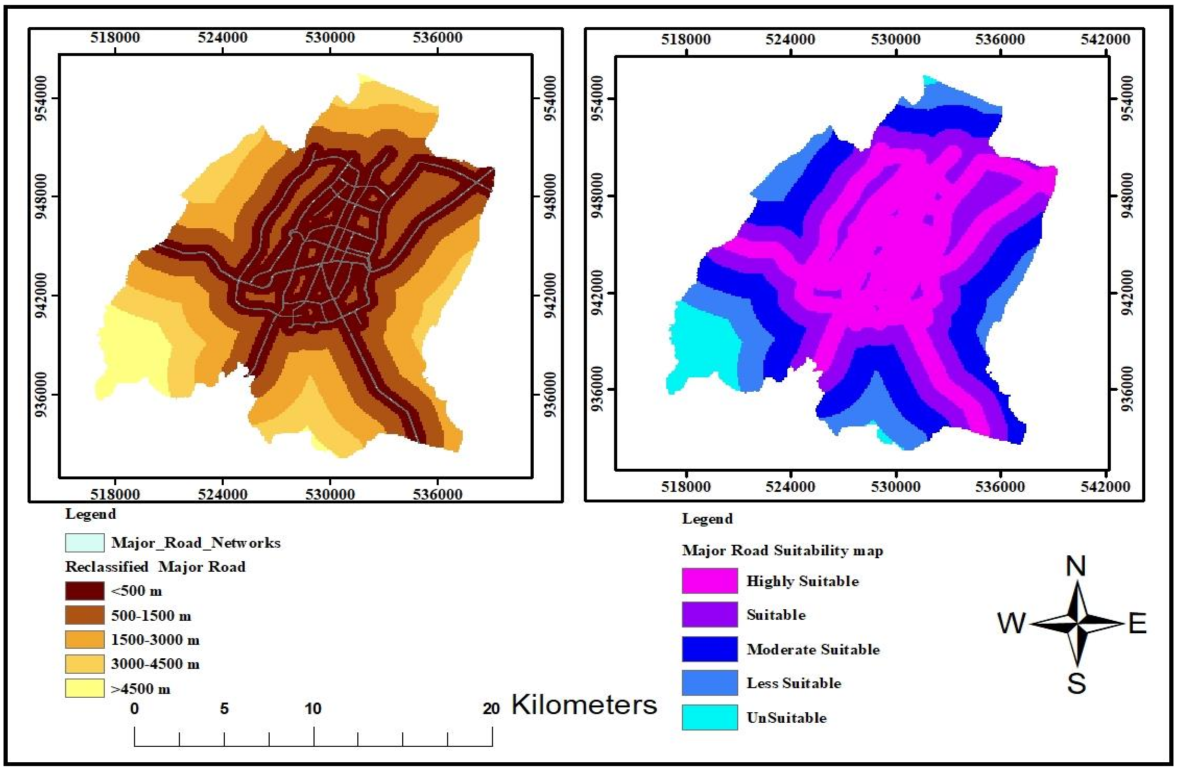

Figure 17: Major Road Factors map (a) reclassified and (b) suitability map.

4.2.15 Proximity to Rail Way Road Networks

The railway is an important and cost-effective means of transporting industrial products (Jiang, 2007). As a result, areas near the railroad may be more suitable than other locations. Because of the economic impact on business establishments, the railroad spatial information component was used in this study. The railway road network was digitized from Google Earth Pro in kml format. In addition, converted to a shape file in ArcMap 10.8, and their buffer was generated using ArcGIS software's Euclidean distance analysis tool (Johar et al., 2013, Jiang, 2007; Abushnaf et al., 2015; Jiang, 2007). As discussed in their study, buffer zones falling under 1500 m of distance are highly suitable for industrial development. The suitability decreases as the area is far away from the rail line, and areas > 7000 m away from the rail line are considered unsuitable for industrial development. Finally, the buffered zone was converted to raster, and the map was reclassified into five classes. Furthermore, students are graded in order of their suitability.

Table 18: Reclassified distance from Railway and area coverage of suitability levels

Proximity to Rail Ways	Level of Suitability	Rank	Area (km^2)	By %
<1500m	highly suitable	9	85.69	27.37%
1500-3000m	Suitable	7	74.86	23.91%
3000-5000m	moderately suitable	5	71.29	22.77%
5000-7000m	Less suitability	3	52.38	16.73%
>7000m	unsuitable	1	28.87	9.22%
Total			313.09	100%

from 313.09 km^2 total area of Adama City, as shown in table 18 above out of 85.69 km^2, 27.37% of the area is highly suitable, 23.91 % of the area is suitable, 22.77 % of the area moderately suitable, 16.73% of the area is less suitable, and 9.22% of the area is unsuitable for future industrial development.

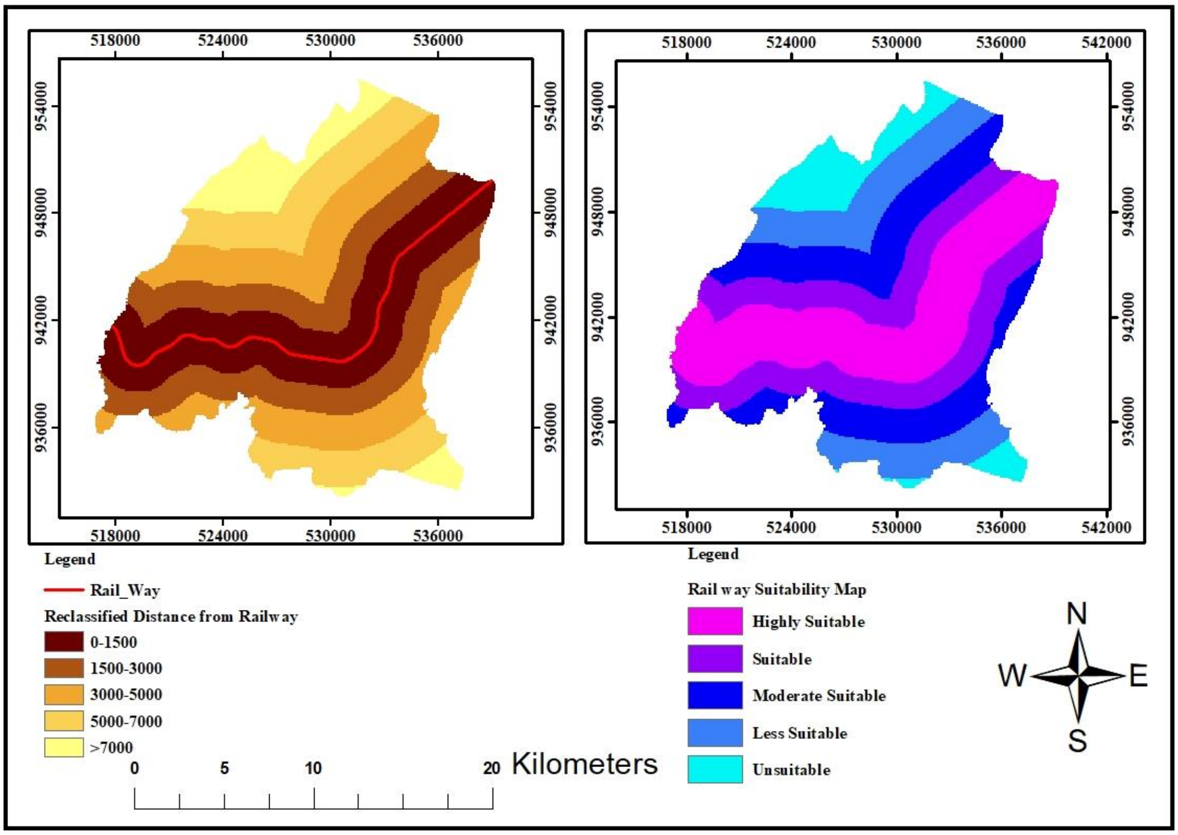

Figure 18: Railway factor map (a) reclassified distance from railway and (b) suitability.

4.2.16 Proximity to Highway Road Networks

Industrial land serves as manufacturing, warehousing, and distribution centers, which require priority locations necessary for receiving, storing, and distributing goods. The location of these establishments is becoming increasingly important as firms compete to deliver their products as efficiently as possible (Berube, 2014). Highway roads are one of the transportation infrastructures that support and facilitate industrialization. According to Alzamili et al. (2015), highways are used 75% of the time for industrial purposes. This statement shows that highways are a fundamental factor in the establishment of an industrial area. Therefore, in this study, the areas near highway roads were considered highly suitable for the demarcation of industrial sites. The highway road networks used in this study were digitized from Google Earth Pro in kml format and converted to shape files in ArcMap 10.8. So as demonstrated in Figure 20, the high-way road network was reclassified into five groups that range from unsuitable to less suitable, moderately suitable to suitable, and highly suitable based on proximity distances produced through the Euclidean spatial analysis tool. The respective scores assigned were 1, 2, 3, 4, and 5.

Table 19: Reclassified distance from Highway and area coverage of suitability levels

Proximity to Highways	Level of Suitability	Rank	Area (km^2)	By %
<100m	highly suitable	9	6.49	2.07%
100-200m	Suitable	7	4.7	1.50%
200-300m	moderately suitable	5	3.27	1.04%
300-400m	Less suitability	3	4.62	1.48%
>400m	unsuitable	1	294.07	93.93%
Total			313.07	100%

from 313.09 km^2 total area of Adama City, as shown in table 20 above out of this total coverage, 85.69 km^2 (2.07%) of the area is highly suitable, 1.50% of the area is suitable, 1.04 % of the area moderately suitable, 1.48% of the area is less suitable, and 294.07% of the area is unsuitable for future industrial development.

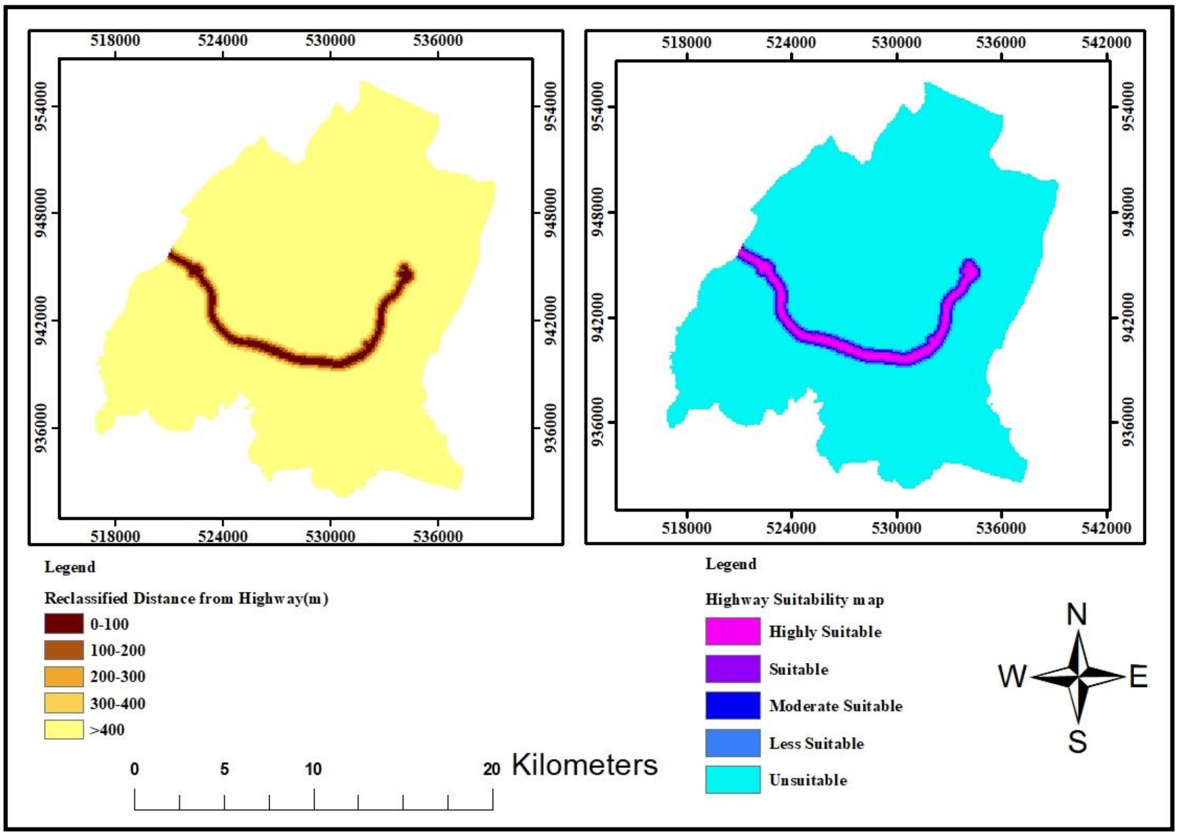

Figure 19: Highway road factor map (a) reclassified and (b) suitability index.

4.2.17 Proximity to Landfill Site factors

One of the most significant sources of risks to human health and the environment is waste production (Hashemi et al., 2017). When landfill sites are close to industrial locations, they may dump discarded garbage straight into the industry during wet seasons, posing a major threat to both industry productivity and the environment. Different types of industry and production, such as food and beverage, materials, and chemical factories, might be found in the industrial zones. Some of these industries are sensitive to contamination from any source, which lowers the quality of the product provided by the facility, either directly or indirectly. According to Alzamili et al. (2015), the industrial site may include industries that cannot tolerate any contamination; a distance of at least 2–5 km should be maintained. To avoid this sensitivity, an existing landfill waste disposal site was used as an input for spatial information. parameter. The existing waste disposal area was extracted from the master plan of Adama City by utilizing ArcGIS 10.8 software extraction tools. Because of the lower risk of contamination, areas further away from landfills are more suitable for industrial plants. However, places that are too far away from landfills are not cost-effective since industries must travel long distances to dispose of their trash. Unsuitable, less suitable, moderately suitable, highly suitable, and suitable were the score ranges used for landfill site categorization into five classes with intervals of 0–4000, 400–600, 6000–8000, 8000–10,000, and >10,001

Table 20: Reclassified distance from Landfill site and area coverage of suitability levels

Proximity to Landfill site in (m)	Level of Suitability	Rank	Area (km^2)	By %
<4000m	Unsuitability	1	105.86	33.81%
4000-6000m	Less Suitable	3	74.34	23.74%
6000-8000m	moderately suitable	5	62.66	20.01%
8000-10,000m	highly suitable	9	51.05	16.31%
>10,000m	suitable	7	19.13	6.11%
Total			313.09	100%

The overall contribution of each suitability class for industrial site demarcation in terms of area was 105.86 km2, 74.34 km2, 62.66 km2, 51.05 km2, and 19.13 km2 based on the reclassified map of landfill site factor depicted in Figure 20. The suitability ranks assigned in linguistic variables for landfill factor are unsuitable, less-suitable, moderately-suitable, highly-suitable, and suitable. To compensate for the environmental impact and economic benefit in the current study, locations located at a medium distance from the landfill site were considered highly suitable, while sites located too far from the dumpsite were reclassified as suitable for achieving the study's goal. From this perspective, the study area was primarily suitable for industrial zoning in regards to landfill suitability.

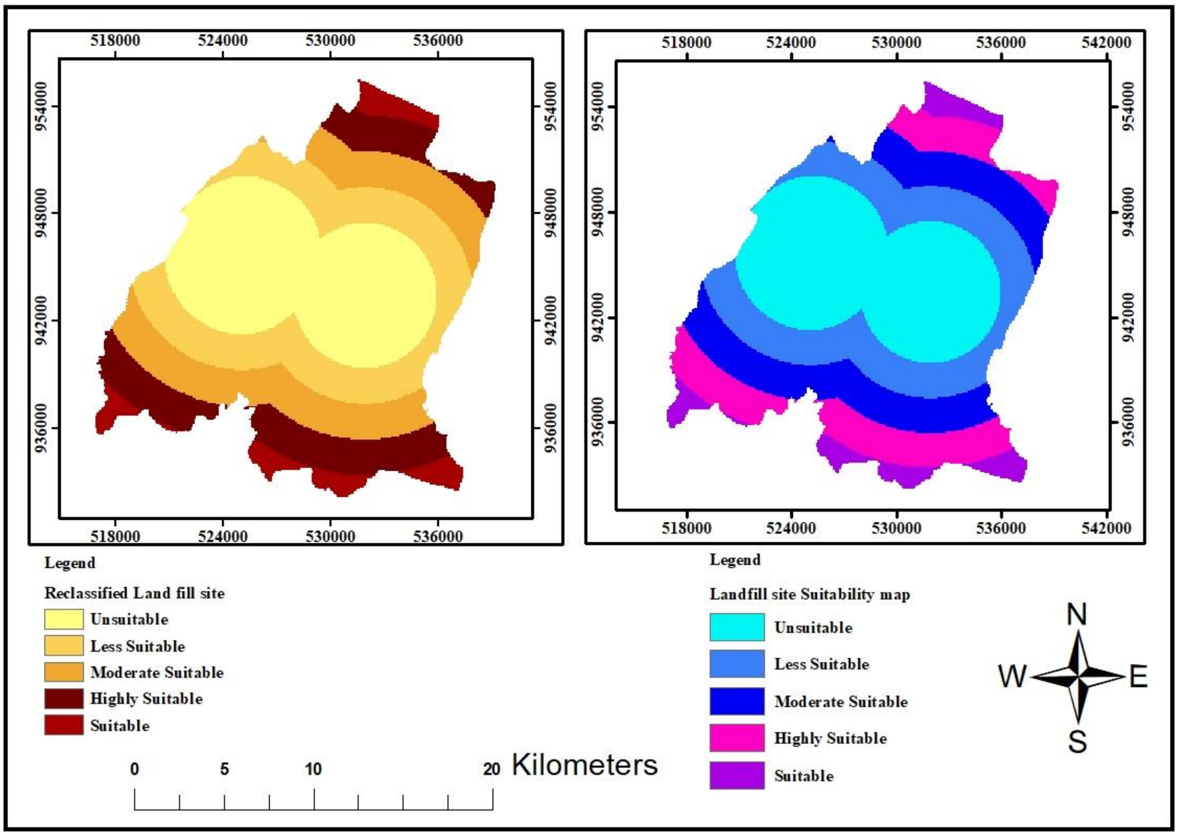

Figure 20: Landfill site factor map (a) reclassified distance and (b) suitability map.

4.2.18 Availability of reliable electricity supply

From the perspective of the safety of constructed industrial facilities, humans and the environment, require that industrial sites be located at some safe distance from heavy electric power lines. Unfortunately, if an accident occurs on a power line, the consequences for industry, humans, and the environment may be unanticipated. As industries are generally characterized by medium-to-high investment, care should be taken in such a manner that investment is not at stake with hasty decisions (Sarath et al., 2018). As a result, considering heavy electric power lines as one criterion for industrial site selection is a critical and important decision. The heavy electric power line was one of the criteria that influenced the placement of a feasible industrial site in the current study. From the Adama city base map, heavy electric power lines are digitized and exported. According to the Ethiopian Electricity Agency directive (2005, as cited in EEP 2021), a minimum horizontal distance of 30 meters is required between any structure and overhead electric lines carrying 66KV to 230KV. To reclassify the heavy electric power line based on this standard, their Euclidean distance was computed using the spatial analysis extension toolbox in ArcGIS 10.8 map and then reclassified with distance ranges of 0–30 m, 30–60 m, 60–90 m, and 90–120 m, based on the above statement. Their suitability map in the linguistic variable was less suitable, moderately suitable, suitable, and highly suitable, in that order. Below (Table 22 and Figure 21) is a description demonstrating its distance range and suitability index for heavy electric power lines.

Table 21: Suitability map of reclassified heavy power line-proximity distance in (m)

heavy power line proximity distance in (m)	Level of Suitability	Rank	Area (km^2)	By %
0-30	Less suitable	3	8.02	2.56%
30-60	Moderate Suitable	5	13.42	4.29%
60-90	suitable	7	7.45	2.38%
90-120	Highly suitable	9	284.23	90.78%
Total			313.09	100%

From the reclassified map, as it can be seen from (Figure 21) the overall contribution of each suitability map for optimal industrial site selection in terms of heavy electric power line suitability, 8.02 km2 was less suitable, 13.42 km2 was moderately suitable, 7.45 km2 was suitable, and 284.23 km2 was highly suitable. To generalize, in terms of heavy electric power line factor the majority of the study area was highly suitable whereas the least of the area was moderately suitable for industry establishment.

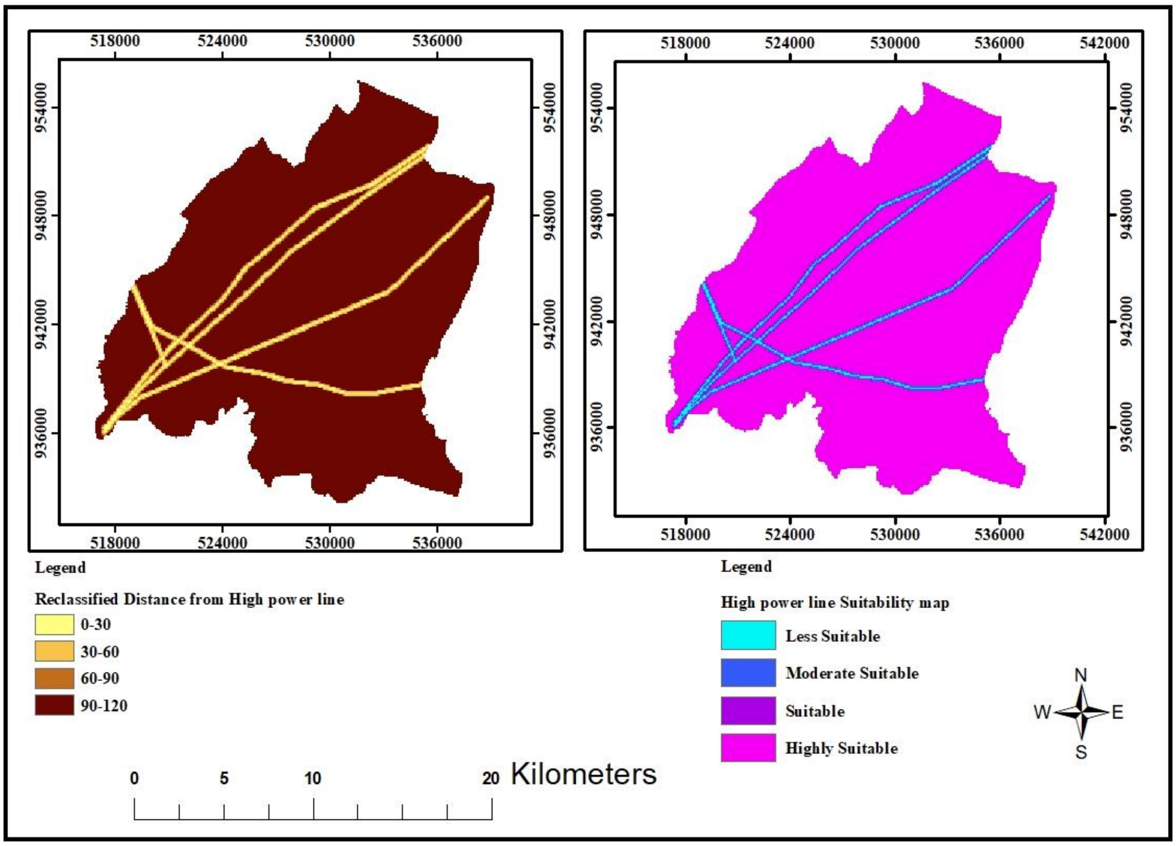

Figure 21: High Power line factor map (a) reclassified distance and (b) suitability map.

4.2.19 Availability of Ground Water Potential.

According to Chan (2005), for industries, water is the most commonly used natural resource. In processing, it may be incorporated into the product, used for processing, steam generation, power generation, cooling, and in normal sanitary uses, hence both the quality and quantity of the water supply are very important determinants for location of an industry. Regarding quality, groundwater sources are preferred to industrial plants, such as those in the beverage industry. The iron and steel industry, Textile industries and chemical industries require large quantities of water for their proper functioning. Volcanic aquifers are sources of groundwater for both urban and rural areas. Groundwater is obtained from volcanic aquifers that are stored in the fractured and weathered parts of volcanic rocks. Groundwater provides more than 90% of the freshwater used for domestic and industrial supply in Ethiopia (Kebede et al., 2018) and is predominantly abstracted from volcanic aquifers. Its occurrence varies spatially owing to the complexities of regional. In addition, local geology and associated geological structures. Since surface waters are becoming increasingly unreliable due to climate change and pollution, they are the least suitable for industrial use. Surface water, igneous intrusive, and volcanic aquifers were moderately suitable, suitable, and highly suitable, respectively. Underground water potential used in this study was derived from free-to-download shape files (.shp) from the Africa Groundwater Atlas country hydrogeology maps.

Table 22: Reclassified Ground Water Potential value and area coverage of suitability levels

Ground Water Potential in Yield(l/s)	Level of Suitability	Rank	Area (km^2)	By %
2-5	Moderately suitable	5	7.93	2.53%
5-10	Suitable	7	269.61	86.13%
10-20	Highly suitable	9	35.50	11.34%
Total			313.09	100%

from 313.09 km^2 total area of Adama City, as shown in table 23 above out of this total coverage, 35.50 km^2 (11.34%) of the area is highly suitable, 86.13% of the area is suitable and 2.53 % of the area moderately suitable for future industrial development.

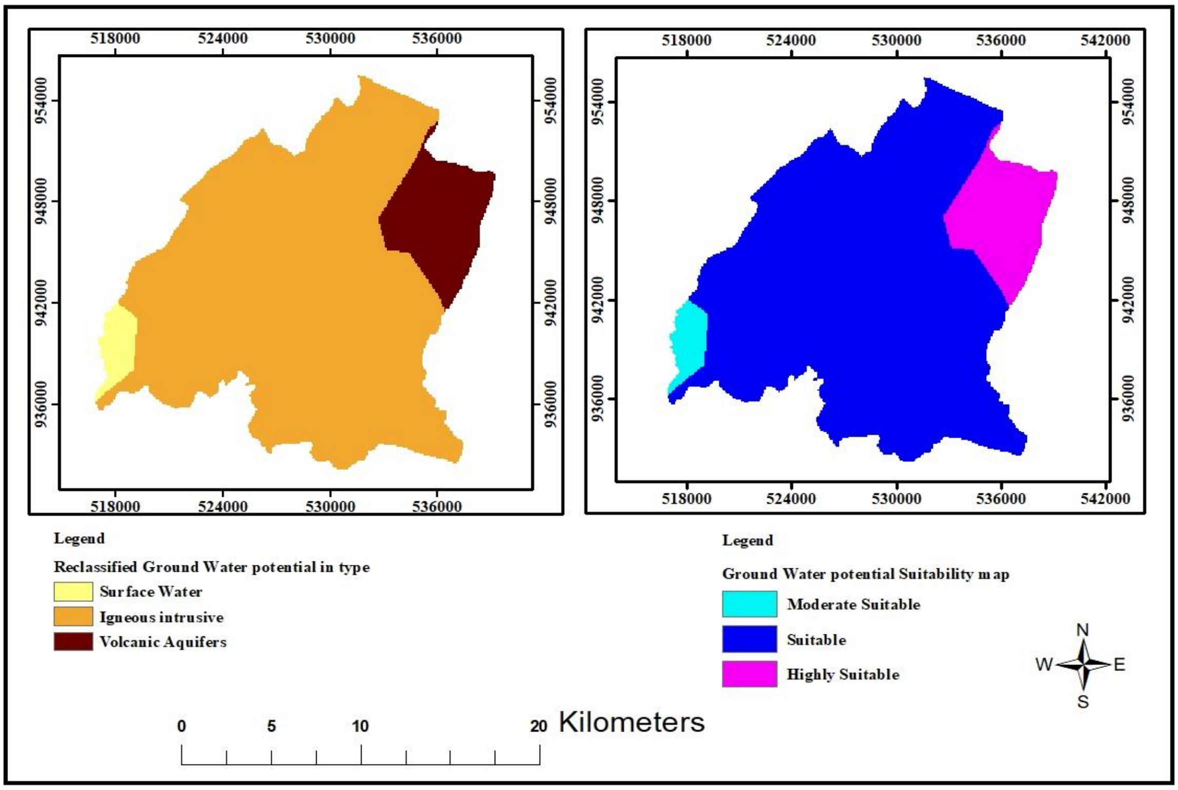

Figure 22: Ground water potential map (a) reclassified and (b) suitability map.

4.2.20 Population density

Urban density is a term used in urban planning and urban design to refer to the number of people inhabiting a given urbanized area per given building. Urban density is considered an important factor in understanding how cities function. It was believed that as the number of buildings increased, the built area would increase and the neighborhood would become denser. According to ground reality, most municipal service delivery is related to population density (Gemeda, 2018). The density of the population varies from area to area. According to the analysis results, the central parts of the city have a high population density in comparison with the urban expansion areas. The urban Ganda with the biggest population is irreecha (099), whereas, the urban Genda with the least population is Gurmu (0606)However, Gada Gurmu (06), as opposed to Badhatu (07), is the first densest. . Densely populated urban area as particularly in low and middle-income countries, are vulnerable to the effects of environmental and climate change (Dodman, 2009). Lower population density is consider as more suitable than higher population density for optimal industrial site selection since the cost of land property, and effects on population decreases with decreasing density. In addition to this industrial al waste are the main source of pollution worldwide; therefore, are highly dense population is easily exposed to pollution. For this study, the population density of the study area was reclassified into five grades as depict in the table in the below (table 24).

Table 23: Suitability map of the reclassified population density per km2

Population density per km^2	Level of Suitability	Rank	Area (km^2)	By %
27.45 - 1074.142	Highly suitable	9	250.65	80.06%
1074.142 - 3466.54	Suitable	7	28.43	9.08%
3466.54 - 9597.072	Moderately suitable	5	24.32	7.77%
9597.072 - 19914.30	Less suitable	3	8.36	2.67%
19914.30- 38156.36	Unsuitable	1	1.34	0.43%
Total			313.09	100%

from 313.09 km2 total area of Adama City, as shown in table 24 above out of this total coverage, 250.65 km2 (80.06%) of the area is highly suitable, 9.08% of the area is suitable,

7.77 % of the area is moderately suitable, 2.67% of the area is less suitable, and 0.43% of the area is unsuitable for future industrial development.

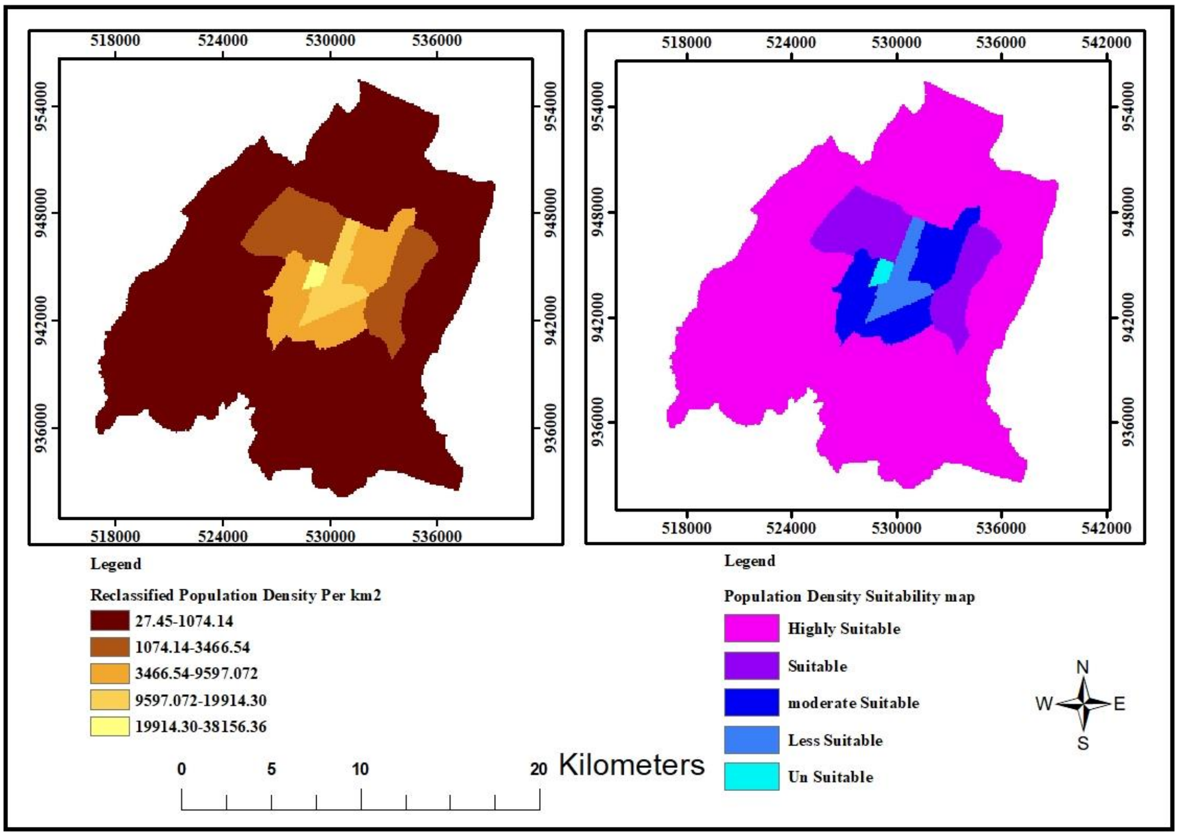

Figure 23:-Population factor map (a) reclassified population and (b) suitability map.

4.3 Calculating the Weights of parameters

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

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

Table 24: Scale for pairwise comparison of Parameters (Saaty, 1980)

Intensity of importance	Definition
1	Equal importance
2	Equal to moderately importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

The weight of each parameter was derived by taking the principal eigenvector of a square reciprocal matrix of pair-wise comparisons of the relative importance of factors to the suitability using IDRISI selva 17. These pair wise comparison was then analyzed to produce of weights that sum to 1 and the total weight should be added up to 100% in order for the output map to be meaningful and consistent (Saaty, 2008; as cited by Lamessa kenate, 2017 and Getahun Kafe, 2020). The AHP weight derivation interface to derive the weights for each parameter, with its consistency ratio, for Industrial Area site selection was shown by figure 25 below.

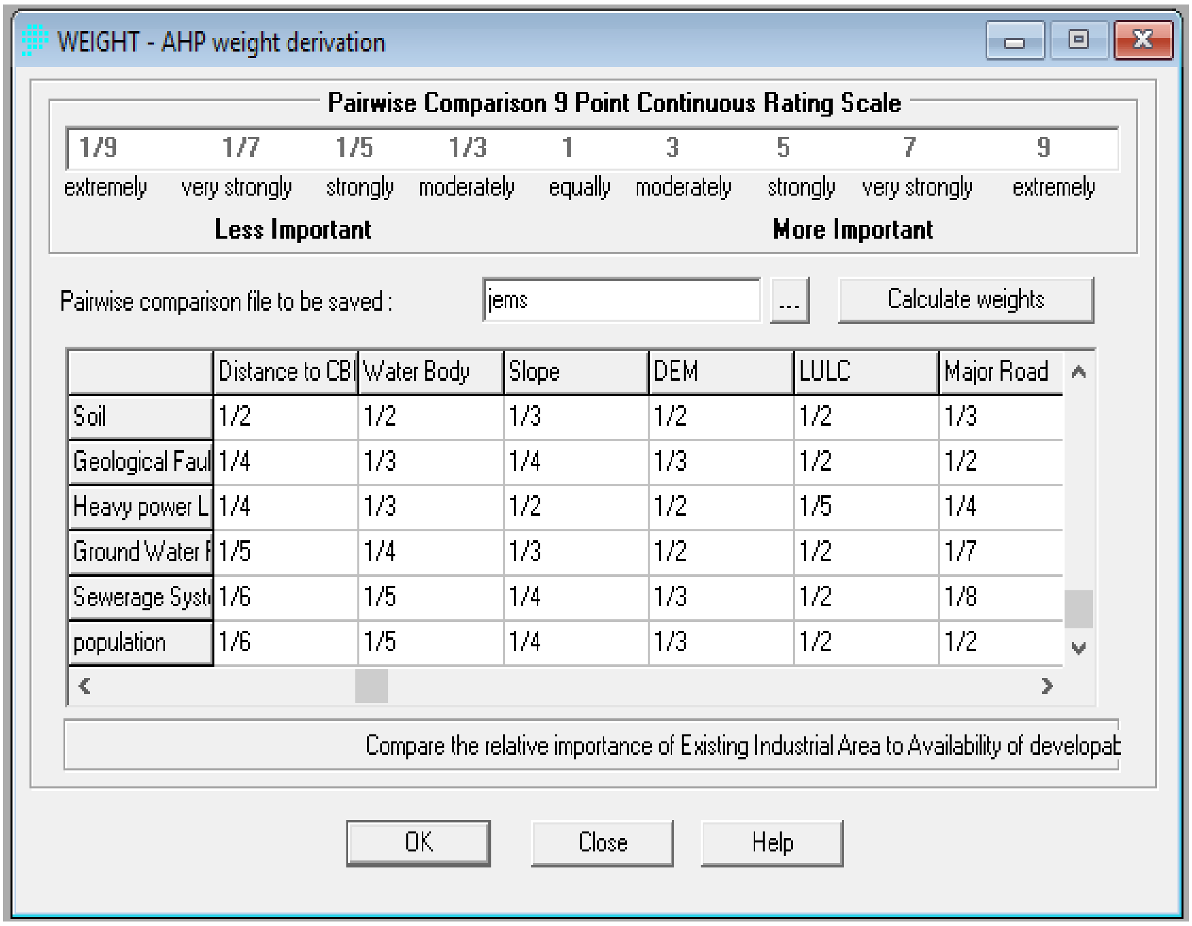

Figure 24: AHP weight derivation method of PWC Point Continuous Scale (Author, 2021)

4.3.1 Ranking parameters by AHP

The main use of AHP is ranking and prioritization of parameters. Priority framework quality affects the effectiveness of available sources, which are the essential judgment from the decision maker (Andi et al., 2017). Furthermore, the experts usually use their experiential judgment when making the decision. Each of the expert participants determined the weight to the design factors and gave the weights depend on the Table 26 parameters of the factors. The responses of the experts, professionals and researchers on related area were shown in Table 26 below: The computation of weights for parameters using Analytical Hierarchical Process (AHP) involves three main steps. The steps followed to calculate the weight of parameters used in this study are detailed as below. The first step is the summation of the values in each column of the matrix (see table 26 last row).

Table 25: Pair-Wise Comparison Matrix

	Availability of developable land	Existing industrial Area	Raw Material source	population	Distance to CBDS	Water Body	Slope	DEM	LULC	Major Road	Highway	Rail-Way	Health and Social facilities	Soil	Geological- Fault lines	Heavy power Line	Ground Water Potential	Sewerage System	Landfill
Availability of developable land	1	2	2	3	3	3	2	2	3	3	3	3	3	4	5	5	5	7	7
Existing industrial Area	1/2	1	2	2	2	2	2	3	2	2	2	2	2	3	4	4	4	6	6
Raw Material source	1/2	1/2	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	5	5
population	1/3	1/2	1/2	1	2	2	2	2	2	2	2	2	3	2	2	2	2	4	4
Distance to CBDS	1/3	1/2	1/2	1/2	1	3	3	3	3	3	3	3	2	4	2	2	2	3	3
Water Body	1/3	1/2	1/2	1/2	1/3	1	2	2	2	2	2	2	2	3	5	5	5	2	2
Slope	1/2	1/2	1/2	1/2	1/3	1/2	1	2	2	2	2	2	3	4	4	4	4	2	2
DEM	1/2	1/3	1/2	1/2	1/3	1/2	1/2	1	3	3	3	3	2	3	3	3	3	5	5
LULC	1/3	1/2	1/2	1/2	1/3	1/2	1/2	1/3	1	2	2	2	2	2	2	2	2	4	4
Major Road	1/3	1/2	1/2	1/2	1/3	1/2	1/2	1/3	1/2	1	2	2	3	2	2	2	2	3	3
Highway	1/3	1/2	1/2	1/2	1/3	1/2	1/2	1/3	1/2	1/2	1	3	2	4	5	5	5	2	2
Rail-Way	1/3	1/2	1/2	1/2	1/3	1/2	1/2	1/3	1/2	1/2	1/3	1	2	3	4	4	4	2	2
Health and Social facilities	1/3	1/2	1/2	1/3	1/2	1/2	1/3	1/2	1/2	1/3	1/2	1/2	1	2	3	3	3	2	3
Soil	1/4	1/3	1/2	1/2	1/4	1/3	1/4	1/3	1/2	1/2	1/4	1/3	1/2	1	2	2	2	2	3
Geological- Fault lines	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1	2	2	3	3
Heavy power Line	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1	2	2	3
Ground Water Potential	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1/2	1	2	2
Sewerage System	1/7	1/6	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1/2	1/2	1/3	1/2	1/2	1	2
Landfill	1/7	1/6	1/5	1/4	1/3	1/2	1/2	1/5	1/4	1/3	1/2	1/2	1/3	1/3	1/3	1/3	1/2	1/2	1
Total Column	6.8	9.75	11.9	15	15.3	18.4	19	20.6	24.5	26	26.7	30	31.3	41	48.7	50	52	58	62

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

This third, computation estimate from 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. The value obtained here were an estimate of the relative weights of the criteria being compared. As shown in table 28 above the last column indicates the weight of each parameter.

Table 26: Normalized Pair-Wise Comparison Matrix

	Availability of developable land	Existing industrial Area	Raw Material source	population	Distance to CBDS	Water Body	Slope	DEM	LULC	Major Road	Highway	Rail-Way	Health and Social facilities	Soil	Geological- Fault lines	Heavy power Line	Ground Water Potential	Sewerage System	Landfill
Availability of developable land	0.15	0.21	0.17	0.20	0.20	0.16	0.11	0.10	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.12	0.11
Existing industrial Area	0.07	0.10	0.17	0.13	0.13	0.11	0.11	0.15	0.08	0.08	0.07	0.07	0.06	0.07	0.08	0.08	0.08	0.10	0.10
Raw Material source	0.07	0.05	0.08	0.13	0.13	0.11	0.11	0.10	0.08	0.08	0.07	0.07	0.06	0.05	0.06	0.06	0.06	0.09	0.08
population	0.05	0.05	0.04	0.07	0.13	0.11	0.11	0.10	0.08	0.08	0.07	0.07	0.10	0.05	0.04	0.04	0.04	0.07	0.06
Distance to CBDS	0.05	0.05	0.04	0.03	0.07	0.16	0.16	0.15	0.12	0.12	0.11	0.10	0.06	0.10	0.04	0.04	0.04	0.05	0.05
Water Body	0.05	0.05	0.04	0.03	0.02	0.05	0.11	0.10	0.08	0.08	0.07	0.07	0.06	0.07	0.10	0.10	0.10	0.03	0.03
Slope	0.07	0.05	0.04	0.03	0.02	0.03	0.05	0.10	0.08	0.08	0.07	0.07	0.10	0.10	0.08	0.08	0.08	0.03	0.03
DEM	0.07	0.03	0.04	0.03	0.02	0.03	0.03	0.05	0.12	0.12	0.11	0.10	0.06	0.07	0.06	0.06	0.06	0.09	0.08
LULC	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.04	0.08	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.07	0.06
Major Road	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.04	0.07	0.07	0.10	0.05	0.04	0.04	0.04	0.05	0.05
Highway	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.04	0.10	0.06	0.10	0.10	0.10	0.10	0.03	0.03
Rail-Way	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.03	0.06	0.07	0.08	0.08	0.08	0.03	0.03
Health and Social facilities	0.05	0.05	0.04	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.05	0.06	0.06	0.06	0.03	0.05
Soil	0.04	0.03	0.04	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.04	0.04	0.04	0.03	0.05
Geological- Fault lines	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04	0.04	0.05	0.05
Heavy power Line	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.05
Ground Water Potential	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03
Sewerage System	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03
Landfill	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02

Table 27: Eigen vector weight

	Availability of developable land	Existing industrial Area	Raw Material source	population	Distance to CBDS	Water Body	Slope	DEM	LULC	Major Road	Highway	Rail-Way	Health and Social facilities	Soil	Geological- Fault lines	Heavy power Line	Ground Water Potential	Sewerage System	Landfill	Weight(%)
Availability of developable land	0.15	0.21	0.17	0.20	0.20	0.16	0.11	0.10	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.12	0.11	12.96
Existing industrial Area	0.07	0.10	0.17	0.13	0.13	0.11	0.11	0.15	0.08	0.08	0.07	0.07	0.06	0.07	0.08	0.08	0.08	0.10	0.10	9.73
Raw Material source	0.07	0.05	0.08	0.13	0.13	0.11	0.11	0.10	0.08	0.08	0.07	0.07	0.06	0.05	0.06	0.06	0.06	0.09	0.08	8.14
population	0.05	0.05	0.04	0.07	0.13	0.11	0.11	0.10	0.08	0.08	0.07	0.07	0.10	0.05	0.04	0.04	0.04	0.07	0.06	7.11
Distance to CBDS	0.05	0.05	0.04	0.03	0.07	0.16	0.16	0.15	0.12	0.12	0.11	0.10	0.06	0.10	0.04	0.04	0.04	0.05	0.05	8.11
Water Body	0.05	0.05	0.04	0.03	0.02	0.05	0.11	0.10	0.08	0.08	0.07	0.07	0.06	0.07	0.10	0.10	0.10	0.03	0.03	6.62
Slope	0.07	0.05	0.04	0.03	0.02	0.03	0.05	0.10	0.08	0.08	0.07	0.07	0.10	0.10	0.08	0.08	0.08	0.03	0.03	6.31
DEM	0.07	0.03	0.04	0.03	0.02	0.03	0.03	0.05	0.12	0.12	0.11	0.10	0.06	0.07	0.06	0.06	0.06	0.09	0.08	6.54
LULC	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.04	0.08	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.07	0.06	4.7
Major Road	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.04	0.07	0.07	0.10	0.05	0.04	0.04	0.04	0.05	0.05	4.39
Highway	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.04	0.10	0.06	0.10	0.10	0.10	0.10	0.03	0.03	5.12
Rail-Way	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.03	0.06	0.07	0.08	0.08	0.08	0.03	0.03	4.19
Health and Social facilities	0.05	0.05	0.04	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.05	0.06	0.06	0.06	0.03	0.05	3.57
Soil	0.04	0.03	0.04	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.04	0.04	0.04	0.03	0.05	2.7
Geological- Fault lines	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04	0.04	0.05	0.05	2.46
Heavy power Line	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.05	2.21
Ground Water Potential	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	1.97
Sewerage System	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03	1.68
Landfill	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	1.49
Total																				100%

4.3.2 Estimation of the consistency ratio

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

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

Table 28: weighted sum vector

	Availability of developable land	Existing industrial Area	Raw Material source	population	Distance to CBDS	Water Body	Slope	DEM	LULC	Major Road	Highway	Rail-Way	Health and Social facilities	Soil	Geological- Fault lines	Heavy power Line	Ground Water Potential	Sewerage System	Landfill	Weight Sum
Availability of developable land	0.13	0.19	0.16	0.21	0.24	0.20	0.13	0.13	0.14	0.13	0.15	0.13	0.11	0.11	0.12	0.11	0.10	0.12	0.10	2.72
Existing industrial Area	0.06	0.10	0.16	0.14	0.16	0.13	0.13	0.20	0.09	0.09	0.10	0.08	0.07	0.08	0.10	0.09	0.08	0.10	0.09	2.06
Raw Material source	0.06	0.05	0.08	0.14	0.16	0.13	0.13	0.13	0.09	0.09	0.10	0.08	0.07	0.05	0.07	0.07	0.06	0.08	0.07	1.74
population	0.04	0.05	0.04	0.07	0.16	0.13	0.13	0.13	0.09	0.09	0.10	0.08	0.11	0.05	0.05	0.04	0.04	0.07	0.06	1.54
Distance to CBDS	0.04	0.05	0.04	0.04	0.08	0.20	0.19	0.20	0.14	0.13	0.15	0.13	0.07	0.11	0.05	0.04	0.04	0.05	0.04	1.79
Water Body	0.04	0.05	0.04	0.04	0.03	0.07	0.13	0.13	0.09	0.09	0.10	0.08	0.07	0.08	0.12	0.11	0.10	0.03	0.03	1.43
Slope	0.06	0.05	0.04	0.04	0.03	0.03	0.06	0.13	0.09	0.09	0.10	0.08	0.11	0.11	0.10	0.09	0.08	0.03	0.03	1.36
DEM	0.06	0.03	0.04	0.04	0.03	0.03	0.03	0.07	0.14	0.13	0.15	0.13	0.07	0.08	0.07	0.07	0.06	0.08	0.07	1.39
LULC	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.05	0.09	0.10	0.08	0.07	0.05	0.05	0.04	0.04	0.07	0.06	0.99
Major Road	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.04	0.10	0.08	0.11	0.05	0.05	0.04	0.04	0.05	0.04	0.92
Highway	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.05	0.13	0.07	0.11	0.12	0.11	0.10	0.03	0.03	1.08
Rail-Way	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.04	0.07	0.08	0.10	0.09	0.08	0.03	0.03	0.87
Health and Social facilities	0.04	0.05	0.04	0.02	0.04	0.03	0.02	0.03	0.02	0.01	0.03	0.02	0.04	0.05	0.07	0.07	0.06	0.03	0.04	0.74
Soil	0.03	0.03	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.03	0.05	0.04	0.04	0.03	0.04	0.55
Geological- Fault lines	0.03	0.02	0.03	0.04	0.04	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04	0.04	0.05	0.04	0.50
Heavy power Line	0.03	0.02	0.03	0.04	0.04	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.04	0.45
Ground Water Potential	0.03	0.02	0.03	0.04	0.04	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.40
Sewerage System	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.01	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.35
Landfill	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.32

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

Table 29: Consistency vector

weight sum	Criteria weight	Consistency Vector (WS/CW)
2.72	0.13	21.69
2.06	0.10	22.20
1.74	0.08	23.75
1.54	0.07	21.63
1.79	0.08	24.25
1.43	0.07	24.17
1.36	0.06	22.50
1.39	0.07	22.33
0.99	0.05	19.60
0.92	0.04	21.00
1.08	0.05	21.80
0.87	0.04	22.25
0.74	0.04	22.33
0.55	0.03	22.00
0.50	0.02	26.50
0.45	0.02	22.00
0.40	0.02	31.00
0.35	0.02	26.00
0.32	0.01	22.33

2. Compute lambda max (λmax) which is the average value of the consistency vector and compute Consistency Index (CI), which provides a measure of departure from consistency by using 2 formula:

$$CI = \frac{\lambda max - n}{n - 1} \text{ --2}$$

***λ*max=**(20.99+21.18+21.38+21.65+22.06+21.59+21.55+21.26+21.05+20.98 +21.11+20.77+ 20.74+20.35+20.32+20.36+20.28+20.80+21.54)19= **21.05**

$$CI = \frac{21.05 - 19}{19 - 1}$$

$$\mathrm{CI} = \frac{2.05}{18}$$

$$\underline{\mathrm{CI} = \mathbf{0.11}}$$

4. Calculation of the Consistency Ratio (CR) by using 3 formula:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \text{ --3}$$

Where RI is the random index and depends on the number of parameters being compared and detailed in table 31 below:

Table 30: Random Index

Order n	10	11	12	13	14	15	16	17	18	19	20
RI	1.49	1.52	1.54	1.56	1.58	1.59	1.5943	1.6064	1.6133	1.6207	1.6292

The number of parameters used in this study were nine (19). RI value for nine parameters is 1.6207 using this value consistency ratio was calculated as shown below

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

$$CR = \frac{0.11}{1.6207}$$

$$CR = \underline{\mathbf{0.068}}$$

The consistency ratio of this study indicated that 0.068 which is less than 0.1. Thus, consistent matrix was formed which was acceptable in order to combine all the layers to process overlay analysis. Accordingly, the determined factor weights were accepted to use in the fourth step, which is synthesis using weighted linear combination.

Table 31: Summarization of the overall normalized weights of criteria used and ranking

General factor	Local weight	Sub factor	weight Local	Global weight	importance Ranking by
Physical Factors	0.26	Slope	0.06	0.02	7
		Elevation	0.07	0.02	6
		Soil	0.03	0.01	9
		Proximity to geo. Fault lines	0.02	0.01	10
Economic factors	0.50	A/ of developable land	0.13	0.07	1
		Distance to CBDS	0.08	0.04	3
		A/P to raw materials source	0.08	0.04	4
		Existing Industrial area	0.10	0.05	2
		P/ to health and Social facilities	0.04	0.02	5
Social factors	0.03	LULC	0.05	0.0015	15
Environmental infrastructures factors	0.07	Sewerage system	0.02	0.0014	18
		Proximity to Rivers (streams)	0.07	0.0049	11
		Proximity to major Road	0.04	0.0028	13
		Proximity to Rail Way Road	0.04	0.0028	14
		Proximity to Highway Road	0.05	0.0035	12
		Proximity to Landfill Site	0.01	0.0007	19
		Availability of power supply	0.02	0.0014	16
		Av. of Ground Water Potential.	0.02	0.0014	17
Demography Factors	0.13	Population	0.07	0.0091	8

4.4 Weighted linear combination (WLC)

WLC is the most prevalently used multi-criteria evaluation analysis method in GIS (Siefi et al., 2017; Malczewski, 2000). Land-use suitability analysis using weighted overlay method leads to more rational urban planning decision-making. In this method, manipulation of the overlay process allowed by assigning different weights for each input layers, so the factors that play a more critical role will have a more significant impact on shaping the outcome of the overlay analysis. This is the advantage of weighted overlay over other methods such as fuzzy overlay, binary overlay, or ranking overlay (Malczewski, 2006). However, this method is highly dependent on determination of factor weights, where highly favored factors will result in higher values in the final output raster. This issue is critical, so experts' opinion is crucial in the defining scales applied to input layers and weights given to factors in the AHP process. To be able to combine the attribute of layers and perform calculations on them, before executing the weighted overlay, all vector criteria layers was converted to raster format. Since the WLC method requires all values that included in different attribute layers to be transformed to a comparable unit, all the criteria layers had already been normalized in the scale of 1 to 5 (see Figure 6 - 24 and table 4 - 24). Table 28 shows the influence weight of factors, which were determined based on the literature review, experts' opinion, and AHP method. In this study the new Industrial area should connected to the Availability of developable land, proximity to existing Industrial Area, proximity to Raw materials source is extremely important in industrial planning; thus, Availability of developable land, proximity to existing industrial area factor was given primary weight (13.72%) in the analysis. Secondary weighting (9.81%) was, given to the existing Industrial Area factor due to the significance of pollution in scattering industrial area planning adjacent to residential area. The remaining weights was, listed in the above Table 28: Eigen vector weight and the sum of the criteria weights must be equal to 1 (see Table 29). Finally, the overall weighted linear combination was, performed using equation 4.

$$\boldsymbol{S = \sum w_j \, x_i} \text{ ....} 4$$

Where S is suitability, w is weight of factor j and x is the criterion score of factor i. The resulting map obtained in the above Equation (4) was summarized in (Table 33) in terms of area and percentage share of each land suitability class. The results revealed four suitability index classes were, observed in the study area: restricted, less suitable, moderately suitable and suitable, with percentage coverage of 56.22 percent, 0.58 percent, 23.04 percent and 20.16 percent, respectively.

Table 32: Statistical analysis of industrial site suitability map

Suitability classes	Area in km^2	percentage
Restricted	176.01	56.22%
Less suitable	1.82	0.58%
Moderately suitable	72.12	23.04%
Suitable	63.10	20.16%

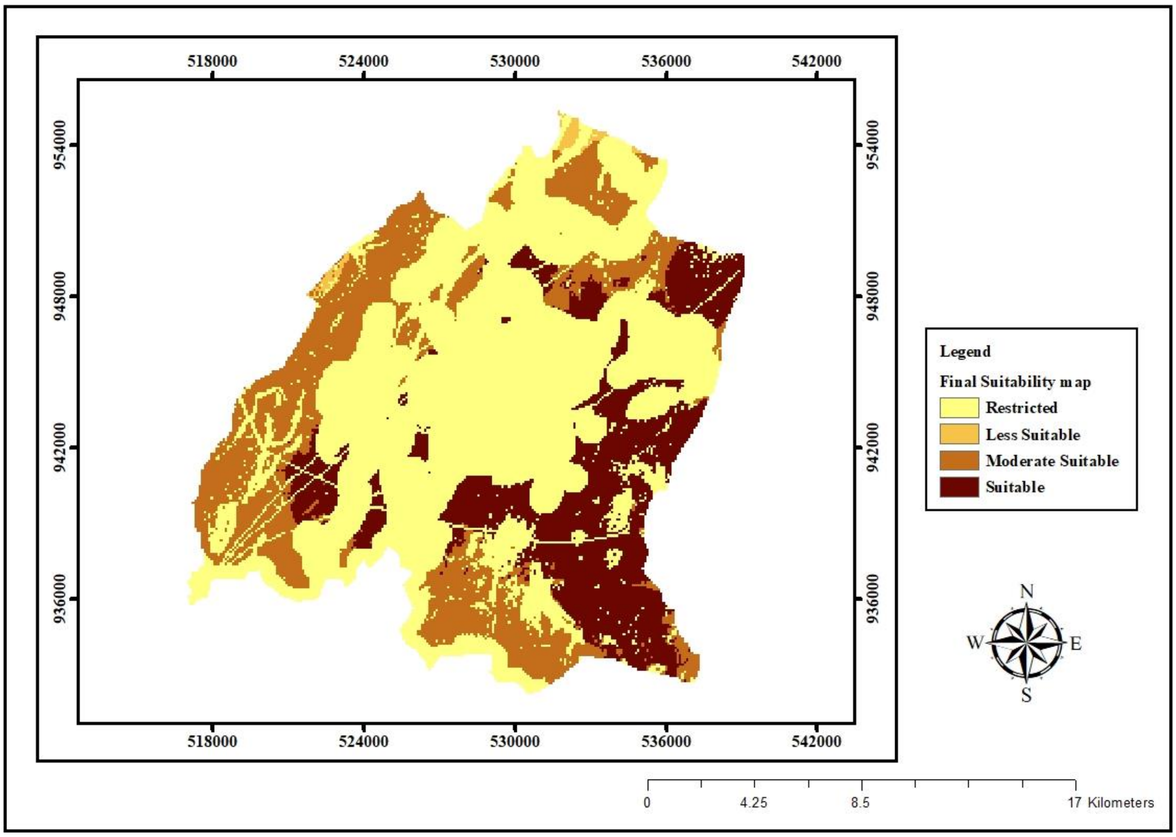

Figure 25: Final suitability map for industrial sites selection

The finding obtained by integrating different spatial and non-spatial factor maps reveals that the study area fell under restricted, less suitable, moderately suitable, and suitable classes only out of the expected result from restricted to highly suitable. According to this study's findings, the majority of the study areas were constrained, while the smallest number of areas were less suitable for industrial utilization. The area coverage of the suitability indexes from the result map was 176.01 km^2, 1.82 km^2, 72.12 km^2, 63.10 km^2

and its suitability classes were restrictive, less suitable, moderately suitable, and suitable respectively. According to this study result, the highly suitable class not found in the study area based on the aggregation of nineteen factors map. The second most suitable land class graded as suitable had a directional distribution in the Eastern, Southeastern, and southwestern parts of the city, whereas the other suitability classes spread out in all directions.

4.5 Assessment of Existing Industrial Area and Proposed Industrial Area.

As a result of the field survey and observation done in Adama City, the area of the city is expanding from time to time, illegal construction is occurring rapidly, fertile agricultural land is being occupied for building purposes, scattered settlements are ongoing at the edge of the area, and industrial activities have increased. Around 934 industrial establishments are found in the city. According to data from the bureau of industries and development of Adama city municipality, of the total number of industries, 90 large-scale, 168 medium-scale, and 178 light-scale manufacturing industries are currently operating in the city municipality, with numerous undocumented multi-purpose, small-scale, and micro-scale manufacturing activities taking place in the city. Around 2829.70 ha of land, or 9.04% of the approved structural plan, have been reserved for industries. Existing industrial development was located in unsuitable areas based on certain parameters.

For the current study, twenty factors utilized to assess site suitability for the best industrial site, including existing industrial areas. However, only nineteen criteria were superimposed to produce an assessment suitability model map. and to evaluate the overall compatibility of the current industrial areas. The independent input variable, which is the Existing and proposed industrial areas and Existing and proposed Residential Area, was used as a controlled variable. In order to determine the degree of influence for the others nineteen criteria, Existing and proposed Residential Area, factor was removed from the pairwise comparison matrix. Thus, the weight allotted for this factor map was distributed to others factors. After that, Existing industrial type areas polygons were overlapped to the generated evaluation suitability map then their suitability was analyzed using zonal statistics tool extension of ArcGIS toolbox. Then the majority of suitability pixel value fallen under polygons was counted and the agreement between the Existing industrial type areas suitability model was analyzed in area coverage as presented in (Table 34)

The result of this comparison map revealed that the existing industrial areas fell under only two suitability classes such as restricted and suitable under all scale industry. Most of the areas dominantly aggregated in restricted areas, whereas there are, no areas observed in unsuitable, less suitable, and moderate suitable classes. According to the portrayed (Figure 26), the areas and percentage coverage of the Existing industrial type areas on the evaluation map were 475.9473 ha (85.70 %) and 79.3825 ha (14.30%) located in restricted and suitable classes for all scale industry respectively.

Table 33: Comparison of suitability model map and Existing Industrial type Area

Existing Industrial type	Suitability class	Area in (ha)	Percentage (%)
Light	Restricted	57.20	10.30%
	suitable	0.0174	0.00%
Medium	Restricted	31.1073	5.60%
	suitable	0.15	0.03%
Heavy	Restricted	387.64	69.80%
	Suitable	79.2151	14.26%
Total		5550	100

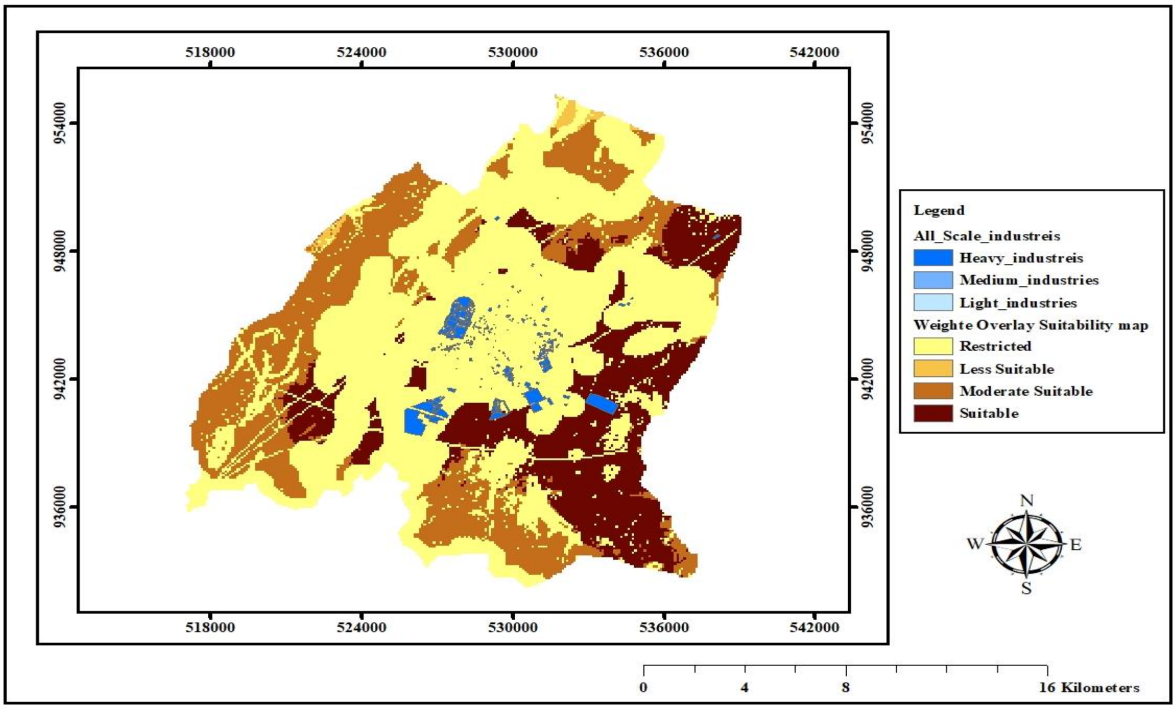

Figure 26: Existing industrial type areas and suitability comparison map

The result of this comparison map revealed that the proposed industrial areas fell under only three suitability classes such as restricted, moderately suitable, and suitable. Most of the areas dominantly aggregated in Suitable areas, whereas there are, no areas observed in unsuitable, less suitable, and highly suitable suitability classes. According to the portrayed (Figure 28), the areas and percentage coverage of the proposed Industrial Land on the evaluation map were 9.04 km^2 (39.29%), 0.14 km^2 (0.61%) and 13.83 km^2 (60.10%) located in restricted, moderately suitable, and suitable classes respectively. According to this study result, the highly suitable class was not found in the study area based on the aggregation of nineteen factors map. The second most suitable land class graded as suitable had a directional distribution in the Eastern, northeastern, Southeastern, and southwestern parts of the city.

Table 34: Comparison of suitability model map and Developable industrial land

Suitability class	Proposed industrial areas	Area in (km^2) Perc (%)
Restricted	9.04	39.29
Unsuitable	Not observed	0.00
Less suitable	Not observed	0.00
Moderately suitable	0.14	0.61
Suitable	13.83	60.10
Total	23.01	100

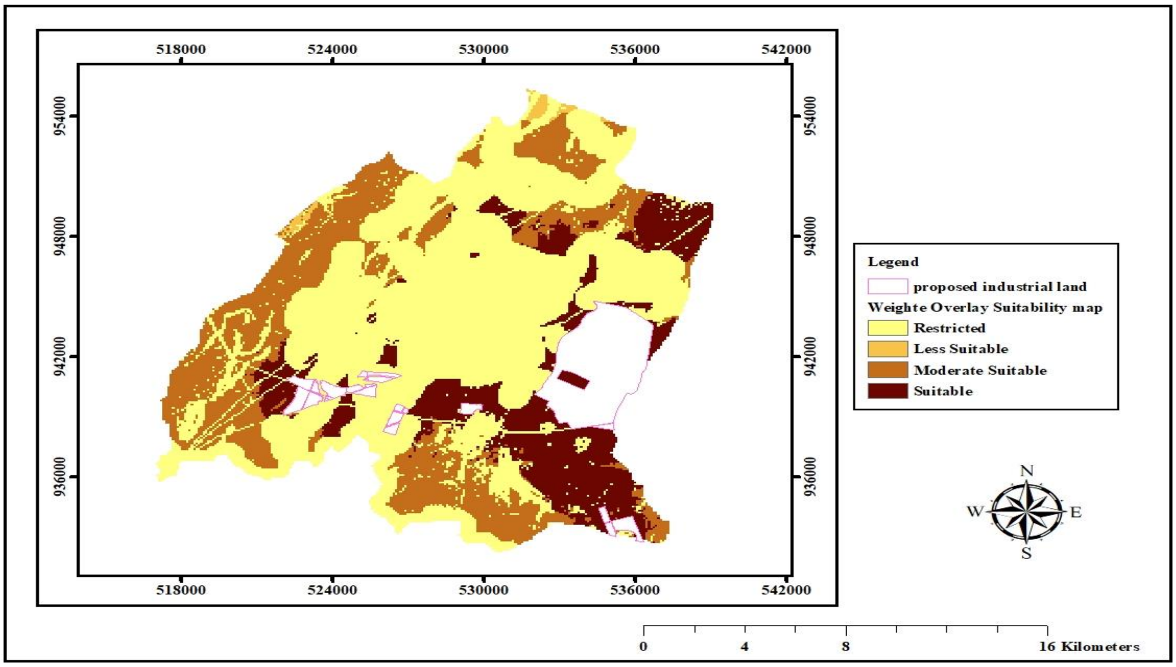

Figure 27: Proposed industrial areas and suitability comparison map

4.6 Comparison of suitability model and Residential Area to check Compatibility

According to (Taleai et al., 2007), As indicated in the urban planning and implementation manual of Ethiopia (MUDC, 2012) the location of the residential area should be in terms of certain predetermined factors such as physical, economic, Social and environmental conditions, which influence the suitability of the site. A residential area is a place classified under land use categories in which housing predominates as opposed to industrial and commercial areas.

For the current study, to check compatibility of land use. As (Malczewski2004:28) points out "Once the GIS raster or vector database has been organized into a number of map layers of the same geometric framework, the land-use suitability procedure can be represented as a flowchart and executed using GIS operations". In this model, each cell of the city (case study area) will gain a value which shows the extent of its compatibility or incompatibility by using raster analysis and intermediate functions based on focal neighborhood analysis (focal statistics) and finally applying and running the model in GIS. Existing and proposed Residential area polygons were overlapped to the generated evaluation compatibility map then their compatibility was analyzed using focal neighborhood analysis (focal statistics).

Table 35: Comparison of suitability model within both Existing and proposed Residential

Suitability class	both Existing and proposed Residential area in (km2)	Influential Percentage (%)
Restricted	16.30	47.78
Unsuitable	Not observed	0.00
Less suitable	4.498	13.19
Moderately suitable	4.00	11.73
Suitable	9.314	27.30
Total	34.112	100%

The result of this comparison map revealed that the Existing and proposed Residential fell under only four suitability classes such as restricted, less suitable, moderately suitable, and suitable. Most of the areas dominantly aggregated in restricted areas, whereas there are, no areas observed in unsuitable and highly suitable suitability classes. According to the portrayed (Figure 31), the areas and percentage coverage of the Existing and proposed Residential area on the evaluation map were 16.30 km2 (47.78%), 4.498 km2 (13.19%), 4.00 km2 (11.73%) and 9.314 km^2 (27.30%) located in restricted, less suitable, moderately suitable and suitable classes respectively.

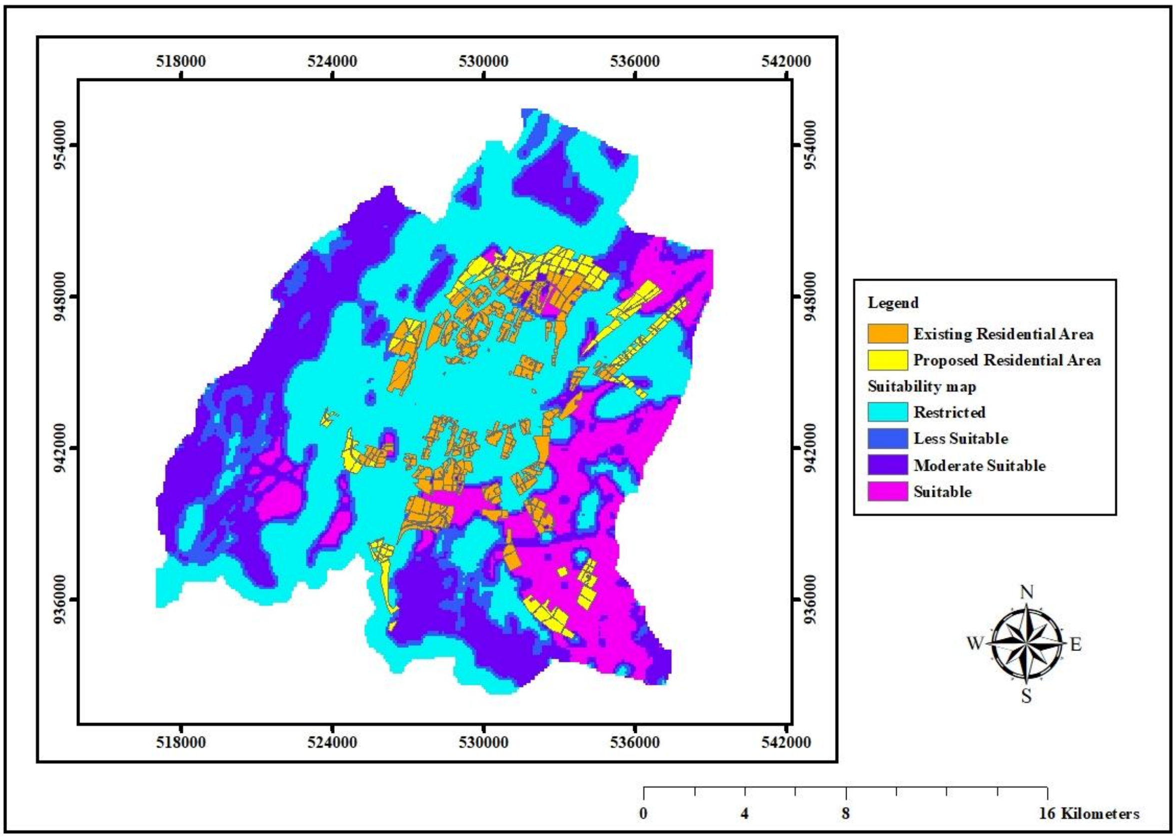

Figure 28: Existing and proposed Residential and suitability comparison map.

Then these cells, which produced from the weight, overlay layers turned into focal statistics then, compatibility degrees are normalized from 0 to 1 and are used to produce a land use compatibility map for industrial area, reclassify this raster in reversed matrix structure process. The compatibility extent of each land use (in comparison to its neighbors, in different effect distances and by applying a reversed proportion for the standard of distance) by allocating the average cellular values of each category of index in each extent. . In order to quantify LU matrix, Analytic Hierarchy Process (AHP) were used this operation conceived by (Thomas Lorie Saaty) and used by several scholars such as (Forman & Peniwati, 1998; Thomas L. Saaty, 1990; Thomas L Saaty, 2008; Vargas, 1990; Zahedi, 1986). This method helps decision makers to define priorities and option for the best decision (Masoomi, 2014; Vaezi et al., 2015). The development of a matrix showing the degree of compatibility was done by relying on the theoretical background and the consultancy of some local well-known experts; Land use compatibility matrix values are usually determined by experts and are representation of different levels of consistency among different land uses (bakhtiarifar et al., 2011). The steps required for measuring land-use compatibility are classifying land use types according to their activity. This operation is based on constituting GIS database of every value of our case of study. Building Land-use Compatibility Matrix. Developing that matrix depends highly on type and characteristics of each activity and its compatibility with surrounding activities (Taleai et al., 2007). Land use compatibility matrix depends on all scales industry of each activity. Assumed Residential Area are compatible in existing residential area, but incompatible in Heavy industry. The Classification of the degrees of land-use compatibility per order was done based on got cell value of the following five levels (0: Compatible, 1: Medium Compatible, 2: Neutral, 3: Medium Incompatible, 4: Incompatible and High Incompatible) are restructured cellular values basis on residential land use compatibility. After that, the Existing and proposed Residential area polygons were overlapped to the generated evaluation compatibility map then their compatibility was analyzed using focal neighborhood analysis (focal statistics) and finally applying and running the model in extension of ArcGIS toolbox. The majority of compatibility pixel value fallen under polygons were counted and the agreement between the Existing and proposed Residential area and Compatibility model was analyzed in area coverage as presented in (Table 37).

Table 36: Compatibility matrix for residential land use type

Industrial suitability model	For Residential compatibility	Area(Km^2)	Percentage (%)
Restricted	Compatible	14.16	41.53%
Light	Neutral compatible	6.66	19.53%
Medium	Medium Incompatible	3.68	10.78%
Heavy	Incompatible	9.61	28.17%
Total		34.11	100

Therefore, the degrees used in this Study opposed of industrial suitability model for Assessment of Land Use compatibility within residential land use type are. However, no areas observed Medium compatible. Table 37 shows the compatibility matrix of residential land use type with industrial land use types, by using clipped feature within value degree of Evaluated industrial suitability analysis.

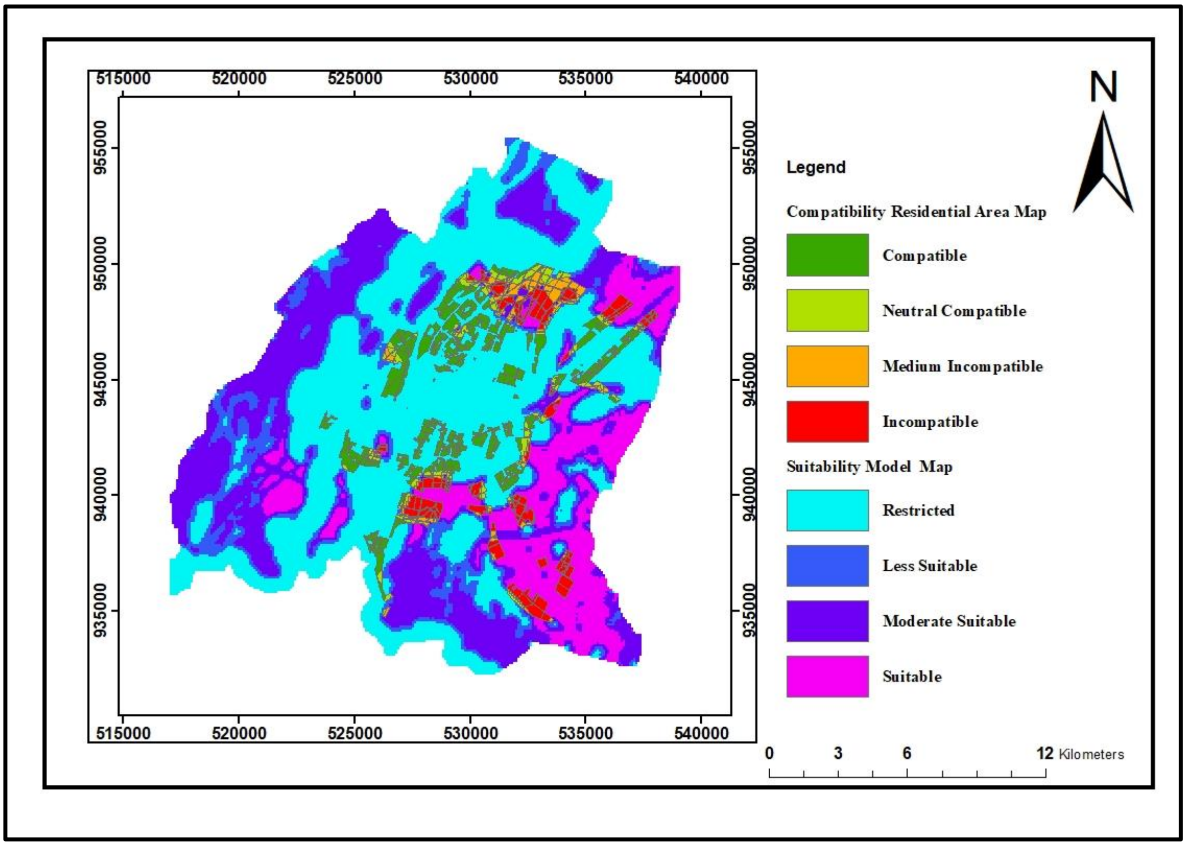

Figure 29: Compatibility of Industrial Area within Residential area.

The result of this comparison map revealed that the Residential area in Heavy industry is incompatible 9.61Km^2 (28.17%), in medium industry is medium incompatible 3.68 Km^2 (10.78%) and light industry is neutral compatible 6.66 Km^2 (19.53%) and residential area in restricted area for industry were compatible 14.16 Km^2 (41.53%) were compatibility assessment Compatibility of Industrial Area within Residential area. However, no areas observed medium compatible and fully incompatible.

4.7 Discussion

The main objective of the study was to examine the overall land suitability analysis for industrial area Using integration geospatial tools within multi-criteria evaluation and analytical hierarchy process nowadays have been put forward with a series of functional capabilities and applications to solve conflicts and complexities in any geospatial decision making.

Spatial parameters upon which suitability decisions would made were determined based on the expert's opinion, relevant literature, and availability of data. Therefore, the result of this research confirms two facts. First; the optimal site selection for the development of industry influenced by several factors (Source. MUDC, 2012). These include Physical Factors (Slope, DEM, Soil, Proximity to geological Fault lines), Economic factors (Availability of developable land, Distance to CBDS, Availability /Proximity to raw materials source, Existing Industrial area, Proximity to Residential Area, Proximity to health and Social facilities). Social factors (Land Use Land Cover (LULC)). Environmental infrastructures factors (Sewerage system, Proximity to Rivers (streams) ,Proximity to major Road, Proximity to Rail Way Road, Proximity to Highway Road ,Proximity to Landfill Site, Availability of power supply, Availability of Ground Water Potential.). Demography Factors (Population density) factors are criteria which have principal effects on suitability analysis for industrial areas in Adama city.

Second, to achieve the aim of this study, selected parameters were analyzed Using AHP with WLC in a GIS and spatial tools have been extensively use in developing industrial lands suitability maps in a number of diverse situations, there is no commonly accepted method for assigning the relative weights to the criterion maps (Malczewski, 2004). As a result, different weighting schemes can produce different outcomes (Chen Y. et al., 2010; Vander Merwe, 1997). For instance, Heywood et al. (1995), reveals different multi-criteria evaluation rules result in different suitability pattern.

The study found that among the identified major criteria, approximately economic has the most weighing influence (43%), followed by Physical Factors (18%), Environmental infrastructures factors (27%), population factors (7%) and Social factors (5%) and the results of the final weighted suitability model is here by presented in figure 26. As demonstrated, the Availability of proposed developable land had a significant influence 60.10% on the pattern of suitable industrial locations in the municipality. This means that more of areas that fell within the developable land area assessed for suitability.

According to the industrial site suitability map, result of the current study in Adama city only restricted, less suitable, moderately suitable and suitable zone for industrial site development. In addition to this, the result demonstrates that an unexpectedly unsuitable and highly suitable class not observed in the final suitability model map. This occurs more frequently than expected because of the fact that the number of criteria used for suitability analysis increases the suitability index will decrease. This is consistent with the findings of (Sarath et al., 2018) which suggest that there was no excellent (highly) suitable site found for the industry zone. However, the study area was different from the current one. The result revealed that the majority of the study area found in restricted or constrained for the establishment of industry that covers 176.01 km^2, which takes the maximum piece of the total area. In the second place, moderately suitable classes occupied 72.12 km^2 of the area while less suitable, suitable cover 1.82, and 63.10 square kilometers of the study area respectively. This result shows two things; first, the number of constraint factor used for the study increase the area coverage of restricted land suitability index in the final-result also increased. Second, the result was-extremely affected by the Residential Area and built-up area constraint factor because the used buffer distance significantly affected the result by aggregating the overall suitability area in one land suitability index. Based on the available literature, Residential areas are barriers for industries development.

Compatibility matrix, the degrees used in Study where opposed of industrial suitability model for Assessment of Land Use compatibility within residential land use type are 0: Compatible, 1: Medium Compatible, 2: Neutral, 3: Medium Incompatible, and 4: Incompatible. Make this statement inevitable because the subsequent largest areas of Residential detected in restricted suitability classes for industry (compatible classes for Residential area) whereas very little coverage of areas observed in moderate suitable index for industry (Medium incompatible classes for Residential area) .

The result of this comparison map revealed that the Residential area in Heavy industry is incompatible 9.61Km^2 (28.17%), in medium industry is medium incompatible 3.66 Km^2 (10.78%) and light industry is neutral compatible 6.66 Km^2 (19.53%) and residential area in restricted area for industry were compatible 14.16 Km^2 (41.53%) were compatibility assessment Compatibility of Industrial Area within Residential area. However, no areas observed medium compatible and fully incompatible.

According to (DoE, 2004) Implementation of the buffer zone is one-step that can used to reduce noise pollution. To minimize the adverse impact of heavy industries due to their noise disturbance and environmental contamination and create safer and attractive health conditions, the location of residential areas separated from the existing heavy industrial areas by creating buffer zones of restriction. (Rahim et al., 2014) suggested that residential area should be at least 500 meters far away from heavy industry. However, the analyzed result of this study showed that, Buffer zone recommended based on types of industries. For restricted area Buffer distance <50m,for Light industries Buffer distance 50-250m,for Medium industries Buffer distance 250-500 and for Heavy industries Buffer distance >500m from residential area are appropriate for industrial development location of Adama City was generated with considering physical, environmental, economic and socially acceptable. Therefore, this study presented advantages of integrated geospatial within AHP and WLC for land suitability analysis and simplifies such complicated decisions.

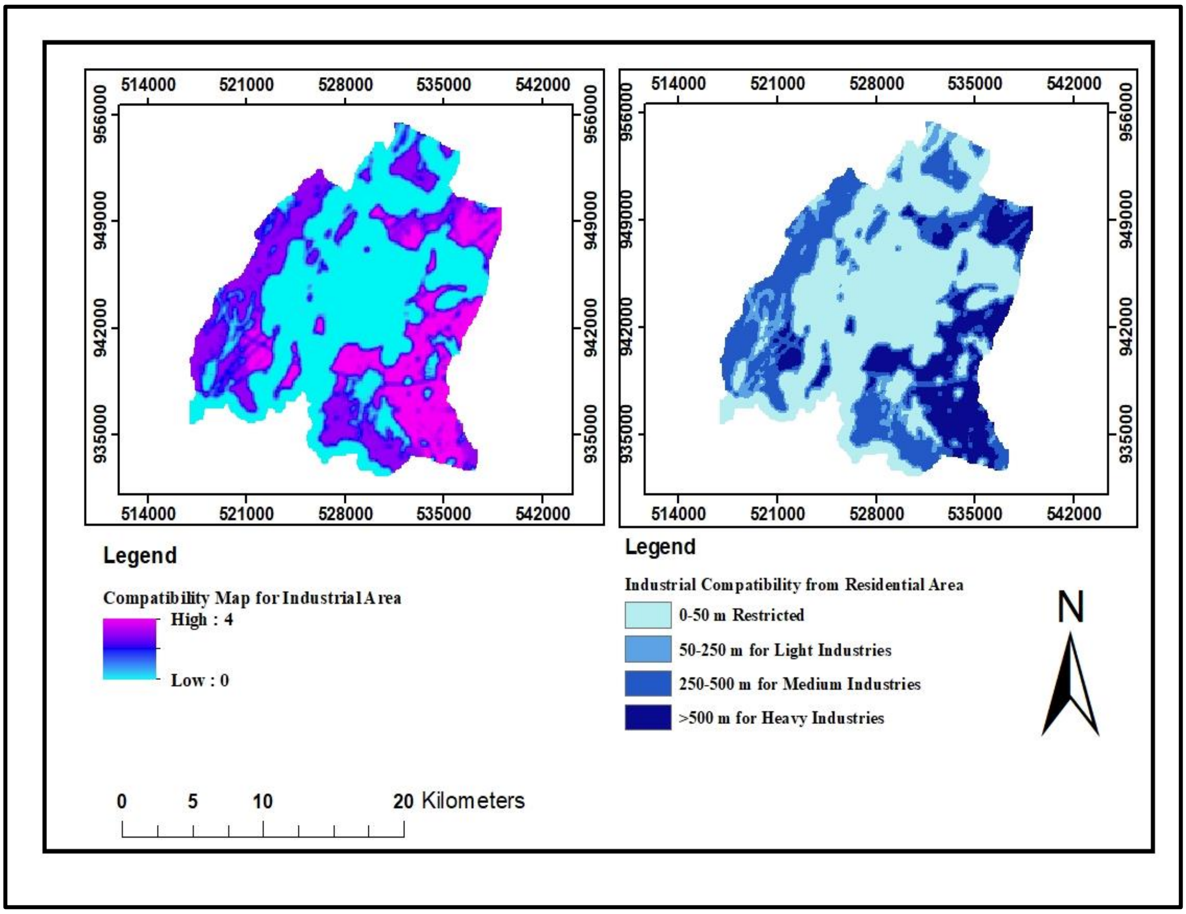

Figure 30: final zoning for compatibility of Industrial Area within Residential area.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The development of industrial areas has a substantial good and negative impact on the national economy and environment. As a result, select appropriate sites in order to minimize the negative effects on people and the environment. Therefore, this study, examine land suitability for industrial area in Adama City based on twenty criteria that are coined under five pillars physical, economic, social, environmental, and population major factors.

In this study, twenty criteria were considered (slope, DEM, soil, proximity to geological fault lines, availability of developable land, distance to CBDs, proximity to raw materials sources, existing industrial areas, proximity to residential areas, proximity to health and social facilities, LULC, and sewerage systems, proximity to rivers and proximity to major roads, proximity to railways, proximity to highways, proximity to landfill sites, availability of power supply, availability of groundwater potential, and population density) for proper industrial development site selection in Adama City and prepared as input map layers for input.

The result of this comparison map revealed that the existing industrial areas fell under only two suitability classes such as restricted and suitable under all scale industry. Most of the areas dominantly aggregated in restricted areas, whereas there are, no areas observed in unsuitable, less suitable, and moderate suitable classes. According to the portrayed (Figure 26), the areas and percentage coverage of the Existing industrial type areas on the evaluation map were 475.9473 ha (85.70 %) and 79.3825 ha (14.30%) located in restricted and suitable classes for all scale industry respectively.

The result of this comparison map revealed that the Residential area in Heavy industry is incompatible 9.61Km^2 (28.17%), in medium industry is medium incompatible 3.68 Km^2 (10.78%) and light industry is neutral compatible 6.66 Km^2 (19.53%) and residential area in restricted area for industry were compatible 14.16 Km^2 (41.53%) were compatibility assessment within residential land use type. However, no areas observed medium compatible and fully incompatible. The second most of the existing industrial areas are clustered in the neighbor of (residential, social service and other purposes) of the city. As a result, could have to release high noise disturbance and environmental contamination or Incompatibility problems.

Scientific-based industrial site selection is critical in maintaining a clean environment and sustainable economic growth. Consequently, this study provides further insight to the decision-makers to consider the negative impact of industrial sites on the environment and residence based on multiple criteria before decisions, therefore, this study presented advantages of integrated AHP with WLC in Geospatial tools for industrial land suitability analysis and simplifies such complicated decisions.

Finally weighted suitability model of this analysis revealed that for the selected parameters out of the total area of 313.05 Km^2 found in study area. The area coverage of the suitability indexes from the result map was 176.01 km^2 (56.22%), 1.82 km^2 (0.58%), 72.12 km^2 (23.04%), 63.10 km^2 (20.16%) and its suitability classes were restrictive, less suitable, moderately suitable, and suitable respectively. the highly suitable class not found in the study area based on the aggregation of nineteen factors map. This was the overall aim of the research. According to this study result showed on figure, 28 were evidently the optimal location of industrial area in Adama city. Were the second most suitable land class graded as a directional distribution in the Eastern, Southeastern and southwestern parts of the city due their proximity to the highway and the CBDs as well as their endowment with large Area of proposed industrial land.

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5.2. Recommendations

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

i. The combination of GIS with MCE is powerful tool for land suitability analysis for future Industrial Land development. The method requires only computer skills within a GIS environment. Therefore, GIS-based MCE for land suitability has proven to facilitate efficiency as compared to the traditional methods.

ii. In the study area, the current proposed industrial area on the current city structural plan was, accumulated in the neighbor of (residential, social service and other purposes) of the city. This may result in different social and economic problems (interruption) on the residents. Therefore, environmental and urban planners need to pay attention to those areas order to plant industries far away from residential and other economic areas of the city.

iii. The outcome of this study will help the local people as well as urban planners, decision-makers, and developers can identify and recognize that where is optimal land for future industrial development to keep urban sustainable development while utilizing the land properly.

iv. The results obtained showed that there is a strong reverse relationship between land use compatibility of industrial and residential Hence, in application of land use planning policy in order to avoid negative impacts between the different land use activities. Therefore, environmental and urban planners need to pay attention to compatibility of every land use with other neighbor land uses.

v. It is important to study the relationship between all land use compatibility because knowing the nature of that relation in details leads to conceive more sustainable environment by hindering negative externalities.

vi. The land use land cover and existing built-up maps used in this study were mapped from Landsat 8 image of 30m resolution. Therefore, further study should be recommended to use high-resolution image for generating LULC and existing built-up.

vii. Data handling system in the industry and investment department and Urban Development and Housing Department was very poor. Therefore, they have to give recognition for those currently accepted technologies like land information system, GIS, QGIS and remote sensing to address information up to date information goals.

viii. Finally, Future works should focus on selecting a suitable industrial area for specific industry type such as food, chemical, and material separately based on additional spatial and non-spatial factors including availability of fiber-optic service areas, Communications, Fire protection, availability of workforce and the income of the community preferences. Further, future works should focus on MCDM model based on the integration of the comparison of AHP, OWA and FAHP methods in industrial site selection.

REFERENCES

Abbaspour, M. M. ((2011).). *Integrated Approach for Land use Suitability Analysis.* . International Agrophysics,25(1993), 311–318.

Abdulhasan, M. J.-R. ((2019)). *Combining GIS, Fuzzy Logic, and AHP Models for Solid Waste Disposal Site Selection in Nasiriyah,.* Iraq.: Applied Ecology and Environmental Research, 17(3), 6701–6722.

https://doi.org/10.15666/aeer/1703_67016722.

Abedini, A., Lotfian, M., & Moradi, M. (2015). *Land Use Compatibility Assessment Using a Modified Topsis Model:.* a Case Study of Elementary Schools in Tehran.

Abushnaf, F. (2015). *A Land Evaluation Model for Irrigated Crops using Multi- Criteria Analysis.* Sheffield Hallam University.

Acioly Jr., C. C. ((2000).). *Can Urban Management Deliver the Sustainable City? Guided Densification in Brazil versus Informal Compactness in Egypt. In M. Jenks & R. Burgess (Eds.),Compact cities: Sustainable urban forms for developing countries (pp. 127–140).* London, UK:: Spon Press.

https://doi.org/10.1103/PhysRevD.64.077501.

Adam, I. &. (2014.). *Perceived Spatial Agglomeration Effects and Hotel Location choice.* Anatolia, : 25(1), 49–60. https://doi.org/10.1080/13032917.2013.822818.

Adel, M. &. (2016.). *Land Suitability Analysis as Multi-criteria Decision Making to Support the Egyptian Urban Development.* . Proceedings of Science and Technology,(Khalifa 2011), 1–11.

Adhikari, B., & Li, J. (2013). *Modelling ambiguity in urban planning.* Annals of GIS, 19(3), 143-152.

Ahmed, A. D. (2011). *Urbanisation and the Challenge of Development Controls in Ghana:.* A Case Study of Wa Township. : Journal of Sustainable Development in Africa, 13(7),210–235. https://doi.org/1520-5509.

Ahmed, G. B. (2016). *Agriculture Land Suitability Analysis Evaluation Based Multi criteria and GIS Approach.* In IOP Conference Series:: Earth and Environmental Science (Vol. 37, p. 12044).

Aleksander Rikalovic, Dordo Cosic, Srdan Popov and Dorde Lazarevic. (2013). *Spatial MultiCriteria Decision Analysis for Industrial Site Selection.*

Al-Hanbali, A. A. (2011). *Using GIS-Based Weighted Linear Combination Analysis and Remote Sensing Techniques to Select Optimum Solid Waste Disposal Sites within.* Mafraq City, Jordan.: Journal of Geographic Information System, 03(04), 267–278.https://doi.org/10.1016/j.isatra.2011.10.006.

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

Alter, S. L. (1980). *Decision Support Systems: Current Practice and Continuing Challenge.* Reading, MA: Addison Wesley. https://doi.org/10.1371/journal.

Alter, S. L. (1980.). *Decision Support Systems: Current Practice and Continuing Challenge.* Reading, MA: Addison Wesley. https://doi.org/10.1371/journal.pone.0066043.

Badri, M. A. (2007). *Dimensions of Industrial Location Factors: Review and Exploration.* Business and Public Affairs, 1(2), 4–26.

https://doi.org/10.1017/CBO9781107415324.004.

Bagdanavičiute, I. &. (2013). *GIS-based Land Suitability Analysis Integrating Multi-criteria Evaluation for the Allocation of Potential Pollution Sources.* . Environmental Earth Sciences, 68(6), 1797–1812.https://doi.org/10.1007/s12665-012-1869-7.

Bagheri, M. S. (2012.). *Land Use Suitability Analysis Using Multi criteria Decision Analysis Method for Coastal Management and Planning: A Case Study of Malaysia.* Journal of Environmental Science and Technology, 5(5), 364–372.

https://doi.org/10.3923/jest.2012.364.372.

Bagheri, M. S. (n.d.). *Land Use Suitability Analysis Using Multi criteria Decision Analysis Method for Coastal Management and Planning:*. A Case Study of Malaysia. : Journal of Environmental Science and Technology, 5(5), 364–372.

. https://doi.org/10.3923/jest.2012.364.372.

Bakhtiarifar, M., Mesgari, M., Karimi, M., & Chehreghani, A. (2011). *Land use change modeling using multicriteria decision analysis and GIS.* Journal of Environmental Studies, 37(58), 43-52.

Banai-Kashani, R. (1989). *A New Method for Site Suitability Analysis: The Analytic Hierarchy Process.* Environmental Management, 13(6), 685–693.

Batista E Silva, F. K. (2014). *Estimating DDemand for Industrial and Commercial Land Use Given Economic Forecasts.* PLoS ONE, 9(3), e91991.

. https://doi.org/10.1371/journal.pone.0091991.

Beedasy, J. &. (1999). *Diverting the Tourists : A Spatial Decision-Support for Tourism Planning on a Developing Island.* . JAG, 1(3), 163–174.

https://doi.org/10.1016/S0303-2434(99)85009-0.

Bhatnagar, R. a. (2005). *Supply Chain Competitiveness: Measuring the Impact of Location Factors, Uncertainty and Manufacturing Practices.* Technovation, 25(5), pp. 4434.

Brunelli, M. &. (2014). *Boundary Properties of the Inconsistency of Pairwise Comparisons in Group Decisions.* European Journal of Operational Research, 240(3), 765–773. https://doi.org/10.1016/j.ejor.2014.07.045.

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

Commission., A. U. (2015). *Agenda 2063: The Africa We Want.* https://doi.org/978-92-95104-23-5.

Commission., A. U. (2015). *Agenda 2063: Urban Planning in Industrial Cities:the Reversibility of Decay.* The Africa We Want. https://doi.org/978-92- Águeda, B. F. (2016).

Corona, P. S. (2008). *Land Suitability for Short Rotation Coppices Assessed through Fuzzy Membership Functions.* . In R. Lafortezza, G. Sanesi, C. T. R., & J. Chen (Eds.), Patterns and Processes in Forest Landscapes Multiple (pp. 191–211). Springer.

Creswell, J. W. (2013). *The Selection of a Research Approach.Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, California, USA:: 4th ed., pp. 3–23). SAGE Publications, Inc. https://doi.org/45593:01.

Cutler, P. &. (2002). *Down to Earth: Geographic Information for Sustainable Development in Africa.Development. Washington, DC:.* National Academy Press.

Dang Khoi, D. &. (2010). *Delineation of Suitable Cropland Areas Using a GIS Based Multi-Criteria Evaluation Approach in the Tam Dao National Park Region, Vietnam.* . Sustainability, 2,2024–2043. https://doi.org/10.3390/su2072024.

Deichmann, U. L. (2008a). *Industrial Location in Developing Countries.* World Bank Research Observer, 23(2), 219–246. https://doi.org/10.1093/wbro/lkn007.

Deichmann, U. L. (2008b). *Industrial Location in Developing Countries.* The World Bank Research Observer, 23(May 2014), 220–246. https://doi.org/10.1093/wbro/lkn007.

Dennison, S. R. (1937). *The Theory of Industrial Location.* The Manchester School, 8(1), 23–47.https://doi.org/10.1111/j.1467-9957.1937.tb01400.x.

Dennison, S. R. (Dennison, S. R. 1937). *The Theory of Industrial Location.* . The Manchester School, 8(1), 23–47. https://doi.org/10.1111/j.1467-9957.1937.tb01400.x.

Djwa, P. D. (1960.). *An analysis of industrial location factors with particular reference to Indonesia.* . University of British Columbia. https://doi.org/10.14288/1.0102437.

Dodgson, J. S. (2009). *An Overview of Multi-criteria Analysis Techniques. In Multi-criteria Analysis:.* A Manual (pp. 6–161). London, UK: Department for Communities and Local Government.

Douglas, I. H. (2002). . *Industry, Environment and Health through 200 years in Manchester*. Ecological Economics, 41(2), 235–255.

https://doi.org/10.1016/S0921-8009(02)00029-0.

Drobne, S. &. (2009). *Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging.* Informatica, 33, 459–474.

https://doi.org/10.1017/CBO9781107415324.004.

Drobne, S. &. (2009.). *Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging.* Informatica, 33, 459–474. https://doi.org/10.1017/CBO9781107415324.004.

Eastman, J. R. (2005). *Multi-criteria Evaluation and GIS. In P. Longley (Ed.), Geographical Information Systems: Principles, Techniques, Applications and Management (2nd ed., a, pp. 493–502).* Chichester, New York: Wiley.

https://doi.org/10.1080/095008396180344.

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

Eberts, R. W. (1999). *Agglomeration economies and urban public infrastructure. In CPaul & M. E. S (Eds.),*. Handbook of Regional and Urban Economics (Vol. 3, pp. 1455–1495). Oxford, UK: Elsevier. https://doi.org/10.1016/S1574-0080(99)80007-8.

Enache, M. G. (2016). *Structural Transformation in Africa - A Historical View (No. 7743).* The World Bank Policy Research Woriking Paper. New York, NY, USA.

Erdoğan, A. &. (2016). *Spatial Decision Making Under Determinism vs. Uncertainty: A Comparative Multi-level Approach to Preference Mapping.* Hacettepe Journal of Mathematics and Statistics, 45(4), 1245–1273.

https://doi.org/10.15672/HJMS.20157712084.

Ethiopia. (2021). *Statistical Service.* Adama.

FAO. (2001). *Lecture Notes on the Major Soils of the World.World Soil Resources Reports,*. 94,Rome.Food and Agriculture Organization of the United Nations,334 Pp.

FDRE. (2019). *Industrial Parks Regulation Regulation No……/2015 .* Industrial.

Fenta, K. (2014). *Industry and Industrialization in Ethiopia : Policy Dynamics and Spatial Distributions. 6(34), 326–345.*

Fernando, G. M. (2015). *A GIS Model for Site Selection of Industrial Zones in Sri Lanka (A Case Study of Kesbewa Divisional Secretariat Division in Colombo District).* International Journal of Scientific & Engineering Research, 6(11), 172–175. http://www.ijser.org.

Ferretti, V. &. (2013). *An Integrated Approach for Studying the Land Suitability for Ecological Corridors through Spatial Multicriteria Evaluations.* Environment Development and Sustainability, 15(3), 859–885. https://doi.org/10.1007/s10668-012-9400-6,.

Florida, R. (2002). *The Rise of the Creative Class.* T, the Washington Monthly,: pp. 15-25.

García Márquez, J. R.-A. (2017). *Effectiveness of Conservation Areas for Protecting Biodiversity and Ecosystem Services: a Multi-criteria Approach.* . International Journal of Biodiversity Science, Ecosystem Services and Management, 13(1), 1–13. https://doi.org/10.1080/21513732.2016.1200672.

GIS., Wu Qiang & Chen Ping. (2000). *The agricultural land suitability assessment based on GIS Geotechnical. 4, 47–51.*

Hoover, E. M. (1937). *Location Theory and the shoe and Leather Industries (Vol. 55).* Cambridge, Massachusetts:Harvard University Press.

Huang. (2018). *Comprehensive Geographic Information Systems.* (T. J. Cova & M. H. Tsou, Eds.), Comprehensive Geographic Information Systems (1st ed., Vol. 3). Waltham, MA: Oliver Walter.

Isard, W. ((1956). *Location and space-economy.* Cambridge, MA: The Technology Press of Massachusetts Institute of Technology AND John Wiley & Sons, Inc., New York.

Isard, W. (1960.). *The Scope and Nature of Regional Science.* . Papers in Regional Science, 6(1), 9–34 https://doi.org/10.1111/j.1435-5597.1960.tb01698.x.

Jaglan, M. S. (2018). *Significance of Geospatial Technology and Status of Education.*

Jankowski, P. (1995). *Integrating Geographical Information Systems and Multiple Criteria Decision Making Methods.* International Journal of Geographical Information Systems, 9(3), 251–273. https://doi.org/10.1080/02693799508902036.

Jirásková, E. (2002.). *A Comparison of Location Factors Evaluation in the Secondary and Tertiary Sectors.* Business Administration and Management, XVIII(1), 217. https://doi.org/10.15240/tul/001/2015-1-004.

Johar, A. J. (2013). *Land suitability analysis for industrial development using GIS.* Journal of Geomatics2, 7(2), 101–106.

Kalantari, A. H. (2013). *Facility Location Selection for Global Manufacturing.* The University of WisconsinMilwauk Milwaukee.

Keenan, P. B. (2003.) , *Decision Making Support Systems: Achievements and challenges for the New Decade (pp. 28–39).* Idea Group Inc. https://doi.org/10.1016/B978-0-08-097086-8.72060-5.

Keenan, P. B. (2006). *Spatial Decision Support Systems: A Coming of Age.* . Control and Cybernetics, 35(1), 9–27.

Kushwaha, S. P. (2005). *Geospatial Technology for Forest Resources Management.* International Journal of Ecology and Environmental Sciences, March 2005.

Malczewski, J. (2004). *GIS-based Land-use Suitability Analysis: A Critical Overview.* Progress in Planning, 62(1), 3–65. https://doi.org/10.1016/j.progress.2003.09.002.

Martin, R. L. (2004). *A Study on the Factors of Regional Competitiveness. A draft final report for The European Commission Directorate-General Regional Policy, Cambridge:.* University of Cambridge. Cambridge, MA

https://doi.org/10.1002/2014JD022376.Received.

Mediaty Arief, U. Y. (2018). *An Accurate Assessment Tool Based on Intelligent Technique for Suitability of Soybean Cropland: Case Study in Kebumen Regency,Indonesia.* Heliyon, 4, 28. https://doi.org/10.1016/j.heliyon.2018.

Mehdi, Z. F. (2015.). *A Combined Model of GIS and Fuzzy Multi Criteria Decision Analysis (FMCDA) for Suitable Evaluation / Selection of Industrial Areas , (Birjand , Iran).* . Recent Researches in Environmental Science and Landscaping, 174–179. https://www.researchgate.net.

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

Mohammed, N. Z. (2013). *Positional accuracy testing of Google Earth.* International Journal of Multidisciplinary Sciences and Engineering,4(6), 6–9

. http://www.ijmse.org/Volume4/Issue6/paper2.pdf.

Mousseau, V. &. (2015). *Multicriteria Decision Making, Spatial.* International Journal of Applied Engineering Research, 10(30), 22757–22762. https://doi.org/10.1007/978-0-387-35973-1.

Palacios, J. (2005). *Economic Agglomeration and Industrial Clustering in Developing Countries: The Case of the Mexican Silicon Valley.* In Joint Research Program Series (pp. 161–271).

Predöhl, A. (1928.). *The Theory of Location in Its Relation to General Economics.* . Journal of Political Economy, 36(3), 371–390. https://doi.org/10.2307/1822752.

Proclamation, e. I. (n.d.). *No.886/2015).*

Proclamation, Ethiopia Industrial Parks. (2015). *No.886/2015).* Industrial Parks Proclamation No.886/2015".No.886/2015". 39(I).

Ramcharan, E. K. (2005). *The role of Environmental Factors in Industrial Site Selection Activities: A case of limestone quarry expansion in Barbados West Indies.* Impact Assessment and Project Appraisal, 23(2), 147–154.

.https://doi.org/10.3152/147154605781765670.

Rauber, A. M. (2015). *Repeatability and Re-usability in scientific Processes: Process context, data identification and verification.* In CEUR Workshop Proceedings (Vol. 1536, pp.246–256). Vienna, Austria.

Reisi, M. A. (2011). *Industrial site selection by GIS in Isfahan, Iran.Proceedings - 2011 19th International Conference on Geoinformatics, Geoinformatics.*

https://doi.org/10.1109/GeoInformatics.2011.5981171.

Rikalovic, A. C. (2014). *GIS based Multi-criteria Analysis for Industrial Site Selection.* . Procedia Engineering, 69(December), 1054

1063.https://doi.org/10.1016/j.proeng.2014.03.090.

Saaty, T. L. (1980). *the Analytic Hierarchy Process : Planning, Priority Setting, Resource Allocation (Ist).* New York: McGraw-Hill International Book Co.

Saaty, T. L. (2008). *Decision making with the Analytic Hierarchy Process.* Int. J. Services Sciences, 1(1), 83–98.

Safari, H. &. (2014). *Select a Hypermarket Location Based on Fuzzy Multicriteria decision making (F-MCDM) TECHNIQUES (HYBRID OF F-DELPHI, F-AHP, F-LLSM and FPROMETHEE).* Arabian Journal of Business and Management Review, 4(1), 76–95.

Sarath, M. S. (2018). *Site Suitability Analysis for Industries Using Gis and MultiCriteria Decision Making.* ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, IV(November), 447–454.

https://doi.org/10.5194/isprs-annals-IV-5-447-2018.

Sheppard, E. (2001). *Geographic Information Systems: Critical Approaches. In International Encyclopedia of the Social Behavioral Sciences (pp. 6182–6185).* . Pergamon.https://doi.org/http://dx.doi.org/10.1016/B0-08-043076-7/02524-9.

Sieber, R. (. (2006). *Public Participation Geographic Information Systems: A Literature Review and Framework.* Annals of the Association of American Geographers, 96(3), 491–507.

Singh, P. (2015). *Role of Geographical Information Systems in Tourism Decision Making Process: A Review.* Information Technology and Tourism, 15(2), 131–179.

https://doi.org/10.1007/s40558-015- 0025-0.

Store, R. &. (2001). *Integrating Spatial Multi-criteria Evaluation and Expert Knowledge for GIS-based Habitat Suitability Modelling.* Landscape and Urban Planning, 55(2), 79–93.https://doi.org/10.1016/S0169-2046(01)00120-7.

Sugumaran, V. &. (2007). *Web-based Spatial Decision Support Systems (WebSDSS):Evolution, Architecture, Examples and Challenges.* Communications of the Association for Information Systems, 19, 844–875.

https://doi.org/10.17705/1CAIS.01940.

Sultani, R. M.-h. (2009). *The Use of Geographic Information System (GIS) Based Spatial Decision Support System (SDSS) in Developing the Urban Planning Process.* Architecture & Planning Journal, 20(February 2016), 97–115.

Taleai, M., Sharifi, A. Sliuzas R. & Mesgari, M.,. (2007). *Evaluating the compatibility of multi-functional and intensive urban land uses.* International Journal of Applied Earth Observation and Geoinformation, 9(4), 375-391.

. https://doi.org/10.1016/j.jag.2006.12.002.

Tennøy, A. H. (2016). *How Planners' Use and Non-use of Expert Knowledge Affect the Goal Achievement Potential of Plans: Experiences from Strategic Land-use and*

Transport Planning Processes in three Scandinavian cities. Progress in Planning, 109, 1–32. https://doi.org/10.1016/j.progress.2015.05.002.

Thomson, A. J. (2001). *Computers and Electronics in agriculture Ethics in computer software design and development.* . Computers and Electronics in Agriculture, 30, 85–102.

Tienwong, K. D. (2009). *Integration of Land Evaluation and the Analytical Hierarchy Process Method for Energy crops in Kanchanaburi, Thailand.* . ScienceAsia, 35(2), 170–177. https://doi.org/10.2306/scienceasia1513-1874.2009.35.170.

Ullah, K. M. (2016). *Evaluation of Land Suitability for Urban Land-Use Planning: Case Study Dhaka City.* Transactions in GIS, 20(1), 20–37.

https://doi.org/10.1111/tgis.12137.

UNECA. (2013). *Industrialization for an Emerging Africa.* Abidjan,: Côte d'Ivoire.

UNECA. (2017). *Economic Report on Africa :.* : Urbanization and Industrialization for Africa's Transformation Addis Ababa, Ethiopia.

UN-HABITAT. (2011). *The Economic Role of Cities. (X. Q. Zhang & T. Osanjo, Eds.),* . The Global Urban Economic Dialogue Series. Nairobi, Kenya: UN-HABITAT.

Vaggione, P. (2013). *Urban Planning for City Leaders. (V. Quinlan, Ed.). Nairobi, Kenya: UNON.* , Publishing Services Section.

https://doi.org/10.1007/SpringerReference_168760.

Vernon, H. J. (2009). *Cities and development.* Cities and Development, 50(1), 1–267. https://doi.org/10.4324/9780203086452 .

Weber, A. (1929.). *Alfred Weber's Theory of location of Industries.* (C. . Friedrich, Ed.). Chicago, Illinois , USA.

Zhou, L. &. (2012). *GIS-Based Multi-Criteria Analysis for Hospital Site Selection in Haidian District of Beijing.* Gävle University College.