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ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

COLLEGE OF SOCIAL SCIENCES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES
(SPECIALIZATION IN GIS, REMOTE SENSING AND DIGITAL CARTOGRAPHY)

GIS AND REMOTE SENSING BASED ANALYSIS ON INDUSTRIAL SITE SELECTION IN HAWASSA TOWN, ETHIOPIA

BY: MULUNEH BEYENE TSALA

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ART IN GEOGRAPHY AND ENVIRNMENTAL STUDIES (SPECIALIALIZATION IN GIS, RS AND DIGITAL CARTOGRAPHY)

BY: MULUNEH BEYENE TSALA

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STATEMENT OF APPROVAL

Addis Ababa University

School of Graduate Studies

This is to certify that the project prepared by Muluneh Beyene, entitled: GIS and Remote Sensing Based Analysis on Industrial Site Selection in SNNPRS : The case of Hawassa Town and submitted in partial fulfillment of the requirements for the degree of Master of Arts in Geography and Environmental Studies (Specialization in GIS, Remote Sensing and Digital Cartography) complies with the regulations of the university and meets the accepted standards with respect to the originality and quality.

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ACRONYMS AND ABBREVIATIONS

AGOA- African Growth and Opportunity Act

AHP: Analytical Hierarchical Process

CEO- Chief Executive Officer

CSA- Central Statistical Agency

DSS- Decision Support System

FDI- Foreign Direct Investment

FIS- Fuzzy Inference System

GDP- Gross Domestic Product

GIS-Geographic Information System

GPS- Ground Positioning System

GTP- Growth and Transformation Plan

IPDC- Industrial Parks Development Corporation

JICA-Japan International Cooperation Agency

MADA- Multi Attribute Decision Analysis

MCDA- Multi Criteria Decision Analysis

MCDM- Multi Criteria Decision Making

MODA- Multi Objective Decision Analysis

PVHC-Phillips Van Heusen Corporation

SNNPRS-Southern, Nations, Nationalities and Peoples Regional State

SRTM-Shuttle Radar Topographic mission

UNESCO- United Nation Education Social Cultural Organization

USD- United State Dollar

WLC- Weighted Linear Combination

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ABSTRACT

The significance of GIS and Remote Sensing techniques and technologies currently in every aspect of human beings day to day activities initiated the researcher to conduct this study. Industry is important to enhance the economic level of a given country and GIS and remote sensing technologies would provide a variety of options during site selection process. The overall objective of the study is to *identify suitable industrial site location by using Geographic Information System and Remote Sensing based analysis in Southern Nations, Nationalities and Peoples Regional State, Hawassa town. In order to conduct this study, multi criteria evaluation system to identify factors influence during site selection by pair-wise comparison matrix was employed. Nine determining factors/parameters identified in this study to identify suitable site for the industrial establishment. These factors were slope, land use land cover, soil types, distance from geological faults, proximity to main road, distance from residential area, distance from water bodies (lake, river and swamp), The findings revealed that land use land cover factors and distance from geological faults highly determines the selection for industrial sites; and elevation and slope determines minimum compared with other factors. Majority of the study area (47.5%) is suitable to establish industries and a small portion (0.2%) are less suitable. Conducting environmental impact assessment prior to establishing industries in the study area was not fully covered by the concerned government organization. Application of GIS and Remote Sensing technologies in the study area is not fully employed. In order to select suitable sites for the industry, the town administrators should focus on those important parameters by using Geographic Information System and Remote Sensing technologies.*

Keywords: GIS, Remote Sensing, Industry, Site Selection, Suitability Analysis

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Principally in developing countries of big cities, a number of directors took the initial step of creating special regions for industry, essentially to isolate them from heavily populated or affected areas. Government agencies, in charge of regulating the industry site selection commenced considering the inclusion of environmental criteria in the selection process as a measure to lessen potential environmental impacts to local communities. In the past, site selection was based almost purely on commercial and technical criteria. Today, a higher degree of refinement is expected. Selection criteria must also meet a number of social and environmental elements, which are enforced by law and government regulations (Aleksandar, *et al* 2013). GIS is an efficacious tool for the management and analysis of data required for any land development activity (Manish and Vivekananda, 2013). GIS system has the ability of display needed in the context of decision making. A set of tools has been used to manage the proper site for a city improvement facility, including GIS, and Multi-Criteria Decision Making (MCDM) techniques (Zahra *et al*, 2014).

Industrial site selection is critical point in the process of starting, expanding or changing the location of industrial systems of all kinds. One of the main objectives in industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. In a site selection process, the analyst strives to determine the optimum location that would satisfy the selection criteria. The selection process attempts to optimize a number of objectives desired for a specific facility. Such optimization often involves numerous decision factors, which are frequently contradicting, and the process often involves a number of possible sites each has advantages and limitations. Decision making is based on numerous data concerning the problem of selection appropriate site. Decisions about industrial location typically involve the evaluation of multiple criteria according to several, often conflicting, objectives. While many decisions we make are prompted by a single objective (Eldin and Sui, 2003).

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 development of industrial field with minimizing its negative impacts on people and the environment. This has been very important as a better environ-mental management tool which can be used 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 (Thanuja *et al*, 2015).

Site selection of industrial zones in a given area has become a critical issue and a sensitive decision making process that may create a range of socioeconomic and environmental problems over time. Hence, several site selection criteria and appropriate methods for establishing industries have to be concerned by the decision makers and authorities before locating industrial zones in particular regions. Though, at present the enormous data volume and complex criteria regarding this field are available, the suitable site selection process is still problematic (Fernando *et al*, 2015).

Site selection is one of the primary decisions in the start-up process and town planning, development or relocation of industries of all kinds. Building of a new industrial system is related with long term investment, and in this sense planning the site are a significant point on the road to progress or failure of the industrial system and that effect on all other services in the city. One of the main objectives in industrial site selection is finding the most suitable site with required conditions. A large number of researchers depend on GIS because of its availability and its wide uses in site selection process. GIS is used in combination with other systems and methods such as the method for multi-criteria decision making (MCDM). Multi-criteria decision analysis (MCDA) techniques can be used in such conditions to classify and rank options for subsequent complete evaluation, or to specify acceptable from unacceptable potentiality for many sites (Mahmud, 2015).

This research thesis focuses on how to apply GIS based analysis to select industrial sites in Southern Ethiopia, Hawassa town. Site selection with minimum impacts is very difficult to achieve considering criteria one by one, because of the big list of criteria including very important spatial factors. But still in Hawassa town this process is conducted as politicians need. In this study, the researcher considered the criteria that need to be undertaken before establishing industrial zones in Hawassa town. That is the one of major significance of this study. The GIS based analysis was developed in this research that can be used for every where to get very accurate steps for site selection process. It is very important especially for the sustainable development of industrial field. Therefore, this paper assumes that, in some extent, such failures can be overcome by applying Geographic Information System (GIS) and Multi-criteria Decision Making Techniques into the site selection process of industrial zones. In this study, a GIS and Remote Sensing based analysis was applied to screen most suitable locations for establishing Industrial Zones in Hawassa town.

1.2. Statement of the Problem

Development is fundamentally a process of structural transformation from traditional agriculture to modern agriculture, industries and services. Especially after the Industrial Revolution, industrial development has become a base of the economy in each country. Industrialization began in 19th century around the central Europe and was gradually spread towards Asia and other regions of the world. Rapid development of the industrial field caused to rapid distribution of the industries as well. But Most of the investors face high transaction costs because of a lack of infrastructure and weak institutions on the one hand and, people and environment are influenced in various fields by the industrial pollution on the other. In that phase, the industrial zone began to be constructed with the aim of creating a space where industry could be removed from population centers, with all the facilities and infrastructure has been given (Thanuja *et al*, 2015).

The goal in a site selection exercise is to find the best location with desired conditions that satisfy predetermined selection criteria. Site selection typically involves two main phases: a) site screening (identification of a small number of candidate sites from a broad geographic area and a range of selection factors) and b) site evaluation (in-depth examination of each candidate site to the most suitable (Davis, 2001).

According to Davies (2001), the selection process attempts to optimize a number of objectives in determining the suitability of a particular site for a defined facility. Such optimization often involves a multitude of factors, sometime contradicting. A number of tools were used to determine the proper site for capital improvement facilities. These tools include Expert Systems, geographic information systems (GIS), and Multi-criteria decision-making (MCDM) techniques. These tools have played an important role in solving site selection problems.

According to the Hawassa Town Sanitation, Beautification and Parks Development Department report (2012), there are many of potential sites that could be chosen for the facility. Each of these sites usually satisfies the selection criteria at varying levels. It is fairly common to find contradiction between the multiple objectives for a sitting problem. Land use designation problem (residential, industrial, commercial) sites were not as such differentiated. i.e. residential, commercial and industrial sites located near to near. The town administrators are simply selecting those areas that are inhabited/bare lands/ for industrial sites without identifying other preconditions like social integration of communities, proximity to the town, safety of the community since industrial sites has their own negative impacts on society.

For instance, the objective of keeping minimum capital investment may contradict with the objective of keeping a long-term safe environment. Many objectives lack means for quantitative measurement. Examples of those are the aesthetic deterioration of the view of a natural mountain scene as a result of the installation of transmission towers/lines, the social disruption felt by a community as a result of the expected rapid influx of workers during construction, and similar issues.

Different studies undertaken in relation with industrial site selection in Hawassa town mainly focused on identifying sites without considering parameters and factors based on GIS and remote sensing techniques. For example, Mamo Mihretu and Gabriela Llobet (2017) conducted a case Study of PVH’s Commitment in Ethiopia’s Hawassa Industrial Park. In this study, on page 17, they tried to describe how industrial sites screened/selected. But they ignored about the way how industrial sites screened or selected by the help of GIS and remote sensing technologies

Another study undertaken by Dejene *et a*l (2018), on industrial park development in Ethiopia mainly discussed about integrated agro-industrial parks are under development in the selected regions. The study focused on the importance of industry in relation with job creation, strong linkages to the agricultural sector, high export potential and capacities to attract private sector investment. The study did not stated about site selection process since effective industrial development has direct relation with the site it established.

Therefore, this study considered different factors/parameters that affect the selection of industrial sites by applying GIS and remote sensing techniques.

1.3. Objective of the Study

1.3.1. General objective of the study

The general objective of this study is to identify optimal industrial site location by using GIS and remote sensing based analysis in SNNPRS, Hawassa town.

1.3.2. Specific objective of the study

The following listed points were the specific objective of the study.

- To identify different parameters that determines the selection of industrial site location in the study area.
- To identify suitable sites for industrial location for the future by applying GIS based analysis in the study area.
- To produce final suitability output map that shows suitable sites for industrial locations in the town.

1.4. Research Questions

The researcher identified the following as leading questions to attain the objectives of the study:

- What are different parameters that determine the selection of industrial site location in the study area?
- Which sites are important to locate industries in the future in Hawassa town?
- What seems final suitability output map that shows suitable sites for industrial locations in the town?

1.5. Significance of the Study

The findings of the study will be helpful to provide the required precondition to locate industrial sites in the study area. The study also hopefully to give the direction how to implement GIS tools in executing industrial site location in order to enhance the economic development of the town. And finally, this study will provide information for those interested researchers to conduct further analysis on applying GIS modeling in industrial site selection in the study area.

1.6. Scope of the Study

In real world, it is too difficult to cover all the existing problems and different parts of the world at once in research study. This tells us about the researcher to be selective in identifying problems and the area that have to be covered in the study. For this reason, GIS modeling in industrial site selection identified as the research focusing part and from different towns of Ethiopia, Hawassa town taken as the study area. From this perspective, the researcher interested to focus on GIS modeling in industrial site selection in SNNPRS, the case of Hawassa town.

1.7. Limitation of the Study

The scope of this study is identifying suitable site for industries using multi-criteria decision making techniques in GIS and remote sensing environment. The study focused mainly on industry site selection since they are the dominant types in most towns of the country. The site selection criteria were formulated based certain criteria's and also GIS and Remote Sensing experts were as such important. But in the study area, lack of desired criteria's and shortage of experts in the area of GIS and Remote Sensing challenged the research to obtain how the study area selects sites. However, the researcher collected the necessity data without any tiredness.

1.8. Organization of the Paper

This study has the following parts. Part one covers introduction of the study which further includes background of the study, statement of the problem, objectives of the study, research guiding questions, significance of the study and delimitation of the study. Part two covers on related literatures which are so important in relating those studies previously conducted on industrial site selection. Part three gives emphasis on the methodology which includes methods and materials to be considered when implementing this research work. Part four discussed about data analysis and findings. And finally, conclusion and recommendations were included under this research study.

CHAPTER TWO

2. LITERATURE REVIEW

In this part, that information that was studied before by other authors 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 (Aleksander *et al*, 2013).

According to Aleksander *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 are 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 economical and technical criteria. Today, a higher degree of sophistication is expected. Selection criteria must also satisfy a number of 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 be 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 (Kotler, et al, 1993).

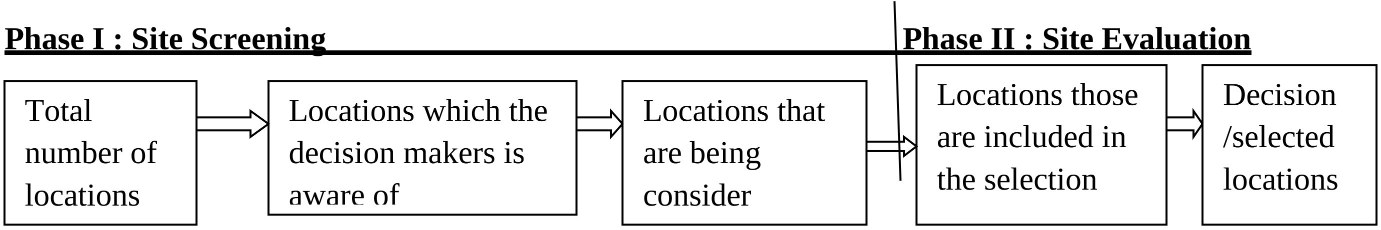

Figure 1: Site Selection Process (Source: Kotler, et al, 1993)

The process of site selection includes: Establishing a set of influential factors relevant to site selection, predicting and evaluating the intensity and direction of their effects in time and given conditions and evaluation of possible variants of solutions and selection of optimal variants.

2.2.3. GIS and Multi-Criteria Analysis for Industrial Site Selection

2.2.3.1. Geographic information systems

It is obvious that many factors must be involved in the decision-making process, which makes the problem challenging choice in the selection of appropriate tools to enable concentration data, information and knowledge.

New trends in information technologies put Geo-information systems (GIS) in the center of events in industrial locations science. The placement of a major facility means to satisfy a number of competing objectives and criteria. To accomplish task such as industrial site selection, we need to prepare number of maps, each with a different theme. Geographic information system (GIS) is a group of procedures that provide data input, storage and retrieval, mapping and spatial analysis for both spatial and attributes data to support the decision-making activities of the organization (Grim, 1996).

Since, geographical information systems provide the capability to enter, edit, retrieve, analyze, map, and visualize spatial data; it is not surprising to see that spatial data is marketed primarily in a GIS format. Looking towards the future, one can project an ever-increasing role for GIS to help support location studies (Church, 2002)

There are a number of different methods used to analyze geographic data in Geographic information systems (GIS). There are methods of analysis of geographic data and methods of analysis of attribute data. When we are speaking about geographic data there are analysis performed over the vector data and raster data.

The most commonly used spatial analysis in GIS is: Analysis of attributive (tabular) data, overlapping layers (i.e. query of spatial data) analysis of the distance, network analysis and nonparametric techniques.

Analysis of attribute data of one thematic layer can be performed: as SQL query against a table with attribute data; using different arithmetic operations (addition, subtraction, multiplication, division), logarithmic functions, trigonometric functions, and so on; application of some nonparametric techniques like Multi-criteria methods and methods based on artificial intelligence, and one of them is method that uses artificial neural network (Aleksandar, 2013).

Geographical information can be defined as geo-referenced data that has been processed into a form that is meaningful to the recipient decision-maker and which is of real or perceived value in the decision-making process.

In general, the MCDA in GIS should be viewed as a process of conversion of data to information that adds extra value to the original data. GIS techniques & procedures have an important role to play in analyzing decision problems recognized as a decision support system for industrial site selection especially in site screening phase. In industrial site screening phase role of GIS is to geo-referenced and analyzes feasible alternatives that will be later consider in evaluation phase. In evaluation phase roll of GIS is to produce criteria, constraints and suitability maps according to the results from Multi-criteria decision analysis and value judgments of decision makers (Malczewski, 2006).

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2.2.3.2. Multi-criteria decision analysis

Multi-criteria decision-making problems can be classified on the basis of the major components of multi-criteria decision analysis: multi-objective decision analysis versus multi-attribute decision making, individual versus group decision-maker problems, and decision under certainty versus decision under uncertainty. The distinction between MODA and MADA is based on the classification of evaluation criteria into attributes and objectives (Drobne *et al*, 2009). Decision is a choice between alternatives. Criterion is some basis for a decision that can be measured and evaluated. It is the evidence upon which a decision is based. Criteria can be of two kinds: factors and constraints.

A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. It is therefore measured on a continuous scale.

A constraint serves to limit the alternatives under consideration. In many cases constraints were expressed in the form of a Boolean map: areas excluded from consideration being coded with a 0 and those open for consideration being coded with a 1 (Eastman *et al*, 1993).

Multi-attribute decision making methods are data-oriented. An attribute is a concrete descriptive value, a measurable characteristic of an entity, including inter-entity relationships. Multi-attribute techniques are referred to as discrete methods because they assume that the number of alternatives is explicit. Multi-attribute decision problems require that choices be made among alternatives described by their attributes. This implies that attribute objective relationships are specified in such a form that attributes can be regarded as both objectives and decision variables. Attributes are used as both decision variables and decision criteria (John Wiley and Sons, 1999).

The most significant factors that describe decision problems or affect the choice and implementation of MCDA methods the most significant: Number of decision makers, Number of objectives, Number of alternatives, existence of constraints and risk tolerance (Bal, 2006).

2.2.3.3. GIS-MCDA solution for industrial site selection

Spatial multi-criteria decision analysis can be thought of as a process that combines and transforms geographical data (input) into a resultant decision (output). Geographical information can be defined as geo-referenced data that has been processed into a form meaningful to the recipient. The data in geographical information systems are most commonly organized by separate thematic maps or sets of data, referred to as a map layer. The alternative to the layer approach is object-oriented GIS, where the objects are intended to closely represent real world elements. Irrespective of spatial data organization, the ultimate aim of GIS is to provide support for spatial decisions. The multi-criteria decision-making procedures define a relationship between "input maps" and "output maps." One of the most important rules governing the use of GIS for spatial decision support systems that GIS themselves do not make decisions but people do (Malczewski, 2006).

2.2. Compressive method for selecting industrial sites

The comprehensive method uses a coordinated set of interacting decision support systems: an intelligent decision support system for industrial location criteria analysis, a geographic information system for generating alternatives, and a spatial decision support system for alternatives evaluation. The developed intelligent decision support system for industrial location criteria analysis is a hierarchical environment, based on a fuzzy expert system, which uses a set of fuzzy inference systems to interpret, standardize, and fuse heterogeneous data in order to estimate normalized industrial location criteria. The geographic information system based on the spatial database created from the environmental analysis is used for mining data and generating alternatives in the screening process (Drobne, 2009).

In compressive method, the decision-making process is divided into the following steps

2.2.1. Problem definition

The first step in all decision-making processes is to recognize and define the relevant characteristics of the decision problem. Depending on the business environment and the company’s overall objectives, the problem definition specifies the essential inputs for the decision making process. Managers would like to have everything in one location: low labor costs and a quality workforce, simultaneously. These objectives are contradictory and very difficult to achieve. This problem can only be solved through compromise. Therefore, it is necessary to explain the problem and to find the space for compromise. In this step, we define the main objectives that should not be in conflict and identify the decision makers (either an individual or a group) for the location problem under consideration (Zelenovic, 2003).

2.2.2. Site selection criteria evaluation

Once the decision problem is defined, compressive method evaluates the site selection criteria, i.e., location characteristics that influence the decision process for the envisioned case. A selection criterion may consist of either a single quantity observed in the analyzed environment or a group of quantities collectively defining the desired characteristics of the environment itself (in this second case, the criterion is obtained by merging the observed quantities into a single figure of merit). These criteria are stored as attributes associated with the specific location. In this step, criteria are analyzed according to a specific problem definition and ordered according to their relevance for the envisioned case (USAID, 2008).

2.2.3. Spatial database creation

The third step involves the creation of a spatial database that contains data for all of the selected criteria in the region of interest. For such a purpose, it is necessary to collect and store all data related to the decision problem, with specific reference to data related to the selected criteria. Spatial data collection includes GIS maps, satellite and aircraft images, and descriptive data related to the observed location. Geographic data are obtained by remote sensing, by entering existing data (statistics), by collecting data and geo-locating them with GPS, or by digitizing and scanning maps. Collected data should be first analyzed to ensure consistency and then stored. This step is the most demanding in terms of time and costs ((Zelenovic, 2003).

2.2.4. Location alternatives generation

This step focuses on generating decision alternatives by using the GIS in a screening process. By screening the geographic locations in the region of interest, we obtain the necessary information for the subsequent multi-criteria analysis, which requires clearly defined location alternatives for analysis. Each location alternative should be a feasible location for the industry and should meet the basic construction requirements. For mining data and generating the location alternatives, we developed a GIS by using Arc-GIS (McCoy, 2001)

2.2.5. Fuzzy criteria analysis

To provide a consistent framework for knowledge management under uncertainty, criteria analysis and standardization, we developed an intelligent decision support system for industrial location criteria analysis based on a set of fuzzy inference systems. This system is a method that uses fuzzy rules to map inputs to outputs (Czogala, 2000).

2.2.6. Criteria suitability maps generation

To support an effective analysis of each criterion, we adopt suitability maps, which enable visual thinking and spatial data mining. To produce the suitability maps, the normalized data of each criterion are evaluated for each alternative (McCoy, 2001).

2.2.7. Multi-criteria decision analysis

The multi-criteria decision analysis is performed in three phases: definition of the criteria weights, estimation of the consistency ratio, evaluation and ranking of the location alternatives. To determine the criteria weights in the first phase, the Analytical Hierarchy Process (AHP), a pair wise comparison technique developed by Saaty to identify the relative relevance of criteria. This analysis produces a pair wise-comparison matrix ranking criteria from those of extreme importance to those of equal importance (Saaty, 1997).

The researcher therefore, applied multi criteria decision analysis to prioritize each factors based on their importance and influences.

2.2.8. Suitability map presentation

The final suitability map represents the output values from the multi-criteria decision analysis. These outputs are expressed in the range [0, 1] and presented in the final suitability map. For visual representation, we adopted the same color ramp that has been used in subsection for graphic visualization (Rinner, 2013).

In this study, the researcher employed the null (0) value in order to indicate those restricted areas that are not preferable to locate industry.

2.2.9. Sensitivity analysis

The sensitivity analysis tests how much the sensitivity map and, therefore, our decisions are sensitive to criteria variations. Thus, in the sensitivity analysis, we test the accuracy and the robustness of the multi-criteria analysis. This allows decision makers to be confident in their choices even though the values of the criteria may not be highly accurate.

In this study, the researcher employed weight normalized procedure how the processed data ensures its influence in prioritizing parameters.

2.3. Factors that are Determining Industrial Site Selection

In the past, site selection was based almost purely on economical and technical criteria. But currently, a higher degree of sophistication is expected. Selection criteria must also satisfy a number of social and environmental requirements. 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 be considered and managed during each of the stages (Aleksandar *et al*, 2013).

According to USAID research conducted on Serbia, the following points are important criteria to select industrial location: labor costs, geographic position, availability of a quality workforce, transport infrastructure availability of raw materials, licensing and permitting procedures for the land, telecommunication infrastructure, efficiency of local authorities, availability and cost of business premises, references from local partners and previous experience, cost of construction land, availability of construction land, level of political interference in business, ecology utility costs accommodations (Aleksandar *et al*, 2016).

As it was stated above, in Serbia, industrial sites were not selected as simply and only vacant land availability is not enough to establish industry. Different accessibilities have to exist in the area in which industry located. Besides to physical factors that determining site selection, government commitment and security issues were also highly determining private investors to invest in the given area. In addition, previous experience of industrial establishment is also one of criteria to select industrial sites, which is important to take a lesson in order to identify failures and achievements. This would help the newly establishing industry from being stagnant and failure. Therefore, a given administration has to desire a specific criterion that ensures environmental, social wellbeing and security issues of the communities during industrial site selection phases.

2.4. Empirical Review of the Study

2.4.1. Industry site selection process in Africa

Africa had been on PVH's radar screen since (2012), when it started to develop its Africa Strategy. At this time, PVH was sourcing limited products from Egypt, Kenya, Lesotho, and Mauritius, and wanted to explore whether there was additional untapped potential in Africa to be developed. Having worked for more than 25 years deciding where to locate and establish Greenfield manufacturing operations, Bill McRaith (2015), had extensive experience in textile and clothing manufacturing. He wanted to locate in East Africa in order to start afresh and build a model operation. He advocated full verticality and compliance with standard and safety regulations.

Africa. As a result of our trip, we identified a great opportunity for the industry to invest nearly a billion dollars to create a vertically integrated apparel supply chain in some regions of Africa. In other words, create jobs in Africa not just in apparel, but also in the textile and even agricultural industry through better cotton production techniques (McRaith, 2015).

The apparel industry's mistakes of the past have often been the result of near-sighted investment in lawless environments. That model must and will change rapidly countries in Africa where we invest will be the beneficiaries of a new and more inclusive model of investment and growth in which we will be able to put in place, right from the beginning, facilities, norms and values that will guide the work at the factories and the relationships between workers, managers, associations, civil society groups, governments and any other stakeholders. That is why when we look at Africa we do not just look for a place to quickly set up a sewing operation.

So, it simple to understand in that establishing industries and inviting private investors on industries requires a clear process and regulations to be effective and productive. But as stated above, Africans did not conduct impact identification mechanisms before establishing and participating on industries. Therefore, Africans have to conduct impact mitigation analysis before establishing industries.

2.4.2. Industrial site selection in Ethiopia

In deciding its new location, PVH considered five key factors: government stability, land and port accessibility cost of energy, and labor availability. In order to commit to investing, industry needed assurance of true long-term commitment by government authorities that they would satisfy these essential conditions (PVHC, 2015).

Ethiopia scored well on most of the indicators. However, the key deciding factor was the clear commitment of the Ethiopian government to the textile and garment sector as a strategic area of investment. The government underscored its commitment to attract PVH by providing industrial land and infrastructure as well as favorable lease terms for the development of industry (Mamo and Gabriela, 2017).

Political stability and rule of law, favored Ethiopia as industry new location. Most important, Ethiopia demonstrated its capacity and willingness to establish textile and garment production capacity. Ethiopian officials consistently followed through on their commitments building trust with the company and ultimately cementing location decision. Also important was the direct channel of communication with senior government officials.

Such follow-through helped set Ethiopia apart from its closest competitors. The aggregate of the factors strong government commitment, costs, power, and potential incentives, etc coupled with the Government of Ethiopia's commitment to creating an environment that supports workers, safety and sustainable production made Ethiopia the clear choice for PVH's investment. Supporting the manufacturing sector and achieving structural transformation is at the center of Ethiopia's growth strategy, as stated in the Growth and Transformation Plan (GTP). This is underscored by strong political will and political consensus to implement the strategy. "The number one reason for investors' interest was because of what they saw in the governmental side and that to me, after doing this for the last 26 years all over the world, the biggest difference we see is in this effort (http://www.ethiopians.com/Ethiopia_GTP_2015).

2.4.3. Ethiopia's experience in industry

The strategy of industrial parks development which is being implemented by the Industrial Parks Development Corporation (IPDC) has a purpose of attracting foreign direct investment (FDI) in key strategic manufacturing industries, which in turn, would assist transfer technology to the local entrepreneurs, diversify the structure of the country's export, and generate employment. The IPDC, which has the vision of becoming an "innovative and leading eco-industrial parks developer and operator in Africa by 2025, is mandated to activate both pre and post investment servicing, availing land, and pre-built sheds equipped with all-encompassing utilities and infrastructural facilities with international standards of quality of service, labor security, and environmental safety.

About 12 industrial parks for export processing, have been identified across the country based on proximity to market outlets, infrastructure, economic potential, and regional balance in development. Almost all industrial parks are established along corridors of railway networks that are either completed or under construction and are on schedule. The construction of two major industrial parks in Addis Ababa and Hawassa has been completed with nine firms having started production in Addis Ababa and Hawassa (Kenichi, 2017)

The Ministry of Industry of the Federal Democratic Republic of Ethiopia has prepared three documents on the industrial strategy, roadmap to industrial development, and institutional setup for the implementation of the industrial development. These documents are believed to lead the country's direction on industrial development for the next fifteen years. The industrial development objectives, goals and strategies on the GTP II document are therefore the reflections and highlights of the more elaborated documents prepared by the Ministry of Industry.

2.4.4. Existing Industrial Parks in Ethiopia

The lion's share of this economic growth goes to agriculture which accounted, in 2014–2015, for about 38.8 percent of the Gross Domestic Product (GDP), 90 percent of the foreign currency earnings and 85 percent of employment. In the same fiscal year, the industrial sector, which mainly comprises small and medium enterprizes, accounted for about 15.2 percent of the GDP. The service sector comprising social services, trade and real estate among others accounted for about 46 percent of GDP***(https://medium.com/@EthiopiaEU/industrial-parks-development-in-ethiopia-f09eb704d741, 2016, 03:25).***

The report from Ethiopia Embassy from Belgium, Brussels states about the Government of Ethiopia has given due attention to the agricultural sector through its successive policies and strategies such as RDPS, PASDEP, ADLI and the Growth and Transformation Plan (GTP). However, as clearly indicated in the policies and strategies and the GTP II, the manufacturing sector must achieve annual growth of 24 percent and increase its contribution to export revenues from the current 10 percent to 25 percent. The export revenues of the whole economy should register an annual growth of 29 percent. To ensure a sustainable development of the economy, the part of agriculture in the total economy should be reduced and more labor should move to the industry. In order to realize this, the government created enabling conditions to encourage both domestic and foreign private investment and has been heavily investing on infrastructure, energy, rural finance, research, access to improved technology and information, market development, agricultural extension services, promotion of cooperatives, among others.

Ministry of Industry is vigorously working to develop 100,000 hectares of land between 2016 and 2025, for a total factory floor area of 20 million m2. The below listed are some of industrial parks that are owned by IPDC in the country:

Bole Lemi

Bole Lemi is Ethiopia's first industrial park developed by IPDC with a focus on exports. Bole Lemi Phase 1 (156 hectares) has started operations in 2014, with all pre-erected factories already rented-out to more than 12 different corporations including several investors from Taiwan, China, India and South Korea in sectors such as textile, garment and shoe production, creating about 10,000 jobs. According to the agreement with the investors, almost 95 percent of the products are supplied to foreign market, and thereby enhance the nation's currency earning capacity. Moreover, the firms use local raw materials such as skin and hides as an input for their products. Bole Lemi Phase 2 (186 hectares) is currently being developed in collaboration with the World Bank Group.

Kilinto

Located in the south of Addis Ababa, Kilinto is currently being developed as IPDC's second park in Ethiopia's lively, cosmopolitan capital. With a total size of 337 hectares, Kilinto will be a mixed-use park and the number one destination for manufacturers in agro-processing, pharmaceuticals, electric and electronics products, wood and furniture, both for export and to serve local consumers. Serviced land in Kilinto will be available from early 2016, with pre-erected factory sheds available from the 4th quarter of 2016.

Hawassa Industrial Park

Hawassa Industrial Park is located 275 km from Addis in proximity to one of Ethiopia's premium holiday destination, Lake Hawassa. Upon completion, it will be 300 hectares Eco-Park, centered on textile and garment products, and fully integrated to the city, in collaboration with the newly built Hawassa University, and will be mostly powered by renewable hydroelectricity. The design and construction of Hawassa will be conceived around energy and water conservation principles including maximization of natural lightning and natural ventilation, fitting of low consumption bulbs, recycling of rain water, and solar powered led street lights making it Ethiopia's most important eco-friendly site. In Phase 1 cycle 1, 100 hectares of land were developed.

Ethiopia government is currently on progress in establishing huge Industrial Parks in different parts of the country. So, those industrial park site establishment and process should be selected based on technological equipments, environmental impact assessment also would be conducted prior to its establishment by using GIS and Remote Sensing technologies. This would help those industrial sites preference by both private investors including foreigners.

2.5. Theoretical Literature of the Study

Industrial site selection is one of the key decisions in the process of starting, expanding, or changing the location of an industry. The industrial location problem can be represented as a selection process of potential sites in which the attempt is made to satisfy all requirements in the best possible way. Traditionally, industrial site selection has been based almost exclusively on economic and technical criteria. Currently, a higher degree of sophistication is desired in order to also satisfy a number of social and environmental requirements, which may be enforced by legislation and government regulations. The industrial site selection process becomes, therefore, a complex multi-criteria analysis, which includes a set of criteria encompassing technical, economic, social, environmental and political issues, possibly resulting in conflicting objectives (William and Massa, 1983).

2.5.1. Weber's theory of industrial location

The economic and noneconomic variables determining the location of industry may seem to form a network complex and diversity elements often individual instances, so arbitrarily there appears to be no place more than an analysis of the individual case. Weber stated that if we approach individual manufacturer a question the choice of his location, he will most give as a quaint concoction of general and particular reasons unless he points to the past and says: "I am here because this industry grew up here"(David, 1966).

The general location theory can be regarded as falling in to two sub-categories. In the first places, the dimension of space introduces factors which pull industry to and fro because of various regionally operating variables. Three such variables can be distinguished: they are:-

i. the relative price of deposits of raw materials,

ii. The costs of transportation and

iii. The cost of labor

Of these, the relative price differential of raw materials from various sources can be expressed in terms of transportation costs. For theoretical purposes, it is equivalent to thinking in terms of cheap deposits situated relatively near to the plant and dear deposits further away. Consequently, we can work with two general regionally operating location factors, namely the cost of transportation and cost of labor. Being strictly function of space, regional factors can all be analyzed from the point view of the individual isolated production process.

All the other factors of location work between industries and therefore are not to be found in any examination of an isolated production process. They are grouped together under the title "agglomeration factors" and work to create groupings of industrial in agglomerations of various sizes. The aggregate of agglomerative factor is treated as a "uniform agglomerating force". This is the third and last of the general location factors.

From this concept, the researcher understood that the relative price of raw materials and its transportation cost determines industrial establishment, i.e. it the area is not accessible, private investors will not have interest to invest on that inaccessible areas. Therefore, proximity to the accessible road is important for industrial development.

2.5.2. The Growth pole theory

The concept of growth poles was originally introduced and put into systematic use by French regional economist Francois Perroux in his classical article of 1955. The concept of growth poles suggested in that paper/industry is closely related to his particular notion of abstract economic space as a field of forces, consisting of centers', poles from which centrifugal forces emanate and to which centripetal forces are attracted. Each centre being a centre of attraction and repulsion, has its proper field, which is set in the field of other centers.

From the outset, it is important to note that Perroux was originally concerned with economic growth, primarily with firms, industries and with their interrelations. It is not with the geographical pattern of economic activity, or the geographical implications of economic growth and intra/inter-industrial shifts. He maintains that it is possible to distinguish as many economic spaces as there are constituent structures of abstract relations that define each object of economic science (Francois, 1955).

Thus, inter- industry linkages and theory of industrial interdependence play a major role in the growth pole theory. As a matter of fact, this theory together with the Schumpeterian theory of development can be said to constitute the two cornerstones upon which Perroux bases his theory.

The external economies that become available in the area constituting the growth pole of a region are basically of the following three types:

- ✓ Economies internal to the firm: These are the lower average costs of production resulting from an increased rate of output. These are the economies which any single firm by their own organization and effort can enjoy.
- ✓ Economies external to the firm but internal to the industry: These are associated with localization of industry. On account of close location proximity of linked firms, as industry expands at a particular location, cost per unit of output to a firm declines.
- ✓ Economies external to the industry but internal to the urban area: These can be termed urbanization economies. They include development of urban labor markets, access to a larger market, and provision of a wider range of services.

The growth pole theory is a useful concept for spatial analysis. The theory is attractive to policy makers because it presents opportunities for integrating industrial policy, physical planning and inter-regional and intra-regional economic planning.

In this concept, the existence of one industry may attract the establishment of another industry. For example, if there is car production/seller in a given area, garages may interest to open at near there to obtain customers easily. So, industrial site selection also considers the existence of other industries near or far away from the newly desired industrial establishment.

2.5.3. Hoover's theory of location

Hoover also tried to propound a least cost theory of location, in which he tried to overcome some of the weaknesses of Weber's theory. Hoover starts with the assumption of perfect competition between producers or sellers at any one location. Secondly, he assumes perfect mobility of factors of production and takes transportation costs and production or extraction costs as the determinants of location. He considers extractive industries first, with the location of deposits given, and attempts to find the area that each producing point will serve. The delivered price for any buyers will be the cost of extraction plus transport costs (Greenhut, 1956).

He has represented this by a system of isotims, radiating from the point of production and joining places of equal delivered price. Buyers will obtain the commodity from the source that offers the lowest delivered price and the boundary between the market area of two producers will be a line joining the points at which delivered price is the same from both sources.

As long as the cost of extraction does not vary with output, transport costs are the only variable affecting price, but Hoover extends his analysis to include the influence of diminishing returns to scale. He follows Weber, fairly closely at first, pointing that in the absence of production cost differences the best location will be at the point of minimum transport costs, which may be at a material source, at the market or at an intermediate point: The least-transport-cost location is found by drawing isotims around given material and market points, from which lines of equal total transport cost 1 can be constructed. But Hoover goes further than Weber by showing how different sections of the market will be served by different producing points.

He also differs with Weber's emphasis on least transport cost points within location triangles. Even with the assumption of uniform transport costs, the possibility of a separate minimum point not at one corner of the triangle is much less than might be thought at first sight. It is far more likely than what Weber suggested that a material or the market will have a pull which will be greater than that of the other corners. The chance of a location not at one corner is even less likely, if the fact that transfer costs are actually less than proportional to distance is also considered. In addition, loading costs and other terminal changes operate against least cost location inside the triangle. If a separate point away from material sources and market does occur, Hoover suggests that perhaps this is a sign that industry is not primarily transport oriented at all and that possibly a low labor cost location enters into the picture.

In this theory, transportation only does not determine industrial location, but also labor cost also determines the effectiveness of industries. That means, even though there is transport accessibility in the area, shortage of labor force would impose negatively the effectiveness of industries. This directly related with the multi-criteria decision support system in that only one or two factors did not give a clue whether the desired site is optimum or not.

2.6. Conceptual Framework of the Study

Different studies have been undertaken in how to apply GIS based models in selecting industrial site location. Those studies tried to indentify factors and constraints that hinder suitable industrial location. In our country, updating the workflow of software is still lagging behind when compared with other countries experience.

Appropriately evaluating physical factors and constraints allows cities to tactically attract developers with minimum complication. The decision process identifies optimal sites while taking into account economic benefits and environmental sustainability.

The following factors, assessed by proximity to industrial land, are sewer service areas, fiber-optic networks, and public transportation. The model inventories and prioritizes industrial land in a two-part process. First, zoning policies and GIS data identify town districts that allow industrial activity. After selecting these zones, a constraint analysis removes all undevelopable land in each area. The purpose is to eliminate any existing development hurdles, according to environmental regulations and development standards, inhibiting the development process, in order to improve project feasibility.

The second part of the procedure, also conducted in GIS, applies a factor analysis, which incorporates specific variables essential for industry. A factor analysis examines the spatial relationship between developable industrial land and proximity to existing infrastructure amenities (or factors). The closer the distance of industrial land to each factor, the more suitable the location becomes. The weighted overlay analysis then measures suitability for development and ranks locations as either having a high priority or a low priority for protection and investment. This process applies weighted values to each factor, which vary based on specific requirements or business needs.

Finally, after suitability is measured, a more detailed analysis identifies highest priority industrial parcels not adjacent to residential parcels. Large contiguous parcel sizes are compatible for future investment; they allow a community to readily absorb industrial growth with the least amount of restrictions. Communities can efficiently use existing infrastructure to take advantage of investment opportunities for green technology, niche manufacturing, or eco-industrial parks. These spaces are also critical locations, positioned at the crossroads of major arterials, within utility service areas, and in walking distance to public transportation systems. With respect to industrial land, proximity to residential areas is least desirable.

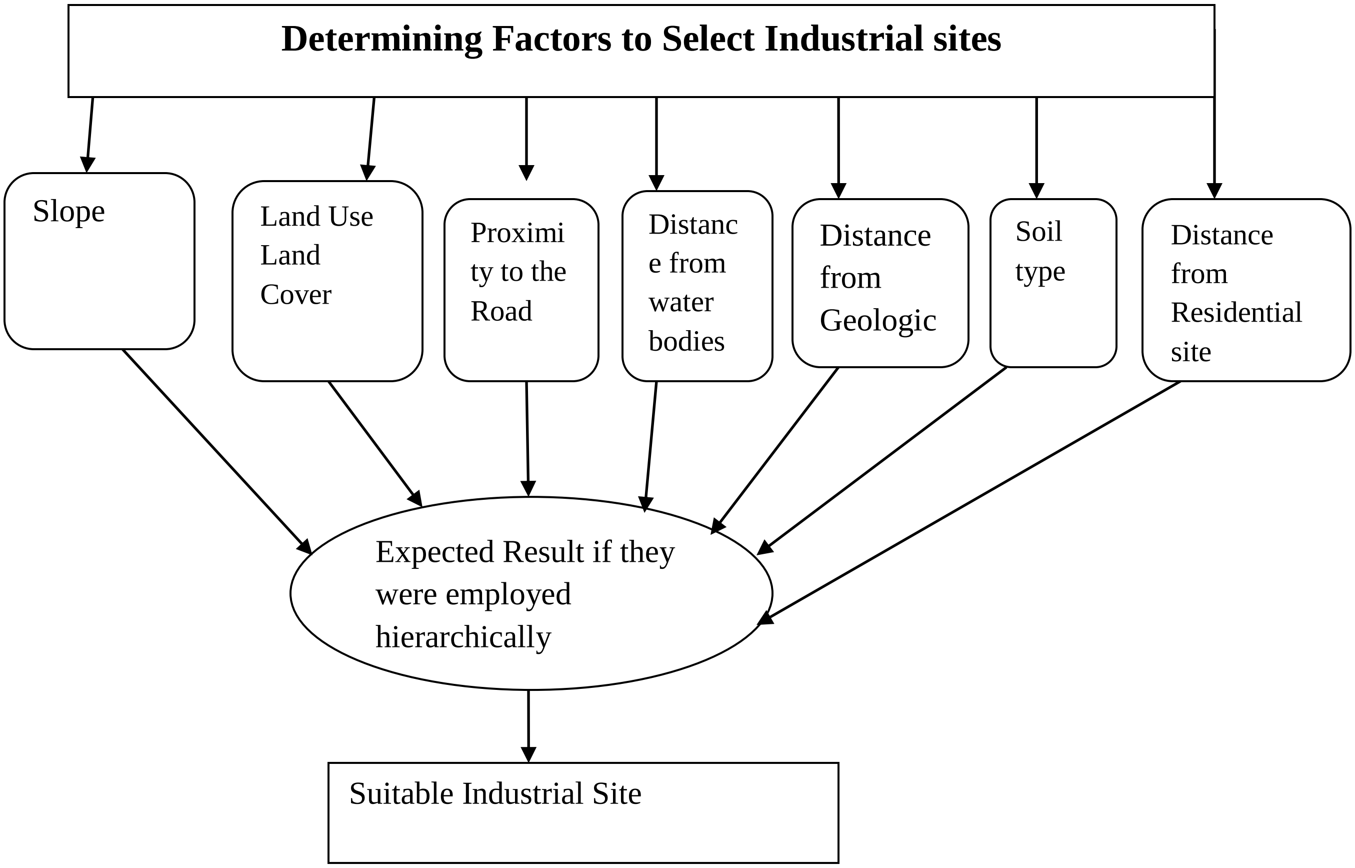

Figure 2: Conceptual framework of the study

From the above concepts:

Independent Variables are: elevation, slope, land use land cover, distance from the main road, distance from the geological faults, and distance from residential area, soil types, and proximity from water bodies (lake, river and swamp).

Dependent variable is: suitable site for industry. The characteristics and nature of the independent variables determines the characteristic of dependent variable. In short, site selection for industries primarily depends on the above listed independent variable selection mechanisms.

CHAPTER THREE

3. DESCRIPTION OF THE STUDY AREA AND RESEARCH METHODS

3.1. Description of the Study Area

3.1.1. Location of the study area

Hawassa town is the capital city of the Southern Nations, Nationalities, and Peoples' Region, and is also a capital city of Sidama Zone. Its geographical location is between 6^{0}55'30" to 7°5'15" and 38^{0}23'15" to 38°38'15"E with an elevation of 1708 meters above sea level. It is located 273 km South of Addis Ababa via Bishoftu, 130 km East of Soddo, and 75 km North of Dilla (Haw/Fi/Ec/Dev/Dep, 2015).

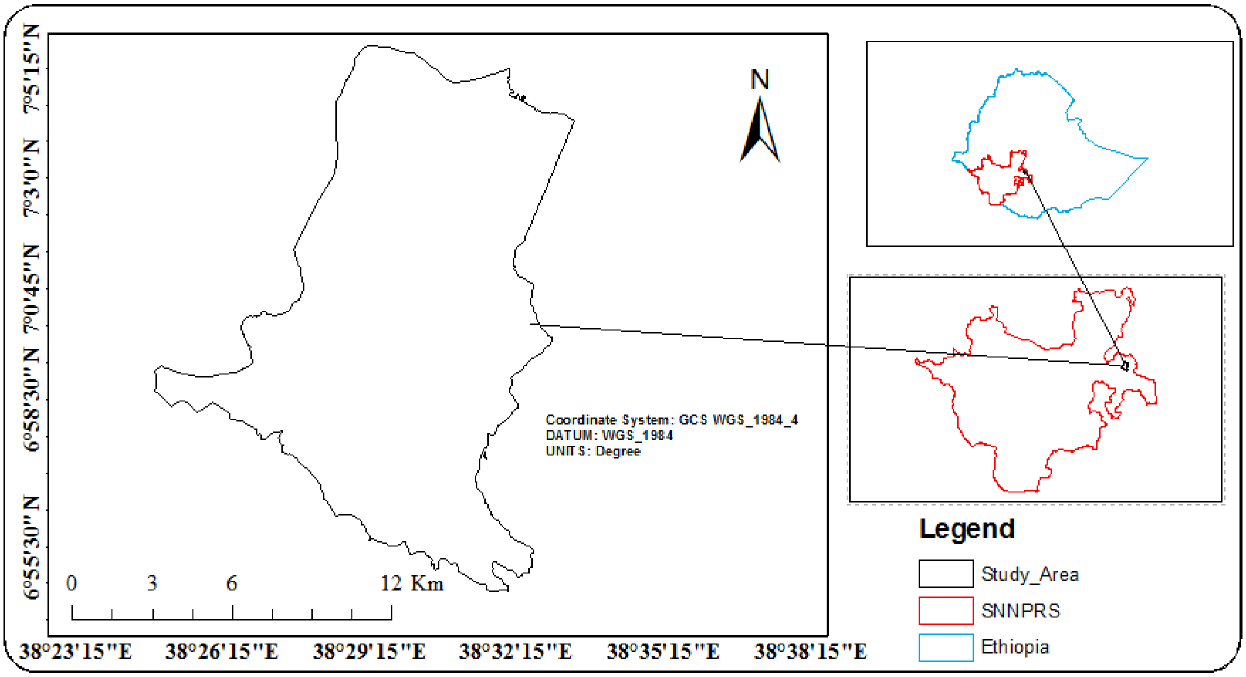

Figure 3: Location Map of the Study Area

Hawassa city is bounded by Lake Hawassa in the West, Oromia Region in the North, Wendogenet woreda in the East and Shebedino Woreda in the South. The town administration has an area of 157.7 km^2. The town administration is divided in to 8 sub-cities and 32 Kebeles. These Eight sub cities are Hayk Dar, Menehariya, Tabor, Misrak, Bahil Adarash, Addis Ketema, Hawela-Tula and Mehal sub city (Ayele, 2017).

3.1.2. Physiography and drainage

Hawassa is a town in Ethiopia, on the shores of Lake Awasa in the Great Rift Valley. Other prominent volcanic features surrounding the city are Hill Tabor and Hill Alamura and spring water(http://www.geology.cz/projekt681700/vystupy/Hawassa_subsheet_0738_C4.pdf,2019:4:18:24 am).

Hill Tabor: Tabor hill has majestic presence in the western end of the city. This attractive hill is perfect for a walk in the afternoon or early morning, and offers beautiful panoramic views across the whole area. Said to resemble Tabor Mountain in Israel, it sweeps dramatically down to the lakeshore, mirroring the ridge of the mountain on the opposite side of the lake Hawassa.

Hill Alamura: It is a small mountain situated at the south western end of the town. From the top of the mountain, one can enjoy a partial view of the town and the lake stretched below it. Paying a visit to this mountain and ascending to its top is worth a day of any one's time.

Spring Waters: There are three natural heritage sites (spring waters) surrounding Hawassa town. These are: Burqito (12km from Hawassa city), Wendogenet located 39 km from Hawassa and Gidabo 41 km south of Hawassa.

3.1.3. Climatic characteristics of the study area

The temperature and rainfall maps of the study area generated from twelve years mean monthly temperature and mean annual rainfall data collected from the national meteorological services agency. The data collected from 2007 up to 2018 years which was from Awassa stations.

Temperature

The climate of Hawassa area exhibits typical characteristics of arid and semi-arid environments. Its mean minimum and mean maximum monthly temperature ranges between 10.6^0c-15.2^0c and 25.2^0c-31.1^0c respectively as described in figure 4. Its mean monthly temperature within a year ranges between 18.3^0c up to 22.1^0c in the months of December and June. The yearly maximum temperature ranges from 32.7 to 34.8_0C while the minimum temperature ranges from 16.5 to 18.8_0C (NMA, 2019).

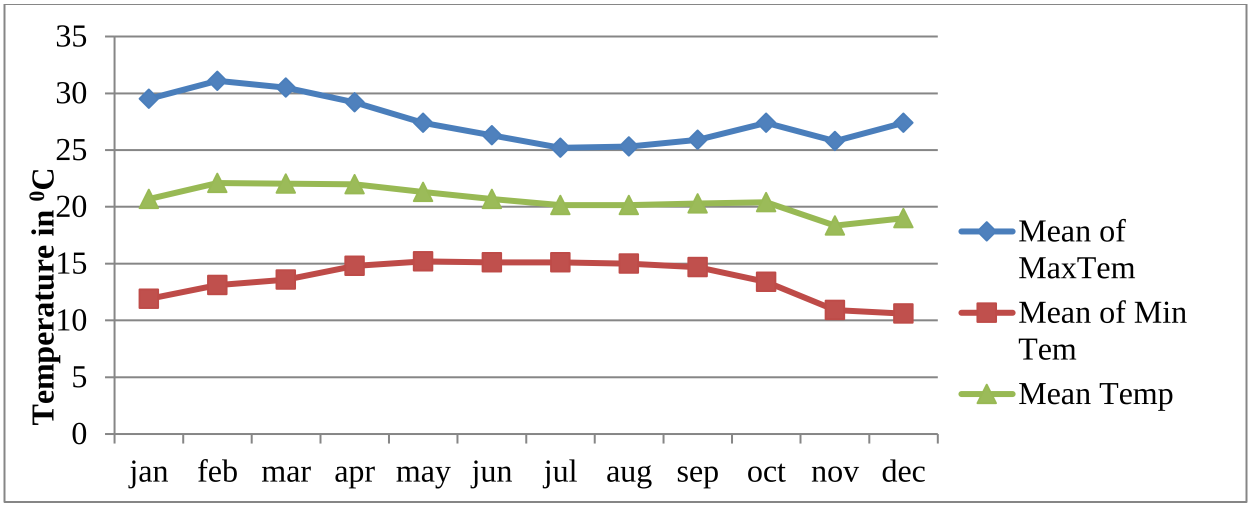

Figure 4: Temperature distribution of the study area

Rainfall

The mean annual rainfall of the study area is about 977.5 mm. The main rainfall season, which accounts for the largest total rainfall of the year occurs from April to September. The mean monthly rainfall of the area ranges between 18.2 mm in December and 153.5 mm in May (NMA, 2019).

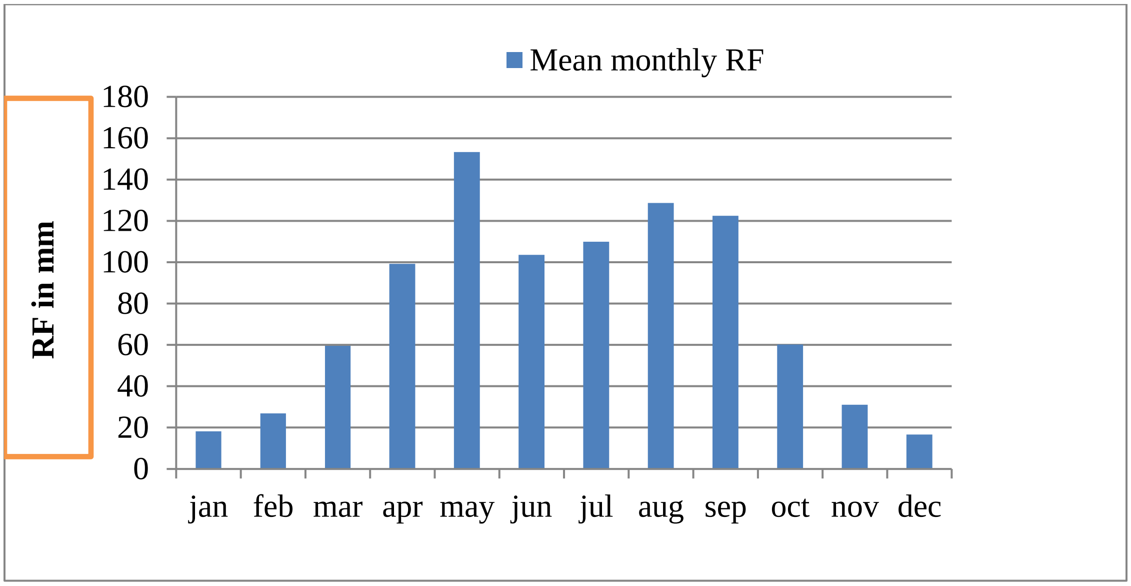

Figure 5: Rainfall distribution of the study area

3.1.4. Population of the study area

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia, the study area has a total population of 258,808, of whom 133,123 are men and 125,685 women. A total of 61,279 households were counted in this town, which results in an average of 4.22 persons to a household, and 57,469 housing units. Much of the population growth has been the result of internal migration and expansion of educational and other facilities, also widening of the city's boundaries has caused some of the increase. Hawassa has a young population. Around 65% of the people are under 25 years of age, and only about 5.5% of the population is over 50 years of age. (CSA, 2007).

3.1.5. Geology of the study area

The area of Hawasa is located within the central part of the Main Ethiopian Rift. Hawasa town covers the north-western segment of the Lower Pleistocene Hawasa Caldera. Significantly smaller Middle Pleistocene Corbetti Caldera overprints the north-western margin of the Hawasa Caldera. Basaltic lavas and pyroclastics were erupted in the Hawasa basaltic belt in south-eastern part of the town during the Middle Pleistocene. The rhyolitic volcanic activity continued in the area of Corbetti Caldera also after Middle Pleistocene. The early predominantly explosive Artu Volcano was later buried by the newly emerging Wendo Koshe Volcano to the west and Chabi Volcano to the east. Some of the geological features of the town are (Basalfew, 2012).

Hawasa rhyolitic ignimbrites: this was produced by voluminous eruptions of a rhyolitic magma from the Hawasa Caldera. These ignimbrites are the oldest rocks exposed in the area of the Hawasa subsheet. The thickness of this unit remains unclear due to the lack of borehole data and difficult distinction of the overlying Corbetti ignimbrites.

Hawasa basalt: it forms a ridge transecting the Hawasa Caldera in a NNE-SSW direction. The ridge subdivides the caldera into the western part (with Lake Hawasa) and the eastern part (with Chaleleka Lake –Shashemene subsheet). Lavas of the Hawasa basaltic ridge were emitted from several scoria and tuff-cones arranged along the ridge.

Wendo Koshe obsidian IV: In the accessible eastern part of the Wendo Koshe Volcano, obsidian lava flows were documented beneath the younger obsidian and pumiceous accumulations of the older Wendo Koshe Volcano.

Wendo Koshe pumice fall and minor flow deposits: The deposits are mostly well sorted and clast-supported suggesting fall deposition. These were produced during the last big explosive event of the Wendo Koshe Volcano. The pyroclastic (mostly fall) deposits cover a large area of the northern part of Hawasa subsheet and extend as far as Bura and Shashemene.

Along the Shashemene to Alaba-Kulito road (just north of the subsheet), 0.5 m of young Wendo Koshe pumice overlays a 6 m thick accumulation of ochre fine ash with abundant accretionary lapilli of an unclear source. Even along the Hawasa-Shashemene road, the thickness of the young Wendo Koshe pumice reaches 2 m. The exact age of this violent eruption has not been determined, as no charcoal was found at the base or within this deposit (JICA (2012).

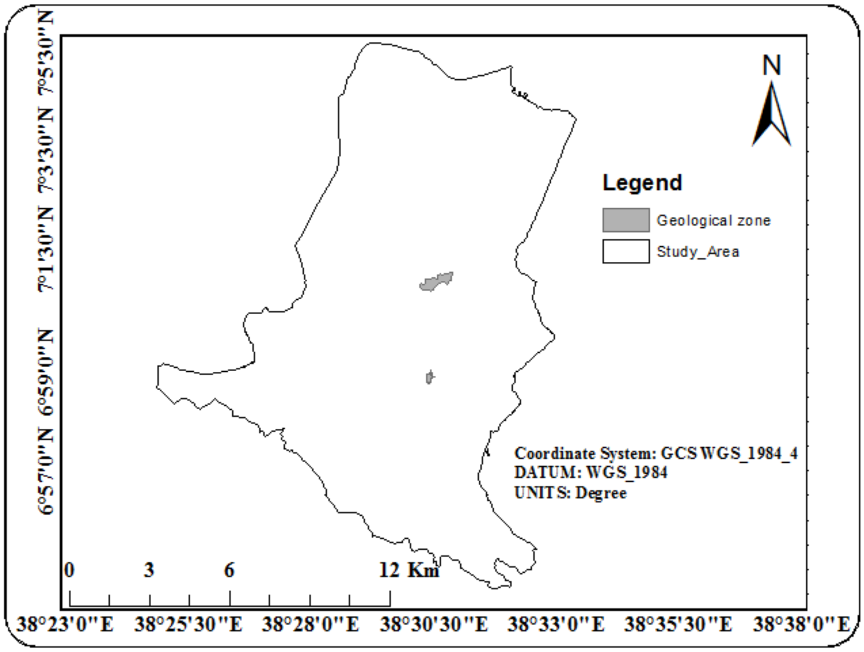

Figure 6: Geology fault map of the study area

3.1.6. Soil types of the study area

The five soil forming factors namely climate (temperature and rainfall), topography, parent material, biological activities (flora and fauna) and time determine the types of soil that are formed at a particular area. As a result soil can vary from place to place. Accordingly, the soil of Hawassa town is classified in to four major types namely eutric fluvisols, chromic luvisols, Haplic luvisols, eutric vartisol and fibric histosols (Yemane, 2004).

Fibric Histosol: it is a soil consisting primarily of organic materials. They are defined as having 40 centimeters (16 inch) or more of organic soil material in the upper 80 centimeters (31 inch).

Organic soil material has organic carbon content (by weight) of 12 to 18 percent, or more, depending on the clay content of the soil.

Eutric Fluvisol: these soils are genetically young soils. They are zonal soils in alluvial deposits, which found in alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones. Many Fluvisols under natural conditions are flooded periodically. Most Fluvisols are wet in all or part of the profile due to stagnating groundwater and/or flood water from rivers or tides. So they are poorly drained soils.

Chromic Luvisols: is a soil with a clearly developed clay leaching horizon and a high cation exchange capacity . The parent material of Luvisolen consists of unconsolidated material. Luvisols mainly occur in landscapes with a flat to slightly hilly relief with a cool temperate climate or a warm climate with clearly dry and wet seasons.

Eutric Vertisol: they are dark colored cracking and swelling clays. Vertisols are soils with a high content of clay minerals that shrink and swell as they change water content. The clay minerals adsorb water and increase in volume (swell) when wet and then shrink as they dry, forming large, deep cracks. Surface materials fall into these cracks and are incorporated into the lower horizons when the soil becomes wet again.

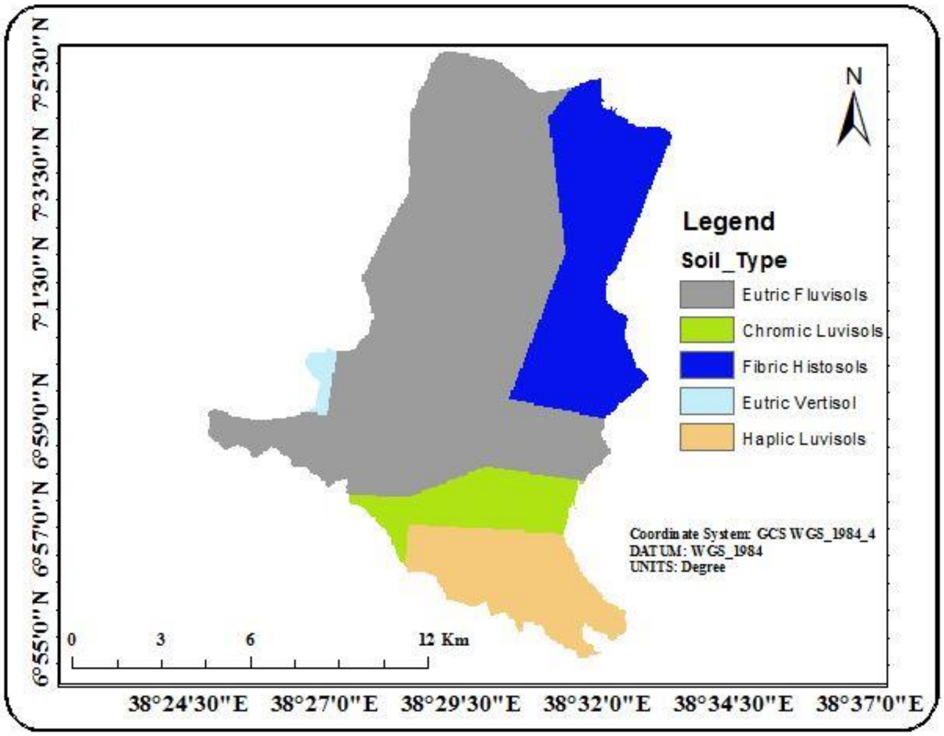

Figure 7: Soil types of the study area (EGIA, 2006)

3.1.7. Infrastructure in the Town

The town finance and economic development department report on socio-economic profile 2015 of the town states that, the economic growth and overall development of the town depends on the presence and improvement of infrastructure facilities. These facilities are Road, transportation.

Road Network: Hawassa City has transportation service since 1952. During the time transportation activity was done by Ministry of works. First, gravel roads constructed followed by Asphalt roads after the Municipality established.

Road infrastructure of the City has made a radical change since 2004. Upgrading of the gravel roads to an Asphalt road (Arterial Asphalt Road) has began in 2004, and made a significant change in road infrastructure of the City.

Transportation: Transport systems in Hawassa include the buses, Taxis/Bajaj/, Motor bicycles, Carts and other types of vehicles. During the past years there has been tremendous growth in the number of vehicles specially Bajaj Taxis in the city, resulting in immense traffic pressure and increasing road bottlenecks. So, road network and transportation availabilities also considered as one of those factors that determining industrial site selection, the researcher will give high attention on those factors in this research study.

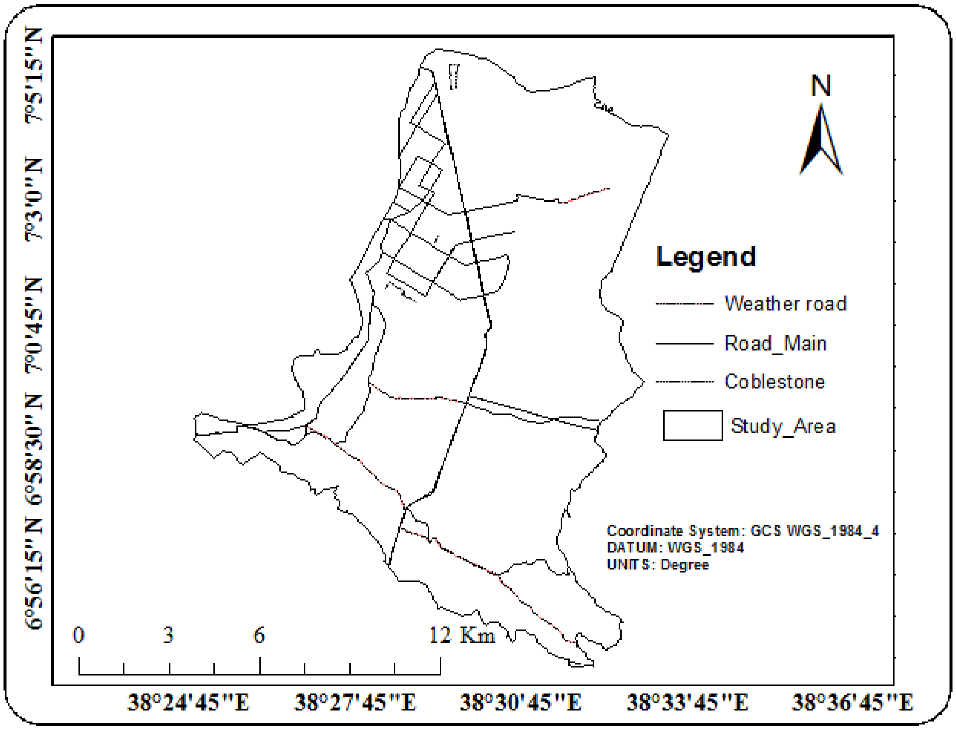

Figure 8: Road network of the study area

3.1.8. Industrial Development in the Study Area

The Ethiopian economy has recorded continuous and double-digit growth since 2003/04. The service sector outperformed other sectors in this period, and its share of GDP increased from 39.7% in 2003/04 to 46% in 2009/10. Despite 10 per cent annual average growth in the same period, the agriculture share in GDP declined from 47% to 42%. The industry sector also grew by about 10% per annum between 2003/04 and 2009/10. However, its share in the economy remained relatively static (12–14%) over the last decade (WB, 2013).

The following industrial types were currently operating in the town: grain mills, house and office furniture, textile, soap factory, stone crusher, printing, laundry, bakery, HCB manufacturing, metal works, oil mills, industrial parks, etc (Hawassa City Trade and Industry Office, 2017).

And also, the data collected by the hand GPS about the distribution of main industrial types shows that industries condensed almost all in one parts of the town as described in the figure 6 below. In the future, it needs a high attention to focus on those newly incorporated structural plan of the town. Especially at the fringe of the town and the surroundings, it is possible to establish industries and in doing that it is had better to avoid industrial noises emission at the central part of the town.

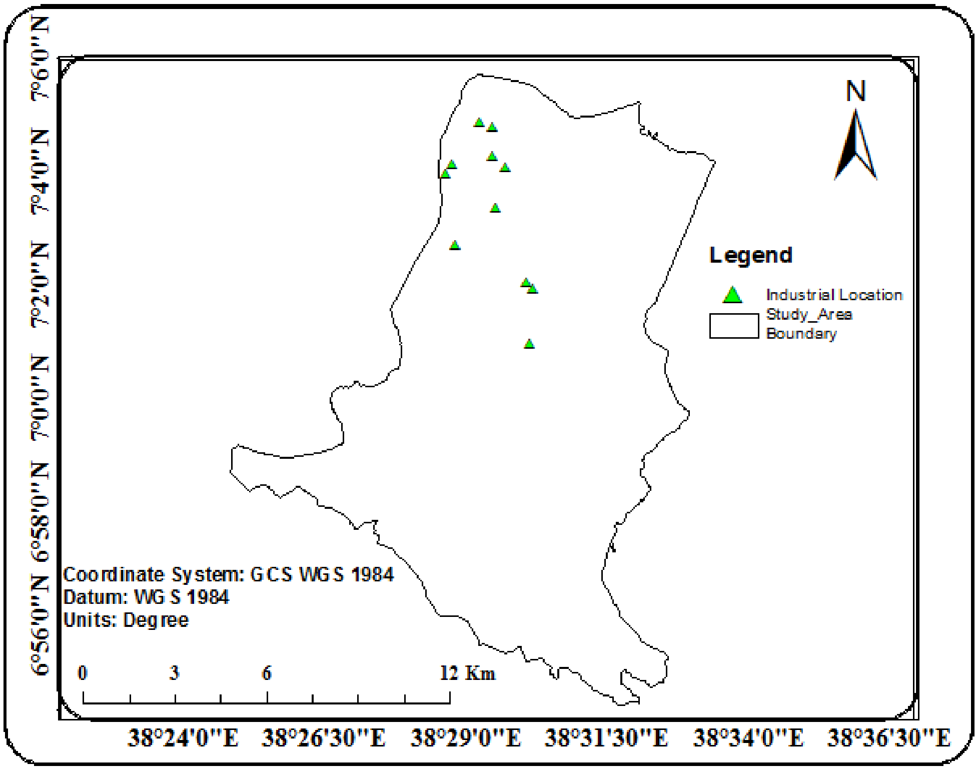

Figure 9: Major industrial distribution in the study area

3.2. Research Methods

3.2.1. Types of data used for this study

Both primary and secondary data were used for the industrial site mapping of the study area, which were obtained from field survey and concerned institutions. The data and materials used include satellite imagery Landsat8), climatic data (rainfall and temperature), Digital Elevation Model (DEM) 30 m resolution data, soil map and industrial data of the study area. Types of data used and their sources are described in Table 2 below.

Table 2: Types of Data Used for this Study

Types of data	Source of data
Land Sat8 image	Google Earth USGS
DEM Data	Google Earth (ASTER)
Rainfall and Temperature Data	National Metrology Agency of Ethiopia(2019)
Study Area boundary shape file data	ArcGIS DIVA
Ground Control Points	Field Survey and Google Earth Pro
Soil Map	Ministry of Agriculture (FAO, 2006)
Industrial related data	Hawassa town Industry Department
Geology data	extracted from Google earth

Source: Compiled by the Researcher, 2019

3.2.2. Software and material applied in this study

Table 3: Software and Material Applied in this Study

Software	The Purpose why they have been applied
ArcMap 10.3.1	Reclassification of factors, weighted overlays, etc.
ERDAS IMAGINE 2015	Land use land cover classification and for accuracy assessment
ENVI 5.3	Land use land cover image classification for accuracy assessment
GPS	For collection of ground control points
IDRIS SELVA 17.0	For pair wise comparison/overweight analysis

Source: Compiled by the Researcher, 2019

3.2.3. Suitability requirements rating for the selected factors

Table 4: Suitability requirements rating for the selected factors in the study area

Parameters	Units	Suitability Range				
		Unsuitable(1)	Less-suitable(2)	Moderately suitable(3)	Suitable(4)	Most suitable(5)
LULC classes	type	Settlement	recreation	Business site	shrub land	Vacant land
Soil type	type	Eutric vertisol	Chromic luvisol	haplic luvisol	Fabric histosol	Eutric fluvisol
Distance from geological fault	meter	0-2000	2001- 4000	4001- 10000	>1000	-
Distance from lake	meter	0-200	201 -500	501-1000	1001-10000	-
Distance from river	meter	0-250	251-500	501- 1000	1001-2000	>2000
Distance from swamp	meter	0-250	251-500	501- 1000	1001-2000	>2000
slope	%	0-6	7-10	11-15	15-20	>2-0
Distance from residential area	meter	0-1000	1001-1500	1501-3000	3001-6000	>6000
Proximity to road	meter	0-300	301-500	501-3000	3001-5000	>5000

Source: Sarath *et al*, 2018, Ebraim *et al*, 2015, Amita Johar 2013, FAO, 2009

3.2.4. Data analysis methods for the study

3.2.4.1. Topographic factors

Slope:

Slope map of the study area was generated from ASTER GLOBAL 30 meter resolution Digital Elevation Model. Then, the slope map was reclassified based on suitability of the slope for industry sites by using spatial analyst tools in Arc GIS. When the degree of slope becomes high, site suitability becomes less. The slope is classified in to five degrees as: 0 - 6%, 6 - 10%, 10 - 15%, and 15 - 20% and >20% and assigned new values as 5, 4, 3, 2, and 1, respectively (Ebrahim *et al*, 2015). Slope based industrial suitability level is described as Most suitable, suitable, moderately suitable, Less suitable and Unsuitable, respectively.

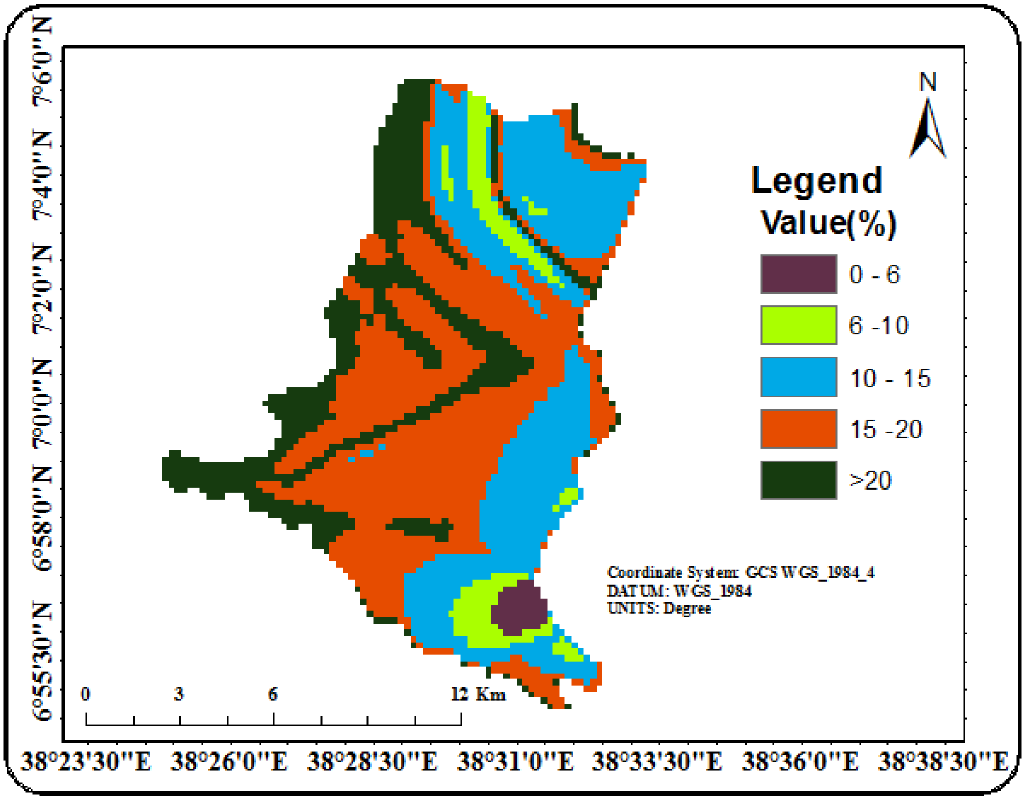

Figure 10: Slope map of the study area

3.2.4.2. Proximity to water bodies related factors

The map which shows proximity of the study area to water bodies such as rivers, lakes and swamps generated from shapefile (FAO, 2006). The generated shapefile map of rivers, lakes and swamps are digitized by Arc GIS 10.3.1. The distance calculation from water bodies and the reclassification processes was also done in ArcMap 10.3.1.

Proximity to lakes

Proximity to lakes map is generated and reclassified in Arc GIS by using ring buffer distance calculation in spatial analyst tools. New values were assigned for regions located within 0 – 200 meter, 201 - 500m, 501 – 1000 m, 1001 – 10000 m, and above 10,000m (Ebraim *et al*, 2015). The study area reclassified as unsuitable, less suitable, moderately suitable and suitable. The reason why most suitable criterion rejected is about its range is out of the study area boundary.

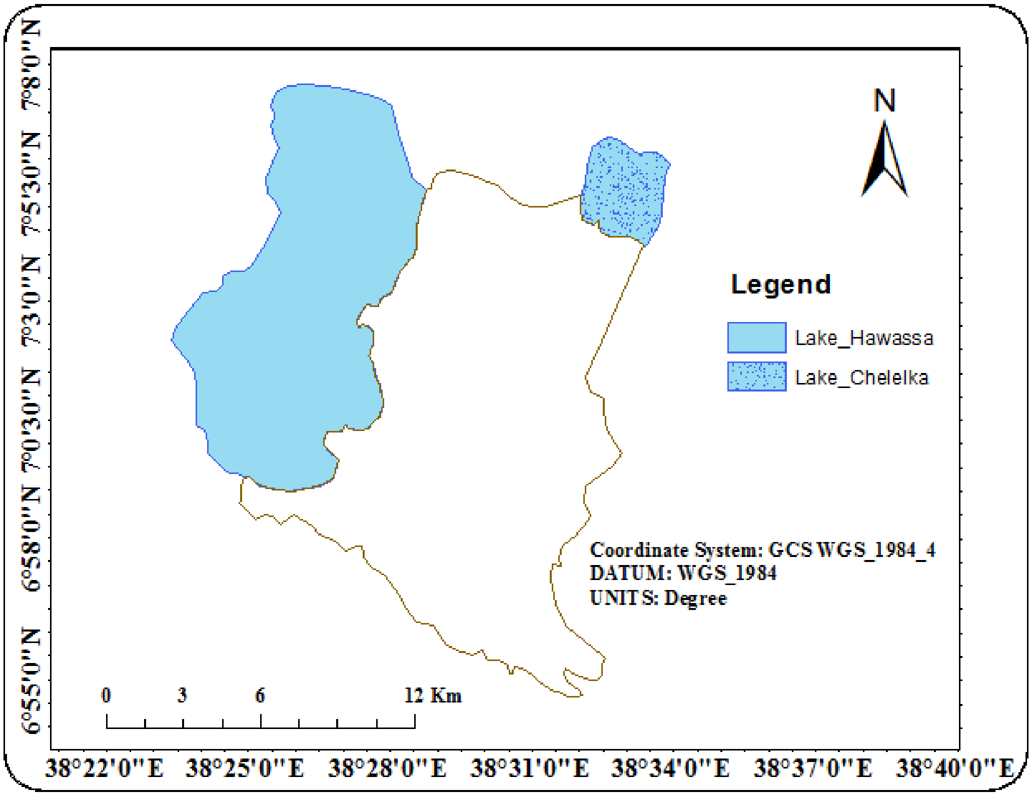

Figure 11: Lake map of the study area

Proximity to rivers

Traditionally, industrial land is located along rivers and canals because of its proximity to inexpensive hydropower (Mark, 2014). Sites overlapping or adjacent to these areas pose greater insurance costs and risk potential flooding, requiring expensive flood mitigation strategies like barriers and retaining walls. Therefore, development within river zones is an unattractive characteristic and considered an industrial location constraint.

The river through Tikur Woha and Wosha River the way to Wondegenet was digitized from Google earth. The map showing proximity to rivers is generated by using ring buffer distance in spatial analyst tools of Arc Map from digitized rivers and canals. The reclassification of rivers map is based on suitability criteria. Areas found 0- 250 m, 250 – 500 m, 500 – 1000 m, 1000 – 2000 m and above 2000 m from rivers. The assigned new values as 1, 2, 3, 4 and 5 and classified as unsuitable, less suitable, moderately suitable, suitable and most suitable, respectively.

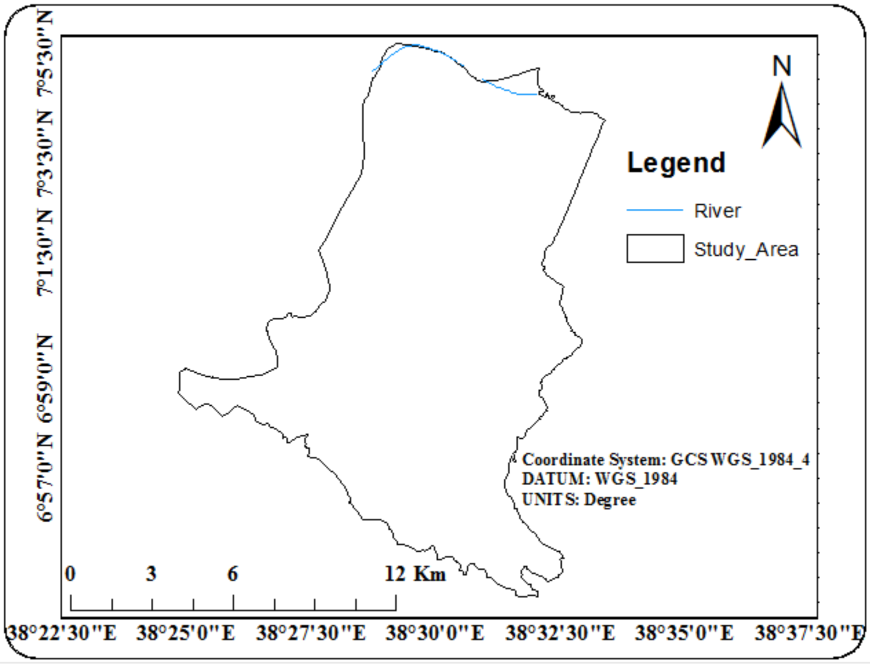

Figure 12: River map of the study area

Proximity to swamps

As it was mentioned above, swamps were digitized from shapefile data obtained from FAO 2006 and the map was generated in ArcMap 10.3.1 environment by using ring buffer distance calculation. The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within 0 – 200 meter, 200 - 500m, 500 – 1000 m, 1000 – 2000 m and above 2000m. The assigned new values were 1, 2, 3, 4 and 5.

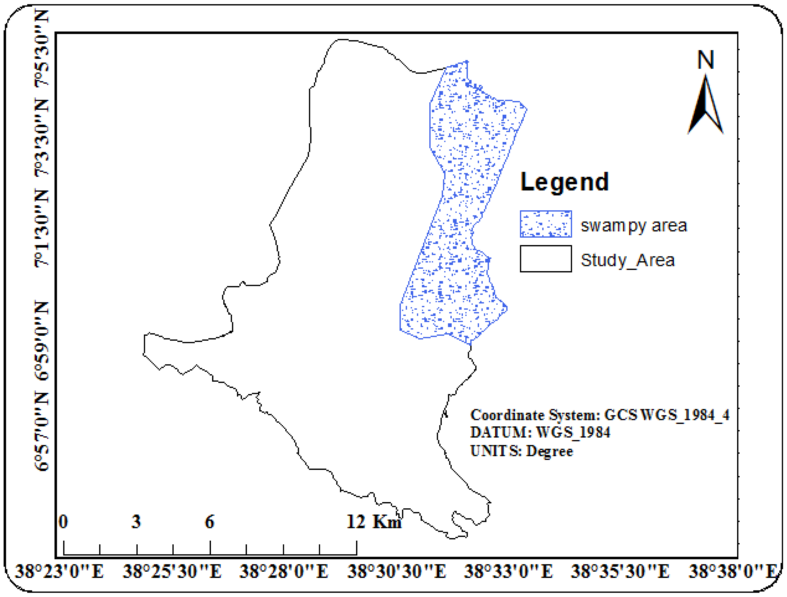

Figure 13: Swamp map of the study area

3.2.5. Land use land cover factor

Land use situation with regard to different environmental effects and the condition of industrial establishment is very important. Forest and farming lands shouldn't change to industrial land use and only a negligible damage to the plant cover can be allowed. Undersigned, in boundary, open space and free lands is preferable (Eldin *etal,* 2013).

The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within forest and water bodies are restricted it does not be represented with value whereas, settlements assigned as new value 1, recreation center as 2, business sites as 3, shrub lands as 4 and vacant land as 5. Then reclassified as unsuitable, less suitable, moderately suitable, suitable and most suitable, respectively.

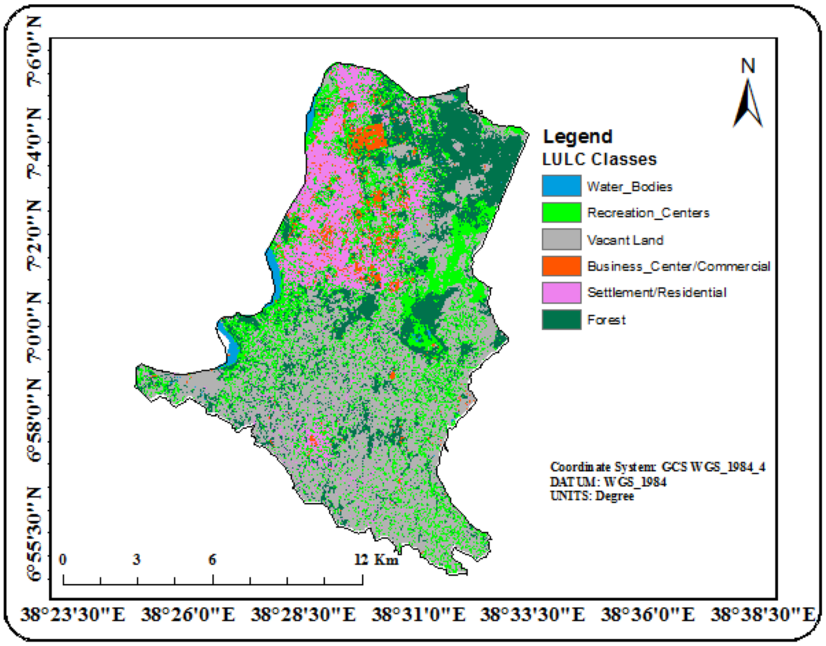

Figure 14: Land use land cover map of the study area

3.2.6. Road network

Roads and other infrastructures that facilitate different cities and regions connection are very important in industrial site selection. According to the data obtained from Ebrahim *et al*, (2015), industries needs transport facility and therefore its establishment should be near to the road. The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within 300 meter as 5, 301 – 500 meter as 4, 501 m – 1000 meter as 3, 1001 - 5000 meter as 2 and above 5000 meter as 1.

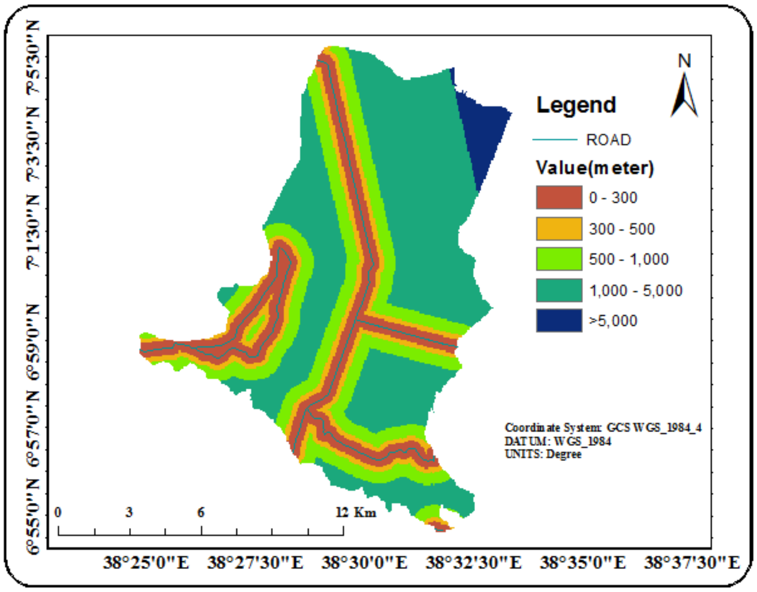

Figure 15: Road network of the study area

3.2.7. Residential area factor

The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within 1000 meter as 1, 1000 – 1500 meter as 2, 1500 m – 3000 meter as 3, 3000 – 6000 meter as 4 and above 6000 meter as 5. Then, the newly reclassified value represented as unsuitable, less suitable, moderately suitable, suitable and most suitable respectively.

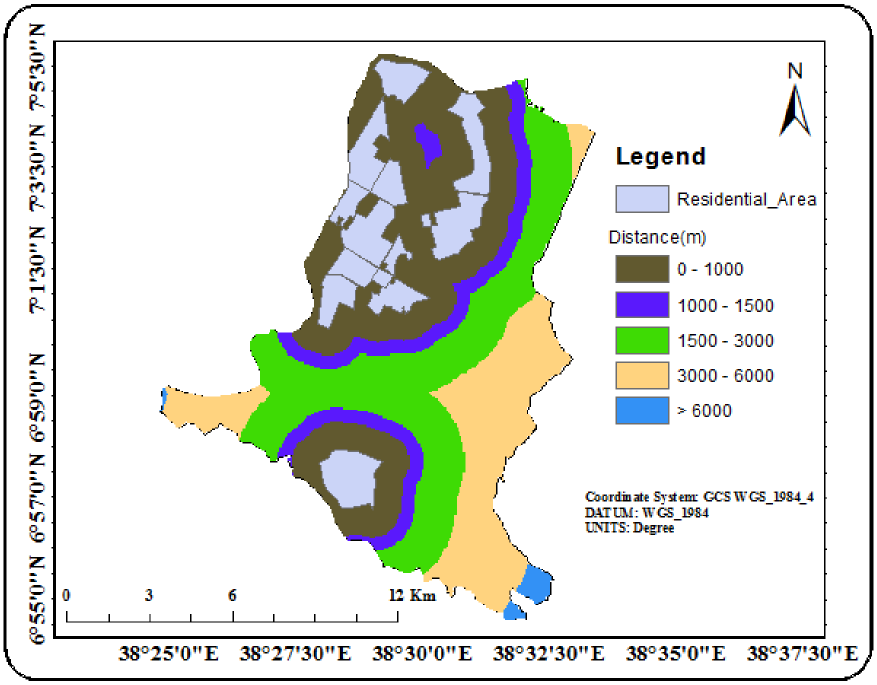

Figure 16: Residential area map of the study area

3.2.8. Geological fault factor

The Awassa town has a volcanic origin. It was formed due to intensive tectonic activity. This tectonic activity is a direct result of the Main Ethiopian Rift valley. The geology of the Awassa area consist of different volcanic deposits such as alkaline and peralkaline rocks Late Miocene, Basaltic lava flows from Pleistocene to recent, Acidic volcanics from Pleistocene to recent, and Volcano clastic lacustrine sediments from Pleistocene to recent (Alemayehu A, 2008).

Distance to geological fault is one of the hindering factors for industrial site selection. The more far away from this event is the better. The map of fault distribution was constructed from geological maps. The geological fault zones of the study area were digitized from Google Earth pro and converted to the shapefile data format in order to undertake further analysis.

The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within 2,000 meter as 1, 2,001 – 4,000 meter as 2, 4001 m – 10,000 meter as 4, and above 10,000 meter as 5. Then, the newly reclassified value represented as unsuitable, less suitable, suitable and most suitable respectively.

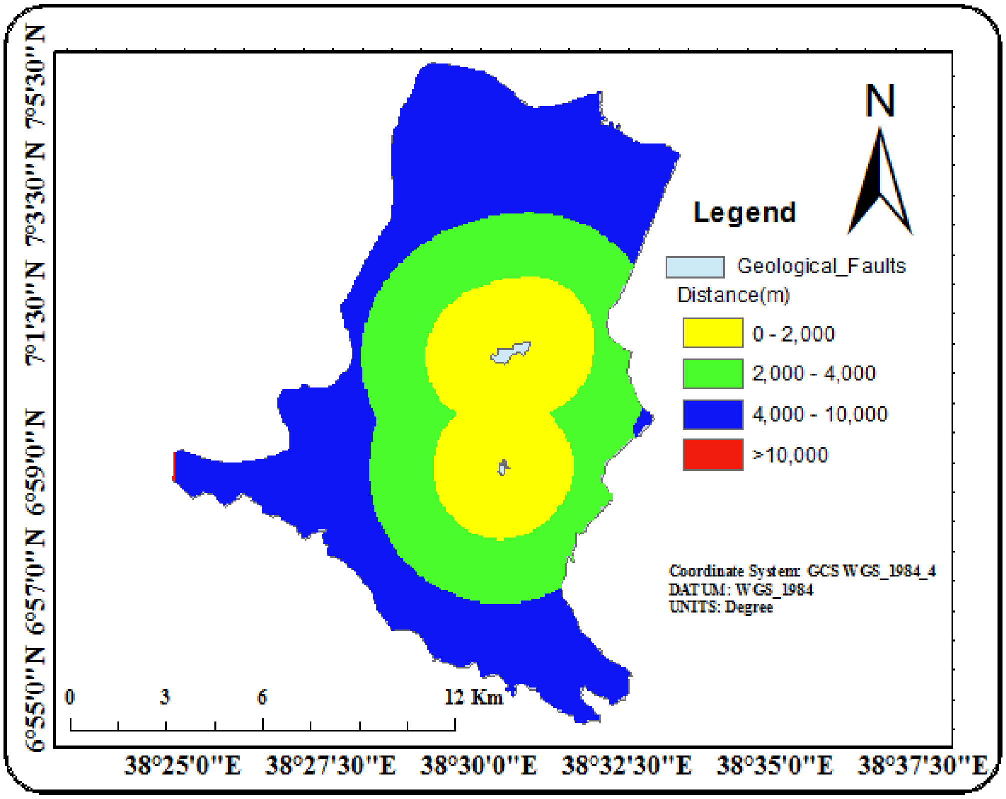

Figure 17: Map of distance from geological fault of the study area

3.2.9. Soil factor

According to Anurag Ohri *et al* (2010), those soils with clay, alluvial and loam deposits are suitable for industrial establishment, whereas soils with cracking, swelling and porous are not suitable for industrial establishment.

The reclassification was done on the basis of industrial site selection criteria. New values were assigned for regions located within eutric vertisol as 1, chromic luvisol as 2, haplic luvisol as 3, and fabric histosol as 4 and eutric fluvisol as 5. Then, the newly reclassified value represented as unsuitable, less suitable, moderately suitable, suitable and most suitable respectively.

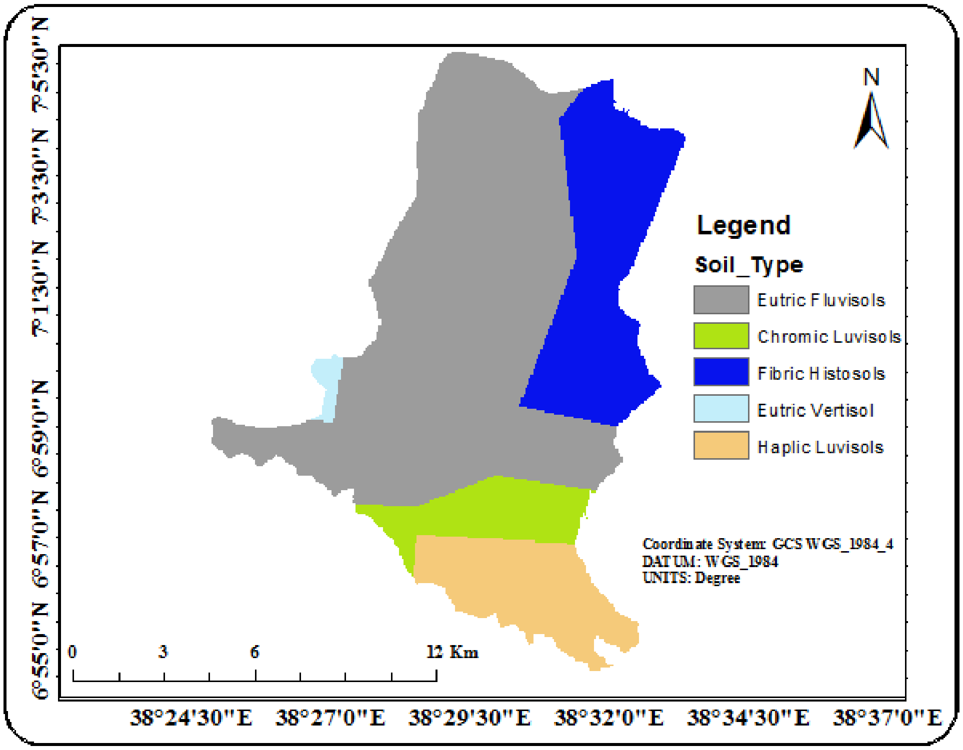

Figure 18: soil type map of the study area

3.2.10. Interview and discussion

The primary data collection was accomplished by using an interview and discussion which is one of the important social research methodologies. The discussions were held with experts of manufacturing site evaluation and implementation core work process teams in identifying industrial site selection criteria and finding out the buffer distance that the site should be separated from relevant geographic features.

Direct and indirect unstructured interviews were conducted with the experts during the field survey to gather more information. The information derived from this study was used to identify and develop priority criteria and factors for the selection of industrial site. It was also used to identify problem in the study area and prioritize the potential industrial sites in the study area. Additional discussions were made particularly with those experts, who are involved in the urban land preparation of Hawassa town, in order to acquire some appreciation of the study area. In particular, the following experts working at the town Industrial and Enterprise department, Housing and Urban Development Department and finally with Regional Bureau Industry experts discussion were held. Those who were involved in the discussion were interviewed: Ato Matusala Semaye, Yaregal Debebe, Sileshi Getahun and Walelign Awashe.

3.2.11. Multi-Criteria Decision Making (MCDM)

This research study was mainly used spatial Multi-Criteria Decision Making (MCDM) approach integrated with Geographic Information System (GIS) techniques in order to determine suitable site for industry. Spatial multi-criteria decision making is a process that combines and transforms geographical data into a decision (Malczewski, 1999).

MCDM, combined with GIS data, is a powerful approach to systematically and comprehensively analyze a problem. The fundamental components of a multi-criteria problem are human value judgment and assessments of the importance of criteria. The main purpose of the multi-criteria evaluation techniques is to investigate a number of alternatives in the light of multiple criteria and conflicting objectives (Voogd, 1983).

To combine and determine the importance of each factor, multi-criteria decision making method was applied.

3.2.12. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a widely used method in MCDM and was introduced by Saaty (Saaty, 1980). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives. AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment (Table5). This scale consists of nine points. In general, nine objects are the most which an individual can simultaneously compare and consistently rank.

The score of differential scoring assumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7 have been used where the row criterion is less important than the column criterion. To ensure the credibility of the relative significance used, AHP also provides measures to determine inconsistency of judgments mathematically. Based on the properties of reciprocal matrices, the consistency ratio (CR) can be calculated. CR < 0.1 indicates that level of consistency in the pair wise comparison is acceptable. Saaty (1980) suggests that if CR is smaller than 0.10, then the degree of consistency is fairly acceptable. But if it is larger than 0.10, then there are inconsistencies in the evaluation process, and AHP method may not yield meaningful results.

Table 5: The preference scale for pair wise comparison in AHP

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

Source: Adopted from Saaty, 1980

3.3. Over All Workflow of the study

The main objective of this project work is to generate suitable maps for Industrial sites of Hawassa town based on desired factors. These environmental factors were selected depending on previous research works and by collecting information from experts of the industrial department of the town. According to this slope, soil, land use land cove type and proximity to water bodies, distance from road, distance from residential, distance from geological faults and soil types are selected as major factors for selecting suitable sites for industries.

For each environmental factors mentioned above, maps were generated and then reclassified depending on their suitability for industrial sites. In the process of reclassification, new values 1, 2, 3, 4 and 5 were assigned and they represent unsuitable, Less suitable, moderately suitable, suitable and most suitable respectively. Finally, weighted overlay carried out using ArcMap 10.3.1 to generate the final industrial map of the study area.

The overall work flow used to accomplish the study was presented in the figure (20) below:

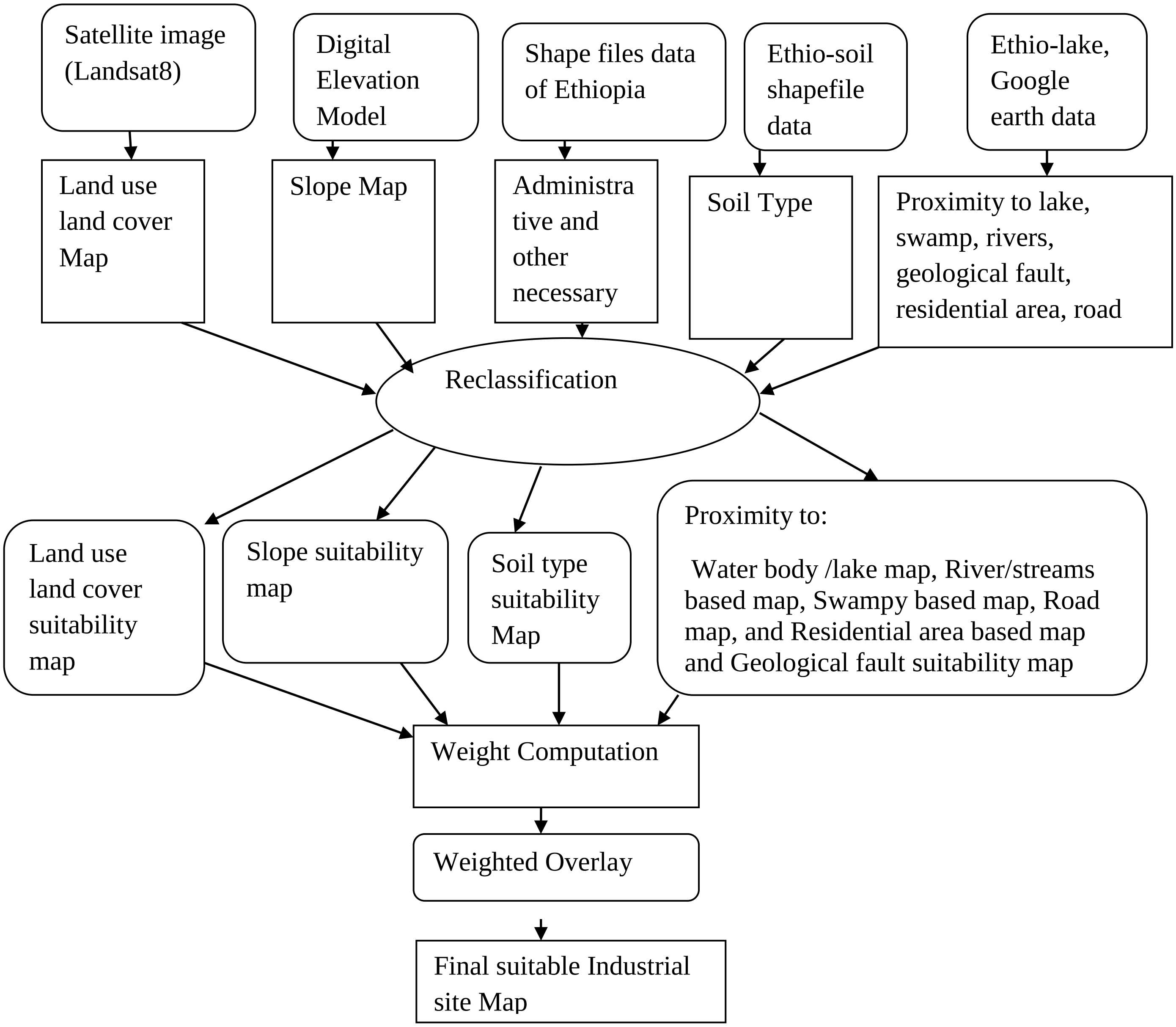

Figure 19: Over all workflow of the study

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

Under the data analysis, discussion and presentation part, those questions raised in chapter one were deeply analyzed, discussed and presented by data collected from different sources; reports of the industry and enterprise respective sectors and housing and urban development office of the Hawassa town administration.

The following factors were deeply discussed in this part. These are: Land use land cover types, distance from geological faults, distance from main roads, soil types, and distance from residential areas, distance from water bodies (lake, swamp and river/stream), slope and elevation.

4.1.Relationship between Topographic Factors and Industrial Sites

4.1.1. Relation of slope and industrial sites

Topographical features are key factors in building and output flows. Because of land use, water flowing, drainage and latex infiltration to underground water tables this factor was considered as important. Plain areas have especial importance because of lesser costs during site preparation. Slope is an important criterion in hilly terrain for finding suitable sites for urban development. Steep slopes are disadvantageous for construction, increase construction costs, limit maximum floor areas and contribute to erosion during construction and subsequent use.

In this study slope factor was generated from the Digital Elevation Model (DEM) using the ArcGIS 10.3.1 spatial analyst extension of surface module, which enabled to classify the area according to the steepness and the gentleness of the terrain. Every cell in the output raster had a slope value. The lower the slope value, the flatter the terrain was and the higher the slope value the steeper was the terrain. Then the slope raster was reclassified in to five classes of slope percent by examining the value and the frequency of slope percent in the study area table 6)

The reclassified slope was given a rank value 1 to 5 with the higher value of 5 showing high influence, i.e. highly suitable, while the lower value of 1 showing low influence, least suitable. According to Ebrahim *et al*, 2015, slope with degree ranges from 0-6 considered as level slope, 6-10 degree as gentle, 10 -15 degree as strong sloppy, 15- 20 degree as moderately steep slope and > 20 degree slope as considered as steep slope). As indicated in the figure 21 below, most of (68.6%) the study area has gentle slope and 3.2% has a moderately steep slope

Table 6: Reclassified Slope Value and Suitability Level

Slope in Degree	Rank	Area (km^2)	Area (%)	Suitability Level
>20	1	9.8	6.2	Unsuitable
15 - 20	2	5.1	3.2	Less suitable
10 - 15	3	11.7	7.4	Moderately Suitable
6 – 10	4	23	14.6	Suitable
0 - 6	5	108.2	68.6	Most Suitable
Total		157.7	100	

Source: Extracted from Reclassified Slope, 2019

The less the slope amount, the more suitable will be the area for the industry. Based on the suitability of the slope for industrial sites, the reclassified slope map shows 108.2 km² (68.6 %) area is most suitable, 23 km² (14.6%) is suitable, 11.7 km² (7.4%) is moderately suitable, 5.1 km² (3.2%) is less suitable and 9.8 km² (6.2%) unsuitable for industrial location.

From the total area of the study, majority of the slope initiates public and private investors to participate on industrial sectors in which Plain areas have especial importance because of lesser costs during site preparation.

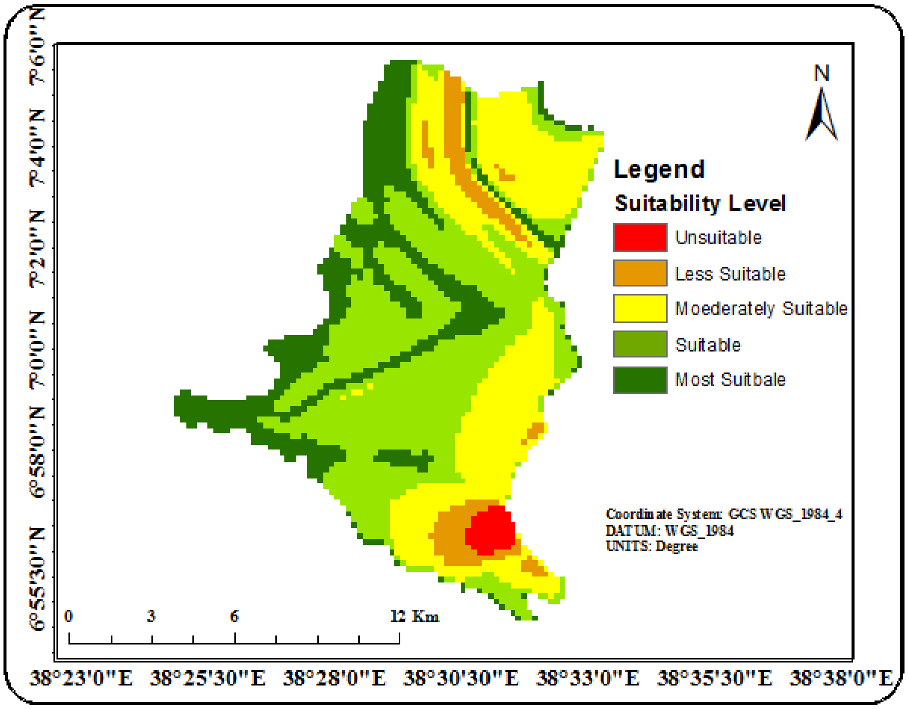

Figure 20: Suitability map of slope

4.2.Proximity to Water Bodies and Industrial Locations

4.2.1. Proximity to Lake

Water accessibility is one of the main affecting factors for industrial site selections. Industry must be located at some safe distance from water bodies. Water bodies and areas within 1000 meter are considered unsuitable for an industrial establishment. Waste water from industry is one of the major sources of pollution in river distance of at least 1000m (Jain, 2008). According to Ebrahim et al (2015), land suitability for industrial location within proximity to lake as follows:

Table 7: Reclassified Proximity to water bodies and Suitability Level

Distance from Lake (m)	Rank	Area (km^2)	Area (%)	Suitability Level
0 - 200	1	6.8	4.3	Unsuitable
200 - 500	2	8.1	5.2	Less suitable
500 - 1000	3	21.3	13.5	Moderately Suitable
1000 - 10000	4	121.2	76.8	Suitable
total		157.7	100	

Source: Extracted from Reclassified Water Body, 2019

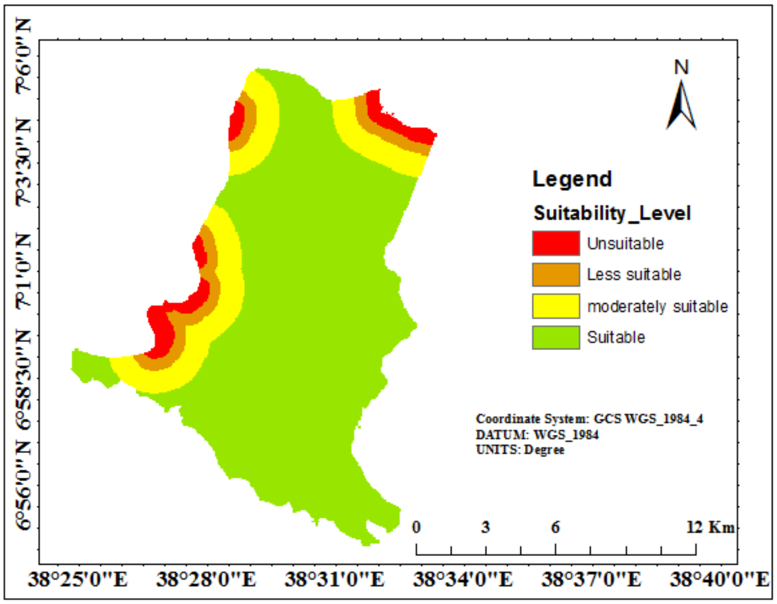

Figure 21: Lake suitability map of the study area

The proximity to water bodies map is the result of overlaid proximity to Lake Hawassa and Chelelka maps. As indicated in the figure below, 6.8 km2 of the total area is within 200 meter of the water bodies, 8.1km^2 is found between 200 meter up to 500 meter, 21.3km^2 is found between 500 meter up to 1000 meter, and the remaining 121.2km^2 found beyond 10000 meter. This implies that most parts (76.8%) of the study area are suitable, 13.5% is moderately suitable, 5.2% is less suitable, and 4.3 % is unsuitable for industrial location.

4.2.2. Proximity to river

Both stream flow of the Wosha and Tikur Woha River which found in North Eastern part of the study area were taken as the base line to measure the proximity. During rainy season, runoff would be high and that could disturb if there is industry near at those stream flow area. According to Amita Johar (2013), land suitability for industrial location within proximity to river as follows: those areas up to 500 meter far from the river are unsuitable, 501 meter -1000 meter are less suitable, 1001 meter - 3000 meter are moderately suitable, 3001 meter up to 5000 meter are suitable and above 5000 meter are most suitable to establish industry.

Table 8: Reclassified Proximity to River and Suitability Level

Distance from River (m)	Rank	Suitability Level
0 - 250	1	Unsuitable
251 - 500	2	Less suitable
501 - 1000	3	Moderately Suitable
1001 - 2000	4	Suitable
>2000	5	Most Suitable

Source: Extracted from Reclassified River Value, 2019

As indicated in the figure (23) below, majority of the study area which is suitable to settle industry is 2000 meter far from the river. Those areas which are within 1000 meter from the river are not suitable for industrial location. The reclassified map of distance to rivers indicates that most suitable sites for industrial establishment cover 86.5 km² (54.8%). The remaining 27.7km² (17.5%) is suitable, 29.8 km² (18.9%) is moderately suitable, 5.9 km² (3.7%) is less suitable and 5.4 km² (3.3%) is unsuitable to locate industries in the study area.

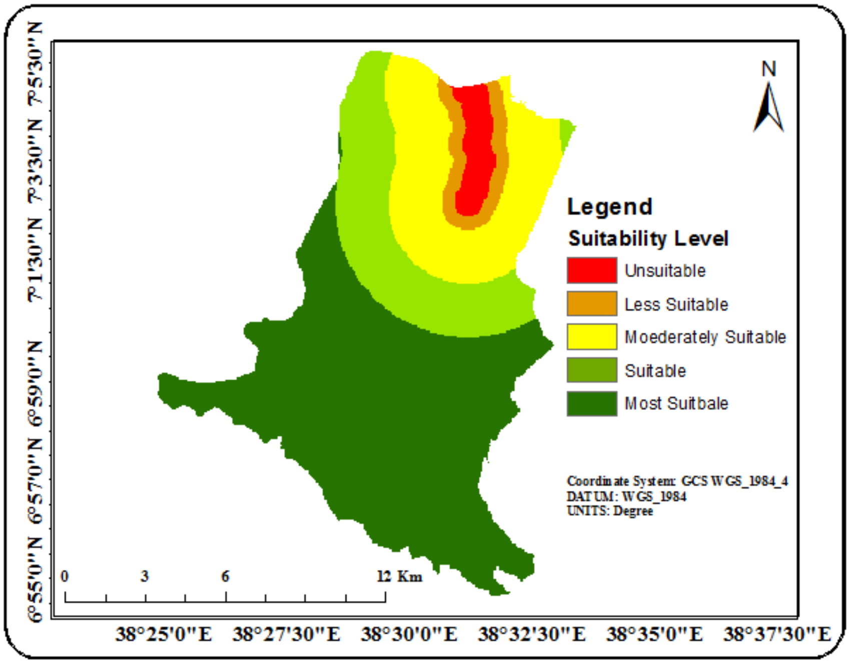

Figure 22: River suitability map of the study area

4.2.3. Proximity to Swamps

Cheleleka Swamp which found on the way to Wendogenet gradually transformed in to a swamp around 1970 is fed with around 11 perennial rivers emerging from the eastern highlands. A few decades ago, Lake Cheleleka was the second lake in the area located about five kilometers to the east of Awassa. This lake was about 11 km long and 6 km wide, but disappeared decades ago (Ayenew, 2004; Hengsdijk and Jansen, 2006; Ayenew, 2007; Dessie and Kleman, 2007). The former Lake Cheleleka is now a swampy area. Swampy areas are not suitable to establish industry in a given area because they have a reputation for being unproductive land that cannot easily be utilized for human activities, other than perhaps hunting and trapping.

According to Amita Johar (2013), land suitability for industrial location within proximity to swamps as follows:

Table 9: Reclassified Proximity to Swamp and Suitability Level

Distance from Swamp (m)	Rank	Suitability Level
0 - 250	1	Unsuitable
250 - 500	2	Less suitable
500 - 1000	3	Moderately Suitable
1000 - 2000	4	Suitable
>2000	5	Most Suitable

Source: Extracted from Reclassified Swamp Value, 2019

Based on the proximity to swamps, the majority of study area is most suitable for industrial location. As described in the table below, 94.5 km^2 (60%) of the total area is most suitable and 34.7 km^2 (22%) is unsuitable to locate industry in the study area. Besides that, 3.7km^2 (2.3%) less suitable, 7.7km^2 (4.88%) is moderately suitable and 16.6km^2 (10.5%) is suitable to locate industries in the study area. Figure (24) below portrays proximity to swamps based industrial site selection.

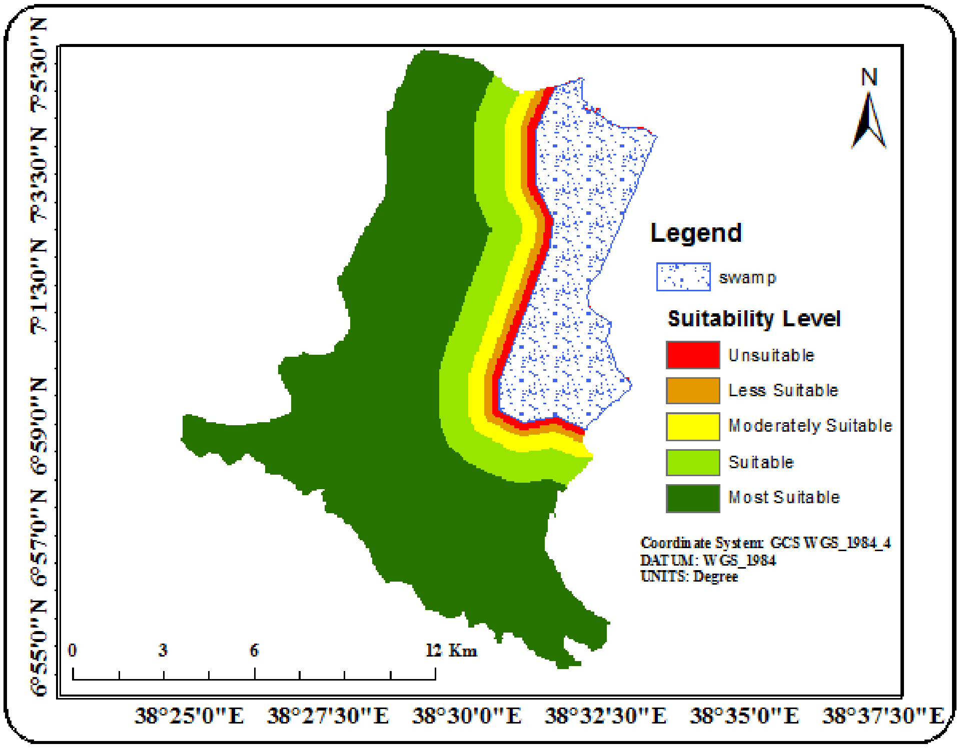

Figure 23: Swamp suitability map of the study area

4.3.Land Use Land Cover Maps

Land use classification is the process of categorizing the data based on their data file values. If pixels fulfill a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion. In this study, the existing land use map was extracted from Google Earth USGS LandSat8, 2019.

Based on the supervised classification done for the satellite image, the study area has seven major land use land cover types, such as recreational center, shrub lands, water body, vacant land, forest coverage, commercial or business centers and residential/settlements. Mixed type of land use is dominant, especially residential development mixed with commercial and other activities which are common in the central parts of the study area. In general, the majority (65.7

km^2) of land use land cover map of the study area was vacant land since newly desired master plan of the town incorporates the surroundings of Sidama zone and 32.2km^2 of the total area is residential/settlements and 30.6 km^2 of the total area is shrub lands and 17.7km^2 is about forest coverage. On the other hand, a small portion of the study area was covered by water bodies, recreational centers and business activities.

4.3.1. Accuracy assessment matrix and proportion of mapped area

Based on accuracy assessment done for land use land cover map, the overall classification accuracy is 85.6% and an overall kappa statistics is 0.7941. The kappa coefficient shows that 79.41% errors were avoided that could be generated by simple random classification. According to Landis and Koch (as cited in Cunningham, 2009), the values of kappa can ranges from +1 to 1. The agreement between the remotely sensed classification and the reference data is poor when the kappa value is < 0, slight between 0 - 0.2, fair 0.21 - 0.4, moderate between 0.41 - 0.6, substantial 0.61 - 0.8 and almost perfect from 0.81 to 1.Thus, the kappa coefficient of **0.7941** is in almost perfect agreement range. The producers and users accuracy of the classification ranges between 73.2% - 98.3% and 76.4% - 94% respectively. Table (11) below shows the classification accuracy assessment of land use land cover map.

Table 10: Accuracy Assessment Matrix

LULC	**Settlement**	**Business**	**Recreation**	**Vacant**	**shrub**	**forest**	**water**	**Total**	**Wi %**
Settlement	18	1	0	2	3	0	0	24	0.2
Business	2	13	0	1	0	1	0	17	0.03
Recreation	0	0	7	0	1	0	1	9	0.03
Vacant	1	0	0	115	2	0	0	118	0.4
shrub	0	0	1	0	20	1	0	22	0.2
forest	4	0	0	1	2	40	0	47	0.11
water	0	0	0	0	0	1	2	3	0.02
Total	25	14	8	119	28	43	3	240	1

Source: Compiled by the Researcher, 2019

4.3.2. Error matrix of the estimated area proportion

The proportion of mapped area (wi) is calculated as the ratio of mapped area to the total area of the study area. Eg: - The proportion of forest mapped area: 17.75/157.7 = 0.11

An error matrix can be reported in terms of sample counts. However, error matrix is usually expressed in terms of (the unbiased estimator) estimated area proportion rather than in terms of sample counts. After this the area of each land use/cover class is estimated based on the reference classification, which can be calculated using the equation proposed by Olofsson et al. (2013) as follows:

Pij = wi*nij/ni, i denotes the rows and j denotes column

Where, wi: (the proportion of area mapped as land use class *i* that means mi/mt);

mi: is the mapped area of land use class *i*, mt: is the total area of the map, *nij:* is the cell value at row *i* and columun *j*; ni.: is the total sample count of land use class i(total number of samples for the mapped category but not for the reference category).

For example: e.g: for Forest. Wi=17.7(Mapped area for forest/157.7(total area of the study area) = 0.11; nij=40; ni.=47 pij= 0.13*40/47= 0.1 as stated in the table (11) below.

Table 11: Error Matrix of the Estimated Area Proportion

LULC	**Settlement**	**Business**	**Recreation**	**Vacant**	**shrub**	**forest**	**water**	**Total**	**Mapped Area**	**Producer**	**User**
Settlement	0.15	0.008	0	0.002	0.025	0	0	0.17	32.14	0.937	0.88
Business	0.0035	0.024	0	0.002	0	0.002	0	0.03	3.6	0.75	0.8
Recreation	0	0	0.022	0	0.003	0	0.003	0.026	4.06	0.733	0.846
Vacant	0.003	0	0	0.4	0.007	0	0	0.42	65.5	0.983	0.95
shrub	0	0	0.008	0	0.18	0.008	0	0.19	31.2	0.818	0.947
forest	0.1	0	0	0.03	0.005	0.11	0	0.13	17.7	0.846	0.846
water	0	0	0	0	0	0.01	0.026	0.034	3.5	0.896	0.764
Total	0.166	0.032	0.03	0.407	0.22	0.13	0.029		157.7		

Overall Accuracy: 0.856

Overall Kappa Statistics = 0.7941

Source: Compiled by the Researcher, 2019

Estimated Land Use Land Cover and confidence interval

Confidence interval for the estimated area of each land use class should be estimated after the standard error of each land use class is calculated. The estimated standard error (SE) of the estimated area proportion (the column total) of each land use class is estimated as Olofsson et al. (2013):

$$SE(pj) = \sqrt{\sum_{i=1}^{n} wi^2 \frac{\frac{nij}{ni.}\left(1 - \frac{nij}{ni.}\right)}{ni. - 1}}$$

pj refers to land use class j (based on reference class). The standard error for the error adjusted estimated area of each land use class is calculated as the product of the proportion area of a given class and the total map area.

Table 12: Estimated Land Use Land Cover and confidence interval

Classes	Proportion area	SE	SE of adjusted area (km^2)	"Z" Value	Interval	Confidence interval (km^2)	
						Lower limit	Upper limit
Settlement	0.166	0.02	3.2	1.96	6.3	19.9	32.5
Business	0.032	0.009	1.4	1.96	2.7	1.8	7.2
Recreation	0.03	0.0099	1.6	1.96	3.1	1.6	7.8
Vacant	0.407	0.012	1.9	1.96	3.7	61.1	68.5
shrub	0.22	0.02	3.2	1.96	6.3	28.4	41
forest	0.13	0.01	1.6	1.96	3.1	17.2	23.4
water	0.029	0.007	1.1	1.96	2.2	2.4	6.8

Source: Compiled by the Researcher, 2019

Table 13: Area estimates of each land use class based on reference data (Km^2)

Land use land cover class	Estimated	Mapped
Forest	28.18	17.75
Vacant/open land	4.5	65.74
recreational Center	4.7	4.06
Residential area/settlement	64.8	32.14
commercial site/business	34.7	3.59
water body	20.3	3.2
shrub land	4.6	30.6
Total	157.7	157.7

Source: Compiled by the Researcher, 2019

Figure (25) below shows land use land cover based industrial site suitability. According Amit Johar 2013, water bodies, swamps, forest coverage and residential areas are not suitable for industrial establishment. Whereas areas like open spaces, vacant lands, range lands area suitable for industrial site location.

Table 14: Land Use Land Cover Classes and Suitability Level

LULC Classes	Rank	Suitability level	Area(km$^{2)}$	Area (%)
Vacant Land	5	Most suitable	65.6	41.6
Shrub land	4	Suitable	30.5	19.3
Business site	3	Moderately suitable	3.6	2.23
Recreation site	2	Less Suitable	4	2.5
Settlement	1	Unsuitable	32.2	20.5
Forest and water body	-	Restricted	22.05	13.98
Total			157.7	100

Source: Compiled by the Researcher, 2019

From the total area, the reclassified map in the table above shows that 32.2 km^2 (20.5%) is unsuitable, 30.5km$_2$ (19.3%) leveled as less suitable for industrial location, 3.52km^2 (2.23%) is moderately suitable, 4km^2 (2.5%) as suitable and 65.6km^2 (41.6%) leveled as most suitable. From the total area, 22.05 km^2 (13.98%) are forest and water bodies were assigned zero weights (restricted), hence these sites are not considered for industrial development.

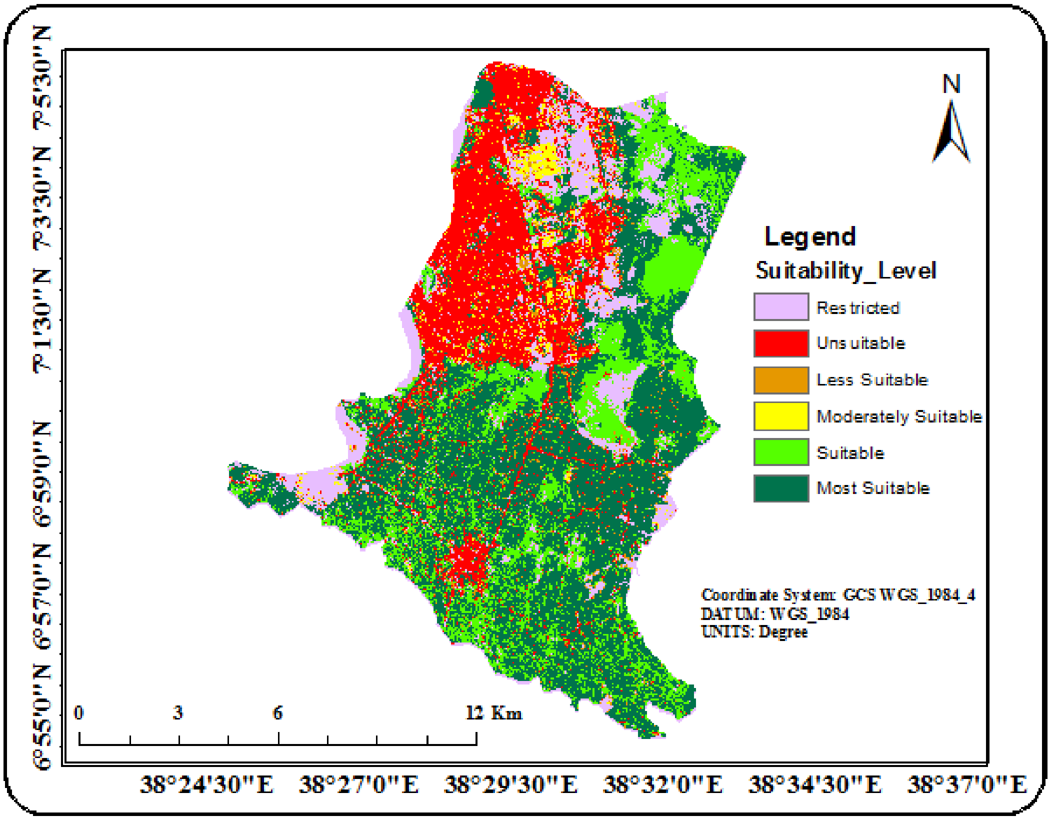

Figure 24: Land use land cover suitability map of the study area

4.4.Distance from the Road and Industrial Location

Road is also an important criterion in site suitability analysis. The need to transport raw materials, processed materials and other important things, carcasses, are dependent on the proximity to transportation facility. In order to find out better accessibility to the existing road, buffer zones have been created by taking distances from 0 to 300 meter from the existing major roads to generate suitable accessibility map. Then the buffer distance zones have been categorized into five levels based on the level of proximity to industry site. Accordingly, the low buffer distance ranked as highly suitable whereas the longer buffer distances ranked as least suitable. Thus, the rank value of 5 was given for highly suitable road buffers and the rank value 1 was given for unsuitable road buffers.

As indicated in the table (15) below, road distance in meter and its suitability level used for this research study.

Table 15: Road Distance and Suitability Level

Access to road (in meter)	Rank	Suitability level	Area in km^2	Area in %
0-300	5	Most suitable	26.6	16.8
301-500	4	Suitable	15.2	9.6
501-1000	3	Moderately suitable	32.3	20.4
1001 - 5000	2	Less Suitable	76.4	48.4
>5000	1	Unsuitable	4.8	3.04
Total			157.7	100

Source: Compiled by the Researcher, 2019

From the total area, about 26.6 km^2 (16.8%) is most suitable for industrial sites and only 4.8km^2 (3.04%) is unsuitable for the industrial establishment. About 76.4km^2 (48.4%) of the study area is less suitable to settle industry, which is related transport accessibility. As newly proposed structural plan of the town stretched to the fringe of Sidama Zone, it requires road construction in the future. The figure (26) below: road suitability map of the study area.

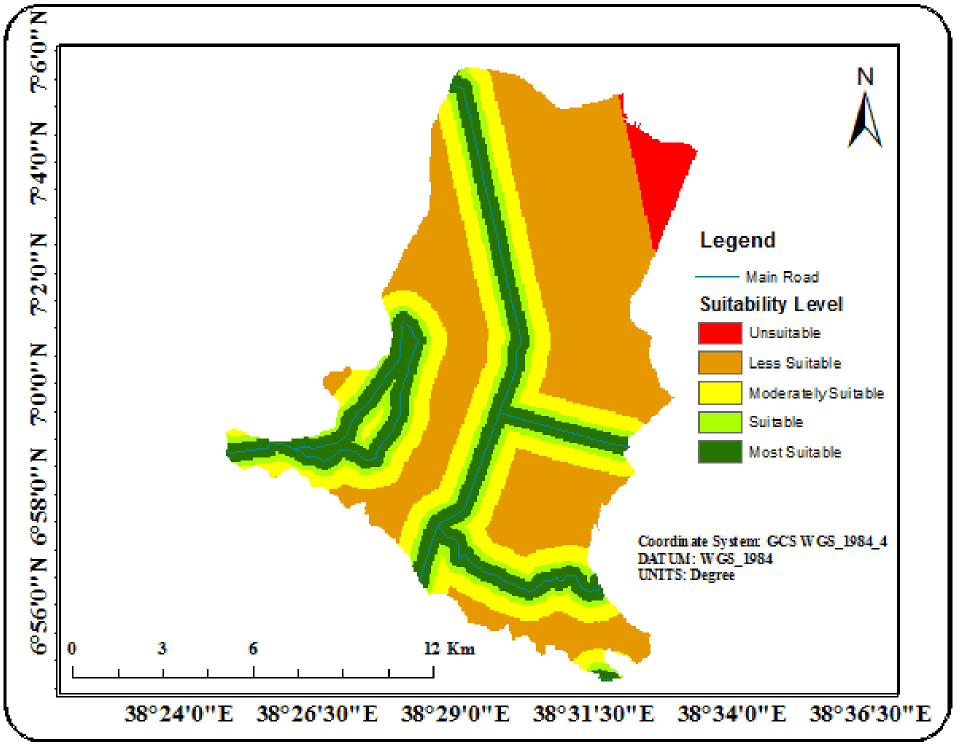

Figure 25: Road suitability map of the study area

4.5.Distance from the Residential Area and Industrial Location

A logical distance should be selected between residential areas and industrial sites. A buffer should be defined as well. These areas are barriers for industries development. The more distance from industrial areas the higher suitability and consistency will be.

According to the data obtained from Ebrahim *et al* (2015), industries needs to be established far from the residential areas. These areas are barriers for industries development. The more distance from industrial areas, the higher suitability and consistency will be. As indicated in the table (16) below, residential areas proximity to industrial sites was described for this research study.

Table 16: Residential Area Suitability

Distance from residential areas	Rank	Suitability Level	Area in Krm^2	Area in %
0-1000	1	Unsuitable	70.03	44.4
1000-1500	2	Less Suitable	14.5	9.2
1500-3000	3	Moderately Suitable	40.5	25.7
3000 - 6000	4	Suitable	30.4	19.3
>6000	5	Most Suitable	2.07	1.4
Total			157.7	100

Source: Compiled by the Researcher, 2019

The buffer distance zones have been categorized into five levels based on the level of distance from residential areas. Accordingly, the low buffer distance ranked as unsuitable whereas the longer buffer distances ranked as most suitable. Thus, the rank value of 5 was given for highly suitable road buffers and the rank value 1 was given for unsuitable road buffers.

As indicated in the table above, from the total area 70.03km^2 (44.4%) is unsuitable as the area occupied by the residents of the town and only 2.07km^2 (1.4%) is most suitable for industrial site selection. And also, 40.5km^2 (25.7%) is moderately, 40.2km^2 (19.3%) is suitable and 14.5km^2 (9.2%) is less suitable for the site selection of the industry. Figure (28) below portrays residential area suitability for the industrial site selection.

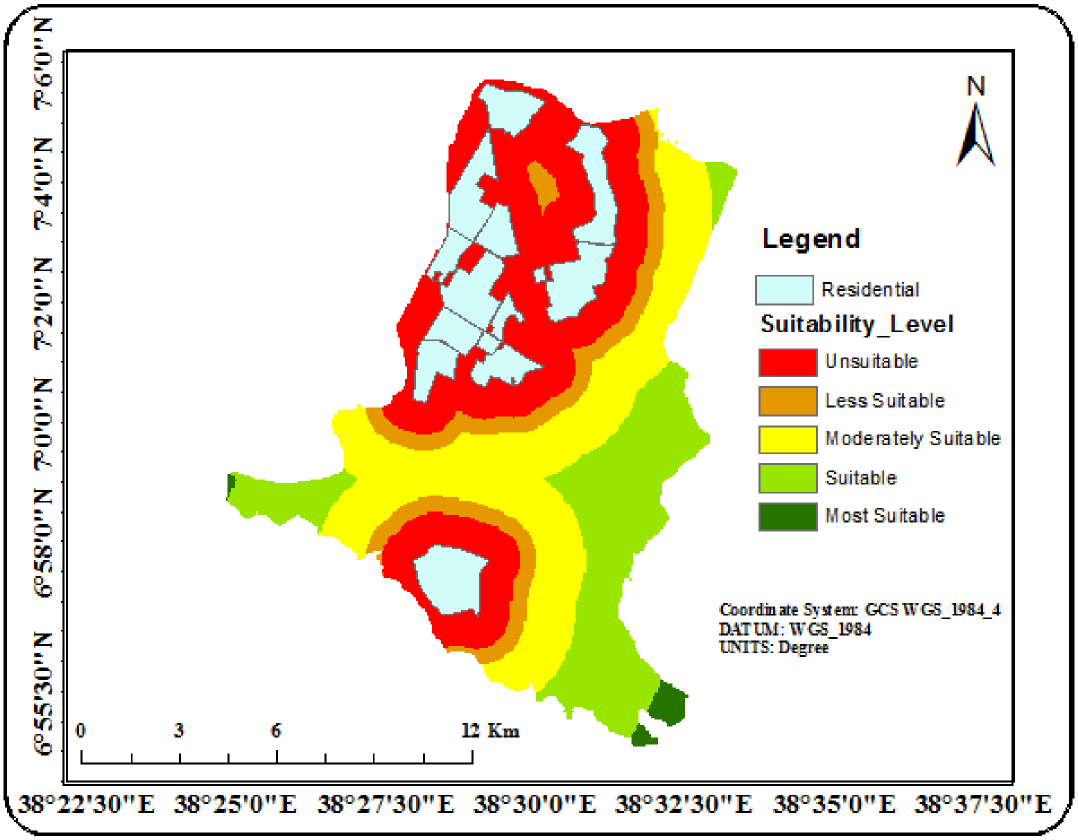

Figure 26: Residential area suitability map

4.6.Distance from Geological Fault and Industrial Location

Geology was considered as it plays an important in the suitability decision of sites for industries. Strength of the rock and absence of fault zones will make the site suitable at the first place. Without this consideration, it is difficult to go forward in the process of site selection at any cost. Seismology and faults are very important in the development planning. The fracture resulted from geological faults will affect neighborhood sediments and rocks. Regarding legal buffer from fault lines and avoiding industrial developments in such areas are considerable factors in the industrial site selection.

Faults are one of the geological phenomena that cause problem for industrial buildings and infrastructure construction. Industries should be 2000 m away from faults. The area that are within 2000 meter are unsuitable, 2001 – 4000 meter are less suitable, 4001 – 10000 meter are suitable, and area >10000 meter are most suitable to establish industries (Marzieh et al, 2011).

Table 17: Geological Fault Suitability

Distance from residential areas	Rank	Suitability Level	Area in Krm^2	Area in %
0 - 2000	1	Unsuitable	32.4	20.5
2000-4000	2	Less Suitable	50.1	31.7
4000-10000	4	Suitable	74.9	47.5
>10000	5	Most Suitable	0.3	0.2
Total			157.7	100

Source: Compiled by the Researcher, 2019

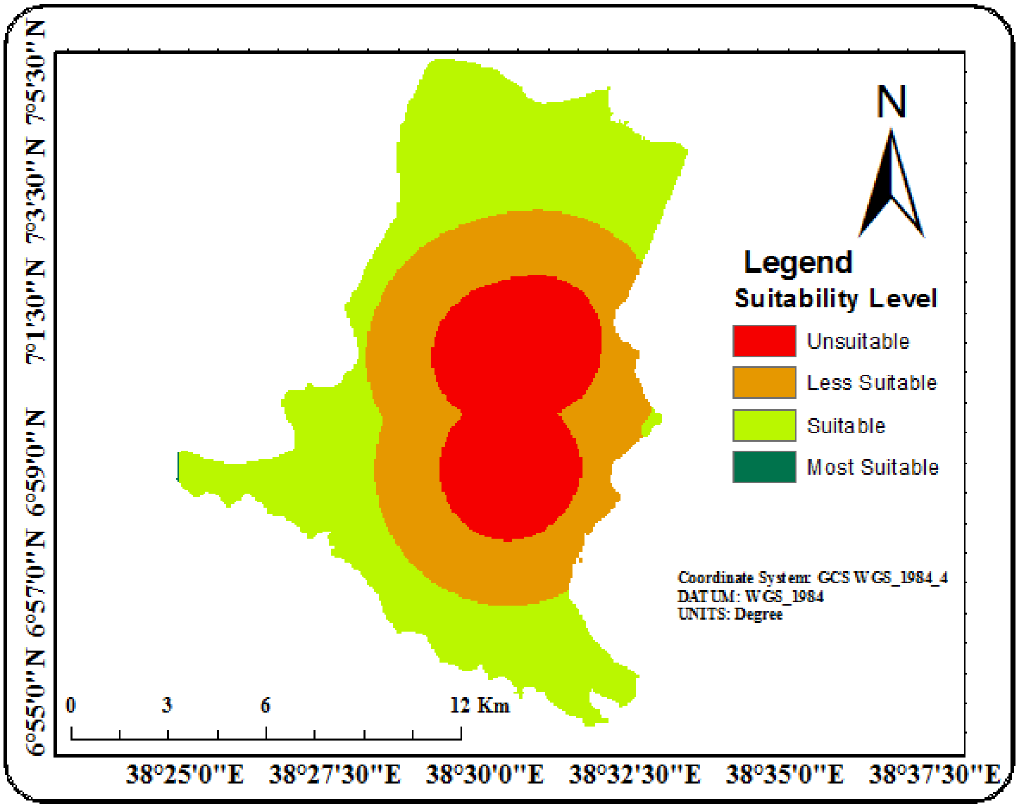

Figure 27: Suitability map of geological fault

4.7.Soil Type and Industrial Site Selection

The soil has a significant impact on the amount of recharge, which can infiltrate into the groundwater and hence, influences the ability of contaminants to move vertically into the industry zone (Burden and Sims, 1999). In the figure (30) below, the extracted soil type of the study area were described. Those are eutric fluvisols, chromic luvisols, fibric histols, eutric vitricsol and haplic luvisols. According to Harmonized World Soil Database 2009:-

Fluvisols: These soils are young soils and rich in alluvial deposits.

Luvisols: Soils with subsurface accumulation, low activity clay, high basic saturation, are porous and crumb characteristics.

Vertisols: they are dark colored cracking and swelling clays.

Histols: Soils which are composed of organic materials.

According to Anurag Ohri, et al, 2010 report, those soils with clay, alluvial and loam deposits are suitable for industrial establishment, whereas soils with cracking, swelling and porous are not suitable for industrial establishment. Based on this information, the researcher classified soil types as described in the table (18) below:

Table 18: Soil Type and its Suitability

Soil Types	Rank	Suitability Level	Area in Krm^2	Area in %
Eutric Vertisol	1	Unsuitable	1.4	0.9
Chromic Luvisol	2	Less Suitable	11.8	7.5
Haplic Luvisol	3	Moderately Suitable	18.2	11.5
Fabric Histosol	4	Suitable	31.6	20.03
Eutric Fluvisol	5	Most Suitable	92.5	58.7
Total			157.7	100

Source: Compiled by the Researcher, 2019

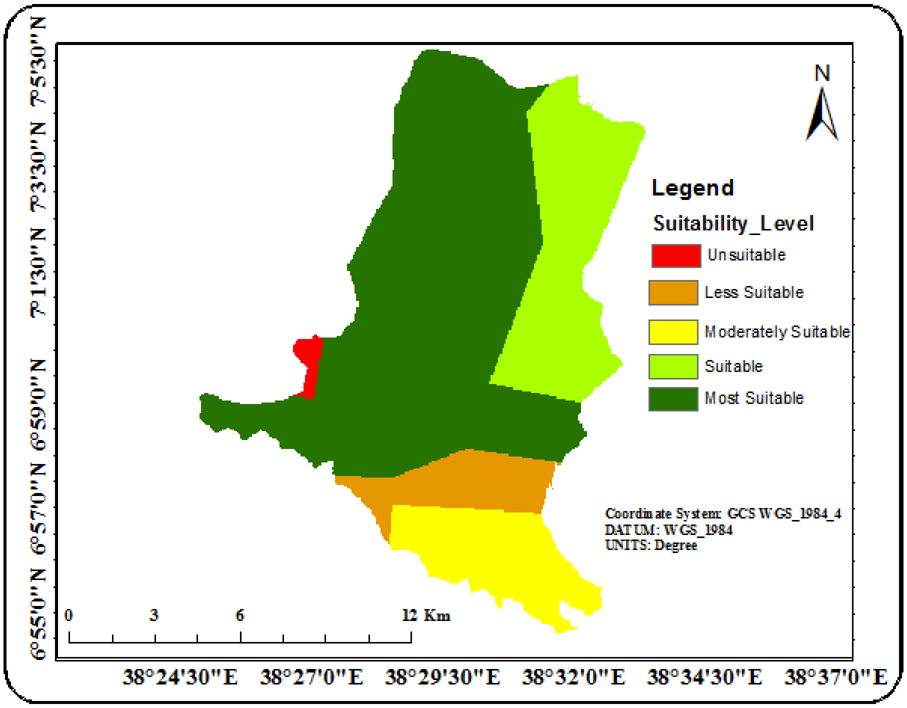

Figure 28: Soil type suitability map of the study area

As indicated in the table (18) above, from the total area 92.5km^2 (58.7%) is most suitable and only 1.4km^2 (0.9%) is unsuitable for industrial site selection as the area filled by the Eutric vertisol. And also, 18.2km^2 (11.5%) is moderately, 31.6km^2 (20.03%) is suitable and 11.8km^2 (7.5%) is less suitable for the site selection for the industry. Figure (29), above portrays soil type suitability for the industrial site selection

4.8.Calculation of the Criteria and Class Weights

In order to generate Industrial site, nine interrelated factors were used as input data sets (factors). Accordingly the selected input datasets were urban land use land cover, Road network, elevation, slope, river/stream, lake, swamp, and distance from residential areas, geological faults and soil types. Each of the factor maps were produced from remote sensing image, topographic maps and different available maps.

Before combining them, the following procedures were taken place; first, rasterization was done for the vector data layers in order to produce similar data layers to perform GIS analysis and secondly standardization of each data set to a common scale of 1 to 5 was done in ArcGIS Software. Prior to combining the factors, weights have to be given based on Satty's Analytic Hierarchy Process (AHP), where a pair-wise comparison matrix will be prepared for each map using a nine point importance scale (Table 19). Weighting is used to express the relative importance of each factor relative to other factor. The larger the weight, the more important is the factor in overall utility.

Table 19: pair-wise comparison, 9-point weighting scale

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very Strongly	Strongly	Moderately	Equally Important	Moderately	Strongly	Very strongly	Extremely
Less Important	More Important							

Source: Adapted from Saaty, 1980 as cited in Malczewsk, 1999

In the process of AHP, the prime task of calculation is the eigenvector corresponding to the largest eigen value of the matrix. Each element in the eigenvector indicates the relative priority of corresponding factor, i.e. if a factor is preferred to another; its eigenvector component is larger than that of the other. A sum/product method is used to obtain the eigen value and the subsequent eigenvector. The weights finally derived by AHP are used for developing the HIS model. To examine the rationality of AHP, it is necessary to determine the degree of consistency that has been used in developing the judgments. In AHP, an index of consistency, known as the consistency ratio (CR), is used to indicate the probability that the matrix judgments were randomly generated.

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

Calculating Consistency Ratio (CR)

CR= CI/RI, Where

CI = λ-n/n-1 , RI=Random consistency index

N=Number of criteria

λ max is priority vector multiplied by each column total.

Where RI is the average of the resulting consistency index depending on the order of the matrix given by Saaty, 1980 and consistency index (CI) is defined as:

$$CI = \frac{\lambda_{max}^{-n}}{n - 1}$$ Where:

λ_{max}^{-n} is the principal Eigen value of the matrix, n is the order of the matrix

The AHP also provides measures to determine inconsistency of judgments mathematically. The CR, which is a comparison between Consistency Index (CI) and Random Consistency Index (RI), can be calculated using the following formula: CR= CI/RI

It is recommended that the consistency ratio presents values below 0.1. CR* was also calculated and found to be 0.06, which is acceptable to be used in the site suitability analysis. The computed Eigen vector is used as a coefficient for the respective factor maps to be combined in weighted overlay in ArcGIS Map.

Table 20: The Criteria Used in Industrial Site Selection

	LULC	geology	Soil type	residential	road	lake	swamp	river	slope
LULC	1	3	5	2	3	3	3	4	5
geology	1/3	1	2	5	5	5	3	5	3
Soil type	1/5	1/2	1	5	3	5	5	5	3
reside	1/2	1/5	1/5	1	2	2	2	3	5
road	1/3	1/5	1/3	1/2	1	3	3	2	3
lake	1/3	1/5	1/5	1/2	1/3	1	1	2	5
swamp	1/3	1/3	1/5	1/2	1/3	1	1	2	5
river	1/4	1/5	1/5	1/3	1/2	1/2	1/2	1	3
slope	1/5	1/3	1/3	1/5	1/3	1/5	1/5	1/3	1
total	3.4	5.9	9.4	14.9	15.4	19.8	18.7	24.3	30.3
Consistency ratio = 0.06 **Consistency is acceptable.**									

Source: Compiled by the Researcher, 2019

4.9.Calculation of the Weight Normalized

The normalization of criteria values allows for the direct comparison of criteria when calculating suitability and reflects the conceptual relationship between the criteria value and a suitability score (Jiang & Eastman, 2000). Priority vector is also called normalized principal Eigen vector. To normalize the values, divided the cell value by its column total and calculated the priority vector or weight by determining the mean value of the rows (Saaty, 1980). In order to check whether the set criteria is correct or not, the researcher computed normalization.

Table 21: Normalized Criteria Selection for Industrial Site Selection

	LULC	**geology**	**Soil type**	**Setlement**	**road**	**lake**	**swamp**	**river**	**slope**	**value**	**weight**	**Influence (%)**
LULC	0.3	0.51	0.5	0.12	0.2	0.15	0.15	0.16	0.15	2.24	0.25	25
geology	0.09	0.18	0.2	0.33	0.3	0.24	0.15	0.2	0.09	1.78	0.2	20
Soil type	0.06	0.09	0.11	0.33	0.2	0.24	0.25	0.2	0.09	1.57	0.17	17
reside	0.15	0.03	0.02	0.07	0.14	0.1	0.1	0.12	0.15	0.88	0.1	10
road	0.09	0.03	0.04	0.04	0.07	0.14	0.25	0.09	0.09	0.84	0.09	9
lake	0.09	0.03	0.03	0.04	0.02	0.05	0.04	0.09	0.16	0.55	0.06	6
swamp	0.09	0.05	0.03	0.04	0.02	0.05	0.03	0.09	0.15	0.55	0.06	6
river	0.07	0.03	0.03	0.02	0.03	0.02	0.02	0.04	0.09	0.35	0.04	4
slope	0.06	0.05	0.04	0.01	0.02	0.01	0.01	0.01	0.03	0.24	0.03	3
total	1	1	1	1	1	1	1	1	1	9	1	100

Source: Compiled by the Researcher, 2019

Table 22: Classified Factor Values and Weights By Pair-Wise Comparison Method

Factor	Class	Value	Level of Suitability	Influence (%)
LULC	Vacant land	5	Most Suitable	25
	Bare/shrub	4	Suitable	
	Business site	3	Moderately Suitable	
	Recreation site	2	Less Suitable	
	Forest/water body/settlement	1	Unsuitable	
Geology	0 - 2000	1	Unsuitable	20
	2000 - 4000	2	Less Suitable	
	4000 - 10000	4	Suitable	
	>10000	5	Most Suitable	
Soil type	Eutric Vertisol	1	Unsuitable	17
	Chromic Luvisol	2	Less Suitable	
	Haplic Luvisol	3	Moderately Suitable	
	Fabric Histosol	4	Suitable	
	Eutric Fluvisol	5	Most Suitable	
Residential area	0 -1000	1	Unsuitable	10
	1001 1500	2	Less Suitable	
	1501 - 3000	3	Moderately Suitable	
	3001 - 6000	4	Suitable	
	>6000	5	Most Suitable	
Road	0 – 300	5	Most Suitable	9
	301 - 500	4	Suitable	
	501 - 1000	3	Moderately Suitable	
	1001 - 5000	2	Less Suitable	
	>5000	1	Unsuitable	

Factor	Class	Value	Level of Suitability	Influence (%)
Lake	0 – 200	1	Unsuitable	6
	200 – 500	2	Less Suitable	
	500 – 1000	3	Moderately Suitable	
	1000 - 10000	4	Suitable	
Swamp	0 – 250	1	Unsuitable	6
	250 – 500	2	Less Suitable	
	500 – 1000	3	Moderately Suitable	
	1000 - 2000	4	Suitable	
	>2000	5	Most Suitable	
River	0 - 250	1	Unsuitable	4
	250 – 500	2	Less Suitable	
	500 – 1000	3	Moderately Suitable	
	1000 - 2000	4	Suitable	
	>2000	5	Most Suitable	
Slope	0 - 6	5	Most Suitable	3
	6 - 10	4	Suitable	
	10 - 15	3	Moderately Suitable	
	15 - 20	2	Less Suitable	
	>20	1	Unsuitable	
Overall Parameters Influence				100

Source: Compiled by the Researcher, 2019

4.10. Integration of Criteria Maps and Preparation of Final Suitability Map

At this stage, all the factor layers are ready to be combined in order to identify suitable site for industrial location in the study area. If all datasets were equally important, it could be possible to combine them simply. However, from the principal eigenvector calculation, the relative importance of each parameter was determined. Therefore, the higher the weight, the more influence a particular factor will have in the suitable site generation.

4.11. Industrial site suitability analysis in the study area

Table 21 below shows that only 0.3 km^2 (0.2%) of the study area are less suitable, 54.8km^2 (34.7%) is moderately suitable, 74.9 km^2 (47.5%) is suitable, 4.9km^2 (3.1%) is most suitable and finally 18.5 km^2 (11.7%) is restricted areas.

Table 23: Statistical Analysis for Overall Weights for the Industrial Sites Selection

Suitability class	Area (km^2)	Area (%)
Restricted area	18.5	11.7
Less suitable	0.3	0.2
Moderately Suitable	54.8	34.7
Suitable	74.9	47.5
Most Suitable	4.9	3.2
Total	157.7	100

Source: Extracted from the Industrial Site Suitability Map, 2019

As can be seen from the suitability map (Fig 30), about half (50.7%) of the study area is suitable for industrial location. The suitable areas are mainly located in the Southern, South Eastern, South Western and central part approaching to the corner of the town. These areas were mainly vacant, bare lands and away from water bodies. In the Eastern part of the study area, on the way to Wondogenet, the new structural plan incorporated vacant lands to the town which favors good condition for the industrial site selection; and areas are free from urban settlements; and are occupied by sparse vegetation. For this reason, those parts are suitable for industrial implantation.

On the other hand, most parts of Huwella Tula sub-city were moderately suitable for industrial sites. Even if the areas were sparsely populated and free from water bodies, because of optimum transport inaccessibility up to the fringe the sub-city; it was a little bit important for the industrial sites. And also, those areas with shrub trees and bare lands are suitable to plant industry for the future. Obviously, those parts in the stated sub-city, the existing weather roads were considered as hindrance for the transportation of raw materials. This would impose private investors not to invest on that transport inaccessible areas. So in this area, small proportions of the study area were leveled as moderately suitable.

Swamps, lakes, streams and forest coverage through Lake Hawassa up to Tikur Wuha area were considered as restricted. For this reason, the researcher masked out those areas and leveled as restricted parts. Therefore, about 11.7% of the total study areas were not permitted to suitability criterion on this study.

In the study area, about 35% of the study areas were less suitable and moderately suitable for industrial site selection. This is because of, central parts were occupied by the recreational centers, settlements and built up areas, business sites and around Hayk Dar areas were considered to be constraints for industrial establishment.

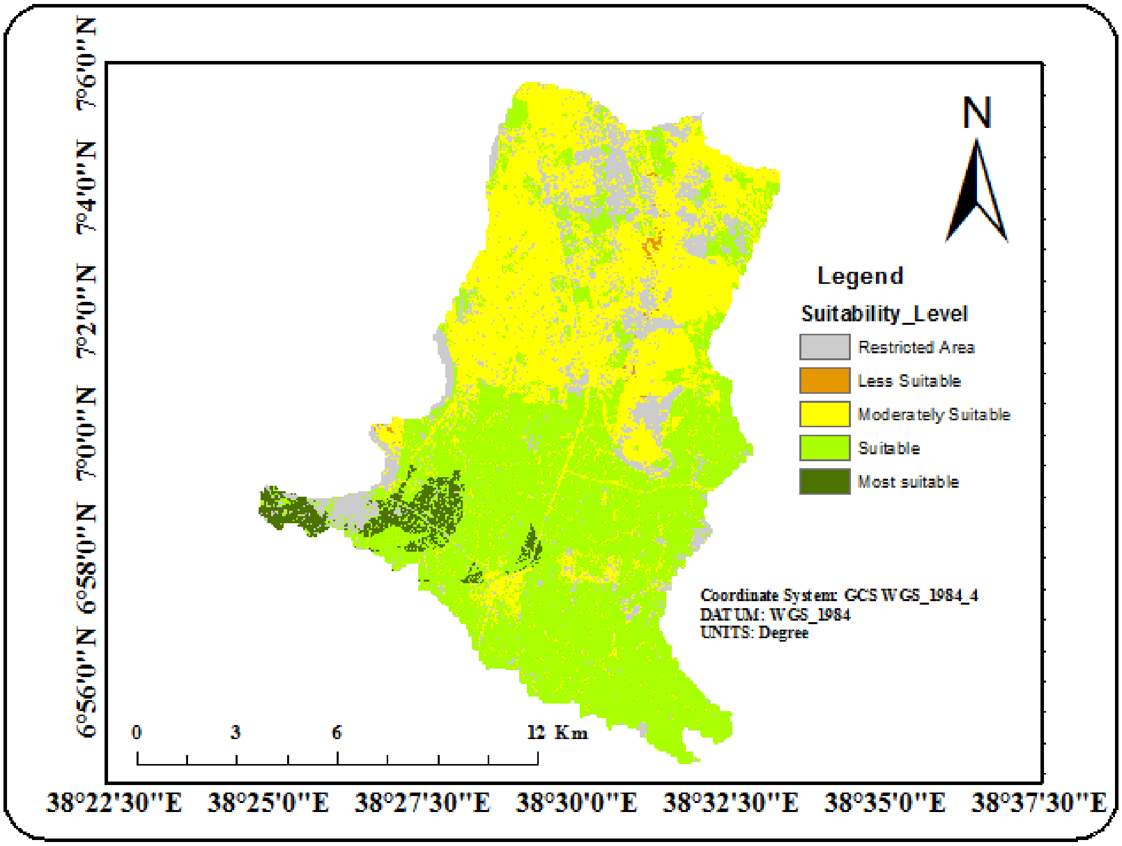

Figure 29: Weighted overlay suitability map of the study area

4.12. Industrial administration in the study area

In the study area, industries were administered by the town Industry and Enterprise Development Department, except Hawassa Industrial Park which administered by Federal Government of Ethiopia (Industrial Park Development Corporation). As the information obtained from the departments manufacturing and industrial controlling expert, the office has the following stakeholders in executing its objectives, vision and mission. Those stakeholders were: Construction department, the town Municipality Office, Environmental Protection and Forest Conservation Authority and Housing and Urban Development Department.

In order to have erect industry, the industry department submits the desired action plan for those stakeholders in order to implements the project properly. By doing this, the housing and Urban Development and Municipality offices provides a vacant land for the proposed project, Environmental Protection and Forest Conservation Authority undertakes environmental impact assessment cases and construction department issues and evaluates construction process.

As the information obtained from urban and housing development department, vacant land identified for industries based on the following factors of importance: transport facilities, availability of construction land, and availability of labor costs, references from local partners and previous experience, accommodation, projects public importance's, compensation paying capacity, noisy issues, capital and availability of local inputs.

4.13. Limitation in industrial site selection in the study area

Site selections are not without problems in the study area. The major problem is that a variety of expansion at an existing facility, or the utilization of a geographic-specific resource, such flexibility may not be available. Almost all the industries were established on one site as the newly desired structural plan of the town most fringe of the study were vacant. The other limitation is the amount of data to be processed and handled systems were very poor. Lack of demonstration whether certain types of industrial establishment would result on impacts on the societies, even at regional level, there is no established regulations and proclamations how industrial sites should be selected.

Besides the above, the expert raised about the intentions of private sectors to invest in the town. As he told, the private sector tends to invest more in the service sector shying away from the manufacturing sector. The agglomeration of industries at central part of the town is also considered as one of the problem in the study area.

During site selection, identifying vacant land for different purposes should be based on documented parameters and criteria. And now a days, different software's were employed to identify land for the respective purposes like Land Information System (LIS), Geographic Information System (GIS), Remote Sensing techniques, AutoCAD, etc. but in the study area, land identified for the desired purposes merely by the experts only by AutoCAD.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATION

5.1. Conclusions

Industries are important development endeavor that supports the economy for the towns and a given region. The ultimate purpose of establishing industry is to transform agricultural to industry, to ensure proper utilization of agricultural products, to establish and control standards, to generate income for the services rendered, and to alleviate impacts on the environment by controlling the environment and settlements from noise/pollution. Industries have some basic features that necessitate the search of unique location for them. Such location ought to satisfy some specific objectives including minimizing the undesirable impacts that the industry can pose on the surrounding environment and vice versa, ensuring the availability of basic facilities necessary for the proper functioning.

GIS and Remote Sensing as analysis tools are valuable tools that can support the decision makers to find best possible industrial sites. The GIS analysis requires collecting data from different sources with different formats to create a complete uniform database. Thus, the GIS data should be updated regularly in order to reflect the current situation of an area under investigation. Remote sensing data can assist to have updated information of the study area. Also, it can support the decision makers to monitor the investigated area using different dates of satellite images to extract the urban land use/cover class for example. The findings have shown the ability of GIS and remote sensing as a genuine tool for analyzing the criteria for decision support.

From those land use land cover factors, water bodies and forest coverage were masked out since these factors were incorporated in suitability level. Vacant/open lands and shrub land covers high percentage from the total area of the study and also they are suitable for industrial location. On the other hand, settlements, business sites and recreational center are not suitable for industrial location since interrupts them.

The analysis has taken land use/cover, slope, surface water, proximity to main roads and streams/river, swamps, distance from residential areas, distance from geological faults and soil types. From those parameters, land use land cover, geological faults and soil types were highly determining the selection of industrial sites in the study area. Since the study area is relatively flat slope, elevation and slope parameters play small portion in determining site selection.

After weight over lay computed, about 50% of the study area is suitable for industrial location and only 0.2 % is less suitable to locate industry.

The application and utilization of GIS and Remote Sensing in identifying sites for different purposes were very limited. Currently, there are a lot of technological instruments that are important to administer land and land related properties. But in the study area, the town Urban Development and Housing Department utilizes AutoCAD highly to administer land. Besides this, there is also shortage of experts who are GIS and Remote Sensing backgrounds. This resulted in ignorance of appreciating those best technologies like GIS and Remote Sensing.

GIS model is limited to the available data, which in this study; nine parameters were considered. Therefore, any additional information such as wind direction, land price, raw material, security issues, and government loan for the private investors and other social and economic factors can enhance the outputs of the GIS model, and provide more realistic results. The planners and the decision makers can get useful information about the possible locations of industry sites using this methodology. Specially, the site ranking process allows for easily readjustment of the criteria weights in case a sensitivity analysis is required. Nevertheless, defining detailed and standard criteria by the Environmental Agency that comply with the local conditions can enhance the outputs of GIS models used for the purpose of finding a suitable industry site. However, getting public agreement on any candidate site is a must, and cannot be avoided. Therefore, the local community should participate in the selection process of industry site to avoid any opposition in the future.

5.2. Recommendations

Based on the findings, the following recommendations are forwarded by the researcher:

- The GIS based multi criteria evaluation technique is simple and flexible which can be used to analyze the potential sites for urban development and encourage public participation in the urban decision making process. Thus, planners and authorities in order to formulate suitable plan for sustained development of the town, they have to undertake the application of GIS and Remote Sensing technologies.

- In the study area, industries were accumulated in the central and main parts of the town. This may result in different social and economic problems (interruption) on the residents. Therefore, the town administration has focus in order to plant industries far away from residential and other economic areas of the town.
- Data handling system in the industry and enterprise 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 and Remote Sensing to address information flow for the public.
- The study area selects industrial sites if there was a vacant land. Existence of a vacant land itself is not enough to establish industry. Those listed factors in this study and additional parameters have to be taken in to account for further industrial development.
- This study has been intended to serve for solving the location problems associated with industries. For private investors and enterprises, which are expected to participate in the country in the near future, some additional factors will probably be required to be considered, depending on the nature and complexity of industries.
- The town Industry and Enterprise, Housing and Urban Development, Forest and Environmental Protection Departments have to provide short term and long term GIS and remote sensing training for the experts.

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Appendix 1:

Questions Used During Discussions with Experts

1. What are the criteria employed for industrial site selection?
2. What is the spatial buffer distances required to separate industrial sites from different geographic features (such as residential areas, rivers, geological faults etc?)
3. Who are stakeholders when your organization needs sites for industrial establishment?
4. Is environmental impact assessment will be conducted before establishment of the industry? If yes, how?
5. How would you assess the site selected using GIS and Remote sensing taking into account all the appropriate criteria and the specific conditions of the study area?

Appendix_2: GPS Reading Taken in Order to Locate Industrial Distribution in the Study Area

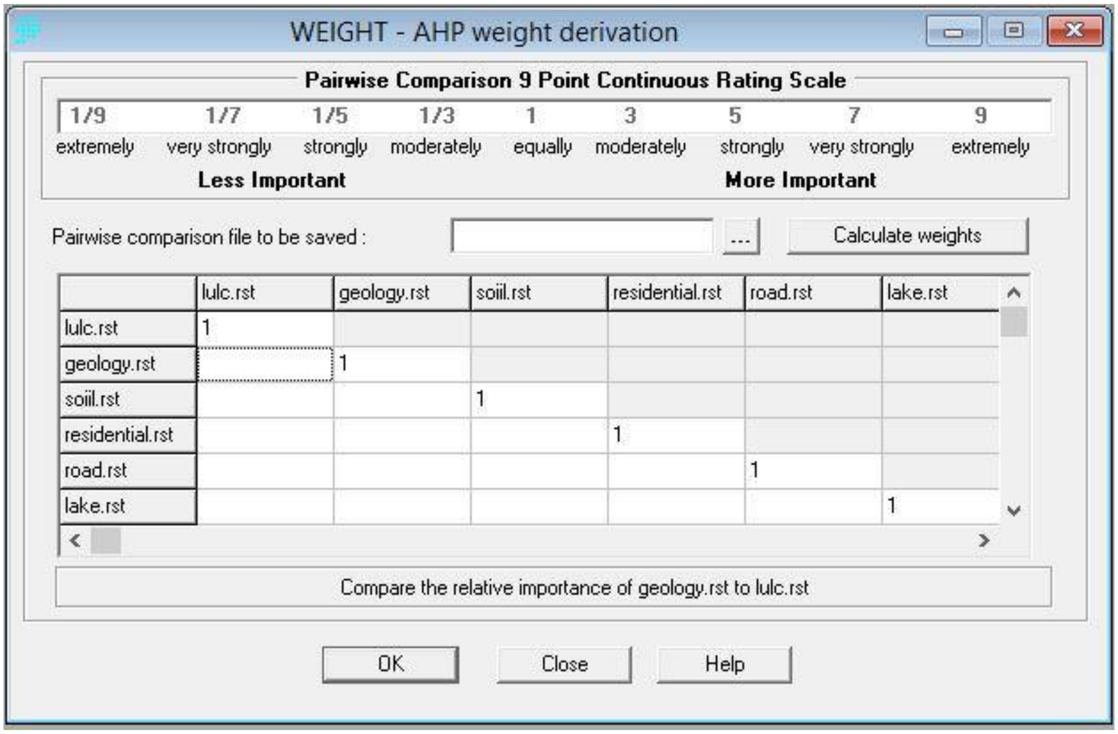
Name of Industries	Longitude	Latitude
Hawassa Industrial Park	38.4947	7.0677
Tabor Ceramic Factory	38.491	7.0795
National Tobacco Monopoly	38.502	7.016
Textile Factoey	38.501	7.034
Markan Soap Factory	38.503	7.032
Admasu Demeke Garage	38.48	7.045
Hawassa Fish Market	38.46	7.04
Hawassa Gloval Automotive	38.47	7.057
Nyala Motors	38.477	7.066
Monaco Automotive	38.479	7.069
A/T/Steal Factory	38.491	7.071
Sky Printing Press	38.492	7.056
Reis Engineering	38.487	7.081

Appendix _3: GPS Readings Used for Land Use Land Cover Map Accuracy Assessment

Longitude	latitude	LULC class	Longitude	latitude	LULC class
38.483422°	7.084835°	Forest	38.474160°	7.041648°	Recreation site
38.482354°	7.083824°	Forest	38.459349°	7.046367°	Recreation site
38.479899°	7.071127°	Forest	38.471404°	7.028855°	Recreation site
38.470564°	7.057837°	Forest	38.476784°	7.041539°	Recreation site
38.470127°	7.057040°	Forest	38.495594°	7.040151°	Recreation site
38.469960°	7.055591°	Forest	38.464736°	7.008926°	Recreation site
38.466613°	7.051973°	Forest	38.462797°	7.006421°	Recreation site
38.457730°	7.044649°	Forest	38.458121°	6.999136°	Recreation site
38.460304°	7.048092°	Forest	38.451511°	6.993929°	Recreation site
38.540977°	7.001802°	Forest	38.458402°	6.999233°	Recreation site
38.542740°	6.999905°	Forest	38.461641°	7.040042°	Recreation site
38.529693°	7.002961°	Forest	38.464040°	7.035738°	Recreation site
38.527465°	6.995638°	Forest	38.478600°	7.077299°	Recreation site
38.529051°	6.990151°	Forest	38.475286°	7.064631°	Recreation site
38.538778°	6.990472°	Forest	38.496536°	7.064692°	Recreation site
38.526979°	6.973656°	Forest	38.542639°	7.048126°	Recreation site
38.483979°	7.094545°	Forest	38.544945°	7.043989°	Recreation site
38.485228°	7.098134°	Forest	38.501390°	7.072204°	Business site
38.487147°	7.097087°	Forest	38.500790°	7.072178°	Business site
38.487804°	7.097241°	Forest	38.500297°	7.067948°	Business site
38.487566°	7.097319°	Forest	38.498353°	7.064447°	Business site
38.484575°	7.094759°	Forest	38.495175°	7.065935°	Business site
38.483628°	7.093887°	Forest	38.494774°	7.068068°	Business site
38.482951°	7.089986°	Forest	38.492494°	7.070574°	Business site
38.482890°	7.090377°	Forest	38.493114°	7.064889°	Business site
38.484911°	7.087895°	Forest	38.491921°	7.080075°	Business site
38.487238°	7.081001°	Business site	38.520374°	7.009348°	Vacant land
38.480184°	7.080300°	Business site	38.521387°	6.990139°	Vacant land

38.489440°	7.083738°	Business site	38.523574°	6.988737°	Vacant land
38.501267°	7.045141°	Business site	38.498822°	6.954458°	Vacant land
38.502040°	7.029669°	Business site	38.502947°	6.965053°	Vacant land
38.484415°	6.961632°	Settlement	38.509205°	6.964049°	Vacant land
38.489884°	6.962129°	Settlement	38.522706°	6.970680°	Vacant land
38.479214°	6.960006°	Settlement	38.497240°	7.075006°	Vacant land
38.476758°	6.958158°	Settlement	38.506624°	7.057388°	Vacant land
38.482228°	6.954142°	Settlement	38.506559°	7.056211°	Vacant land
38.491119°	7.039858°	Settlement	38.515764°	6.922166°	Vacant land
38.482034°	7.040622°	Settlement	38.520660°	6.923297°	Vacant land
38.470807°	7.048367°	Settlement	38.476779°	7.075826°	Water body
38.486432°	7.060467°	Settlement	38.463552°	7.020793°	Water body
38.490518°	7.090974°	Settlement	38.464995°	7.013753°	Water body
38.498486°	7.087838°	Settlement	38.449940°	6.990588°	Water body
38.496174°	7.082727°	Settlement	38.446600°	6.986550°	Water body
38.486918°	7.076236°	Settlement	38.515113°	6.922768°	Water body
38.496522°	7.078295°	Settlement	38.512536°	6.927671°	Water body
38.513905°	7.046099°	Settlement	38.508389°	6.959080°	shrub land
38.514648°	7.042855°	Settlement	38.501551°	6.934354°	shrub land
38.511539°	7.035725°	Settlement	38.527652°	6.995193°	shrub land
38.491288°	7.015194°	Settlement	38.540675°	6.922011°	shrub land
38.526689°	7.011506°	Vacant land	38.540372°	6.918625°	shrub land
38.524142°	7.007826°	Vacant land	38.528368°	6.934358°	shrub land
38.517398°	7.007124°	Vacant land	38.523181°	6.939710°	shrub land
38.517317°	7.006146°	Vacant land	38.516597°	6.944223°	shrub land
38.515958°	7.003167°	Vacant land	38.518440°	6.952380°	shrub land
38.521660°	6.997780°	Vacant land	38.540433°	6.997507°	shrub land

Appendix_4: APH Weight Derivation Procedure

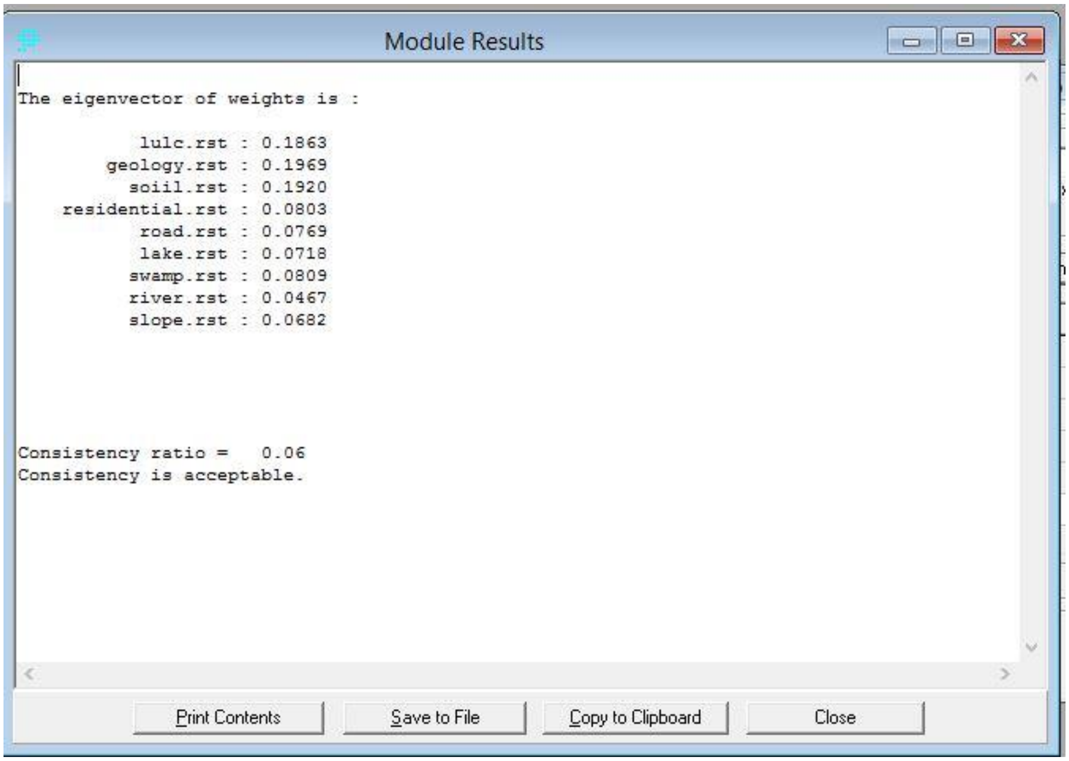


1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely

Pairwise comparison file to be saved :

	lulc.rst	geology.rst	soiil.rst	residential.rst	road.rst	lake.rst
lulc.rst	1					
geology.rst		1				
soiil.rst			1			
residential.rst				1		
road.rst					1	
lake.rst						1

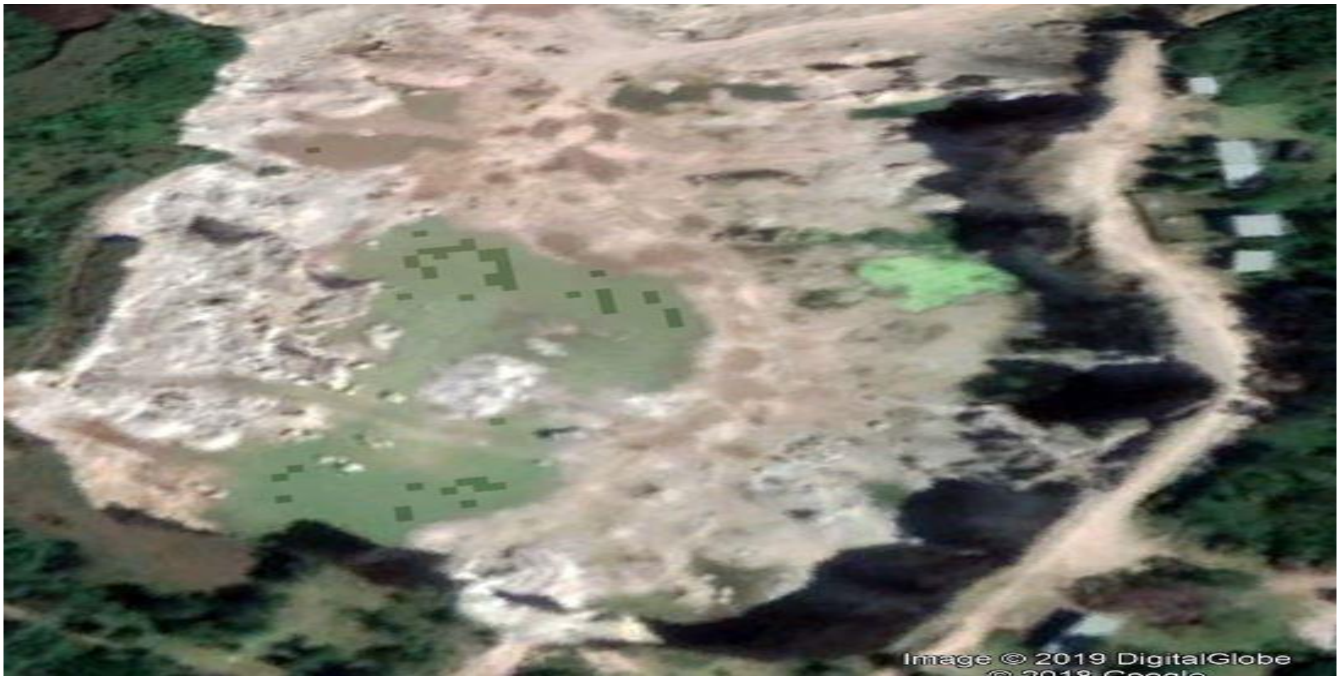
Compare the relative importance of geology.rst to lulc.rst



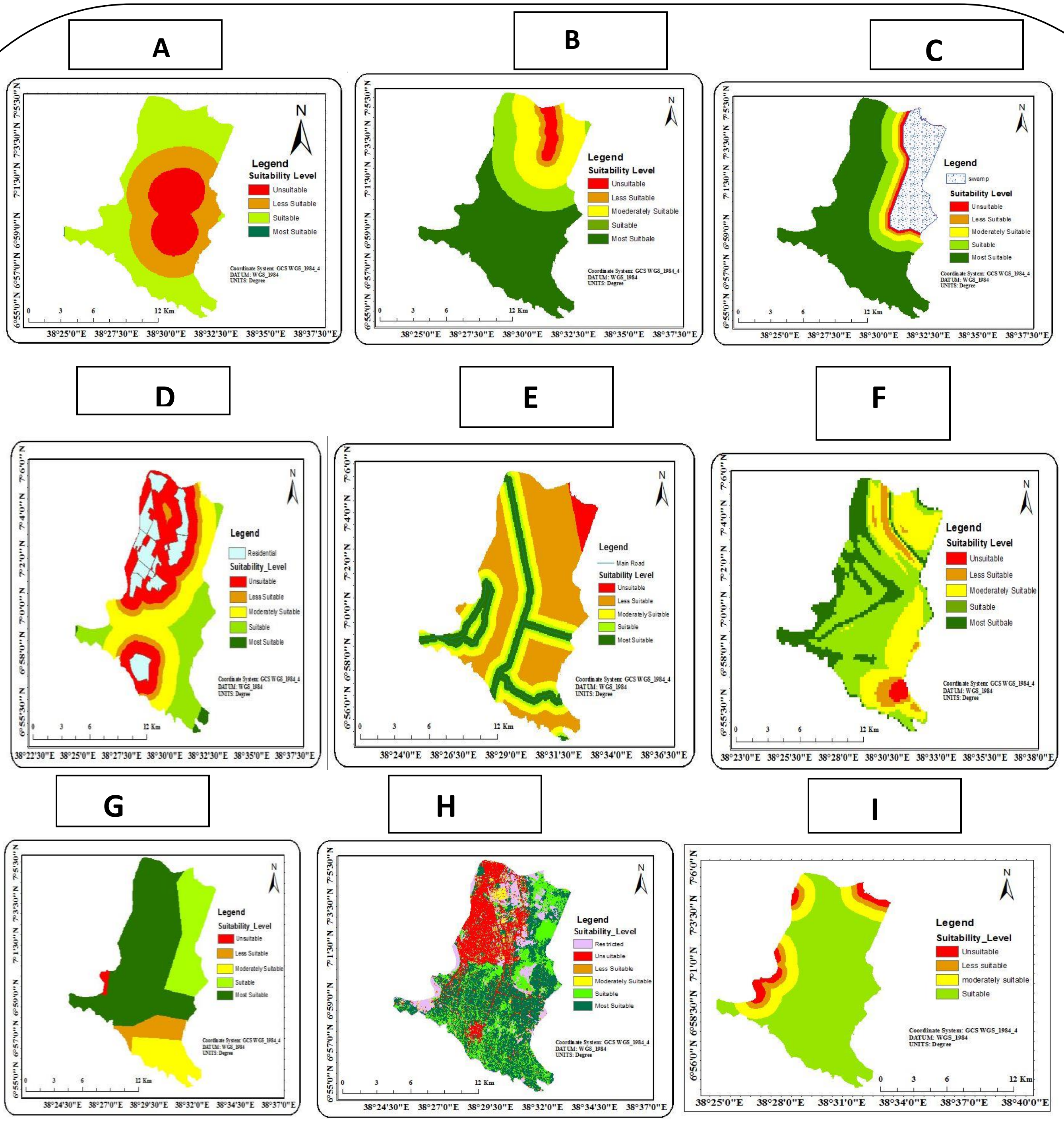
```
The eigenvector of weights is :

          lulc.rst : 0.1863
       geology.rst : 0.1969
         soiil.rst : 0.1920
   residential.rst : 0.0803
          road.rst : 0.0769
          lake.rst : 0.0718
         swamp.rst : 0.0809
         river.rst : 0.0467
         slope.rst : 0.0682




Consistency ratio =   0.06
Consistency is acceptable.
```

Appendix 5:

Sample for Geological Fault Sites of Study Area



Appendix_ 6: Factors Suitability Map



A: Suitability Map of Geological Fault

B: Suitability Map of River

C: Suitability Map of Swamp

D: Suitability Map of Residential Area

E: Suitability Map of Road

F: Suitability Map of Slope

G: Suitability Map of Soil Type

H: Suitability Map of LULC

I: Suitability Map of Lake