SITE SUITABILITY ANALYSIS FOR MUNICIPAL SOLID WASTE DISPOSAL IN JIGJIGA CITY, SOMALI REGION, ETHIOPIA

Eyob Derese Tesma

A Thesis submitted to

The Department of Architecture

School Of Civil Engineering and Architecture

Presented in partial fulfillment of the Requirement for the Degree of Master's in Urban Planning and Design

Office of Graduate Studies

Adama Science and Technology University

June, 2022

Adama, Ethiopia

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Declaration

I hereby declare that this Master Thesis entitled "Site Suitability Analysis for Municipal Solid waste disposal in Jigjiga City, Somali region, Ethiopia" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledge through citation.

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Name of student	Signature	Date

Recommendation of Advisor

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled" Site Suitability Analysis for Municipal Solid waste disposal in Jigjiga City, Somali region, Ethiopia" prepared under my guidance by Eyob Derese submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Urban Planning and Design. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedure.

__________________________ _______________________ ________________

Major Advisor/Supervisor Signature Date

Approval of M.Sc. Thesis

I the advisor of the thesis entitled "Site Suitability Analysis for Municipal Solid waste disposal in Jigjiga City, Somali region, Ethiopia" and developed by Eyob Derese, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Eyob Derese have read and evaluated the thesis entitled "Site Suitability Analysis for Municipal Solid waste disposal in Jigjiga City, Somali region, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Urban Planning and Design.

Chairperson	Signature	Date
Internal Examiner		Signature
Date		
Eternal Examiner	Signature	Date

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

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

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LIST OF ABBREVIATIONS AND ACRONYMS

AHP	Analytic Hierarchy Process
GIS	Geographic Information System
DEM	Digital Elevation Model
GPS	Global Positioning System
LULC	Land use Land cover
MCE	Multi criteria Evaluation
MOA	Ministry of Agriculture
MUDC	Ministry of Urban Development and Construction
UTM	Universal Transverse Mercator
WLC	Weight Linear Combination
RS	Remote Sensing
CR	Consistency Ratio
CI	Consistency Index

ABSTRACT

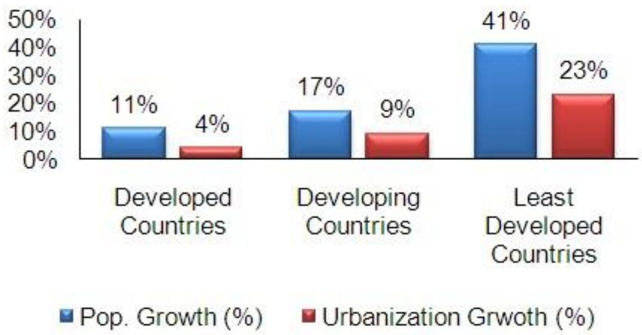
Solid waste management has become a challenge problem in the modern world as a result of increased different activities and rapid urbanization; In the past fifteen years the number of population and rate of urbanization in Jigjiga city was slow, in this case the city administration select a place as solid waste disposal site out skirt of the city without scientific investigation and creating the criteria, but now a days Jigjiga become Somali regional state capital city and the main trade market place in East part of Ethiopia so that the rate of urbanization and population growth become increased in this case the solid waste generation amount become high, in addition the nature of urbanization trained of Jigjiga city is horizontal so disposal site's move to center of the city in this case the disposal site become main source of social health and environment pollution problems, the aim of the study to analyze and identify suitable site for municipal solid waste disposal for Jigjiga City, in this study, the main method used Geographic information system –based Multi-criteria Analysis has been adopted to select suitable sites for solid waste disposal; the main data in this study includes ground survey data, Digital elevation model. Landsat8. As well as questioners, interviews and observation; analytical Hierarchy Process pair-wise comparison matrix was used to derive weight for the factors parameters; based on the consistence ratio obtained 0.083987 > 0.1 so this is acceptable; on the dwellers respond obtained 48.3 % of the respondent use open dump site, 15.5% are use valley , based on the information got from the respondents unprotected and mismanagement of solid disposal system this caused different social health and environmental problem, for example the respondent inform Typhoid, Diarrhea, cough, malaria are the main health problem rise from disposal area, this shows that the disposal areas are open dump site and also dwellers also used self-disposal system, as the result of the final suitability map showed that 26.87 % of the entire study area is categorized as highly suitable site, the suggested areas as highly suitable for solid waste dumping site fall in kebele 22, kebele 12, kebele 18 and kebele 16 the North, North West, South East and South West direction from the city, finally this is recommended to the city administration the rates and volumes of solid waste generated from the municipality should be carefully determined to further decide the dimension of the landfill site during construction

Key Word: Analytical Hierarchy process, Geographic information system, Jigjiga City, Multi criteria Analysis

CHAPTER ONE

1.0 Introduction

Solid wastes could be defined as non-liquid and non-gaseous products of human activities, regarded as being useless. Its source is mainly from households, municipal and construction (Samadder, 2014). The cohort and running of solid wastes are the problems facing both developing and developed countries. Generation of solid waste has become an increasing environmental and public health problem in everywhere part of the world, particularly in developing countries.



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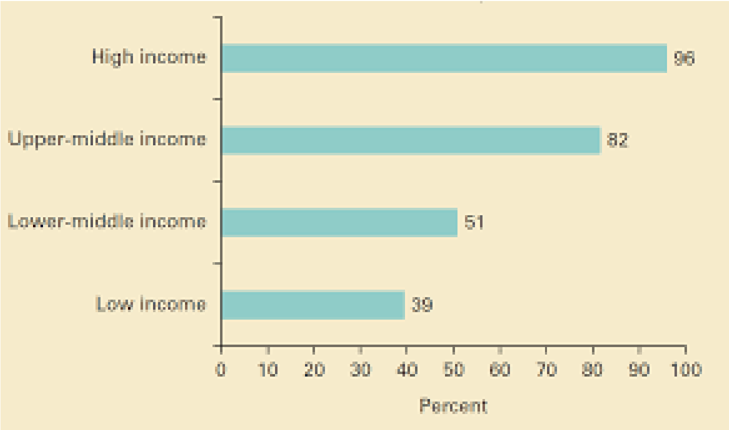
Solid waste management is the one of the most important services which includes by selecting proper site for solid waste disposal site selecting based on different scientific investigations. Due to less concentration of solid waste management it has been observed that there are numerous environmental degradation and vulnerability along with social health risks. (Danesh, 2019)

1.1 Background

Waste is material it could be solid, liquid which is discharged from each house hold and urban activities. This waste leads to adverse impacts on human and environmental health due to informal waste disposal sites. Those activities start from house-hold, communities, municipals, construction sites and industrial parks. (Wegedie, 2018)

Rapid increase of inhabitants, economic growth and rising standards of living in the community gradually increase the solid waste. Solid waste refers to the leaves/ twinges, food remnants, paper/cartons, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, biomedical debris, household hardware. (Suryabhagavan, 2019)



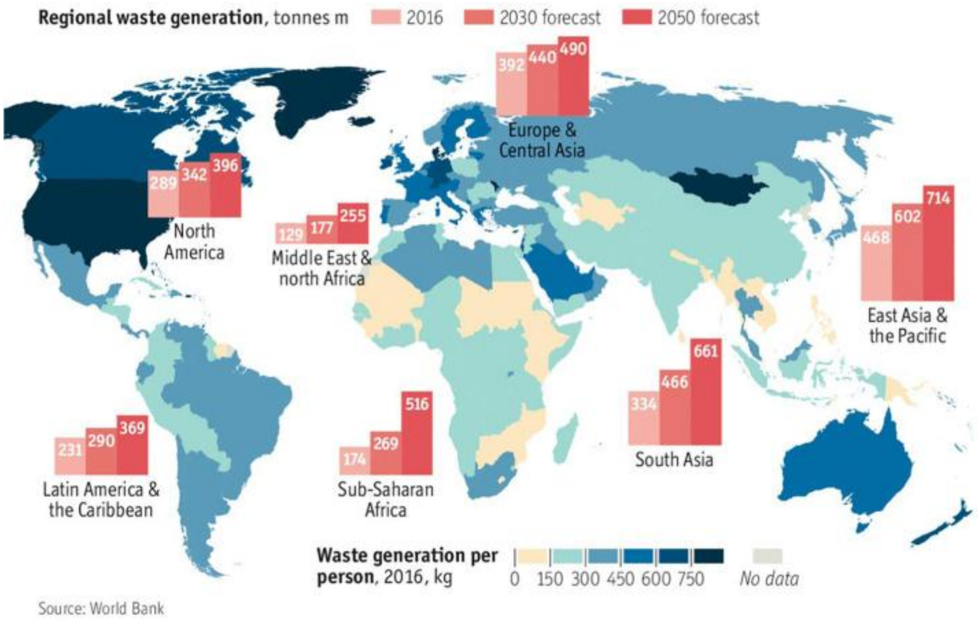
Source: world Bank

At this moment miss management of solid waste products has become a global Environment and health problem in developing as well as developed nations. Due to population growth, rapid economic growth, increasing living standards, exposition of urban, industrial activities accelerate at the same time it will rise waste products. (Ebistu, 2013)

The solid waste disposal system should be environmentally and socially acceptable to protect the environment and the safety of public health. But selecting appropriate site and managing solid waste dumping in developing countries with limited finance and rapid population growth rate and lack of technology is more severe.

Solid waste management issues should be confronted in a more generalized manner which means that new strategies should have designed, select considering the place's diverse and various urban models. (Ambachew, 2016)

In 2016 G.C the world urban based city's generated 2.01 billion tons of solid waste, among to a foot print of 0.74 kg/person per/day. Compared to those in developed nations, residents in developing countries, especially the urban poor, are more several impacted by unsustainably managed waste. In low income countries, over 90 % of waste is often disposed in unregulated dumps or openly burned, there practice create serious health safety and environmentally consequences. Poorly managed waste serves as a breeding ground for disease vectors, contributes to global climate change through methane generation and can even promote urban Violence. (Kaza, 2018)



Source: World Bank Group

It is common in developing countries that the daily amount of waste collected is not equal to the amount of actual waste produced by households. In developing, national trends of solid waste management problems are the results of inadequate plans and implementation. (Noufal, 2020.)

In Ethiopia people and municipalities use unsafe solid disposal systems, for instance burning near homes, damping the solid waste in an open area, damping in the near of stream, because lack of technology, finance, enormous urban policy and strategies based on the limitations municipalities can't manage solid waste and disposal site so that all self-managed solid waste disposal systems don't take guaranties to form clear, safe, and stable urban city; as a result, these trends cause a huge impact to the eco-system and dwellers health. (Dorik, 2014)

Poor conditions of municipal solid waste are represented by the accumulation of waste in the streets, a low waste collection rate, and the random dumping or burning trash in open spaces; Such types of inappropriate solid waste management systems. Without scientific investigations and analysis the selected landfill site may also reduce the ground water quality, drinking water purity and causes the disease so that proper suitable solid waste site selection is mandatory to create sustainable, livable, and clean urban habitats. (Ersoy, 2009)

Integrate different acquires data and software analysis get suitable site for efficient and effective solid waste disposal. Geographic Information System and Remote Sensing are computerized systems that can be integrated to get optimal solutions for efficient and effective solid waste management planning. On the one hand, GIS is a system that helps to capture, store, analyze, manage, and present data that are linked to locations. It is the merging of GIS output, statistical analysis tools, and database technology that help informed decision making. It is a tool that allows users to analyze spatial information, edit data, maps, and present the results of any spatial and non-spatial based analysis. (Karimi, 2019)

1.2 Statement of the problem

Solid waste disposal is a major problem, faced by the majority of cities/towns in the world. Rapidly increasing population growth, urbanization, industrialization, and rural to urban migration created critical and acute problems in solid waste management. (Yusuf, 2013)

In developing, nation's solid waste disposal sites are found on the outskirts of the urban areas, close to water bodies, farmlands, settlements, roads, drainages, and streets. (Ambachew, 2016) This is suitable for incubation of flies and mosquitos. So Solid waste disposal site selection is an important part of the waste management system, which entails much attention to avoid environmental pollution and social health problems.

In Ethiopia, for some towns, different scholars have conducted studies (Asefa, 2019), (Ambachew, 2016), (Ebistu, 2013), on land fill sites selection using GIS and Remote sensing for Debre Birhan, Bahirdar, and Mojo respectively. As Ambachew, (2016) states on his study mojo town use unsafe solid waste disposal practice such as open dumping and burning in the towns the problems severs this cause rapid population growth, shortage of finance. Like other Ethiopian cities, solid waste disposal site problem is still a major challenge for Jigjiga city.

In the past Fifteen years, the population growth of Jigjiga was slow in this case the city administration selected an open solid waste dump site outskirt of the city without any criteria and scientific investigation, However due to rapid urban population growth, erroneous urban policy, carelessness of municipal employee and dwellers, the disposal site is now move into the city center, this makes it a main source of inconvenience to live for the city dwellers and creates suitable for incubation of flies, mosquitos but the city administration is still use as a disposal site. In addition, most of Jigjiga city residents practice self-solid disposal system such as burning, disposing near road drainage, disposing of in surface runoff waters because the city haven't specific site for solid waste and properly scheduled time for collection and transport cost for solid waste, so this gives a chance for improper solid wastes disposing. This have an impact on the city aesthetics.

In order to improve these problems, integrating GIS and remote sensing techniques, to select the optimal site location for solid wastes dumping that is environmentally and socially acceptable, is important. (Pandey, 2012)The selection of solid waste disposal sites using GIS and remote sensing requires many factors that should be integrated into one system for proper analysis and get output.

1.3 Objective

1.3.1 General Objective

The general objective of the study to identify suitable site for municipal solid waste disposal in Jigjiga city.

1.3.2 Specific Objective

- To assess the current condition of solid waste disposal in the city
- To identify major criteria for site Analysis
- To determine the highly suitable site for Solid waste disposal

1.4 Research Question

- What is the current condition of solid waste disposal in the city?
- What are the major criteria use for site analysis?
- Which of the area is a suitable for solid waste disposal site?

1.5 Scope of the Study

1.5.1 Spatial Aspect

Spatially this study has confined to in Jigjiga city capital of Somali regional state, Ethiopia. In this case the spatial location of the project covered Jigjiga City.

1.5.2 Thematic Aspect

Based on the fact still the municipality uses open area, near urban settlement as the solid waste disposal site this cause a critical problem to the dwellers and the eco-system. In order to solve this such kind problem will use different hitch computer software and recent data for making analysis, the data acquisition procedures follow based on the objective and criteria’s. This helps to get appropriate place for solid waste disposal. In this concept suitable site analysis for solid waste disposal is mandatory for one urban-based city. Those disposal sites will be properly constructed far from different urban settlements, natural resources, residential areas, is the main target of this research project depend on relabel and spatial data for showing proper solid waste site.

1.6 Significant of the Study

In this study is expected to select suitable site for solid waste disposal to protect the environmental safety and resident health of Jigjiga City. Since unsuitable and improper solid waste disposal sites affect the social health of communities as well as the environmental resources, like water, soil .This study have two main significances. First it may give information to Planners, solid waste managers and environmental protection company about existing situation municipal solid waste management problem of Jigjiga City. Secondly the study may also be important to the community and the environment to protect from different problems caused from solid waste.

1.7 Limitation

The study is constrained by the following limitations:

- Lack of organized secondary data due to the absence of documentation and organized database system in the study area.
- The resolution of the recent satellite imagery data were the major problem to deal the current land use condition of the city; So that, the writer was used master plan of the city to obtain the current land use condition.
- Due to collection of primary data by questioners sometimes there is lack of cooperation to fill question.

Therefore, the study relies on a combination of different primary data collection mechanisms with special emphasis and secondary data prepared well in GIS environment to carry out the study well. So that, highest effort was made to minimize the negative impact of such constraints on the result of the study

1.8 Organization of the Thesis

This thesis is divided into five chapters. The first chapter provides to the study including introduction, background, statement of the problem, objectives of the study, Research questions, scope, significance and limitation of the study. The second chapter presents review of related literatures, mainly including, the concept and types of solid waste management systems, the concept and process of waste disposal sitting, applications of GIS and RS in different criteria for waste disposal site, Case study. The third chapter deals with the description of the study area including map, materials and methods employed in the study. The fourth chapter presents the Result analysis and Discuss and show the final suitable site selected for the study area. Chapter five presents conclusions and recommendation

CHAPTER TWO

LITERATURE REVIEW

2.0 Theoretical review

2.1 Solid Waste Management System

Waste is generated universally and it is a direct consequence of all human activities. Wastes are generally classified into solid, liquid and gaseous. The subject of this study, are mainly waste disposal of site selection using analytical hierarchical process and multi-criteria approach, because it is the simplest, cheapest and most cost –effective method of disposing of waste. (Buddi, 2016)

These wastes can be generated by the full extent of human activities that range from relatively innocuous substances such as food and paper waste to toxic substances such as paint, batteries, asbestos, healthcare waste, sewage sludge derived from wastewater treatment and as an extreme example, high-level (radioactive) waste in the form of spent nuclear fuel rods. Numerous classifications of solid wastes have been proposed and the following represents a simple classification of waste into broad categories according to its origin and risk to human and environmental health (Amare, 2013)

Household garbage, municipal waste, commercial and non-hazardous industrial wastes, hazardous (toxic) industrial wastes, building and demolition waste, health care wastes created in health care institutions (e.g., hospitals, medical research facilities), human and animal wastes, and incinerator wastes are examples of these. Rubbish created at home and collected by municipal waste collection services is referred to as household waste. This is in addition to shop and office garbage, food waste from restaurants, and other rubbish collected by municipal waste collection systems, as well as waste from street cleaning and green (organic) waste generated in parks and gardens (Özkan, 2019)

Municipal solid waste management (MSWM) encompasses the functions of collection, transfer, resource recovery, recycling and treatment. The primary target of MSWM is to protect the health of the population, promote environmental quality, develop sustainability and provide support to economic productivity.

Waste management is a problem for most countries around the world because of the increasing volume of waste material and the paucity of places to deposit. It has been a threat to environment and public health. However, proper waste management helps protect human health and the environment, as well preserve natural resources (Karimi, 2019). Solid waste should be managed through a number of activities such as waste prevention, recycling, and composting, controlled burning in the order of preference.

Combination of these activities in a way that best protect the community and the local environments is referred to as integrated solid waste management (ISWM). A sustainable waste management philosophy should encompass the following basic principles of solid waste management hierarchy which includes reduction in the generation of waste, waste streaming at source, recycling and reuse, pre-treatment of waste to minimize quantity and volume of residual waste. (Danesh, 2019)

2.2 Solid Waste Management System in Low Income Countries

The open dump approach is the primitive stage of development and remains the predominant waste disposal option in most of Africa countries including Ethiopia. It is a strategy for municipal solid waste management which involve indiscriminate disposal of waste and limited measures to control operations, including those related to the environmental effects of surroundings. An operated or semi-controlled dump is often the first stage in a country's efforts to upgrade use modeling (Kazuva, 2021). Controlled dumps operate with some form of inspection and recording of incoming wastes, practice extensive compaction of waste, and control the tipping front and the application of soil cover. Operated dumps, however, implement only limited measures to mitigate other environmental impacts. Operated dumps still practice unmanaged contaminant release and do not take into account environmental cautionary measures such as leachate and gas management (Shehhi, 2012). But as cities grow and produce more waste and their solid waste collection systems become more efficient, the environmental impact from open dumps becomes increasingly intolerable.

For a sustainable solid waste management system policies and techniques such as waste recycling, reuse, waste reduction, thermal treatment, and biological treatment must be in place. The waste disposal site selection method has been widely recognized as the most used of all waste management techniques (Karsauliya, 2013). However, the communities of small towns and villages in Ethiopia usually cannot afford disposal design, construction and operation standards equal to those applied in large cities, and in many cases, large cities cannot afford to apply standards equal to those of high-income countries. Perhaps the first question to be addressed when sitting a disposal is: What constitutes an appropriate level of environmental protection for the community? This will differ from community to community and will depend on the climate in the area as well as the available resources for construction and operation of the disposal. Often, construction and operation resources are limited and this must be reflected in the sitting process.

2.3 The Role of GIS and Remote Sensing for waste disposal Site Selection

2.3.1 Application of Remote Sensing in Site Selection

Remote sensing is defined as the science or art of obtaining information about an object, area or phenomenon through the analysis of the data acquired by a device that is not in contact with the object, area or phenomenon under investigation. Remote sensing serves as a tool for environmental resources assessment and monitoring. (Ersoy, 2009) Also states remote sensing as one of the excellent tools for inventory and analysis of environment and its resources, owing to its unique ability of providing the synoptic view of a large area of the earth surface and its capacity of repetitive coverage. With the availability of remotely sensed data from different sensors of various platforms with a wide range of Spatio-temporal, radiometric and spectral resolutions has made remote sensing as one of the best source of data for large scale applications and study. The use of remote sensing is becoming increasingly frequent in environmental studies. In the recent years, no serious research of the environment performed without advanced image processing and analysis. (Samadder, 2014)

One of the most important applications of remote sensing can be found in the case of solid waste disposal site selection where remote sensing data (satellite images) are used for extracting most of the site selection criteria used for siting disposal (Sumathi Usha Natesan and Chinmoy Sarkar, 2007) example, mapping land use/land cover, geology and surface water, time and cost effectively. Moreover remote sensing can provide digital data as an input for GIS.

2.3.2 Application of GIS for waste disposal Site Selection

Technological development in computer science has introduced Geographic Information System (GIS) as an innovative tool in disposal process (Ayisheshim, 2013)GIS combine's spatial data (maps, GPS data, aerial photographs, satellite images) with the other quantitative, qualitative and descriptive information databases. This technology offers an analytical frame work for data synthesis that combines a system capable of data capture, storage, management, retrieval, analysis and display. When remotely sensed data are combined with other landscape variables organized with in a GIS environment provide an excellent frame work for data capture, storage, synthesis, measurement and analysis. For assessing a site as a possible location for solid waste disposal, several environmental, social factors and legislations should be considered. The GIS aided methodology presented here utilizes to create the digital geo-database as a spatial clustering process and easily understood way for site selection process. Moreover, waste disposal siting is a complicated process requiring a detailed assessment over a vast area to identify suitable location for constructing a subject to many different criteria (Karimi, 2019). GIS application can help in determining the disposal location in accordance with the technical requirements, with weight overlay the thematic map to get an appropriate site for dispose solid waste (Djokanović, 2016)

GIS is a tool that not only reduces time and cost of the site selection but also provides digital data bank for future monitoring program of the site. The procedure followed under the GIS framework rejects the unacceptable sites considering environmental factors exclusively, other than economic and political issues, contained in the form of multiple layers of attribute information to select the candidate sites for disposal waste through weight overlay analysis performed by GIS software. Therefore, the GIS offers the spatial analytical capabilities to quickly eliminate parcel of land unsuitable for disposal site (Ebistu, 2013)and hence reduce cost and time of siting processes.

2.4 Criteria used for waste disposal site selection

The criteria used in site selection include environmental and socio-political, some of which may contradict to each other. With increase environmental awareness, new rules and criteria developments are emerged over time. (Rahman, 2008)The waste disposal site selection process has become much more complicated, as new procedures and tools have been created. By considering this and other factors to review waste disposal site selection criteria used by different Scholars in different countries like Turkey, Malaysia, Ethiopia, Niger and Uganda, among others have put in place rules and regulations to follow when selecting suitable sites for Structure and sanitary design. These guidelines are used the primary mechanism used to protect the host community and the environment at large. The following are the factors that several researchers have used to determine the appropriateness of a site to be used for waste disposal

Land use land cover: buffer zones should be provided between the waste disposal and sensitive areas or other land uses. For example at least 1000 meters from public roads, at least 2000 meters from industrial developments, at least 1500 meters from urban residential or economic area, at least 2000 meter from rural residential areas.

Surface water: the distance between the waste disposal and the nearest surface water should be a minimum of 700 meters, or 1000 meter to minimize the risk of polluting water with leachate.

Local topography: land forms located in flat or undulating land, in an empty extracts are suitable for waste disposal. Must not be sited in hill areas, those with ground slopes nominally greater than ten percent. However, many scholars recommends that 10 % slope or less.

Soils: soil should be of sufficiently of low permeability to significantly slow the passage of leachate from the site. Thus, sites in clay-rich environments are preferable.

Climate: areas with heavy rainfalls need extra care to avoid side effects of drainage and erosion; sites with prevailing winds require extra efforts to control litter and dust.

Unstable Areas: Must not be located within 100 meter of unstable area.

Distance from environmentally protected areas:

Must not be located in close proximity to sensitive areas such as fish reservations areas for special protection would be excluded. Therefore a 3,000 meter buffer is necessary to surround an environmentally sensitive area.

Distance from urban areas: Should not be placed too close to high-density urban areas in order to mitigate conflicts. Development of landfills should be prohibited within 3000 meter from village or rural settlements, (MUCD, 2012) and a distance of 4000 meter from a city’s.

2.5 Multi-Criteria Decision Analysis (MCDA) for waste disposal Site Selection

Multi-criteria analysis is a set of mathematical tools and methods allowing the comparison of different alternatives according to many criteria, often conflicting, to guide the decision maker towards a thoughtful choice (Karsauliya, 2013). MCDA consists of a series of techniques such as weighted summation or concordance analysis that permit a range of criteria relating to a particular issue to be scored, weighted and then ranked by, for example, experts, interest groups and/or stakeholders according to their degree of suitability or importance for locating/sitting a particular facility/service .

Analytic Hierarchy Process (AHP) is one of the most commonly used MCDA tools. This tool is applied in site selection processes as it assists the decision making process by allowing decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model (Ersoy, 2009). Hence, multi-criteria techniques could be particularly useful in situations where there are a large number of alternative sites for a development, where there are large number of potential criteria to be taken into consideration or where subjective judgments by different stakeholders of the different alternatives is needed to try to reach an objective consensus in the final decision- making process or to make these processes more open and accountable (Vieux, 2015)

A solid waste management program often involves conflicting economical, environmental, and socio-ecological impacts. For example, locating a new site for development at minimal cost is feasible, but the tradeoff could be the likelihood of groundwater pollution. Moreover, site selection by GIS is a multi-criteria evaluation (MCE) and generally has four steps criterion establishment, standardization of factors, establishment of factors weight and weighted linear combination. With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of results to yield a suitability map (Ayisheshim, 2013).

2.6 The Role of GIS in waste disposal Analysis

Gis has been extensively deployed in waste management. Data capture from the aerial photo, optical, thermal, or LIDAR sensors integrated with attribute layers of prerequisite information which could make it easy to understand the area’s waste generation nature and trend. These trends are useful while planning waste management and provide remedies while dealing with such severe environmental and social health issues. Gis is also a tool that not only reduces time and cost of the site selection, but also provide asset management services for further monitoring program of the site. Moreover, GIS can be related spatially, exchanged, compared, evaluated, and processed with a very good flexibility.

2.6.1 GIS Multi-criteria Decision Making (MCDM)

GIS-based multi-criteria decision analysis involves the utilization of geographical data, the decision maker’s preferences and the combination of the data and preferences according to specified decision rules (Karimi, 2019). MCDM is a set of mathematical tools and methods, like weighing, to compare different alternatives according to the criteria. The main components for MCDM are human value judgment and assessment of criteria, to rank potential disposal sites using different criteria. Multi-criteria approaches have the potential to reduce the costs and time involved in siting disposal by narrowing down the potential choices based on predefined criteria and weights. Weighted Linear Combination (WLC) and Analytic Hierarchy Processes (AHP) are the two most known Multi-Criteria Analysis methods that were used for this study.

2.6.2 Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach. The Analytic Hierarchy Process is a decision making method for prioritizing alternatives when multiple criteria must be considered. It offers a methodology to rank alternative courses of actions based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each of the alternatives (Sumathi Usha Natesan and Chinmoy Sarkar, 2007).

AHP is a powerful and flexible decision-making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. It provides a hierarchical structure by reducing multiple variable decisions into a series of pairwise comparisons and develops subjective priorities based upon user judgment. AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives among which the best decision is to be made.

AHP was used in this study to derive weights for each criterion internally and externally. It was also used to breakdown decision problems and aggregates them in structured way so as to facilitate and select waste disposal siting processes. AHP generates a weight for each evaluation criterion according to the decision maker's pair wise comparisons of the criteria. The comparison is about whether the row criterion is equal, greater or lower importance that the column criterion and the higher the weight, the more important the corresponding criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used when the row criterion is less important than the column criterion. AHP also provides measure to determine inconsistency of judgments, in which the CR should be less than one. (Chang, 2007)

2.6.3 Weighted Linear Combination (WLC)

WLC is a type of multi-criteria evaluation method in GIS environment used to evaluate the suitability of a region for waste disposal. The WLC procedure is characterized by full tradeoff among all factors, average risk and offers much flexibility than the Boolean approaches in the decision making process. The approach allows the decision maker to assign weights according to the relative importance of each suitability map and combines the reclassified maps to obtain an overall suitability score (Vieux, 2015). In this particular research, GIS-based Multi-Criteria Evaluation methodology was followed. This methodology is best suited for siting disposal accurately in time and cost effective manner, hence used by many researchers. Because the technique can effectively be used for suitability analysis in GIS environment via criteria establishment, standardization of factors, establishment of factor weights and finally weighted linear combination. Waste disposal site selection methodology is a two-step processes.

The first step employs GIS to screen out unsuitable areas based on standards and criteria set by national and international environmental acts and rules and identify potential candidate sites. In the second step MCDM, is used for ranking the candidate sites and identify the best site/s based on the weights assigned to each criterion. AHP is a powerful MCDM tool to assign weights and rank the candidate sites for selecting the best site among the candidates. Generally, after finding out where the unacceptable areas are, the remaining areas should be classified into classes of high and low priority for being used as waste disposal areas (Kaza, 2018).

This is done through two steps of weighting process. In the first step, each layer was internally weighted based on the minimum and maximum distances and/or requirements. Finally, the layers were standardized and thematic map of each criterion/layer was produced. In the second step, each layer is externally weighted based on the fact that how critical and important the data layer is to the waste disposal problem. (Amare, 2013) After external weight was assigned to each layers, WLC techniques were apply to combine all the factors and prepare map. After creating a final suitability map using GIS, the AHP process was applied again for comparing alternative sites to each other against other criteria (size, distance from the center of the town and from nearby settlements) in order to choose the most suitable site among candidate sites.

2.7 Empirical review

2.7.1 Case study in Katashina Ala town Benue state, Nigeria

As (Muhammed, 2017) stated in their paper study in Katashina Ala town Benue state, Nigeria. As the scholars stated the due to increasing population density and economic activity town solid waste is a serious problem as common as other developing countries. In the town due to lack of scientific investigation and well-unplanned site the solid waste dump randomly near drainage, residential areas, open area, near of river bank. This caused a critical problem on human health and the eco-system. For such a problem, the scholar adopts GIS and RS technology in order to solve it. The source of data is divide into two primary data such as interviews, questioners, observation and secondary data internet, published materials, remotely sensed data.

The material is categorized in to two such as land survey (GPS) and Hitech software for data analysis and overlays to analyze and find the suitable site as an output. In this study the scholars develop criteria for the site analysis process, Such as elevation, road distance, urban settlements, important places, and drainage. For data analysis the scholars use GIS and Remote Sensing techniques.

The scholars used the spatial multi-criteria analysis method this method has the potential to minimize the cost and time involved in sitting facilities by narrowing down to the potential analysis. In addition a pair-wise comparison matrix follows for the given weight for each parameter. As a result the Scholars over lay each map layer and finalize by reclassification and give the rank in order to show potential site for a solid waste dump site.

2.7.2 Case study Bahirdar town

As a scholar (Ayisheshim, 2013)states in Bair Dar town, there are problems with solid waste disposal sites. Even if most of the solid wastes are collected from the source using push carts to the temporary transfer stations, there are no scientifically approved sites. There are no standard transfer stations in the city. All health institutions and industries follow their way of removal of waste, while some others dispose it to the nearby water body, Abay/Blue Nile and Lake Tana. The dumping sites are not well planned, and they are open field disposal (no sanitary landfill), are close to rural settlements, and are not at an appropriate distance from the center of the city.

In order to solve the problem the scholars used on the study integrated GIS and remote sensing to select the best possible site for a solid waste dumping site. The selection criteria should consider and combine surface water, soil type, slopes, settlements, groundwater, protected areas, land use, and road networks

The finding study both primary and secondary data was used in the study. The primary data were collected from field surveys and observation. Whereas, the secondary data for the study was acquired from the internet, reports, books, journals, governmental institutions and other documents. The Scholars on the study used the spatial multi-criteria analysis technique to identify the most suitable solid waste site. Spatial multi-criteria approaches have the potential to reduce the costs and time involved in siting facilities by narrowing down the potential choices based on predefined criteria and weights and permitting sensitivity analysis of the results from these procedures. The solid waste disposal site selection mapping was done using multi-criteria evaluation and creating layers to yield a single output map. The weights were developed by providing a series of pair-wise comparisons of the relative important factors to the suitability of pixels for the activity being evaluated.

As with every investigation and analysis of the basic data the scholar put the result in terms of matrix value. As the result, bare land and grass land are the appropriate sites for solid waste disposal, the lower slope is more highly suitable than the land with a higher slope. The study shows that areas with high slopes will have a high risk of pollution and potentially not a good site for dumping. As the scholar state in the study safe distances from settlements are determined as 7km for urban centers and 3km for rural villages.

The Overlaying and identifying suitable sites selection for a solid waste disposal dumping site involves comparison of different options based on environmental, social and economic impact. The weights were developed by providing a series of pair-wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. After all, the process proceeds the weight comparison method overlay all data layers give rank in order to show the suitable site for solid waste disposal.

2.7.3 Case Study in Logia, Afar

Mussa, (2021) states that in Logia Afar significant impact from the poor solid waste collected by the municipality being dumped, untreated, near the Logia River, Awash River close to the Logia town. The cumulative solid waste quantity exceeds the capacity of Logia town authority management options, resulting in a potentially adverse impact on the environment, human health, and the quality of urban life. The researcher use Applications of GIS to identify potential waste disposal sites in different locations.

The scholar states in the study different types of data adopted to achieve the project objective were used to prepare primary input thematic maps like land-use/land-cover, geological structures, and lithology with the help of field investigations and secondary maps. Shuttle Radar Topographic Mission (SRTM) digital elevation data of 30 m resolution were used for his study. Soil map and agro-climatic zone map of the study area compiled by the Food and Agricultural Organization (FAO) were collected from the Ministry of Agriculture (MOA), Government of Ethiopia.

Open dump sites were collected using GPS. In addition, some sample points from different land-use/land-cover types were also collected to verify the current land-use/land-cover types of the area. Interviews with environmental protection officers and people living around the existing landfills were made to get additional information.

As scholar states that in the study, 10 criteria were selected for evaluating solid waste dump site selection. Factors such as land-use/ land-cover, geological structures, lithology, slope, distance to river, built-up, road, soil, drainage, well points were considered in the analysis.

In his investigation AHP (Analytical hierarchy process) method was used in 3 different stages such as on weighed based on buffer minimum and maximum distances and requirements, to the layers were standardized and thematic map of each criterion and produced. A pair-wise comparison matrix was used from which a set of weights referred to consistency ratios for each of the criteria.

As the Author finalizes his investigation by overlaying and giving the rank and checking the suitable site for solid site disposal. This scientific investigation help to give relief for tenant and the eco-system including the city Administration as a source of basic data to select area for solid waste disposal.

In such empirical review the scholars Muhammed, (2017) used interview only the dwellers this causes some misinformation, As Ayisheshim, (2013) paper used filed survey and observation, Mussa, (2021) only used secondary data for his study but in this study were conduct an interview with both dwellers and specialist this kind of data source help to prepare and get good quality result in addition the scholar’s not use any kind of software to make analysis the targeted population information but in this study SPSS used to evaluate and get real result.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Description of study area

Jigjiga is the capital city of the Somali region, Ethiopia. Jigjiga is found in 630km North East direction from the capital city Addis Ababa , Ethiopia. Jigjiga is located in Ethiopia 9°21’ N, 42°48’E on an elevation 1934m above sea level.

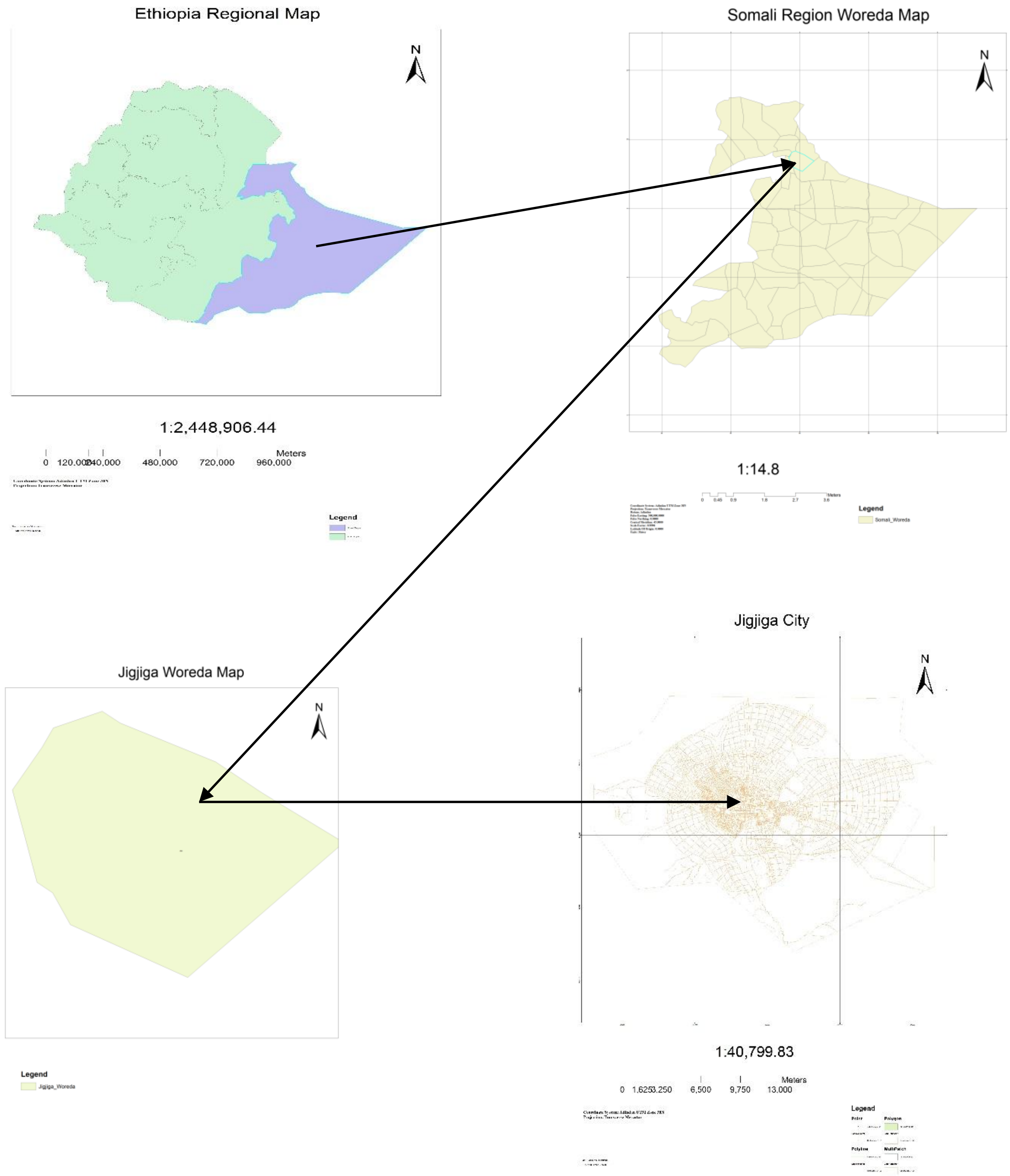


Figure 1 Study area Map

3.1.1 Physiography and Drainage

Jigjiga city is almost located on a flat land with gentle slopes. The existing built up and expansion areas are much suitable for urban development. On the other hand, some parts of the city are characterized by poor drainage, gully and swampy land features. Gully areas that are found in the western, southern, southeastern, and northern parts of the city require immediate intervention or remedy measures since they expand to the expansion and built up areas of the city.

3.1.2 Geology and Soils

The topography slopes down from the Karamara Mountain in the northwest spreads out in the southeastern border of the city, with a few numbers of steep-sided valleys and streams. In general, the topography is characterized by gentle morphology and flat land areas. As a result, the stream drains towards southeastern from the Karamara ridge; southeast direction from

Cinaksan direction and other elevated areas of the eastern outskirts of the city. Wetlands along Biribiris and Toga streams (including Elbahiy and Biyeda streams) and areas south to the southwest of Elbahiy Dam are the major drainage systems in the town vicinity. Jigjiga city and its surrounding hinterland is characterized by the following three categories of geological features: Alluvial and lacustrine deposit sand, silt clay, diatomite, limestone and beach sand; Hamaneli Formation (Oxfordian limestone and shale) and Ashanti Formation: Late Cretaceous-Paleocene Sand stone Information from Jigjiga Woreda's Agriculture Office reveals that the hinterland of the town is dominated by mixed eutric cambisols, chromic vertisols, black vertisols, mixed Calcic Cambisols and black Vertic Cambisols with clay texture soil types.

3.2 Research Methods

In this study use both qualitative and quantitative method. This specific procedures for collecting and analyzing data. In this case to achieve the first specific objective use quantitative method by collecting questioners use SPSS 22 statistics software to analysis and get the output. On this study use qualitative method to select the factors based on interview with specialist.

3.3 Research Approach

In this study use abductive approach because the research devoted to explain the observations and analytical results. In this case the study to explain the phenomena by using inductive and deductive method of data collection and data analysis in an integrate manner.

3.4 Research Design

In this research use descriptive research design. This kind of design help to looking and evaluate the cause of specific topic or phenomena and describe the situation. This method help to know the factors that create troublesome situation. In the study conduct review of the issues, analytical of the issues and create solution for the issues.

3.5 Type and Sources of Data

This study used both primary and secondary data types. Accordingly, necessary data were collected from primary and secondary data sources.

3.5.1 Primary Data

In this study primary data used to achieve the objective of the study. Based on that primary data collected using questioners, interview, and observation. This kind of data collection system conduct to identify the location and existing condition of the Solid waste disposal in the city. For such reason handle GPS instruments used to collect existing site coordinate point. Filed observation were also used to show the existing waste disposal site in photo and location,factors like Borehole and protected areas. Interview with Social health experts, environmentalist and the dwellers who are live near to the disposal site and live in the city far away from the site.

3.5.2 Secondary Data

In this Study use secondary data to perform the study activities and achieves the desire objectives states on the specific objective. These includes: road network, stream/surface water, soil, residential settlement, land uses land cover and DEM also helped to derive the slope, elevation of the study area which are very important for further analysis to select suitable site.

Table 1: Data Type and Source

Data	Data type	Source
Land use land cover	Landsat 8 OLI imagery, pixel 30mx30m Resolution	USGS
Road network	Master Plan	Jigjiga city Municipality
Soil layer	Soil map, Scale 1:250,000	FAO and Ministry of Agriculture
Slope and elevation	Aster DEM 30mx30m Resolution	USGS
Residential Settlement	Land use map	Somali Regional State Urban Development and Construction Bureau
Stream/surface water	Aster DEM 30mx30m Resolution/ DEM	USGS
Geology	Geological Map	Ethiopia Geological Survey
Protected area	Master Plan and observation	Field Survey
Ground Borehole	Existing borehole area	Field Survey

3.6 Sampling Method

In this study use two types of sampling techniques from probability method select Random Sampling and from non-probability method is Purposive sampling method. In the study Random sampling use to conduct the targeted house hold and purposive sampling method to conduct the specialist which is help to achieve the desire specific objective of the study.

3.7 Sampling Size

In this study sampling size determined by counting the number of house found near the disposal site and select other place and multiplied by house hold size. In this calculation found the number of population. In this study sampling size determine using Yamane formula. This formula calculation is a way to determine the sample size for the study. Based on the calculation out of 1920 house hold the targeted house hold is find using formula the result is 116, which is live near disposal site and far from the site. In this study the acceptable sampling error use 0.9% to get more reliable information.

Equation 1-Yamane Formula (1967)

$$n = \frac{N}{1+N(e^2)}$$

n= the sampling size

N = the population Size

e = the acceptable sampling error

3.8 Data Analysis

In this study use qualitative data analysis method and quantitative method of data analysis. Those method of data analysis can be used independently or in combination with the other. In this case software's used to analyze both types of data to address for particular objective of the study. This study use SPSS 22 operational methods of GIS for suitability analysis; such as digitizing, spatial analysis, buffering, Proximity Analysis, AHP and weight overlay were the major ones used in this study to select suitable waste disposal sites.

3.8.1 Digitizing

This function of GIS converts the base map of the area into digital map to use in GIS environment. This is done by using on- screen digitizing by encoding the spatial coordinates of the features on the map. It was used to digitize Settlement boundaries, City Administration Boundary, Road network, River and reserved settlement that exist in the study area from the Master plan. (Karsauliya, 2013)

3.8.2 Buffering

Buffering operation refers the creation of a zone of a specified width around a point, a line or a polygon area. It is also referred to as a zone of specified distance around coverage features. Buffering is one method of spatial analysis called proximity analysis. It is used to produce areas of a given distance around specific criteria that used to select suitable solid waste disposal site. The features that were buffering in this project include: road, protected area, settlement, well point and stream.

3.8.3 Determination of Criteria and sub-criteria

In this study different criteria's and sub criteria's was selected based on the interviews and different scientific analysis results. Those criteria and sub-criteria play a major role to get a best result and help to achieve the final objective by locating best site.

3.8.4 Criteria Weights and Standardized Factor

The distinguishing feature of GIS is its capacity for integration and spatial analysis of multi-source datasets. The data are manipulated and analyzed to obtain information useful for a particular application such as suitability analysis. Waste disposal site selection by GIS is a MCE, which involves aggregation of factors in a systematic way. Once the factor maps are prepared, the last step in suitability analysis is to evaluate the criterion so as to combine the information from the various factors. The present study employs, MCE method to combine all the fact maps considered for site selection. Among MCE procedures WLC is flexible, easy to use and frequently for factors aggregation. (Chang, 2007)

3.8.5 Assigning Criteria Weights

One of the components of GIS-Based MCE methodology is assigning criteria weights for each factor maps. This Wight assigned by the responding answer of the experts in the interview and by reviewed different published and unpublished journal. The purpose of weighting in waste disposal site selection process is to express the importance or preference of each factor relative to other factor effect on dumping siting. A number of criterion-weighting procedures based on the judgments of decision makers have been proposed in the multi-criteria decision literature. The procedures include ranking, rating, pair-wise comparison, and trade-off analysis. They differ in terms of their accuracy, degree of easiness to use and understanding on the part of the decision makers, and in the theoretical foundation (Muhammed, 2017). Accordingly, one of the most promising is pair-wise comparison developed in context of a decision making process is known as the AHP. In MCE using a weighted linear combination, it is necessary that the weights sum to 1. Accordingly, the weight module utilizes the pair-wise comparison technique to help develop a set of factor weights that will sum to 1.0. In AHP, weight can be derived by taking the principal eigenvector of a square reciprocal matrix of pair-wise comparisons between the criteria.

The comparisons concern the relative importance of the two criteria involved at a time, in determining suitability for the stated objective. Accordingly, all possible combinations of two factors were compared based on expert judgment to prepare a pair-wise comparison matrix from which the segment calculates a set of weights and consistency ratio. The consistence ratio value can get by divided consistence index with random index value. This random values depend on the values of the numbers of factors (n). This ratio is very import as it shows any inconsistencies that may have arisen during the pair-wise comparison process.

3.8.6 Weight Overlay

Weight Overlay analysis often requires the analysis of many different factors that are necessary for waste disposal sitting. It is desirable to establish the relationship of all the input factors together to identify the desirable locations for selected sites. For this study, all the weighted factor maps were overlaid using weighted overlay extension of spatial analyst tool in GIS. In this combination approach, it is assumed that the more favorable the factors, the more desirable the location will be.

3.9 Material used

The materials used in this study for data analysis include computer hardware and software. The hardware used in this study includes personal computer, color printer, scanner, and Intel phone camera and handle GPS. The software for preparing and analysis of the data include MS word 2013 for editing purpose, MS excel 2013 to store attribute information collected during field survey, Arc GIS 10.8 for digitizing, buffering, overlaying, intersect, dissolve, data analysis including spatial analysis and GIS was used for Geo-referencing and to weigh each class of criteria were derived in Microsoft Excel software use for AHP.

Methodological Flowchart

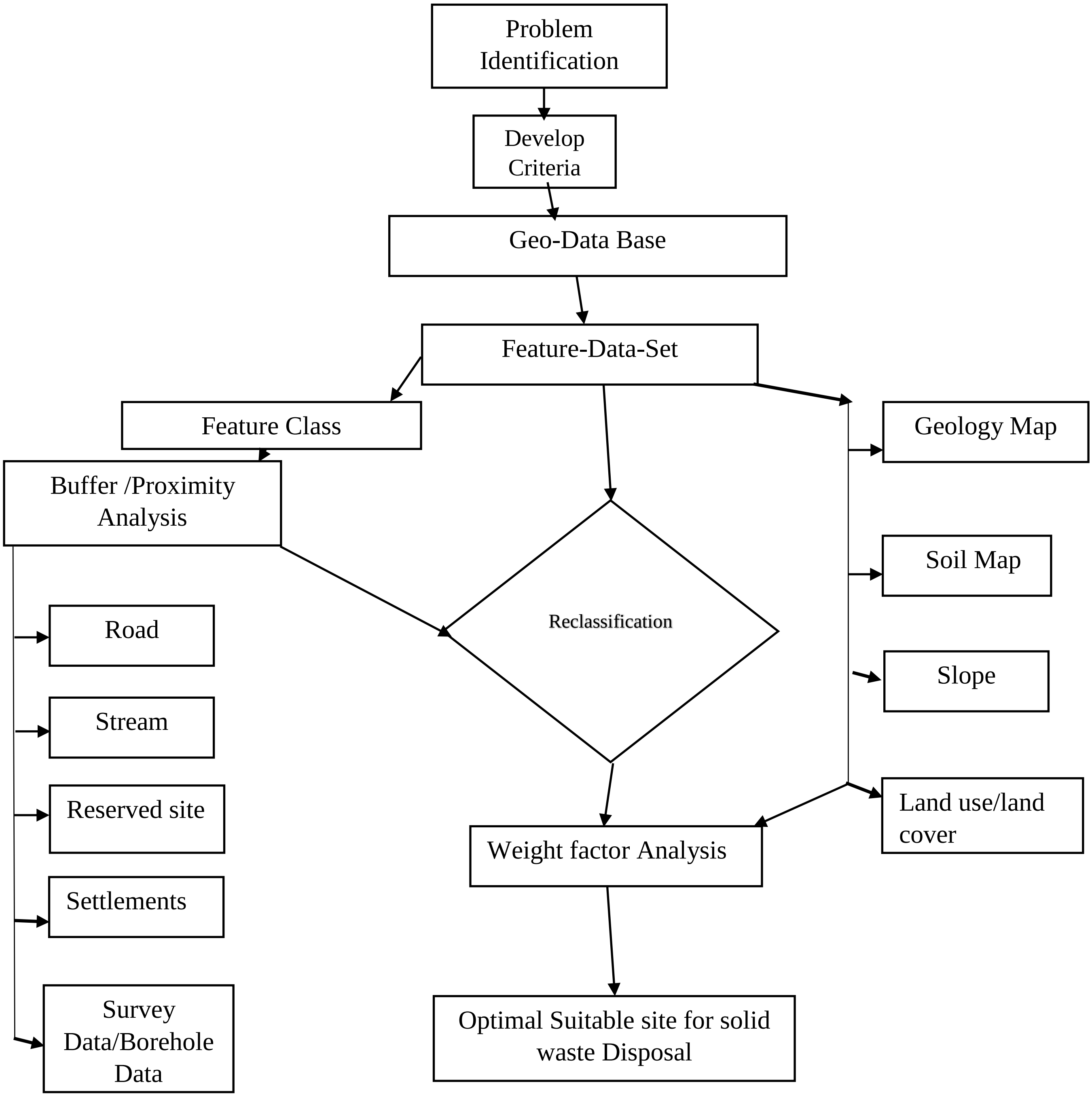


Figure 2: Methodological Flow Chart

CHAPTER FOUR

RESULTS AND DISSCUSSIONS

This part discusses the analysis and presentation of different data sets that were used to select suitable solid waste disposal sites**.** For this study nine suitability criteria (distance from settlement, protected areas, roads network, surface water, ground water, soil type, geology, land use land cover type and slope) were used based on the relevant Ministry of Urban Development and Construction Standard's , in addition to international practices that account for environmental, and social health factors. Maps were created for each suitability criterion and the final composite map was produced by simple overlaying of the individual maps. The layers, buffer zones used, rankings and layer's weights were summarized using tables. The weights were assessed by taking into account the possibility of modifying the natural conditions of the sites so as to increase their suitability**.**

4.1 Solid waste Management System in Jigjiga

According to the observation and interview, the existing solid waste disposal system is not satisfactory, because the existing site does not consider major environmental and health factors, like distance from water bodies, agricultural fields and residential settlement.

The residents near to the existing open dump site are suffering from air pollution and due to pollution of the river they cannot use for animal feeding and irrigation too. In many city of Ethiopia, there are temporary waste disposal at different distances, serving to put solid wastes after collecting from different sources. Since many of these are near to the settlement and public institution, this is a serious problem on human health are shown below the figures.

Figure 3 Disposal Site image from Google Map

The above figure shows existing disposal site found in kebele 5 and 17. The images take from google earth. The disposal site which is find in different kebele like kebele 05, kebele 19, kebele 17, kebele 07, kebele 15. Those disposal site are not selected based on criteria and analysis. Those image evidence capture during filed observation. It's find near settlements, center of city, under bridge so that it cause critical environmental and social health problem. In this sense the existing disposal site find in Jigjiga can't full fill the MUCD standards and WHO standards.

Figure 4: Open Disposal Site

4.2 Respondent Result Analysis

This inquiry aids in determining people's actual habits on where they dispose of rubbish from their homes or some service centers. In this situation, the majority of the respondents, 48.3 percent, select an open dump site, 15.5 percent utilize a valley, and so on. This finding indicates that the residents use a self-disposal method. This is a common practice due to a lack of designated solid trash disposal sites and the city waste management office's carelessness.

Table 2 wastes disposal area

where do you usually put a way collected wastes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	In the itinerant waste van	2	1.7	1.7	1.7
	by the valley/lake side/river	18	15.5	15.5	17.2
	by the road or street side	11	9.5	9.5	26.7
	on an open space	56	48.3	48.3	75.0
	in a hole in own compound	23	19.8	19.8	94.8
	others	6	5.2	5.2	100.0
	Total	116	100.0	100.0	

Based on the information obtained from the respondents unprotected and mismanagement of solid disposal system caused different social health and environmental problem. Based on the respondent different types of health problem caused due to improper solid disposal and managements for example based on the respondent Typhoid, Diarrhea, cough, malaria are the main health problem rise from disposal area.

Table 3 house suffered from diseases due to poor solid waste management

Has anyone in your house suffered from any of these listed diseases during the last six weeks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	diarrhea	22	19.0	19.0	19.0
	typhoid	25	21.6	21.6	40.5
	ring worm	10	8.6	8.6	49.1
	cholera	10	8.6	8.6	57.8
	malaria	10	8.6	8.6	66.4
	cough	25	21.6	21.6	87.9
	skin disease	10	8.6	8.6	96.6
	asthma	2	1.7	1.7	98.3
	others	2	1.7	1.7	100.0
	Total	116	100.0	100.0	

As stated in the problem description, the majority of people use a self-managed disposal system. Problem assertions are supported by this question based on the respondent's answer. According to the respondents, 81% said they place solid waste near the house and burn it after a week to reduce the amount of trash. This has a variety of consequences for the environment and social health.

Table 4 disposal location

Are there any solid waste burn near of your house

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	94	81.0	81.0	81.0
	No	22	19.0	19.0	100.0
	Total	116	100.0	100.0	

More than half of respondents claim there is a solid waste problem, which is caused by a lack of acceptable solid waste disposal sites and the carelessness of the municipal waste management office. In this scenario, the residents use their own waste disposal system, which has resulted in a variety of environmental and health issues in their communities.

Table 5 solid waste disposal problem

Do you think the solid waste disposal system method is a problem in your neighbourhood

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	65	56.0	56.0	56.0
	no	51	44.0	44.0	100.0
	Total	116	100.0	100.0	

According to the information collected from the respondent, the city waste management and collection service office has a service concern. According to the results, 55.2 percent of respondents believe the city's trash management and collection services are inadequate. This means that there is no set schedule for collecting solid trash, and there aren't enough materials to collect the waste and transport it to the disposal location. According to the respondent, there are no rules or regulations in place to sanction any waste management employee who drives carelessly and stays home during their shift. As a result of this, the majority of residents claim to use a self-managed garbage disposal system.

Table 6 service

how do evaluate the state of solid waste collection in your house area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	fair	18	15.5	15.5	15.5
	not good	64	55.2	55.2	70.7
	don't have	34	29.3	29.3	100.0
	Total	116	100.0	100.0	

In general, environmental quality can refer to a variety of factors such as air and water purity or contamination, noise access, open space, and visual effects. The potential consequences of these features could be detrimental to one's physical and mental health. According to the question, the responder believes that the current environment is of great value. This is because as the population grows, so does the amount of trash generated. As a result, individuals utilize various disposal systems, but these systems do not provide adequate protection for human health and the environment.

Table 7 compared quality of environment

over all how would you rate the quality of the environment in Jigjiga as compared to the environmental you had 5 years ago

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	the same	34	29.3	29.3	29.3
	a little worse	41	35.3	35.3	64.7
	much worse	41	35.3	35.3	100.0
	Total	116	100.0	100.0	

Waste is gathered from many sources and disposed of. Collection, transportation, treatment, analysis, and disposal are all part of this process. According to the collected data, 66.4 percent of respondents have no idea how solid waste can be properly managed and turned into a source of income while also reducing the negative effects on the environment and human health, implying that more than half of the respondents are unaware of the proper disposal of solid waste.

Table 8 hear information

have you ever heard about solid waste management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	39	33.6	33.6	33.6
	no	77	66.4	66.4	100.0
	Total	116	100.0	100.0	

Not only do trash disposal processes serve to keep the environment clean, but they also improve the overall health of the community. When waste is correctly disposed of, our environment becomes clean. Basic garbage disposal and management systems should be effectively taught and informed to city residents, yet in my study region, half of the respondents say they receive information about solid waste management, while the other half say they do not receive any knowledge about good waste management. This contributes to the protection of our health and the environment.

Table 9 learn about proper solid waste dispose

have you ever been educated on proper waste disposal by waste management office

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	58	50.0	50.0	50.0
	No	58	50.0	50.0	100.0
	Total	116	100.0	100.0	

4.3 Spatial Suitable site selection and identification of each criterion

Solid waste disposal site selection process pass different requirements. Since the main objective of this study is selecting suitable site used for urban solid waste disposal should minimize surrounding environmental and social health impacts.

4.3.1 Slope Factor

Slope is an important factor in suitability site selection process because it governs the amount of surface runoff produced the precipitation rate and displacement velocity of water to the potential site in addition to the construction cost. It means that when the slope is gentle it decrease the construction cost as compared to the sharp slope area (Wegedie, 2018)

As described in the above section, slope is one of the key criteria to be considered in Solid waste disposal site selection. This is because site topography can reduce or increase adverse effects on the environment. Moreover, steep slope is either not best option for solid disposal because of the difficulty posed in construction or leveling, which incur additional cost. Moreover, high slope areas reduces the stability of the side slopes (increased risk of landslides) and increase leachate movement. Therefore, the best slope for solid waste disposal should be modest slopes, which enable easier storm water control, and site stability measures, as well as facilitating the operation of the site. Different researchers set different slope criteria for waste disposal site selection. The reclassified slope was ranked from 1 to 4, as 4 is highly suitable and 1 is for unsuitable for site selection. The majority of the study area falls under the slope class of 0-10%, covering 89% of the total study area, which is highly suitable for solid waste disposal. Whereas 7%, 3% and 1% of the study area was covered by slope classes 10- 15, 15-20 and >20% respectively. This means that the city is more or less flat in its topography.

Slope class	Relative Weight	Level of suitability	Area(Km2)	% of total Area
<10	4	Highly Suitable	37,696.1	89
10-15	3	Moderate suitable	3171.12	7
15-20	2	Less Suitable	1391.58	3
>20	1	Unsuitable	60.6773	1

Table 10: Slope level and Weight

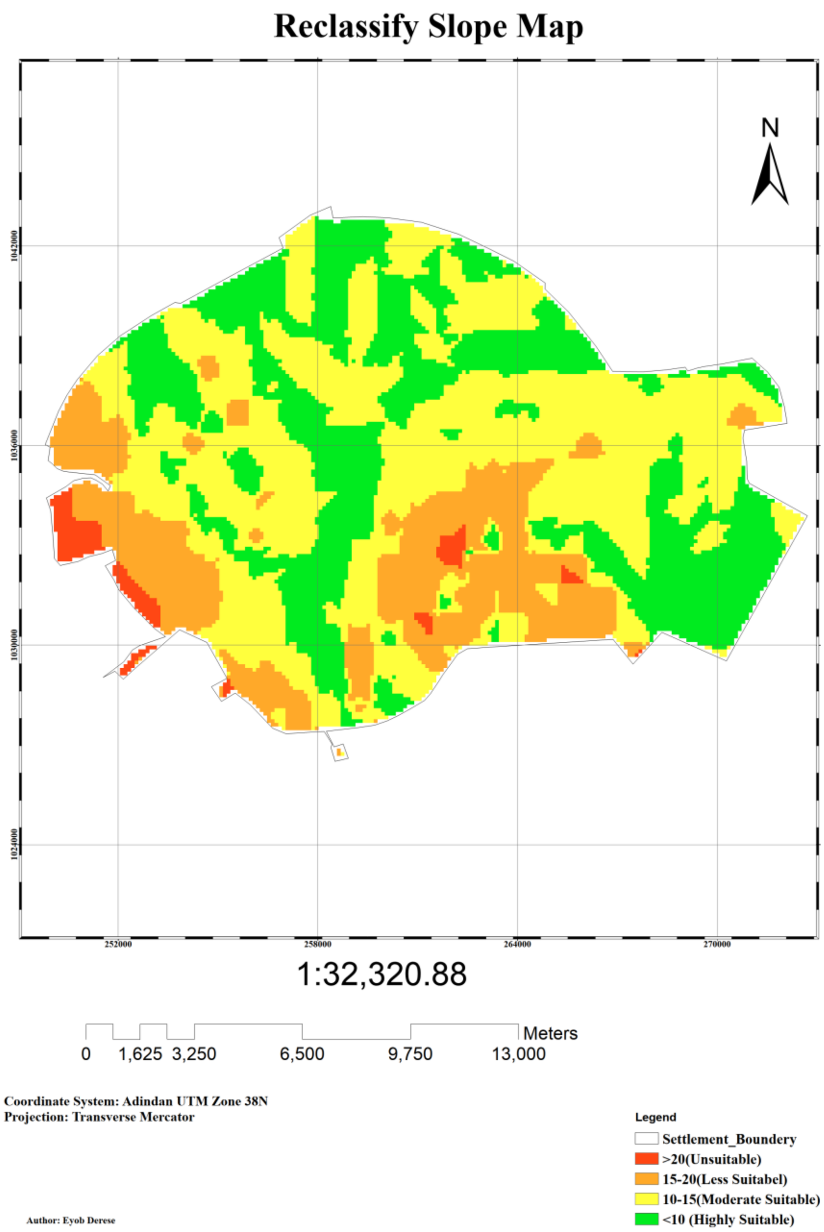


Figure 5 Slope Map

4.3.2 Proximity from road

Proximity from roads is one of the criteria that should be considered from social health Point of views because roads are more activity place during solid waste disposal site selection processes. Because siting waste disposal very close to roads may have public health problem as disposal pose hazardous effect to health and decrease city Aesthetics. Moreover, waste disposal site very far from road network is also not recommended due to high transportation cost. Therefore, to minimize such problems, it must not be sited very close to and far from roads. Minimum and maximum distance from road network of the study area was set after summarizing different literatures. While (Shehhi, 2012)uses 100-300m buffer from road as a minimum distance within which landfill should not be located. However, 300m buffer distance is mentioned as the safest distance. According to the (MUCD, 2012), the waste disposal shall not be located within 400 meter of any major highways, city streets or other transportation routes. For this work, areas within 500 to >2000m away from roads were analyzed as best site for waste disposal. Therefore, Multiple Ring Buffer tools were used to create buffer classes around the roads with 0-500m, 500-1000m, 1000-1500m and >2000m distance ranges. Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation In this study existing roads were digitized from Master Plan of the city, which was accessed from Jigjiga city Municipality.

Table 11: Distance from Road and Suitability

Distance from Road(m)	**Level of Suitability**	**Relative weight**	**Area (Km^2)**	**% of total area**
>2000	Highly suitable	4	10.39	2.60
1000-1500	Moderate Suitable	3	56.18	14.09
500-1000	Less suitable	2	121.07	30.37
0-500	Unsuitable	1	210.95	52.92

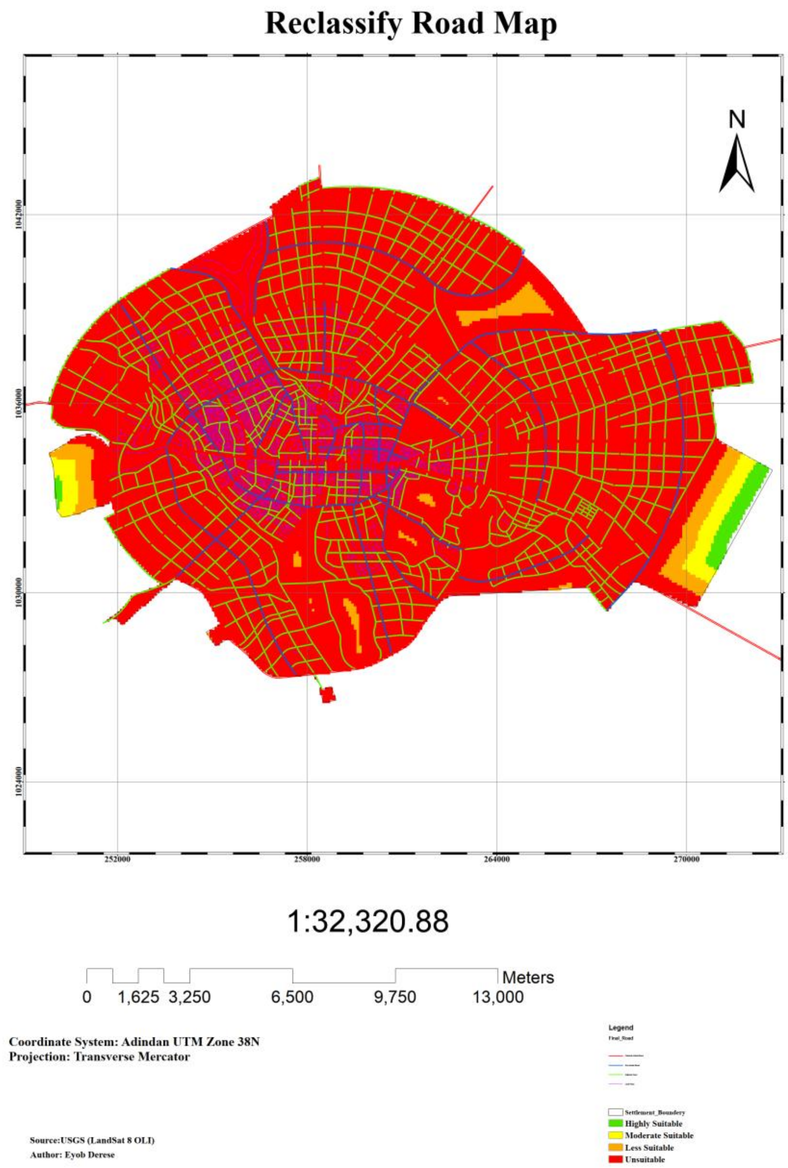


Figure 6 Road Map

4.3.3 Surface/Stream Water

Most of the surface waters in the study area are streams. The waste disposal site must not be close to surface water bodies like streams, rivers and lakes. Because as the distance between the waste disposal and water bodies are nearest, the probability of polluting the water becomes high. The pollution in water resources causes several problems in environment, public health as well as economy. In this study Jigjiga streams/ rivers were generated from DEM, using ArcMap spatial analyst hydrology extension. Then it was buffered using the standards of MUDC 2012, to locate suitable sites for waste disposal. Accordingly, four different zones were specified: in which far buffering from streams are highly suitable while near to streams are unsuitable for waste disposal site.

Table 12: Distance from stream and Suitability

Distance from Stream(m)	Level of Suitability	Relative weight	Area (km^2)	% of total area
>2000	Highly suitable	4	44.83	10.78
1000m- 1500	Moderate Suitable	3	86.15	20.73
500m- 1000	Less suitable	2	115.47	27.78
0-500	Unsuitable	1	169.10	40.69

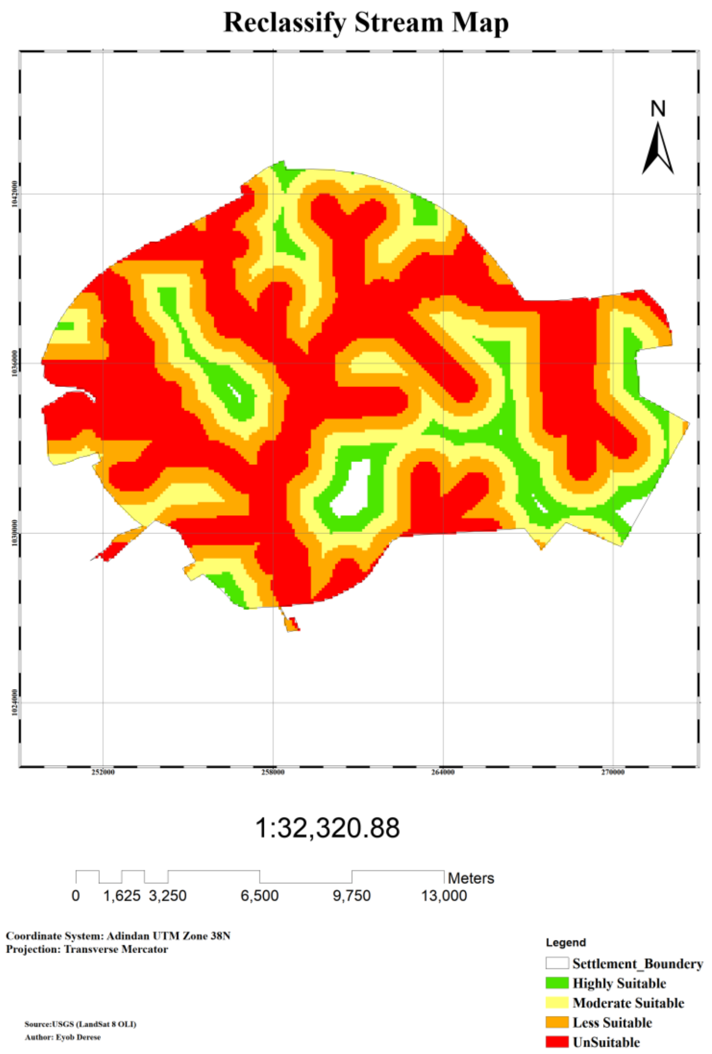


Figure 7 Stream Map

4.3.4 Soil characteristics

Soil characteristics is a basic input for identification of solid waste dumping site. Soil acts as a media to interflow of leachate into ground water. If the soil have high porous the interflow is more and ground water contamination is more and also the leachate was spread, and that affect the soil quality. In the soil formation different factors play great role like climate, flora and fauna (Biological Decomposers), time to form different types of soils in a different area. As Geological formation soil can be vary from place to place. Based on water infiltration, PH values, porosity, and permeability of soil control the vertical as well as horizontal movement of any kinds of contamination caused due to natural or man-made problems.

According to FAO and MOA soil classification of Jigjiga four type of soil that exists. In Jigjiga found Eutric CombiSol, Lithic LeptoSols, Eutric VertiSols, Eutric fluviSols. In Jigjiga city Eutric combiSols the dominant find and cover large area in the city. The character of soil is vary from place to place based on content, depth and coverage area.

Soil characteristics of the study area like texture and depth should also be considered for waste disposal site selection within the study area.

This is due to availability of material and permeability depends on depth and texture soil, respectively. Clay textured soil is more preferred for dumping site as it is impermeable to leachate and also used for lining the base of sanitary design. Moreover, area with deep soil is preferred as it provides soil for covering solid waste after each disposal to minimize air pollution from the site. In this study, identified Eutric fluvisols as highly suitable soil for waste disposal due to its clay amount and very deep soil. Leptosols were identified as unsuitable soil types due to large amount of gravel and shallow soil depth.

Table 13: Soil type and Relative Weight

Soil Type	**Relative weight**	**Suitability class**	**Area cover(km^2)**	**%of total area**
Eutric fluvisols	4	Highly Suitable	13.17	3
Eutric Cambisols	3	Moderate Suitable	327.3	73
Eutric Vertisols	2	Less Suitable	69.54	15
Lithic Leptosols	1	Unsuitable	38.95	9

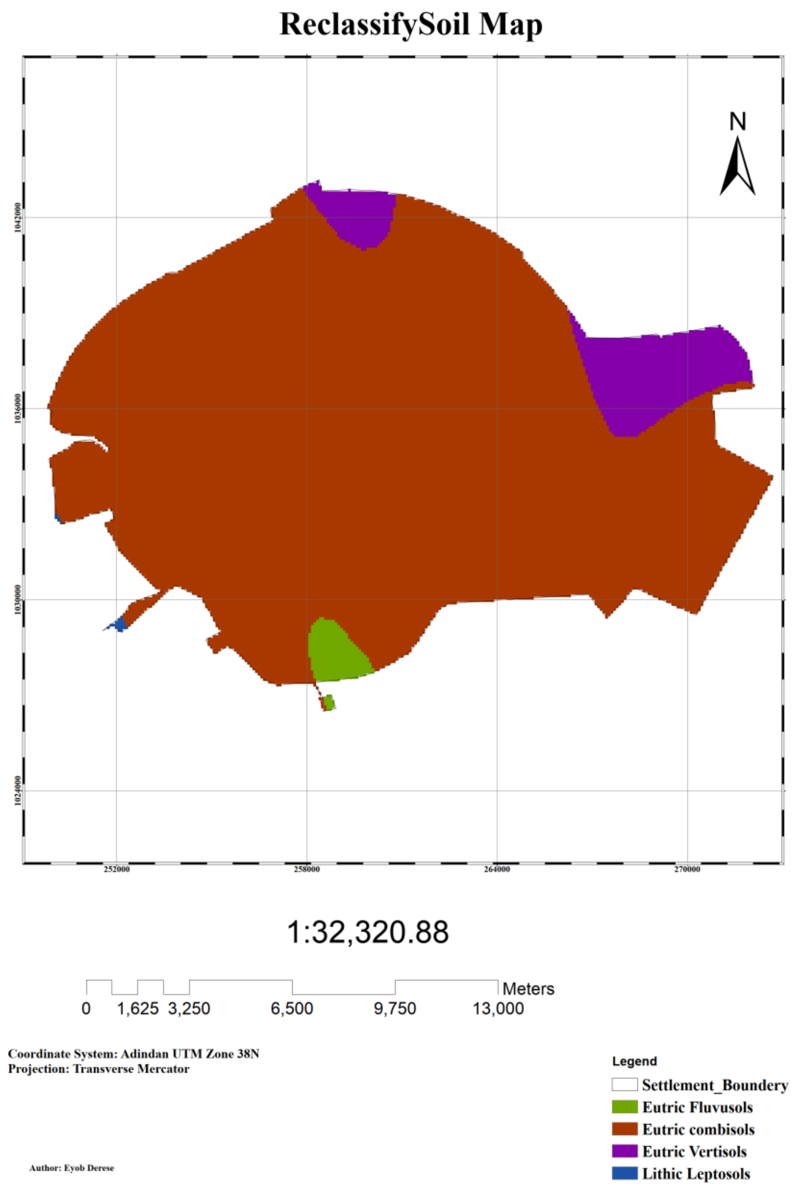


Figure 8 Soil Map

4.3.5 Distance from Resident

The waste disposal sites should not be sited or located near to settlement areas. The extent of the settlement areas were derived by digitization from Master plan and Land use plan of the city, and distance of 2000 m and above are considered as Highly suitable while 500 m and below were considered unsuitable. Hence the land suitability for waste disposal increases with the increase in distance from the residential areas (MUCD, 2012)

Table 14: Distance from Settlement

Distance from Settlement(m)	Level of Suitability	Relative weight	Area (km^2)	% of total area
>2000	Highly Suitable	4	21.84	6.72
1500- 2000	Moderate Suitable	3	47.31	14.55
1000m- 1500	Less Suitable	2	86.62	26.64
0-500	Unsuitable	1	162.39	52.09

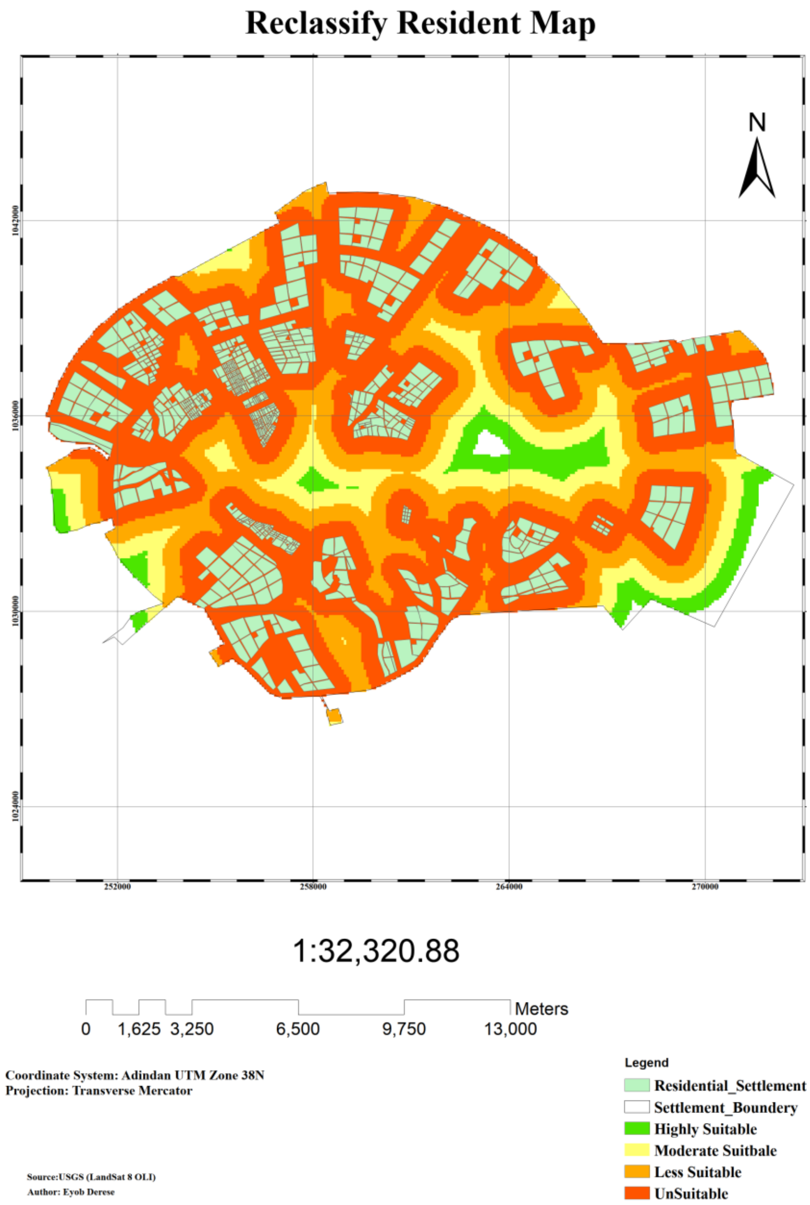


Figure 9 Residential Area Map

4.3.6 Land Use/land cover

The land cover types of the city was analyzed from Landsat OLI acquired in 2020. The image was georeferenced to a projection of Universal Transverse Mercator, Grid of UTM Z 38N and datum with Adindan. Master plan of Jigjiga City was also used as source of information during image classification. The image was undertaken under maximum likelihood supervised classification. Classified pixels were clustered into 4 general categories as: built up area, Agriculture and grass, water bodies, bare/open land. Accordingly, the land use types were ranked based on their importance to evaluate suitable site to locate landfills. These are; bare/open land are ranked as highly suitable, agriculture and forest as moderately suitable, built up less suitable and areas near to water bodies as unsuitable were identified. Accordingly, master plan of the study area was used as a guidance to identify representative land cover classes. This was used for solving the problems of identifying features of similar reflectance. (Mekuria, 2006) Finally, Maximum likelihood classification has been carried out using ArcMap software from the images of Landsat 8. Large parts of the study area are covered by bare/open land area, Built up area, Agriculture land/forest and least area cover water bodies Land use/land cover of the study area is shown below.

Table 15: Land use Categories

Land Use Categories	Level of Suitability	Relative weight	Area (Km^2)	% of total area
Bare/open land	Highly suitable	4	225.77	66.9
Agricultural land / grass	Moderate Suitable	3	23.37	5.2
Built up	Less suitable	2	125	27.83
Water bodies	Unsuitable	1	0.184	0.04

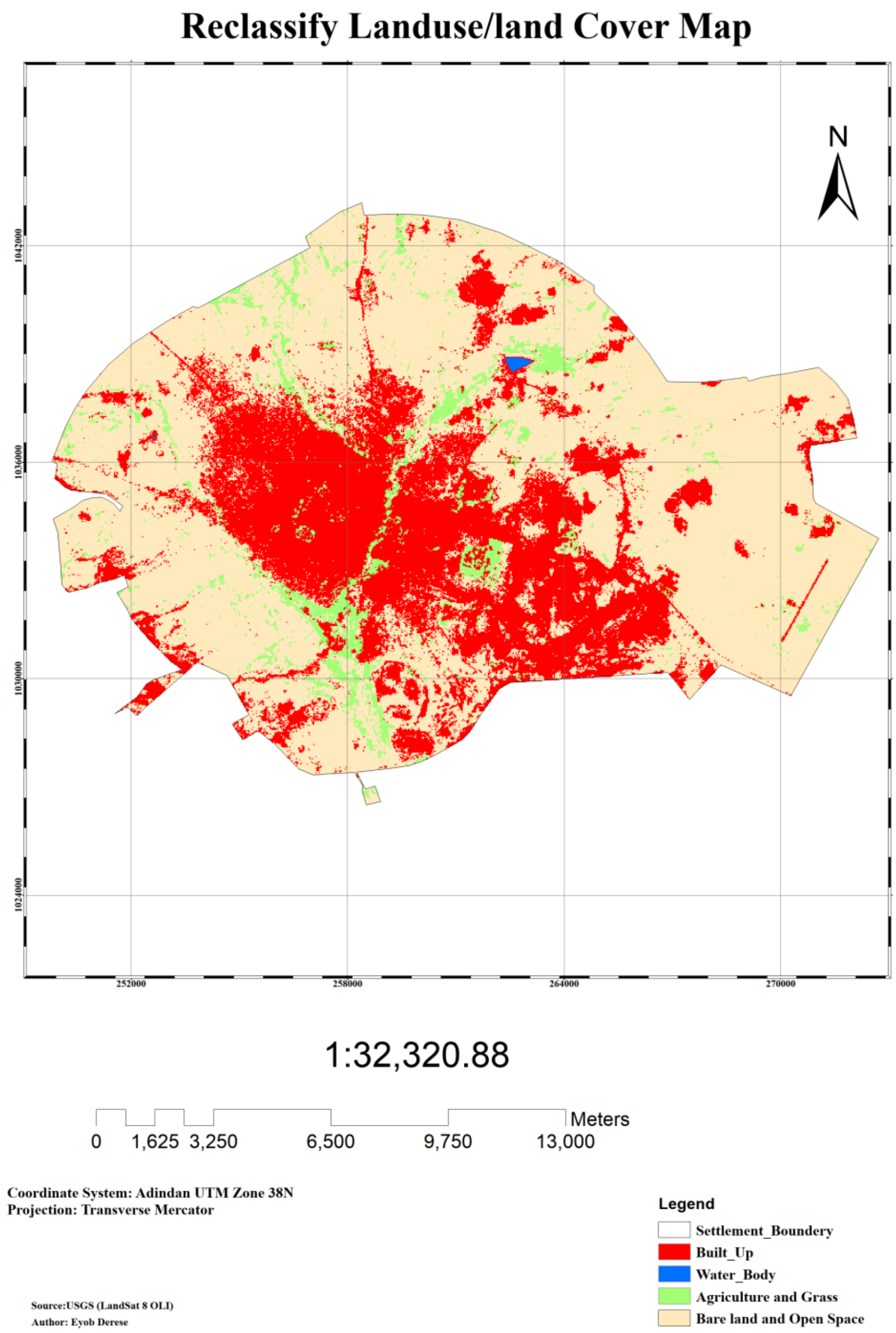


Figure 10 Land use/Land Cover Map

4.3.7 Distance from Protected Area

The protected area in this study includes churches, mosques, schools, administrational zone, police station and health centers. The waste disposal should not be located in close proximity to sensitive areas listed above to a minimum limit of 1,000 meter buffering surrounding. When the distance increases from these areas suitability also increases. In this study the above listed protected areas were identifying using Google map during the office work, field observation and buffer using the standards of (MUCD, 2012), to locate Suitable site. Accordingly, four different zones were specified in which far buffer from protected areas are highly suitable while near are unsuitable for waste disposal site. The study considered the reclassified distance as unsuitable from 0 - 1000meter, less suitable from 1000-1500m, Moderate suitable from 1500-2000m and highly suitable >2000meter.

Table 16: Distance from protected

Distance from protected	**Level of Suitability**	**Relative weight**	**Area (km2)**	**% of total area**
>2000	Highly suitable	4	27	20
1500- 2000	Moderate Suitable	3	30	21
1000m- 1500	Less suitable	2	34	25
0-1000	Unsuitable	1	48	34

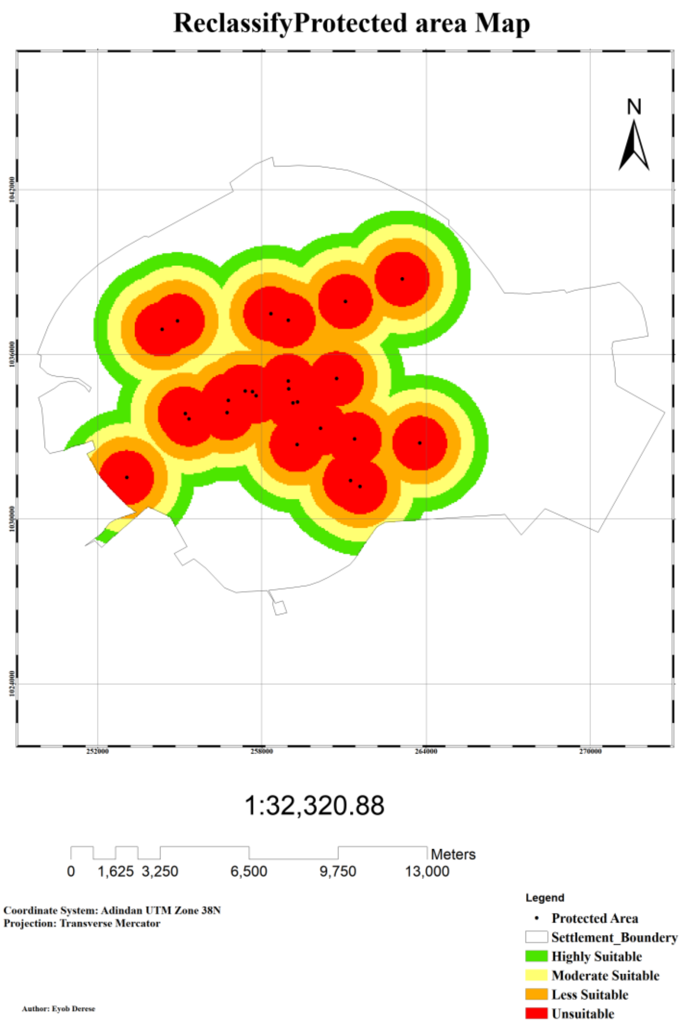


Figure 11 Protect Area Map

4.3.8 Proximity from Groundwater Borehole

Proximity of waste disposal to a groundwater is an important environmental criterion in the site selection; so that wells may be protected from the runoff and leakage of the site. Hence, solid waste disposal should be placed away from water boreholes. Otherwise, it can have irretrievable human and environmental effects. As a result, proximity from groundwater boreholes was considered as an important criterion for this study. Accordingly, 7 ground water points that are currently functional is collected on filed work using Handle GPS and Multiple Ring Buffer tools were used to prepare buffering zones around each boreholes.

Waste disposal should not be sited within 0-500m buffer distance from water boreholes. However, (Dorik, 2014)state on his study used 500- 1000m and use700m as a minimum distance which can be safely sited. For this study, 1000m buffer distance was used as a minimum distance. Moreover, additional buffering was performed around the boreholes in order to identify the best site for waste disposal. Buffer distance of 0-1000m, 1000-1500m, 1500-2000, and >2000m were prepared around each and every well points.

Table 17: Distance from ground water boreholes

Distance from Well (m)	Level of Suitability	Relative weight	Area (km2)	% of total area
>2000	Highly suitable	4	14.10	35.38
1500- 2000	Moderate Suitable	3	12.25	30.73
1000-1500	Less suitable	2	9.28	23.29
0-1000	Unsuitable	1	4.21	10.58

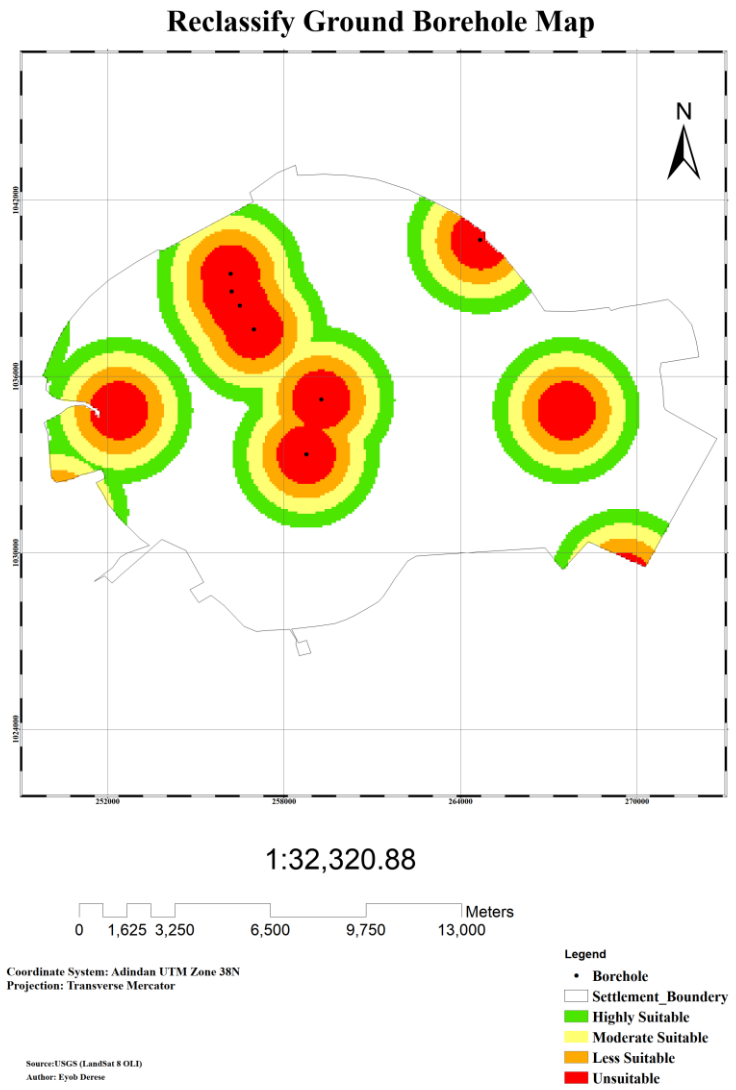


Figure 12 Ground water Borehole Map

4.3.9 Geology

Geology is one of the important environmental factors that should be considered during waste disposal site selection processes. Impermeable layers and consolidated material are suitable for site as they do not allow movement of leakage and hence to minimize the risk of groundwater contamination from disposal leachate. For this study, the degree of porosity, thickness of the rocks and the presence of fracture are the factors or criteria to select the suitable rock type. The more weathered and fracture, the more permeable and instable the rocks. In addition to the geological information, it is important to know about the subsoil of the strata like its composition, the lateral and vertical continuity of the strata, the permeability, resistance to erosion and the stress of deformation behavior. The Geology of

Jigjiga City divided in to 3 major unites: Hamanlei formation, Ashangi formation. Alluvial and Lacustrine.

The geology map of the city obtained from Ethiopia Geologic Survey (EGS). The map was scaled in 1:250,000 and georeferenced then digitalized in GIS to utilize the information. Accordingly, Three (3) different geologic units of the study area were digitized and their thematic map was prepared. The geology type of the city as stated above Hamanlei Formation, Ashangi Formation and Alluvial and Lacustrine with the area coverage of 43.9%, 6.7% and 49.4 % respectively. In this study Hamanlei Formation Highly suitable and alluvial and Lacustrine Unsuitable.

Table 18: Geology Formation and Suitability

Formation	**Level of Suitability**	**Relative weight**	**Area (km2)**	**% of total area**
Hamanlei	Highly suitable	3	90.4	43.9
Ashangi	Less suitable	2	19.59	6.7
Alluvial and Lacustrine	Unsuitable	1	125.85	49.4

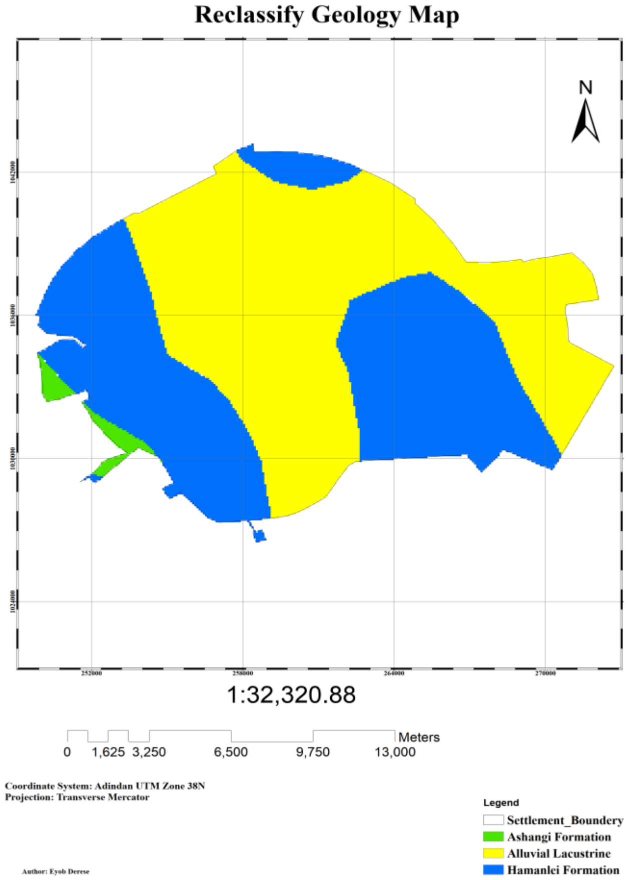


Figure 13 Geology Map

Based on this AHP weight source element, the following of weights for all factors considered for waste disposal site selection are generated. On the table shows that proximity from Road, Land use land cover, and proximity protected are more important than other factors for waste disposal site selection. The main reason for this is to protect community health and environmental pollution from dumping site.

The site selection for solid waste disposal dumping site involves comparison of different options based on environmental and social health impacts. Hence, based on experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility. The weights were developed providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced the logic under the Analytical Hierarchy Process (AHP). Weight rates were given based on pair wise comparison 9 point continuous scale. These pair wise comparison were then analyzed to produce of weights that sum to 1.

The factors and their resulting weights were used as input for the multi-criteria evaluation (MCE) element for weighted linear combination of overlay analysis.

1	3	5	7	9	2, 4, 6, 6	1/3, 1/5, 1/7, 1/9
Equal Importance	Moderate Importance	Strong Importance	Very Strong Importance	Extreme Importance	Intermediate Values	Inverse Comparison

Table 19: Pairwise Comparison Matrix

	Road	Land use-land cover	stream	protected area	slope	Resident	Ground water	Geology	Soil	Weight	Influ%
Road	1									0.202005	20.2
Land use-land cover	1/2	1								0.1846	18.6
stream	1/2	1/3	1							0.106271	10.6
protected area	2	1/3	1/2	1						0.123968	12.4
slope	1/3	1/2	2	1/3	1					0.108296	10.8
Resident	1/3	1/2	1/3	1/3	1/2	1				0.076077	7.6
Ground water	1/3	1/2	3	1/2	1/2	1/2	1			0.074655	7.4
Geology	1/3	1/3	1/3	2	1/2	1/2	3	1		0.068222	6.8
Soil	1/3	1/2	1/3	1/2	1/2	1/2	1/3	2	1	0.055907	5.6

In this Pair wise comparison matrix the consistence ratio value 0.083987 > 0.10 so that depend on the rule of AHP the calculated result of the consistence ratio is accepted.

4.4 Suitability Analysis Result Discussion

The importance's of environmental factors like Geology and soil permeability, proximity from groundwater, streams/rivers and topographic factors like slope and land uses, for determining waste disposal sites are not the same. The analysis of the weight assignment shows that proximity of road and land use land cover related factors like resident, protected area and streams/rivers are more influential than the other factors, as they are very important to protect Surface water pollution from dumping leakage. Weighted Linear Combination result showed four classes of suitability levels. These are unsuitable, less suitable, Moderate suitable and highly suitable. As the overall suitability result shows; there is no area that fulfills the Moderate suitable criteria. This indicates that there is no very highly suitable in all the nine (9) criteria considered.

Table 20 Final suitability result

Level of Suitability	Color	Relative weight	Area (km2)	% of total area
Highly suitable	Green	4	18.40	26.87
Moderate Suitable	Yellow	3	21.63	31.58
Less suitable	Orange	2	19.56	28.56
Unsuitable	Red	1	8.88	12.95

The final map has four classes based on that about 26.87 % (18.40 Km^2) fall under highly suitable area for Solid waste site. The Moderately suitable area covers 31.58% (21.63 Km^2). The area which covers 28.56% (19.56km^2) is under less suitable class and the remaining 12.95 %(8.88 Km^2) under unsuitable class. Depending on the stated criteria, suggested areas as suitable for solid waste dumping site fall in kebele 22, kebele 12, kebele 18 and kebele 16 the North, North West, South East and South West direction from the city.

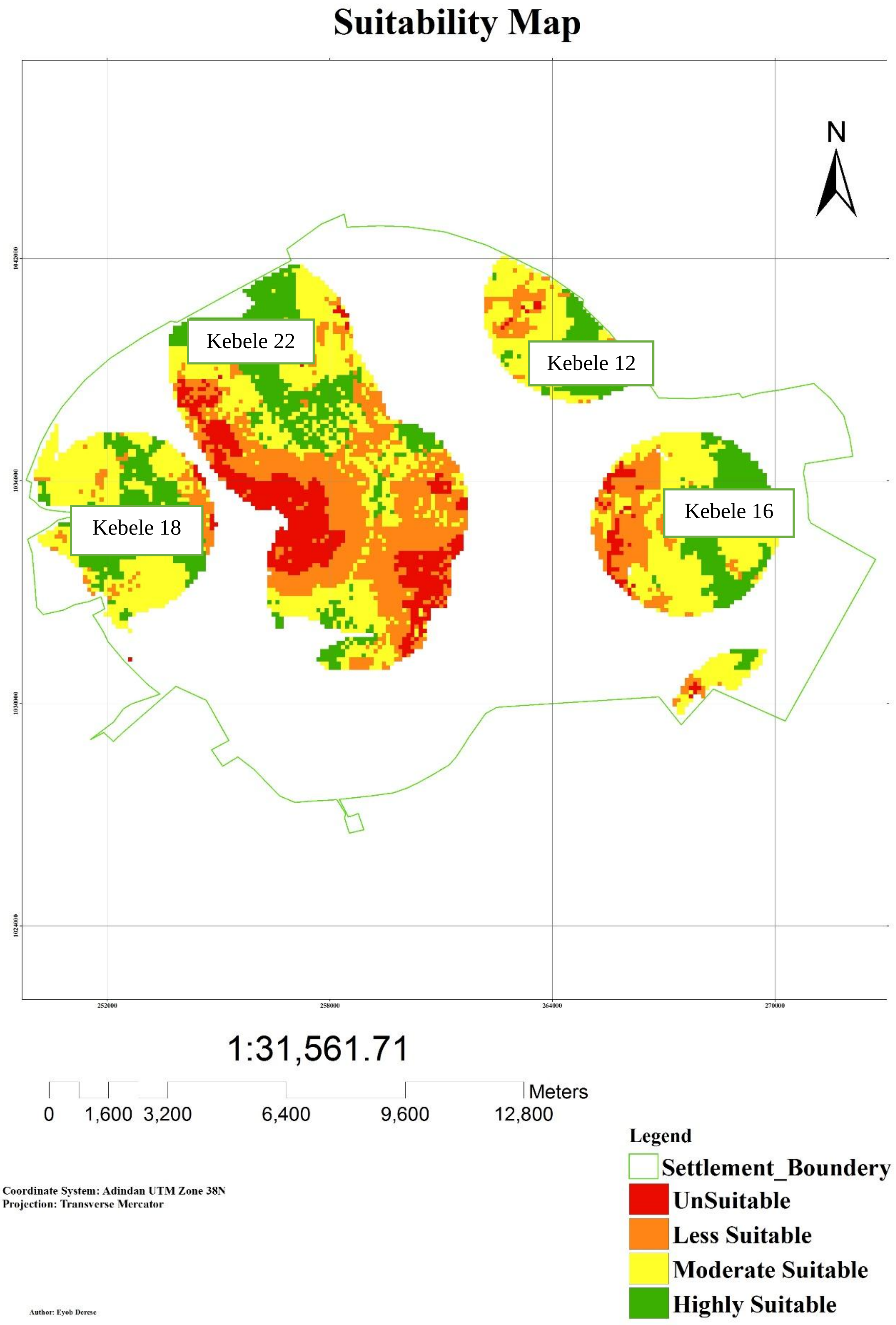


Figure 14 Suitable Map

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In Jigjiga City's solid waste disposal system, open dumping without insight is used also without scientific examination. This finding proves the environmental and social issues that residents of dumping sites face. Solid waste excretes from homes, hospitals, industries, markets, and commercial establishments are piled up and may include leakage toxic substances that are hazardous to the environment and human health. The lack of any type of solid waste treatment or separation has exacerbated the problem. Furthermore, residents are dumping solid waste near their homes at disposal sites such as the back of St'Joseph Catholic School and Z-spark School, which are located along the city's major drainage system and are not at a reasonable distance from residential houses, posing both social and environmental problems, the present study employed GIS techniques to arrive at the most suitable solid waste disposal site by integrating nine factors maps namely: proximity to road networks, land use land cover, distances from residences, Protect areas; surface water /river, boreholes, Soil, Geology and Slope in the study area. The result of the final suitability map showed that 26.87 % of the entire study area is categorized as highly suitable site with various suitability indices ranging from highly suitable to marginally unsuitable. The suggested areas as suitable for solid waste dumping site fall in kebele 22, kebele 12, kebele 18 and kebele 16 the North, North West, South East and South West direction from the city.

5.2 Recommendation

The Following are recommendation

- Owning to adverse effect of the existing dump sites, the academics strongly recommend the administrative body of Jigjiga Municipality to put the finding of this study into effect as soon as possible.
- The rates and volumes of solid waste generated from the municipality should carefully be determined to further decide the dimension of the landfill site during construction.
- Detailed hydrological, Climate and geological studies for the selected disposal should be explored.

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Appendix

Questioner for City Dwellers

Questionnaire for MSc Project paper Jigjiga, Ethiopia

Household questionnaire

This interview is made to undertake a study for Suitable site selection for urban solid waste disposal in Jigjiga city. In terms of this questionnaire I would like to know about the environmental, Social and economic negative issues caused by solid waste disposal sites and faced the city. Your response will help to select and make proper place for suitable site for solid waste dispose this to improved and make clean city with creating sustainable living compound for the dwellers. The interview will take a few minutes and the answers will be completely confidential and strictly for academic purpose. Thus, please answer the questions honestly and as truthfully as you can. Thanks you for accepting the questionnaire

Details of respondents

Date …………………………………………………………….

General Information

Please put x in the appropriate box/boxes for your Answer

A. Household Detail

1. Sex

Male ☐

Female ☐

2. Please mark your age group in the appropriate box

15-17 ☐

18-29 ☐

30-39 ☐

40-49 ☐

50-59 ☐

60-64 ☐

65 and above ☐

3. How many people are currently living in this house?

…………………………………………………………………………………………

4. How long have you lived in this city?

Less than one year (12 months)

1-2 years ☐

3-4 years ☐

5-9 years ☐

10-19 years ☐

20 years of more ☐

7. What is your highest educational level?

a. Never schooled ☐ b. Primary ☐ c. Middle School ☐ d. High School ☐

e. University graduate ☐ f. Vocational training ☐ g. others …………………………

8. What is your Major occupation?

a. Farming ☐ b. Business ☐ c. Government Servant ☐

d. Others …………………………………………………

B. House Hold waste collection and disposal

9. Have you ever heard about solid waste management?

a. Yes ☐ b. No ☐

If Yes, in what way?

a. Public Radio ☐

b. Public TV ☐

c. In Public meeting ☐

d. In School ☐

e. on poster ☐

f. Other……………………………………………………………………………

10. Have you ever been educated on proper waste disposal by the waste management office?

a. Yes ☐ b. No ☐

11. What type of solid waste comes out from your household? (one or more answers)

a. Paper and carton ☐

b. Plastics (bags/bottles) ☐

c. Food waste ☐

d. Tins/cans ☐

e. Fiber bags ☐

f. Glass ☐

g. Others ……………………………………………………………………………………

C. Garbage Collection system and types of waste generate

12. In what type of container do you collect waste? One or more answers?

a. Carton ☐

b. Waste Basket ☐

c. Old bucket ☐

d. Plastic bag ☐

e. Tin/can ☐

13. How often is the waste container emptied?

☐

a. Once a day

b. Once in two days ☐

c. Once in three days ☐

d. Once a week ☐

f. Others…………………………………………………………………………………..

14. Where do you usually put a way collected wastes?

a. In the public bin ☐

b. In the itinerant waste van ☐

c. By the valley/lake side/river ☐

d. By the road or street side ☐

e. on an open space ☐

f. In a hole in own compound ☐

g. Other…………………………………………………………………………………

15. Are there any solid waste disposal near your house?

a. Yes ☐ b. No ☐

16. How can you describe the state of the solid waste disposal near your house? (One or more)

a. Adequate size ☐ c. In a good state ☐ e don't Know ☐

b. Inadequate ☐ d. Not in a Good Condition ☐

17. Do you think the solid waste disposal system method is a problem in your neighbourhood?

a. Yes ☐ b. No ☐

18. What problem do you think exist in your area as for solid waste?

a)____

____

____

____

____

______________________________________.

19. How do you evaluate the state of solid waste collection in your house area?

a. Good ☐

b. Fair ☐

c. Not Good ☐

d. Don't have ☐

20. Do you ever hear of health problem due to solid waste?

a. Yes ☐ b. No ☐

21. Do you ever notice solid waste in the road, land or public area?

a. Yes ☐ b. No ☐

22. Do you ever notice burning waste in public area?

a. Yes ☐ b. No ☐

D. Waste and Sustainable Development

23. How concern are you about sustainable development?

a. Concerned ☐ b. Not Concerned ☐

24. Would you personally say the solid waste is a major issues currently affecting Jigjiga City Dwellers?

a. Yes ☐ b. No ☐

25. Do you think most human health issues related with solid waste in Jigjiga could be minimized solid waste managed properly?

a. Yes ☐ b. No ☐

26. Over all how would you rate the quality of the environment in Jigjiga as compared to the environmental you had 5 years ago?

a. Much better ☐

b. A little better ☐

c. The same ☐

d. A little worse ☐

e. Much worse ☐

27. Have you heard of “sustainable development”?

a. Yes ☐ b. No ☐

28. Are you aware of Sustainable development in Jigjiga City?

a. Yes ☐ b. No ☐

29. Can you explain the importance of sustainable development for you?

____

____

____

____.

30. Do you think Solid waste management has impact on sustainable development?

a. Yes ☐ b. No ☐

31. Do you agree the solid waste management should be developed in Jigjiga City for Sustainable Development?

a. Yes ☐ b. No ☐

32. Do you believe that there should be environmental conservation for sustainable development?

a. Yes ☐ b. No ☐

What is the reason for your answer?

____

____

____

____.

33. Do you agree that every single person has a responsibility to contribute to sustainable development in Jigjiga City?

a. Yes ☐ b. No ☐

34. How do you think about the current solid waste disposal Site?

____

____

____

E. Waste effects on human health and its surround environment

35. In your opinion which of these is a priority concern about waste in the area?

a. Littering and looks bad ☐ b. Effect on human health ☐

c. Effect on environment ☐ d. Others………………

36. Has anyone in your household suffered from any of these listed diseases during the last six weeks?

a. Diarrhea ☐ b. Dysentery ☐ c. Dengue ☐ d. Typhoid ☐

e. Ringworm ☐ f. Scabies ☐ g. Cholera ☐ h. Malaria ☐

i. Cough ☐ j. Asthma ☐ k. Skin disease ☐ l. Others…………………

37. What are you more concerned about?

a. Air pollution ☐ b. Water pollution ☐ c. Compound pollution ☐

d. Damage to city beauty ☐ e. Others ……………………

38. This year, did you or any member of the family participate in any community cleanup activities or other voluntary cleanups?

a. Yes ☐ b. No ☐

39. In your opinion is waste management an environmental problem?

a. Yes ☐ b. No ☐

40. Do you know how your service provider disposes your collected waste?

a. Yes ☐ b. No ☐

41. Are you concerned about the disposal methods of the service provider?

a. Yes ☐ b. No ☐

42. Do you consider that environmental degradation has negative effect on your family?

a. Yes ☐ b. No ☐

43. Do you think that leaving a better environment to future generations is something?

a. Very important ☐ b. Not important ☐

44. Finally, Please tell me are you satisfied with the Jigjiga City Municipality solid waste collection and dumping process?

a. Yes ☐ b. No ☐

Field collected Survey Data

Survey existing disposal site location

Existing Disposal Site			
Point No	Specific place	Easting	Northing
1	kebele 05	259145.95	1034623
2	kebele 17	259027.88	1035734
3	kebele 19	258376.54	1035734
4	kebele 07	257203.96	1037035
5	kebele 15	257040.55	1032195

Survey Ground water Borehole Data

Sample Borehole Survey Data		
Point No	Easting	Northing
1	259262	1035227
2	256971	1037610
3	256489	1038421
4	256215	1038899
5	256180	1039507
6	258757	1033355