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ADDIS ABABA UNIVERSITY

COLLEGE OF SOCIAL SCIENCE

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL
STUDIES

SOLID WASTE LANDFILL SITE SELECTION SUITABILITY
ANLYSIS USING GIS AND REMOTE SENSING: ADAMA TOWN,
IN FOCUSE

A THESIS SUBMITTED TO THE DEPARTMENT OF GEOGRPHY AND
ENVIRONMENTAL STUDIES, IN PARTIAL FULFILMENT OF THE
NECESSITIES FOR THE DEGREE OF MASTER OF ART IN GEOGRAPHY
AND ENVIRNMENTAL STUDIES (SPECIALIALIZATION IN GIS RS AND
DIGITAL CARTOGRAPHY)

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Feb, 2021

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ADAMA TOWN

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Based Suitability Analysis Solid Waste Landfill Site Selection Using Geographic Information System and Remote Sensing: For Adama Town, in focuses

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Declaration

I announce that this project is originally organized by me. It is created on my own effort, with acknowledgments of other sources, and has not been defer to in entire or portion for any other professional qualification.

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ACKNOWLEDGEMENTS

First and for most, always and forever my sincere and unlimited love and gratitude spirits to my Almighty God, chief of this world, who is endlessly with me and giving me this chance and for giving all the strength and everything I ever asked, to keep myself on path. Without his blessing I would never have succeeded and for all accomplishments which I have been able to attain in my life completely.

I am very much thankful to thank respectfully my advisor Prof. Mohammed Assen, for his commitment, reliable follow ups, well-informed direction and productive comment at every phase of this project work. I also thanks for his anxiety and passion whenever I need his support. My appreciation also goes to the institutions and organizations, which have been provided me with all the necessary data.

My genuine thanks to “my beloved dear parents and family members” for their love, taste, guidance, suggestions, reassuring talks where ever and so on. Especially my beloved mother Degitu Bededa and my brother Sena Bayisa, for their normal to deal support and follow up my everyday healthy and working condition during and after my childhood throughout my whole life in general and particular in educational life my thanks is really very great. I would also like to spread my special thanks to my dear brothers Mogos Tufa and dear my sisters Aregash Bayisa whose has been source of my strength, inspiration and help to accomplish my study. I don’t have word rather saying God pay back for them.

Lastly, the decision of this thesis was made possible with direct and indirect contribution of several people and organizations which is not possible to reference everyone, but all of them earn my thankfulness.

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Acronyms

AHP	Analytical Hierarchy Process
MSWL	Municipal solid waste landfill
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis
FAO	Food and Agricultural Organization of the United Nations
GIS	Geographical Information System
GPS	Global Positioning System
LU/LC	Land use / Land cover
MCDM	Spatial Multi-Criteria Decision Making
MCDA	Multi-Criteria Decision Analysis
RS	Remote Sensing
TM	Thematic Map
USGS	United State of Geological Survey
LUTs	Land Utilization Types

Abstract

Solid waste management system is that the foremost difficult task that lots of nation, both developing and developed, are facing. Landfill method is one in every of the easy and cheap solid waste dumping site management systems which are always required for sustainable management of solid waste site selection. The foremost objective of this study was to spot environmentally sound, socially acceptable and economically feasible landfill site for the solid waste dumping in Adama city. To achieve the objectives, this study was conducted by integrating Geographic data System (GIS) and remote sensing for selecting suitable solid waste disposal sites. All factors were represented with map outputs which are classified and standardized by GIS and RS for environment preparation of site suitability analysis map. Analytical Hierarchy Processes pair-wise comparison component was done to derive weights for all aspect parameters. Some criteria in selection suitable site for landfill site selection were set. These were distance to road, distance to river/stream, sort of soil, land use/land cover and degree of slope effects on the study area. Accordingly, 52.04% of the study area was unsuitable, 1.15% of the study area is current not suitable, 44.64% is moderately suitable and 1.77% is extremely highly suitable for landfill supported predefined criteria. The study proofed that the application of GIS and remote sensing technique for the identification of suitable solid waste dumping site will minimize the environmental hazard and human health difficulties. In general, site selection required appropriate data set generation and site identification as, applied within the study.

CHAPTER ONE

INTRODUCTION

1.1 General Background

Waste is a substantial settled from each day-to-day human life activities, which leads to opposing impacts on human health and the environment. Solid wastes can be well-defined as non-liquid and non-gaseous unusable goods of human activities, like from households, municipal, construction and industries. The generation of solid waste has become a global environmental and health difficult in the current world both in developing and developed countries. Increasing population, rapid economic growth, the rise in living standards, expansion of urban and industrial activities accelerates solid waste generation (Tirusew and Amare, 2013).

Municipal solid waste managing is considered as one of the most fast and serious environmental problems challenging urban establishments in developing countries. The most common problems associated with lack of proper management of solid waste include diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Mujior, 2008).

Uncontrolled population growth together with booming economy and rapid rate of urbanization have greatly accelerated the municipal waste generation rate in developing countries (Minghua et al. 2009). Now municipalities have become powerless to overcome the problems of solid waste management due to technical financial worries and absence of institute. This has resulted in serious dissatisfaction among to the inhabitants (Sujauddin et al.2008). Similarly, Burnley (2007) has discussed mainly, financial resources, complexity and system multi dimensionality as the main causes for in efficient and ineffective waste management system in different municipalities in developing countries. This necessitates the effective management and planning of optimum dumping site. Having a properly planned waste disposal site is one of the most important management activities, which need to be carefully planned (Regassa et al. 2011). So to resolve these problems, the application of Geo-information systems has been taken to play a vital role in addressing the difficult and actual management system.

An object which discharged and thrown away from each stage of human life activities is called waste or waste materials, which leads to adverse impacts on human health and the environment (Bringi, 2007). These includes food leftovers, papers, piece goods, materials, skeletons, dead animals, human and animal excreta, building and beating remains, bio-medical remains, domestic hardware or electrical uses, equipment, etc. (Sha'Ato et al., 2007; Babatunde et al., 2013). Waste as the side products of several actions/events in human life and as an outcome of a natural process frequently generates serious problems in areas of settlement. This is a consequence of a combination of human settlements has the potential to produce a big volume of solid waste. Solid waste is global environmental problematic in today's world such as developing and developed countries. Increasing population, rapid economic growth and the rise in community living standards accelerate solid waste generation in the world (Elmira et al., 2010). The significant manifestation of inappropriate disposal of solid waste can be contamination of surface and ground water through leaching, soil contamination through direct waste contact, air pollution by burning of waste, spreading of diseases by different vectors like birds, insects and rodents, or uncontrolled release of methane by anaerobic decomposition of waste (Visvanathan and Glawe, 2006). Solid wastes indiscriminately thrown resulted also in aesthetic problems, pain, and pollution of land and water bodies of an area (Hammer, 2003). Solid waste dumping is a significant parts of waste management system, which requirements much consideration to avoid environmental pollution and health problems. For that intention, locating correct sites for solid waste dumping and selecting suitable landfill site far from residential areas, environmental resources and settlement is the key issue for the managing of solid waste. Sideways with many, one way to position solid waste is to residence it in as it should be planned, built, and managed landfills, where it is carefully contained. African nations (with the exception of South Africa) had the fewest engineered landfills, with the most nations practicing open dumping for waste disposal (Tirusew, 2013). In 1960s in Africa rapid urban growth has Place led to increased generation of waste. Solid waste disposal in most African cities, especially the shantytown areas, the problem is aggregated by the open dump natural disposing waste. Usually, administrations in African states allowed uncontrolled dumping in abandoned quarry site with no condition sanitary landfill, causing huge health problems (Hammer, 2003). However, selecting suitable site and treatment the solid waste removal in countries, like Ethiopia with limited economic and rapid population progress rate is more severe. Degnet (2008) stated that, like in many other developing

countries, the majority of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, such as open dumping, burning and interring. As a result of quick population growing in the city and the wastes are increasing from time to time. The appropriate site for this waste is not selected due to this facts the society of the area are dumping the waste anywhere. So to have the time and cost which spent for other purpose, the GIS and RS based suitability site selection solid waste dumping is very significant to answer that all problems discussed overhead. Even though the problem is cumulative and there is no any investigation done on this area. So this study is predictable to fill this gap to advance socio-economic contentment of the society of the area.

1.2 Statement of the Problem

Waste managing may be a key issue of the world environmental program, as population and consumption advance lead to increasing quantities of unused waste. In developing countries, the population of municipalities is increasing because of both natural increase and movement from rural areas to urban. This high increment and therefore the activities of human consequence within the generation of huge volume of solid waste which aspects problem of their dumping and have potential effect to contaminate the environment like water, soil and air. The contamination of those and other resources of the environment distresses public health. In Ethiopia, most of diseases are associated with poor environmental sanitation and water contamination (Kumel, 2014).

The solid waste dumping system should be environmentally and socially conventional to stay the environment and therefore the attention of public health is necessary. But appropriate site selecting and managing solid waste removal in developing countries like Ethiopia with small finance and fast inhabitants rate of growth is more severe. Degnet (2008) specified that, like in many other developing countries, the bulk of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, like open dumping and burning. Similarly in Adama town, the study area, there's a mischievous of solid waste dumping. The ill-disciplined with the study area is uniform more severe since the solid waste is willing within the nearby water body or river area and road side. This dumping is additional very near agricultural similarly because it distances but 50m from the most road, which is that the Adama to national capital road.

In Ethiopia, for a few cities, researchers have accompanied studies on based suitable landfill sites selection using GIS and remote sensing. For instance, Kumel Beshir by 2014 and Tsegaye Mekuria by 2006, Amare Sewnet and Tirusew Ayisheshim by 2013 have showed studies on landfill sites selection using GIS and remote sensing for Wolkite, New Flower and Bahir Dar respectively. Within the study area, there have been certain studies about how industrial wastes are contaminating water resources. But no GIS based study has been showed on landfill sites selection for the study area. That's why this thesis is fancy to use the integrated GIS and remote sensing techniques to pick solid waste dumping sites selection. Recently Adama city is quickly increasing because of the amount of industries and repair sectors like hotels, restaurants, small and micro enterprises. As city raises the solid waste volume of the world occupied also increasing specially the overhead area listed. Thanks to the unsuitable place of the landfill site selection the river has convert almost useless and other people occupied within the close agricultural fields and people using the road are plagued by the waste product. So as to recover these problems, integrating GIS and remote sensing performs, to pick the most effective solid wastes dumping site selection that's environmentally and socially suitable, is vital. The choice of solid waste dumping sites using GIS and remote sensing requires numerous factors that ought to be combined into one system for site suitable analysis. This is often because remote sensing can make available information about the several spatial criteria like road network, soil type, land use/land cover, drainage, slope, etc., whereas GIS supports exploiting and generating the digital geo-database as a spatial collecting process and effortlessly understood ways for solid waste dumping site selection procedure. The selection measures will consider and combine rivers, soil type, slope, settlement, land use/cover and road networks.

1.3 Objectives and research of the study

The main objective of this study was to spot suitable solid waste dumping sites selection in sight of environmental, economic and social aspects in Adama city by applying Geographic system and Remote Sensing. The précis objectives were,

The specific objectives were

1. To assess current solid waste dumping site system within the study area.
2. To find reasons required for choosing suitable landfill locations.
3. To supply map presentation suitable solid waste landfill locations.
4. To estimate the last selected dumping sites.

The stipulated research questions for this study were

1. What does this time solid waste dumping organization of the study area appearances?
2. What are the critical issues shall be watchful to pick out suitable solid waste landfill site?
3. How will be identified the acceptable area for solid waste landfill locations and mapped?
4. How would the last selected dumping site be estimated?

1.4 Significance of the Study

Ethiopia currently faces numerous problems resulted from unwise use of solid waste dumping location. Landfill site selection should be using technical criteria to avoid any dangerous outcome on resident communities and the environment. This study resolve help to keep environmental protection of Adama city, to recommend a right solution for decision makes and to recover the present solid waste of the city and to make guide-line for solid waste dumping site selection. Meanwhile inappropriate area solid waste dumping site selection may disturb the economic, social, natural resources and the environments. The last result of this plan helps the city to answer the difficulties. So, this study has a distinguished piece of work which clearly shows the prevailing condition and help as a contribution for extra studies. In addition, the study is also predictable to provide an insight about the application of GIS and Remote Sensing skills for the selection of suitable solid waste landfill sites.

1.5 Scope and limitation of the study

The study will have great standing if the investigation topic could have concentrated both on solid as well as the liquid waste problems and management in the study area. However, due to wideness of the issue and time limitation, the study is limited to solid harmful waste problems and managing in Adama city.

Time limitation was a large problem of this thesis as the time of data collection was the corona varies (covid-19) epidemic disease. Most offices were closed for this corona virus disease and the employee back to home for quartering. Due to this epidemic disease the situation was very difficult to collect data in the study area. Especially collecting data and reading GPS of sample data gathering and field work was very difficult.

Data gathering was very hard fieldwork period for epidemic disease situation. It was no allowed to have any instrument or material to collecting important data. This problem has been settled until the permission to collect GPS point data along with personal field observation. The solutions have been careful the epidemic disease and proper to use the world wide servers due to fieldwork. Lastly, the summer field work data collection was almost feasible economically and fruitful with lots of ups and downs with in the specified period of time.

1.6 Organization of the Thesis

This thesis contained five chapters. The first chapter present one is the introduction including introduction, statement of the problem, objectives of the study, research questions, scope, significance and limitation of the study. The second chapter contains a review of the literature, mainly including, the concept and Concerns of Waste, solid waste management and solid waste management, landfill site selection and applications of GIS and RS in appropriate solid waste dumping site selection and Multi-criteria decision analysis for suitable solid waste dumping site selection. The third chapter deals with the description of the study area and the materials and methods. The fourth chapter presents the overall discussion and presents the results of the suitable dumping site selected for the study area. Chapter five deal with conclusions and recommendations.

CHAPTER TWO

2. Literature Review

2.1. Concepts of solid waste

Waste is created universally and it is a direct consequence of all human activities. Wastes are largely classified into solid, liquid and gaseous. Solid wastes, the subject of this study, are mostly willing to landfill, because landfill is the simplest, cheapest and most cost-effective method of dumping of solid waste. These solid wastes can be generated by the full amount of human activities that diversity from relatively harmless substances such as food and paper waste to poisonous materials such as paint, batteries, asbestos, healthcare waste, dirt sludge subsequent from wastewater treatment and as a hazardous example, complex (dangerous) waste in the form of expended 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 (Taylor et al., no date). These contains: household waste, public waste, commercial and harmless industrial wastes, hazardous (poisonous) industrial wastes, construction and destruction waste, health care wastes – generated in health care services e.g. hospitals, medical investigation services);, human and animal wastes and incinerator wastes. Household waste represents waste produced at home and collected by community waste collection services. Public solid waste includes this plus shop and office waste, food waste from cafeterias, etc., also collected by public waste collection systems, plus waste derived from road cleaning, and green (organic) waste created in gardens and parks.

2.2. Solid waste management

Solid waste management is the discipline associated with the control of generation, storage, collection, transfer, transport, processing and disposal of solid wastes in a manner that is in agreement with the best principles of public health, engineering, economics, aesthetics, conservation and environmental considerations, and to change the attitude of people (Zhag *et al.*, 2010). Technical managing of solid waste around human habitation reduces its opposing influences on the environment and human health and supports economic growth and better quality of life. The key methods of solid waste managing systems are a waste decrease, waste

recycle and reprocessing. There are numerous environmental welfares that can be resulting from the recycle, discount and reprocessing methods. They decrease or prevent greenhouse gas release, protect resources, decrease the release of contaminants, save energy, and decrease the demand for waste conduct skill and landfill site. Therefore, it is advisable that these methods be incorporated as part of the solid waste management plan (Debishiree, 2014). Poor waste managing systems joined with hot climatic conditions consequences in increasing environmental problems with important local as well as global sizes. In spite of the increasing stress towards the waste reduction at the source, as well as recovery and recycling of the solid waste, disposal of solid waste by landfilling remains the most commonly employed method (Debishiree, 2014).

Solid waste disposing management (SWM) is becoming one of the critical challenges in the world today. In maximum of city area there is an increasing capacity of wastes. Solid Waste Managing (SWM) is serious issue for environments, public health and the image of cities. A rapid urbanization rate increasing the challenges of solid waste disposal will be increase in next year's due to population increase in urban area;, therefore an urgent need to resolve the current problem (UN-Habitat,2010a).

2.3. Solid Waste Management in Ethiopia

Municipalities throughout Ethiopia are not free of problems of solid waste as they have been facing major challenges with the solid waste collection and management (Issam *et al.*, 2007). Per-capita waste generated in Ethiopia ranged from 0.11 to 0.35 kg/day for rural areas and 0.17 to 0.48 kg/day for urban areas. The collection depends on numerous issues such as income and period. In Ethiopia, the total municipal solid waste generation in 2003 was 2.8 to 8.8 million tons. This can be split to approximately 0.6 to 1.8 million tons from rural areas and 2.2 to 7 million tons from urban areas (World Bank and EPA, 2004). In numerous of the cities in Ethiopia, municipal administration is accountable for waste collection. Though there is a wide difference in the performance in relative to waste collection in cities, it has become a mutual practice to have household waste to be pre-collected by entities that are organized through official or casual association. The pre-collected waste is then transformed into containers, which are collected by cities. Nevertheless, for a long period of time, in many city, there are not enough containers to cover the population and vehicles are typically under maintenance or out of service (CSA, 2007). Adama City, being one of the largest cities in the Oromia National Regional State

and one of the fast urbanizing hearts in the country, has been faced with an increasingly growing city waste managing problem. Taking per capita amount of waste generation in the nation and total population of the city into account, the total municipal solid waste generation of city is 26.4 to 72.4 tones (CSA, 2007). Some studies have shown that only 43% of waste is properly collected in the country and willing at an open dump location. The residual waste is widely disposed of in drainage lines, open spaces, road sides or informally burned.

Uncollected solid waste generation is an environmental danger for all, particularly, in areas where the streets and rivers are not suitable for gathering. Due to these reasons bad odors and attracts numerous vectors and pests subsequent in a worsened artistic quality of the city and spread illnesses. The public waste gathering service is insufficient and divisions of distributed waste are comparable in most part the cities of country. As a consequence, the population has the opinion that the urban solid waste collection facility is not working correctly. As a consequence of this, the willingness of the population to collaborate with waste collection process and to pay for the facility is small. Solid waste composed from hospitals, residential and commercial areas is dumped at the dumpsite outskirts of the city with little incineration in the hospitals. In terms of community waste treating and recovering, little is done at all level of its managing. There is no source separation or categorization and this occurs at disposal locations too. But, some researchers at dump sites practice an informal type of waste recycle. The disposal of waste has showed to be a main public health issue and a vital aspect moving the environmental quality of all living things. These, especially in Ethiopian cities have become one of the most uncontrollable environmental difficulties today. One of the highest problems facing the cities are the open and indiscriminate dumping of waste.

The Ethiopian government has passed a SWM Proclamation in (CSA, 2007). Despite this, there are several challenges in the implementation of the proclamation and hence, a very small level of returns has been gained from efforts put into dealing with SWM. With the aggregate volume of SWM in Adama, the city management is unable to manage the SWM generated from households and diverse organizations. During site observation, it was found that some households and organizations are more than 2kms far from nearby containers and some Kebeles (smallest local managerial units, having about 2000 households) do not have containers and solid waste disposal at all. As a result, the city management currently gathers and arranges 52% of the waste

generated day-to-day in the city. A similar study suggests that the collected SWM is disposed in open throwing away systems. As a consequence, the waste generated from different sources which is not collected by the city administration is indiscriminately collected without actuality divided and is disposed of in lowland areas, in the outskirts of the city, in drainage lines, in vacant places, and beside streets, or is easily burned. Moreover, there has not been improvement in SWM implements in Adama city in the previous period and the tasks sustained. The tasks of SWM in Adama can be categorized by having insufficient facilities to collect and dispose the waste, absence of enough number of centralized containers, lack of consistent waste option up schedule, absence of fee structure for waste gathering and solid waste disposal landfill service. Moreover landfill sites are also not logically designed leading to air, water and soil pollution. The ditches are filled with SW disposed by residents causing flood in the city, and garbage often blocks drainage stations causing pound sterling frequently contaminated with organic waste because of which domestic flies and mosquitoes are upbringing. In addition, SW workers are not provided with appropriate clothing and frequently criticize about their health difficulties. These problems are expected to become more obvious as urbanization lasts to increase in future. In general, the present SWM training in Adama couldn't manage with the fast urbanizing needs of the city. There is a need to address the issues. Hence, by assessing the current SWM physical activity of Adama city, the present study hard work to describe the feature of the current solid waste site system and identify the key challenges as well as suggest actions to be taken and recommend a agenda for an improved SWM.

2.4. Dump Site Selection

Dump site selection is a challenging assignment to accomplish because the site selection method depends on different issues and rules and it needs data from various social and environmental fields such as river stream, land-use/land cover, slope, soil type and road network. These data often involve processing of a significant amount of spatial information, which can be used by GIS as an important tool for land-use/land-cover suitability analysis (Zeinhom *et al.*, 2010).

Dump site selection is becoming gradually difficult due to growing environmental awareness, reduced volume of governmental and urban subsidy with dangerous political and social opposition. Increasing of the human population, public health worries and a scarcity of land accessible for landfill site selection construction adds more difficulties to the problem to

overcome. Environmental issues are very important to be careful in such work due to the fact that landfill site might affect the biophysical environment and the natural balance of the surrounding area. Numerous techniques are used in site selection of solid waste disposal site. Such site selection techniques combine multiple criteria decision analysis (MCDA) and GIS. The result of these techniques is the evaluation of the suitability for the entire study region based on suitability index, which is useful in order to make an initial ranking of most suitable areas (Mohammad *et al.*, 2014). One of the complex steps is finding of waste dump sites have exact phases including site selection and groundwork of waste dump site. If these dump sites are near the individual's workplace or living places, it is considered as a negative outcome and it may cause irreparable consequences to human life (Seiied, 2015).

Sanitary dump site selection requires an wide evaluation procedure in order to identify the finest available disposal site. Therefore, the site selection of a solid waste dump site must also include processing of a significant quantity of spatial data, rules and receipt criteria, as well as an efficient connection between them. The geographic information system has been creating to play an important role in the area of site selection of solid waste dumping sites. Numerous issues must be combined into dump site selection choices and GIS is perfect for this kind of initial studies due to its ability to achieve large capacities of spatial data from a diversity of sources. The integration of GIS and Analytical Hierarchy Process (AHP) is a powerful tool to solve dump site selection problem because GIS provides efficient manipulation and presentation of the data and AHP supplies a consistent ranking of the potential dump site areas based on a variety of criteria (Debishree *et al.*, 2014).

2.4.1 Landfilling

A landfill site, also known as a tip, dump, rubbish dump, garbage dump or dumping ground and factually as a earliest, is a site for the dumping of waste materials by interment and is the firstborn form of waste treatment. Truthfully, landfills have been the most collective technique of organized waste dumping and remain so in many spaces all over the world. Landfill is an environmentally suitable removal of waste on the ground. As Kumel, (2014) notes, many developing countries do not have criteria for landfill site selections and some have rules of developed countries without modifying to their local conditions. But taking regulations of developed countries lacking considering local situations is a problem because the growth of

engineered landfills contains complex work design and structure techniques. These sophisticated engineered landfills can happen where the local economy can afford the high level of spending obligatory for construction and process of the landfill and where the procedural incomes to achieve high standards of construction and process are made accessible. It is therefore significant to ensure that when new landfills are sited, the construction and working capabilities of the local societies are considered in developing sitting standards so that environmental protection objectives can be encountered. As Laura, (2003) noted, in addition to available financial and human resources, the composition of the waste differs, and the climate of the area should be considered. Landfill has been documented as the inexpensive form for the last dumping of urban solid waste and as such has been the maximum used method in the world. However, sitting landfill is an very complex task mostly due to the datum that the identification and selection procedure involves numerous factors and strict guidelines. For good identification and selection of suitable sites for landfills careful and systematic procedures essential to be adopted and followed. Wrong sitting of landfill numerous results in environmental degradation and often time public antagonism. The sitting of a solid waste landfill suitability must also involve processing of a significant amount of spatial data, regulations and acceptance criteria, as well as an efficient correlation between them (Sumathi, 2007). GIS has been creating to play an important role in the area of sitting of waste disposal sites. Many factors must be incorporated into landfill sitting decisions and GIS is ideal for this kind of studies due to its ability to manage large volumes of spatial data from a variety of sources (Debishree., 2014). Land filling is a common answer for the last dumping of wastes in lower-income countries and a large majority of community's practice existence land filling or open dumping as their key method of waste dumping. Recently, due to the urban growing of environmental problems, solid waste management in lower income countries has attracted much attention and there is now a movement toward landfills designed to increase environmental protection (Tsegaye, 2006). Certain landfills are used to recover energy. The usual anaerobic decay of the waste in the landfill produces landfill gases which contain Carbon Dioxide, methane and traces of other gases. These landfills current the smallest ecological and health danger and the archives reserved can be a decent source of information for future use in waste controlling, however, the cost of founding these sanitary landfills are high when associated to the other land disposal methods.

2.4.2 Landfill sitting

Landfill sitting is hard duty to finish because the site selection procedure depends on diverse factors and rules. Moreover, it needs data from different social and environmental fields such as river stream, land use/land cover, degree of slope, soil type and road network. These data frequently involve processing of an important amount of spatial information which can be used by GIS as an important tool for land use suitability analysis) (Zeinhom El et al., 2010. Landfill sitting is becoming progressively difficult due to developing environmental consciousness, reduced amount of governmental and urban funding with extreme political and social antagonism. The increasing of population, public health concerns, and fewer land available for landfill building adds more difficulties to the problem to overcome. Environmental factors are very important to be careful in such work due to the detail that landfill might touch the biophysical environment and the natural equilibrium of the surrounding zone. Numerous techniques can be found for site selection of solid waste disposal. Such sitting techniques combine multiple criteria decision analysis (MCDA) and GIS. The result of these methods is the evaluation of the suitability for the entire study region based on suitability index, which is useful in order to make an initial ranking of the most suitable areas (Mohammad et al., 2014). Landfill site selection in an municipal area is a serious issue because of its massive impact on the economy and the environmental health of the region and several sitting factors and criteria should be sensibly organized and analyzed. One of the complex steps is finding of waste landfill sites have exact stages including site selecting and groundwork of waste landfill site. If these landfill sites are near the individual's work place or living places, it will be considered as a negative outcome and it may cause irreparable consequences to human life (Seied, 2015). Sitting a sanitary landfill needs a wide assessment procedure in order to identify the best available disposal site. Therefore, the sitting of a solid waste landfill must also include processing of a important amount of spatial data, rules and acceptance criteria, as well as an efficient correlation between them. GIS has been found to play a important role in the area of sitting of solid waste disposal sites. Numerous factors must be combined into landfill sitting decisions and GIS is ideal for this kind of initial studies due to its ability to achieve large capacities of spatial data from a diversity of sources. The integration of GIS and Analytical Hierarchy Process (AHP) is a powerful tool to solve the landfill site selection problem, because

GIS provides efficient manipulation and presentation of the data and AHP supplies consistent ranking of the potential landfill areas based on a variety of criteria (Debishree et al., 2014).

2.5 Application of GIS and RS in Solid Waste Landfill Site Selection

Suitability Analysis

2.5.1 Role of GIS for Solid Waste Landfill Site Selection

GIS is a digital database management system designed to achieve large capacities of spatially distributed data from a variation of sources. It is perfect for initial site- selection studies because it professionally stores, saves, analyzes and displays information according to user-defined specifications. Once a GIS database is developed it can provide an efficient and cost effective means of analyzing potential landfill site attributes (Mohhamed . et al., 2015).

GIS is an influential device that can integrate different types of spatial data and perform a diversity of spatial analysis. This evolution has been determined by significant advances in computer skill and the accessibility and number of data. GIS and environmental models functioning with a board spectrum of geospatial data are usually used for divers applications and spatial analyses at different scales (Mohammad et al., 2014).

GIS plays an important role in the area of sitting of waste dumping sites. Numerous issues must be combined into landfill sitting decisions and GIS is ultimate for this kind of studies due to its capability to manage large capacities of 3-D data from a diversity of sources. GIS is a powerful tool to solve the landfill site selection problem, because GIS provides efficient tools for the manipulation and presentation of the data (Debishree, 2014). People can evaluate the sites of different things in order to determine there relation in relations of spatial attributes and its arrangement and processes are dependent on spatial data. GIS is useful to reduce the time and cost of the site selection and also provide spatial data related to positions from different things so people can more easily find out the criteria for site suitability (Shewta ,. 2013). Even though landfill sitting is time taking process, GIS reduces time and cost as well as provides digital data for future monitoring database, using the actual capturing, storage, management, recovery, and analysis and show capabilities.

The Geographic Information Systems in solid waste managing allows people to evaluate the sites of different things in order to determine their relation in terms of spatial attribute and its planning and processes are dependent on spatial data. GIS techniques provide spatial data related to positions from different things so people can more easily find out the criteria for site suitability (Shweta ,. 2013).

Application of GIS technique in the field of waste management using a multi-criteria decision making technique provides the organized approach for assessing and integrating the impact of various factors as indicators of suitability (Shweta . 2013).

Generally, GIS in solid waste management not only save time and cost of design and spatial analysis of site selection, but also provides a digital data bank for future monitoring of the sanitary landfill site, (Zeinhom et al.,2010).

2.5.2 Role of Remote Sensing for Solid Waste Landfill Site Selection

Remote sensing is the discipline and art of gaining information about an object or area without physical contact. Remote sensing is one of the incomparable tools for sensing the earth surface to make the interface of object property and measurement analysis as well as inventory of environment and its resources, and has a unique ability of providing the synoptic view of a large area with the capacity of repetitive coverage (Shweta . 2013). Using remote sensing images like satellite images or aerial photographs we can have information about the resources of the environment. From the application of remote sensing, landfill siting is the one that satellite images are used for extracting the criteria used for landfill siting such as land use land cover identification.

Its multispectral ability provides suitable difference between many natural features where as its repetitive coverage provides information on the dynamic changes attractive place over the earth surface and the natural environment. When remotely sensed data are combined with other landscape variables organized with in a GIS environment delivers an excellent frame work for data capture, storage, mixture, dimension and analysis. For assessing a site selection as a possible location for solid waste disposal, several environmental and political factors and legislations should be considered (Subhrajyoti et al., 2012). One of the most applications of remote sensing

in solid waste landfill siting is where remote sensing data like satellite images are used for extracting landfill siting criteria (example; land use and land cover with saving time and cost).

2.5.3. Spatial Multi Criteria Decision Analysis (MCDA)

Multi criteria analysis is a set of mathematical tools and methods, like evaluating, to compare different replacements according to the criteria. Multi-criteria decision analysis (MCDA) helps to rank potential solid waste landfill sites selection using different criteria -such as river/stream, percent of slope, land-use/land cover, soil type and distance from road., and others by calculating the relative importance weight for individual assessment criteria (Zeinhom El et al.,2010). This technique combines all the spatial factors that are significant and consequences in a map with the best locations for a certain type of solid waste landfill site selection. The MCDA methods were established in the 1960s to address problems and support decision makers in decision-making with numerous options. Multi-criteria methods have the potential to decrease the cost and time involved in siting landfills site by narrowing down the possible choice based on well-defined criteria and weights. GIS techniques and processes have an important character to play in analyzing difficulties. Certainly, GIS is regularly recognized as a decision support system connecting the integration of spatially referenced data in surroundings.

Analytical Hierarchy Process (AHP), one of the methods of MCDA, is a conventional landfill site suitability analysis method that is responsible for right decision-making approach for site choice. AHP has been combined with GIS for landfill site suitability displaying when selecting the best alternatives from a pool of many choices in the presence of multiple criteria. This system provides a means of disintegrating the problem into a hierarchy of sub-problems that can be more easily understood and subjectively estimated. The subjective evaluations are transformed into numerical values that are graded on a numerical scale (Debishree et al., 2014).

Combination of GIS and Multi Criteria Evaluation (MCE) has been regularly accepted as an approach to assess the suitability of an area to crowd a landfill site. Taking into account both technical elements and people's standards and insights is essential to build agreement around a decision, to reduce conflicts, and consequently to cover the way to successful landfill siting involvements.

2.5.4 Role of Analytic Hierarchy Process for Solid Waste Landfill Site Selection

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 process (Eldrandaly et al., 2005). To determine the maximum suitable solid waste landfill site for a region, several standards should be considered. The multi criteria decision analysis is widely used method for site selection process. It is a discipline expected at supporting decision makers who are confronted with making many and contradictory evaluations. Unlike methods that assume the availability of measurements, measurements in MCDA are derived or interpreted subjectively as indicators of the strength of various preferences (Saaty, Thomas. 2005). The process is applied to a set of criteria or sub-criteria to establish a hierarchical structure by giving the weight of each criterion incomplete decision-making process (Kiker et al. 2005).

Using Pair wise Comparison Matrix (PCM), factor weights were calculated by comparing two factors together at a time. The values of the pair wise comparisons in the AHP were determined according to the scale introduced by (Saaty. 1980).

2.5 Criteria for Site Suitability Analysis

Identification of criteria is a technical activity, which is based on theory, empirical research or common sense. Evaluation criteria, objectives and attributes, should be identified with respect to the problem situation. A set of criteria selected should adequately represent the decision making environment and must contribute towards the final goal. Criteria identification can be done using the participatory approach by a group of experts from various disciplines. FAO (1976) has given a framework for solid waste landfill site suitability analysis for dumping in terms of suitability classes from highly suitable to not suitable based on soil types, distance of the road, distance of river/stream, land use/land cover and topographic features of a given area. In this sense, criteria identification was done by the author with assistance of a group of professionals, such as an environmental sanitation engineers, economist, land use planner, and soil scientists based on this

guideline and data availability. Hence, the following evaluation criteria are considered to address the suitability of the land for major crops in the study area. These are

- Distance from the road
- Distance from the river/stream
- Topographic feature (Slope and Elevation)
- Soil type
- Current land use/land cover and LGP

2.6. Theoretical Framework for Solid Waste Landfill Site Selection

The Food and Agricultural Organization (FAO) land evaluation approach was first presented at an expert meeting in Wageningen, Netherlands in October 1972 where it was extensively discussed and further refined. The modern era of land evaluation began with the publication of the United Nations Food and Agricultural Organization (FAO) “Framework for Land Evaluation” in FAO Soils Bulletin 32 (1976) and subsequent guidelines for land evaluation of general kinds of land use (FAO, 1983; 1984; 1985; 1991; 1995). The FAO agenda is not a formal methodology but a collection of concepts, principles, and procedures on the basis of which local, regional and national evaluation systems can be developed (Verheye *et al.*, 2008).

The FAO framework definitely has become the main point of reference for land evaluation (George, 1997) because, the principles of the FAO (1976) Framework specify that land should be assessed with respect to its suitability for a range of alternate land uses based on several criteria which include:

- The requirements of specific land uses
- A comparative multi-disciplinary analysis of inputs versus benefits
- The physical, economic and social context, and
- Potential environmental impacts and land-use sustainability.

CHAPTER THREE

3 Methods and Materials

3.1 Description of the Study Area

3.1.1 The physical setting

Adama city is about 95kms south east of the Ethiopian capital, Addis Ababa. The city is located in Ethiopian rift valley, 39.10N and 8.310E. The city has a total area of 961.64 hectare. The rank of the city administration has been reformed over time such as the capital center of East Shoa Zone, then small period as capital city of Oromia National Regional State (ONRS) and to day it is preserved as a special Zone on its own, directly accountable to the ONRS.

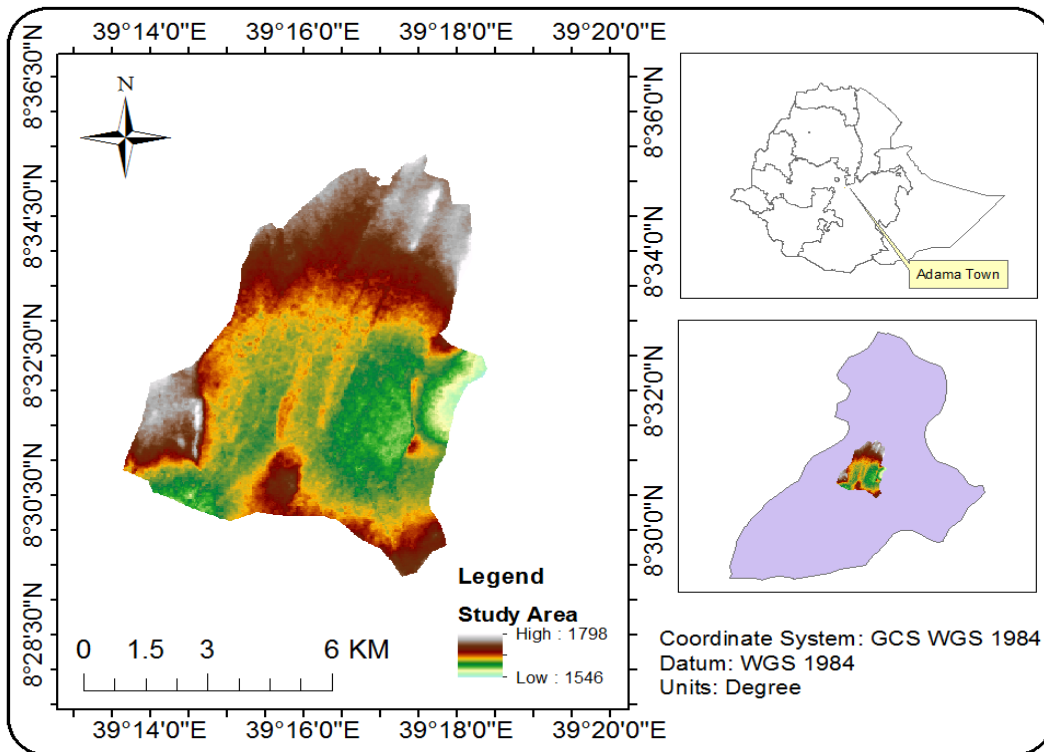


Fig.1: Location Map of Adama City

Adama city is mostly flat and enclosed by vertical foothill slope to east and west where the flat to gentle slopping plain extended towards north-south direction. It is one of the Rift Valley city located on flat lowland with the mean annual ambient temperature between 19⁰C and 22⁰C. It has an elevation ranging from 1590 to 1770 matters above mean sea level (Msl).Its

annual rainfall amount ranges from 400-800mm and mean annual temperature is 22⁰C. The mean annual total rainfall is about 809mm. Precipitation is the lowest in December, with an average of 7mm. The highest amount of precipitation occur in August, with an average of 210mm. May is the hottest the month of the year, when it reaches around 30.5⁰C. The lowest average temperature in the year occur in January, when it is around 11.4⁰C

3.1.2 The Socioeconomic Setting

The changes in rank have been connected with an increase in population number from about 100,000 in 1990 to about 213,995 in 2014. The Adama city divided into 14 sub city and 4-four adjacent rural kebeles.

Based on the data took from population projection values of the Central Statistical Agency of Ethiopia (CSA,2007), the total population of Adama city was 220212 of which 49 percent were males and the rest 51 percent were females. As per CSA (2016), the population of the city is expected to be 356,344.

Population Data of Adama Town

Table.1 Population and Rate of growth (Source-row data: CSA-Adama Bureau, 2016

1994			2007			2016 (CSA projected)			Growth Rate	
Male	Female	Total	Male	Female	Total	Male	Female	Total	1994	2007
									2007	2016
61965	65877	127842	108872	111340	220212	176,487	179,857	356,344	5.6	6.8

As indicated below in Table 3, the study area incorporates 18 kebeles/Ganda (1,2,3,4,5,6,7,8,9,10,11,12,13,14 Boku Shana, Dhaka Adi, Dabe Soloke, Malka Adama and etc.

Table.2 Area coverage of each kebeles in Adama city

study area	kebele	Area of Kebeles in/ha	Population density/ha
Adama City	1	1591.75	17.39092
	2	318.39	62.10936
	3	331.09	87.2512
	4	255.96	115.1
	5	355.83	78.16373
	6	29.94	342.2846
	7	47.72	354.2749
	8	53.68	297.3733
	9	475.65	67.35204
	10	194.61	133.2922
	11	160.57	169.7453
	12	85.95	181.3496
	13	132.94	119.1515
	14	956.78	31.91225
	Boku Shana	3904.68	2.413514
	Dhaka Adi	1701.404	2.580222
	DabeSoloke	1229.57	10.25968
	Malka Adama	1837.77	3.257753
Total Area of solid waste landfill		13664.28	26.0785

The city is a center for commercial and conference tourism where hundreds of thousands of people come and go to and pass through it. Adama town is located at a strategic place along the major transit line (Addis-Djibouti/Dire Dawa/Harer) for the main share of the import and export items of the country and along the main inland port. The city has a various advantageous conditions that attract numerous investors to come to the city to invest in all aspects of commercial: manufacturing (factories), services hotels, schools, and hospitals, medium and micro commercial enterprises.

3.2 Methods

3.2.1 Data Sources

A field investigation was made as part of waste to identify site of accessible exposed solid waste dump sites selection. The success of any GIS application depends on the excellence of the geographic data used. Some sample points from different solid waste removal types were also collected to verify the existing land-use/land-cover of the study area. Aerial Photography and

field observations were also used to display the current landfill site selection. Digital images were also some of the data source used to display the character of land-use/land-cover classes and topography of study space. Interviews with experts of environmental protection officers and residents, who were near to the existing solid waste landfill site, and assessing from environmental sanitary additional information. As results from interviews were used to identify the problem of existing dumpsite in the study area.

Table.3 Data sources and material

Dataset	Source	Resolution	Purpose	Type
Land sat 8 TM	USGA	30 x 30(m)	Classification	Raster
Digital Elevation	SRTM	30 x 30(m)	Percentage of Slope	Raster
Google Earth	Survey	-	For Ground Truth	-
Soil data	Ministry of Agriculture		For suitability analysis	Vector

No	Software	Purpose	Version
1	ARCGIS	General practical secession	10.3 crack
2	ERDAS	Image classification	2015
3	EXCEL	Graphic representation	W-7

Expert Opinion

Expert opinion with GIS techniques helps to ensure realistic applicability of data sets prepared for LSA (Kalogirou, 2002; Elsheikh et al., 2013). The studies like Bojorquez-Tapia et al. (2001), Joerin et al. (2001), Kalogirou (2002) and Shivaji Bhagat et al, (2015) have used expert opinions to determine the criterion, assign the ranks and calculate the weight. The eminent scholars with influenced publications of solid waste landfill site suitability analysis were selected for expert opinions about criterion used in the study and its level of impact in land use. A focus group discussion has been held based on solid waste landfill site selection suitability analysis activities in solid waste dumping site with experts. More than 10 experts have discussed and gave useful information for this study. To obtain spatial and non-spatial datasets different resources were used in multiple GIS tools and remote sensing techniques for mapping and analyzing purposes.

Tabl.4 Details of software used in this study.

S/N	Type	Description	Source
1	Map	Topographic maps and Rainfall Data	EMA
		Google Earth maps	Internet
		Woreda and kebeles shape file	AAU, GIS Lab
2	Software	ArcGIS 10.5, ERDAS IMAGINE 15, ENVI 5.3 ,AHP, Idiris 17.0.MS word, MS excel	AAU, GIS Lab and OWN
3	Instruments	GPS (GARMIN), Digital Camera	WLALU office and OWN

3.2.2 Factors Responsible for Solid Waste Landfill Site Selection

As observed by different authors (Suman, 2012; Enecheet *al.*, 2017), there are numerous criteria used in the mapping of solid waste dumping sites selection in any geographic area. After the data is collected from many sources, datasets analyzed by applying multi-criteria evaluation (MCE) integrating with GIS and RS to allocate the suitable areas for solid waste landfill site selection. The parameters considered in this specific solid waste landfill site suitability study are a multivariate index analysis, integrating them in a GIS environment.

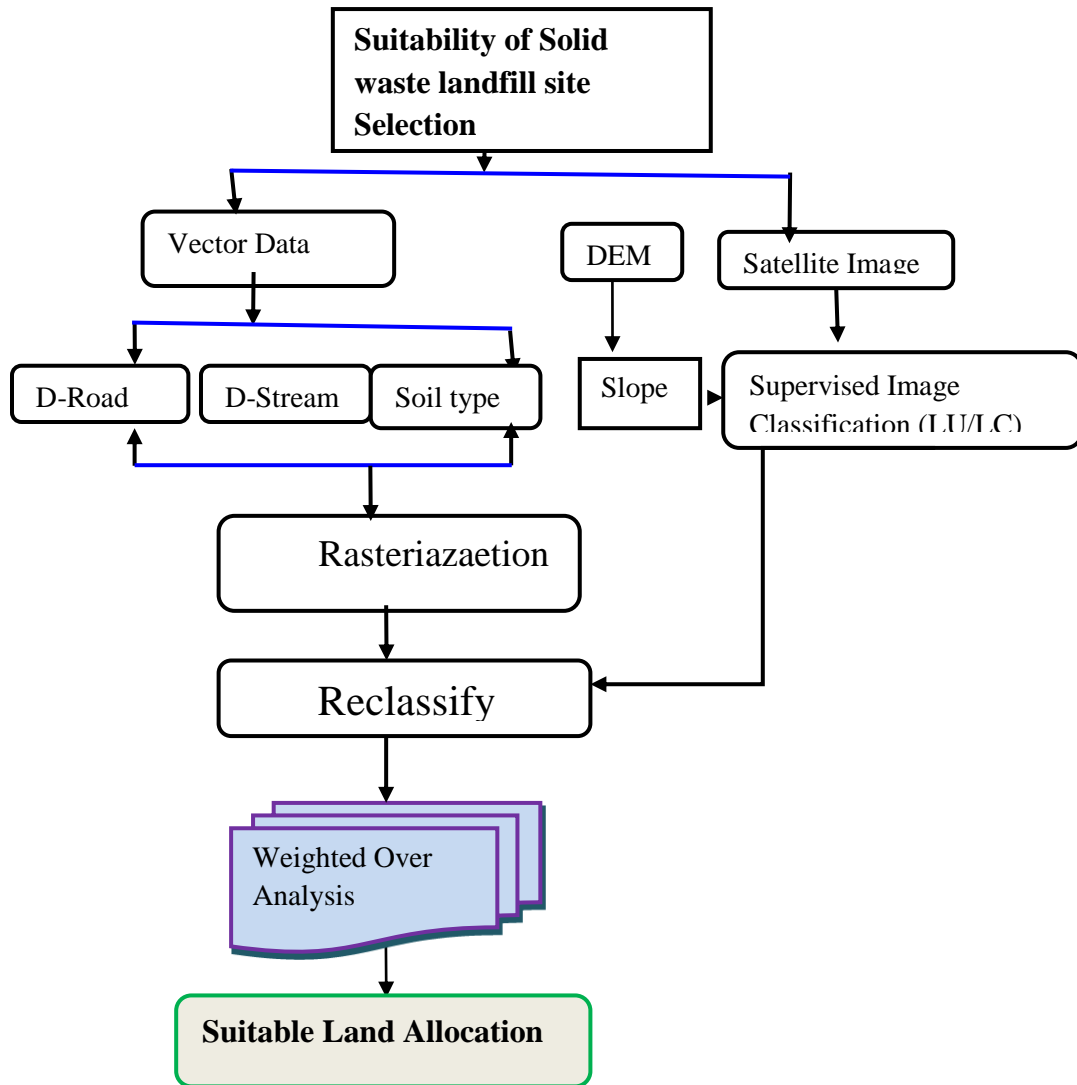


Fig.2 Methodology flow chart.

3.2.3 Selection of Solid Waste Dumping Type

The selections of solid waste landfill site selection types were made based on environmental favorable their such as distance from River/stream, percent of slope, land-use/land cover, soil type and distance from road.

Throughout the leading thesis two types of data were used i.e. the socio-economic and geospatial data. The primary data for this directing thesis are data obtained from field observation and field work (GPS data Collection) for mapping highly exposed areas for sanitary problems and data collected with the investigation inquiry form and GPS data are used to generate accessibility

maps such as contact to social services (to health centers, schools, roads, etc.).GPS reading was also taken from field to map where accurately sanitary exposed areas exist so that I would later help in decision of suitable site situation. These data are mostly point and line features. However, much of the data foundations especially for literatures are secondary data sources such as Books, Articles, and Journals, Satellite images, scanned and hardcopy maps and other published and unpublished documents.

3.2.4 Selection of Evaluation Criteria

Identification of criteria is a technical movement, which is based on model, experimental research or collective intelligence. Evaluation criteria, objectives and attributes, should be identified with respect to the problem condition. A set of criteria selected should adequately characterize the decision creating environment and must contribute towards the final goal. It is known that set of attributes or criteria depends up on the system that is being analyzed. There is no set technique to select the evaluation criteria. Criteria identification can be done using the participatory approach by a group of experts from various disciplines. For the evaluation of major solid waste landfill site selection suitability of the dumping, sets of factors that influence the solid waste landfill site selection suitability assessment in the study area were first established. From these factors, the possibilities and constrains for solid waste disposal were analyzed. A restriction serves to boundary the alternatives under consideration. In this paper among LULC of the study area settlement and vegetation land were considered as constraints for this study. FAO (1976) has given a framework for solid waste landfill site selection suitability analysis for solid waste landfill site in terms of suitability classes from highly suitable to not suitable based on distance from river/stream, percent of slope, land-use/land cover, soil type and distance from road features of a given area. In this sense, criteria identification was done by the author with assistance of a group of professionals, such as an agriculturalist, economist, solid waste landfill site selection planner, and soil scientists based on this guideline and data availability.

3.3 Methods of Data Analysis

After the data is collected from various sources, data was analyzed by applying multi-criteria evaluation (MCE) integrating with GIS and RS to solid waste dumping site selection the suitable

areas for solid waste landfill site using the main relevant factors of distance to surface waters, soil type, distance to main roads, land use/ land cover and topographic factors.

3.3.1 Solid Waste Landfill Site Selection Suitability Analysis

3.3.1.1 Factors of Solid Waste Landfill Site Suitability Analysis

Solid waste landfill site selection is officially defined as 'the assessment of solid waste landfill site piece when used for a specified drive, involving the implementation and clarification of surveys and studies of land forms, soils, vegetation, topography and other aspects of land in order to classify and make a comparison of promising kinds of solid waste dumping in terms of applicable to the objectives of the evaluation' (FAO, 1976).

An issue is a criterion that can determine the suitability site of specific outcomes for activities under thought in this study, the spatial MCDM method was used in the creation of factor maps. Suitability levels for each of the factors were defined; these levels were used as a base to generate the factor maps (one for each factor). Solid waste landfill site suitability evaluation is expressed by qualitative and measurable parameters. Solid waste landfill site Suitability analysis for solid waste dumping site needs the consideration of diverse environmental aspects/criteria. In this particular solid waste landfill site suitability valuation, the criteria that are mostly taken in to consideration are; distance to surface waters, soil type, topography, distance to main roads, and land-use/land cover.

Every criteria map displays solid waste landfill site suitability measured on the ordinal scale, that is, parcels of landfill were allocated values of high, medium or low suitability liable on land attributes. On the other hand, water body, built up areas, roads, and forest areas were recognized as Constrains or limits issues during analyzing this solid waste landfill site suitability for main solid waste dumping site.

3.4 Classifying an Operational Guide and the Setting

Once the criteria maps are willingly an accessible and the toolset and model is shaped, the next stage was specifying the working directory, where all the resulting maps are stored. As a result, the resulting maps and outputs are stored in a folder. Taking ended specifying a working directory, location the situation is done. The border maps of the city is used as a dispensation degree while Slope map have been chosen as Raster analysis mask and snap raster and the cell size choice have been set to defaulting i.e. maximum of the input.

3.4.1 Clipping

Once the map has approved through the above discussed phases, it was necessary to clip (cut) parameters like slope, DEM, stream map, roads map, land use map and facility areas based on the border of the study area. Therefore, the edge map, which is found through onscreen digitizing from the master plan of the city, is transformed to raster format. Change tool from Arc Tool Box and then to raster choice is selected sequentially for all data to complete the change of features to raster arrangement. Lastly, the data in vector and raster arrangement are clipped based on the degree of the borderline of the city.

3.4.2 Buffering

A buffering process is another geoprocessing tool used in this initial phase of data preparation and analysis in this thesis work. Buffering in Arc Map is an Arc Map geoprocessing process that is used to generate specific boundary or define a feature database on the specified distance providing. Criteria maps such as road network, stream map are buffered with both physically inserted and computerized distances. Two types of buffer processes have been used namely single ring and the multiple ring buffering.

3.4.3 Single Ring Buffering

For constriction map since it was wanted classifying just areas that are not suitable due explanations like environmental and related matters a single ring buffer from geoprocessing wizard in ArcGIS menu bar was used. Furthermore, as a constriction map just expected at presentation two options, considered and rejected areas, a single ring buffer with a physically

inserted buffer distance is applied in this specific process. Rejected areas as it is discussed later under constraint maps, are permanently unsuitable areas that are excluded areas from more analysis for having barriers or restraints in development of a landfill site. Considered areas are areas that are largely accepted for extra analysis. See constraint maps above for details.

3.4.4 Multiple Ring Buffering

Different single ring buffering , where only a single buffer zone is shaped to identify just two choice namely suitable and unsuitable classes, multiple ring buffering is used to classify suitability classes with multiple buffer zones of a assumed suitability map in the study area. It can be either three or five suitability classes. The suitability classes used in this study as it is stated on the end of the preceding chapter are three, ranging from actual higher to extremely lower suitability.

3.5 Constraint and Characteristic Maps

3.5.1 Constriction Maps

Restrictions, which are non-compensatory principles that regulate which areas should be omitted from or included in the suitability analysis. The omitted areas get a null performance value in the composite index map, whereas the residual areas gain a value between 0 and 1. Limitations are thus expressed in the form of a Boolean (logical) map (Valentina 2011:239) Therefore, constraint maps, as it is explained above, are areas that have some kind of tightening and are unsuitable due to environmental anxieties and/or any organizational center. Therefore, these maps are recognized as constriction maps based on accepted and defined criteria. In this thesis : road networks, degree of slope, distance from stream/river maps , accessibility maps (social services) all have certain buffer distances set to identify areas that have confident constriction. Likewise, land use has its own constraint for landfill site selection and analysis. As show in figure above, constriction maps created based on accepted distance to a proposed landfill site in the city of Adama. The buffer distances for each criteria maps is made based on studying different local and international research project works and consultation of experts in the municipality of Adama city.

3.5.2 Position, Evaluation and Weighting Factor Maps

The suitability model in this thesis included three steps: identify site selection constriction and suitability issues, evaluation and position the suitability issues, and weighing the factors selected and lastly applying the suitability model. Evaluation, position and weighting are the remaining processes discussed below.

3.5.3 Position/Ranking

After distance calculation, classification of the raster layers has been approved out. Classification is indirectly mentions to putting the suitable values (locations) in their suitability order. This was done simultaneously during the classification process (Meaza 2009). Positioning entities and their attributes is not random complete. Position and specifying the suitability class values have been made based on file analysis and experts comment and suggestions during the field work. The position of suitability classes are gathered in to five suitability classes specifically high suitable, moderately suitable, marginally suitable, and currently not suitable and permanently not suitable areas. Therefore, permanently not suitable areas, area that are rejected from attention are ordered with suitability rank of zero while suitability class 4 , 3,2 and 1 are ranked as high suitable , moderate suitable , marginally suitable and not suitable correspondingly.

3.5.4 Evaluation/ Rating

Once the suitability classes are categorized in order, the following step was to arithmetically value a given feature based on extent of strengthen or weakness of influencing a given variable in judgment with the others. Evaluation is refers to rating, usually expressed in numerical terms, of how suitable a site is supporting a specific land use (Meaza 2009). Numeric scores to a total of five (one as least and five as most suitable) are allocated to each factor attribute class. The judgments between classes were based on their level of suitability with respect to the choice of best site selection for a solid waste landfill site. Since environmental influences for each specific study areas are different with others, there is no uniform standard for evaluation issues. For this thesis however, factors are valued based on the condition of study area, review of literatures and suggestion from experts. For example, a site having a slope over 10 degree is assigned a score of zero (rejected area) while area with slope steepness less than 5 degree is rated one (highly

suitable) for the place of a solid waste landfill site. This is related to cost of construction, transport and accessibility subjects.

3.6 Merging and Weighting Factor Maps

In practice, it is usually unsuitable to give equivalent importance to each of the criteria existence collective. This is because evidence requirements to be weighted depending on its relative implication. Hence, each attributes are evaluated according to weighted criteria, resulted in a ranking on a suitability scale (Saaty 2003).

Major positions are given and based on their rank, their rate of impact or weights are determined using the software. Lastly, the resulted weights are changed in to percentage, which is typically named as normalized weight. Normalized weight is obtained next dividing the weight of each issue by their total weight. Weight of features and variables were determined liable on the importance of each variable in comparison with the others in the same influence group as well as between environmental aspects. As a point of departure, in this thesis work, priorities, positions, rates and weights are given based on studying different literatures, personal judgments and including experts' idea. Distance should get similar weights but higher than others influencing factors in landfill site selection process due to their sensitivity to pollution and health problems followed by social and infrastructural services and a land use (Nas et al. 2010). As much parts of the city area has a relatively gentle slope and flat topography, slope have been given weight in influencing the landfill site selection process.

3.7 Current Solid Waste Landfill Site Use and Cover of the Study Area

It is identified that, exact ground or reference data must be collected in order to sufficiently assess the accuracy of the remotely sensed imagery. Without the provision of field enquiry were most probable liable to integrate errors. Hence, after illustrative sample points were collected from the area to represent the several land use and land cover classes land organization was completed. The study employed supervised image classification procedure and maximum Probability classifier which is the most common method.

According to Tirusew and Amare (2013), it was sensible to select landfill site, which was occupied by bare and grass lands for solid waste landfill site. In the study area, major land cover and use classes were bare land (8.26%), vegetation covers (12.25%), settlement (53%), and Cultivated land (26.42%).

CHAPTER FOUR

4 Results and Discussion

Distance to Road

Road distance and suitability is one of the important parameters assumed due consideration in locating suitable site for a solid waste landfill site. Road network provides connection between the settlements, factories and industrial areas, which are all source for waste making to the remotely located solid waste dumping sites. Cost of transport, efficiency and effectiveness of waste managing system can significantly influenced by the roads distance. Valentina (2011) stated suitable solid waste landfill site should be situated on the minimum distance to the main roads at about 500m buffer zone, where those areas located within a buffer distance of 500m are considered as no suitable and labeled as constraint for solid waste landfill site selection. Areas above 500m are considered in general as suitable for a landfill. On contrary, Nas et al. (2010) said a solid waste landfill site located within a distance of 200m is not suitable as stated below.

“Solid waste landfills site shall not be located within 500m of any major highways and city roads. On the other hand, the solid waste landfill site should not be placed too far away from existed road networks, to avoid the expensive cost of constructing connecting roads” (Nas et al. 2010:496) According to Berisa & Birhanu (2016), local made research output argued that solid waste landfill sites must not be located within the distance of 100m due environmental concerns and a bad smell affecting the surrounding. This buffer distance has been not accepted in this thesis work based on similar environmental and topographic similarities. An interval of 500m from the buffer zone is chosen as most suitable for disposal site in the city of Adama. The long distance the solid waste dumping site trucks travel, the lesser the suitability of a land for dumping site.

Babalola and Busu, (2010) and Al-Hanbali *et al.* (2011) 2000m distance has been suitable for solid waste landfill site. Solid waste dumping site selection must be located at suitable distance from roads network. The study must be buffer distance from main roads by referring to different sources.

Accordingly, the solid waste landfill site is totally unsuitable if distance from roads is greater than 2 km. The distance starting from 0.5 km up to 1 km is considered as moderately suitable. If

the distance is less than 0.5km, the site is highly suitable. Based on these criteria, 35.5% of the study area is found to be highly suitable, 28.57 % moderately suitable, about 20.13% is marginally suitable, and 15.8 % is unsuitable for solid waste landfill area site selection.

Table. 5 Distances to road

Distance from road (Km)	Level of Suitability	Value	Area (Km2)	Total Area(%)
< 0.5	S1	1	19.9	35.5
0.5-1	S4	4	16	28.57
1-1.5	S5	5	8.9	15.8
1.5-2	S3	3	11.3	20.125
Total			56	100

The above table shows that the roads distance distribution in the city of Adama. The main roads with red color are buffered in two distances i.e areas located within 2000m from the key roads and areas covering greater than 500m from the main road to any parts of the city's border. The buffer distance applied here is based on consideration of the topography and infrastructural development status. Therefore, the more the nearness to and away from the main road, is the lesser the suitable for finding of a solid waste landfill site in the town. As a result, areas within the first 500m buffer distance are rejected from reflection due to the possibility of health related effect on the people living along the roadside while the rest areas are careful for the analysis process.

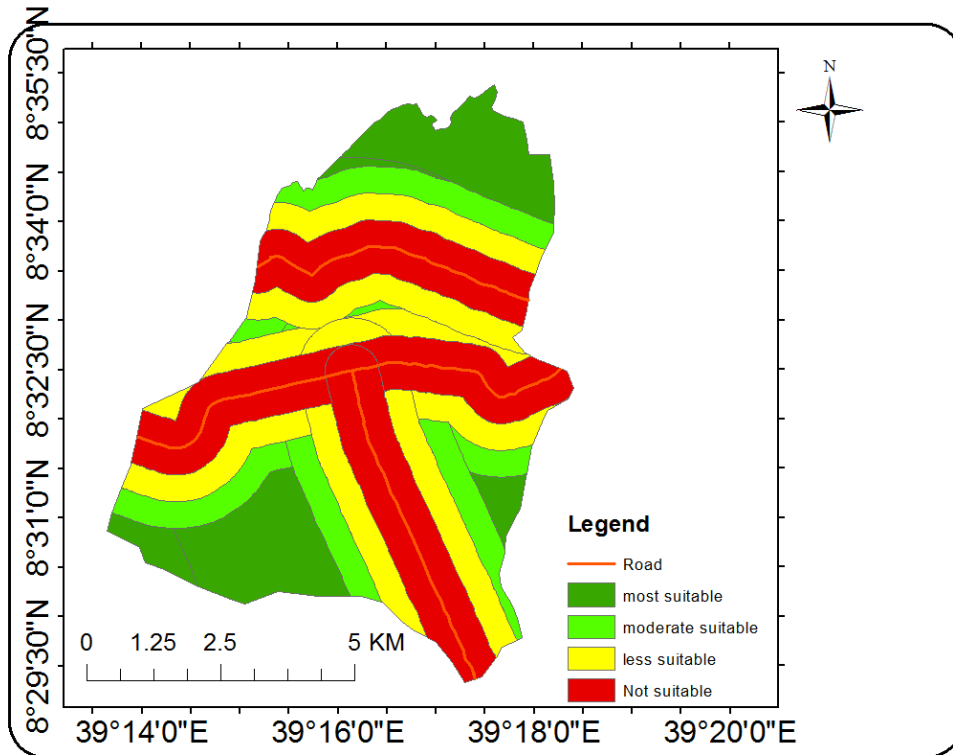


Figure .3 Distances to road map of the study area

Rivers/Streams distance

So as to avoid contamination of surface waters such as rivers, lakes or streams, a solid waste landfill site must be located at 150m minimum distance away from surface waters. All areas under 150m are not suitable and are labeled as constraints and are ignore from consideration (Valentina 2011). Berisa & Birhanu (2016) on the other hand put 200m, as a minimum distance a solid waste landfill site should be located away from water bodies. In consideration of the local setting, a 200m minimum distance buffer zone is used in this research project work. Those areas located within this buffer distance are unsuitable as their under underground water level is high and higher release and greater downstream effect The interval suitability distances are much dependent up on others factors like topography, but 200m is not accepted generally as suitable for solid waste landfill site as there will be less exposure of water bodies for ground water pollution. Areas measuring below 0.5km were considered unsuitable for solid waste landfill site, less suitable between distances from 0.5Km to 1Km. The distance initial from 1Km up to 1.5Km was considered as moderate suitable, while greater than 2km highly suitable area.

Table.6 Distance to river/stream

Distance from stream(Km)	Level of Suitability	Value	area (Km2)	Total Area (%)
<500	S1	1	27.22	48.6
1000	S4	4	8.42	15
1500	S5	5	9.93	17.7
>2000	S2	2	10.45	18.7
Total			56	100

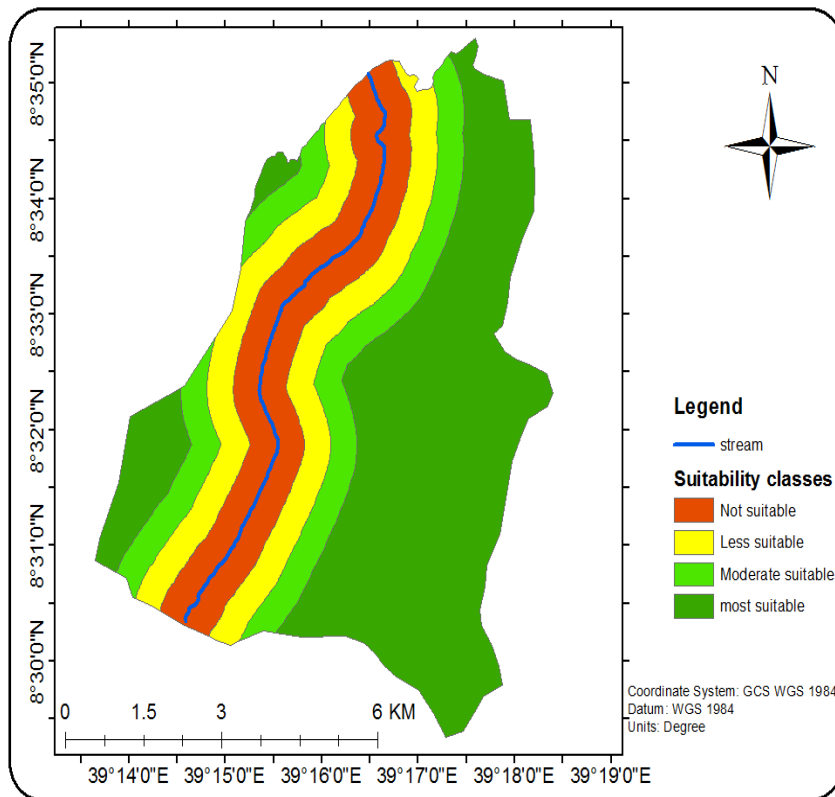


Figure.4 Distance to river/stream map of the study area

There is about main rivers in the city of Adama flowing from north to south the part of the city. A 500m buffer distance is applied to demarcate areas that are permanently unsuitable for locating a solid waste landfill site. These areas are shown with a blue color on the map.

Topography/Slope Degree

Topography plays an oversized role in defining the choice of site for solid waste dumping site selection. Much of the city’s topography lies on a slope flat not greater than five degree. Though this has been understood as a minor constriction, still slope has been well careful as a constraint to seek out an appropriate solid waste landfill site. Slope map of the town is gained from a Digital Elevation Model downloaded from USGS for this particular thesis. The next slope constraint map are obtained supported a define the degree level. Slope steepness with but five degree is appropriate for locating a landfill FAO (2006).

Based on FAO (2006), the slope value 0 to 0.2 % is taken into consideration as flat and up to five gently slope. 5 attempts to 10 we try to 10 to fifteen which there’s called sloping and strongly sloping correspondingly. Whereas 15 to half-hour and above half-hour is moderately steep and steep correspondingly. The slope value layer having a cell size of 30*30 m was created. Therefore, this study reflected the flat and gently slope as further highly suitable than the land with steep slope. The widely held of the study area falls under the slope class of but 5, which covers 35.73 you take care of the total study area best suited,34.16% moderate suitable,12.7% less suitable and 17.9% unsuitable.

Table.7 Percent of Slope

Slope (%)	Level Of		Area (Km2)	Total Area (%)
	Suitability	Value		
< 5	S5	5	20.01	35.73
5_10	S4	4	19.13	34.16
10_15	S2	2	7.1	12.7
>20	S1	1	10.013	17.9
Total			56	100

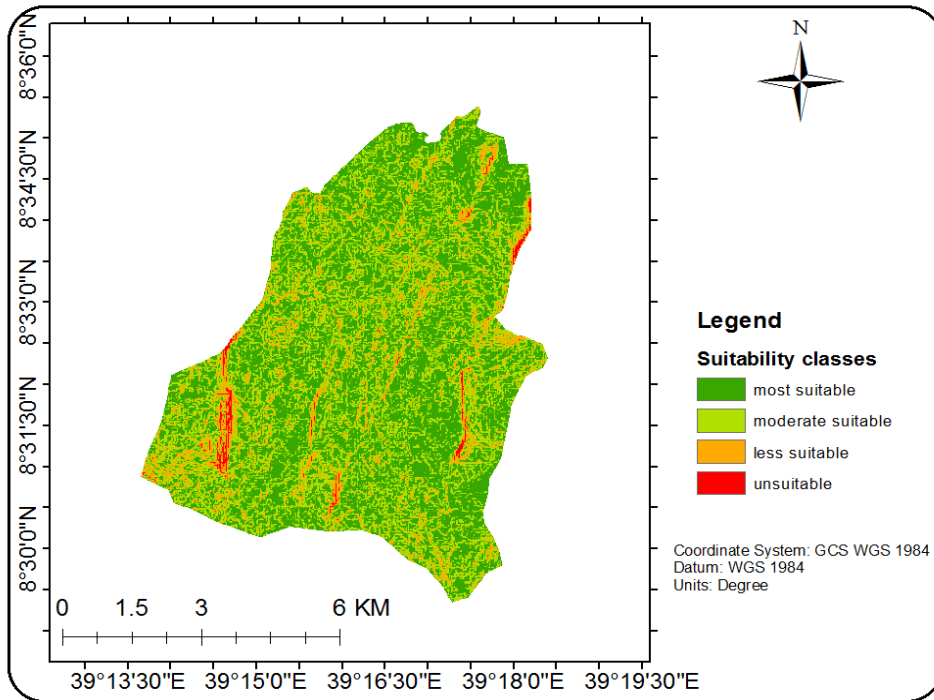


Figure.5 Slope/ area coverage map of the study area

The resulting slope constriction map above specifies that the areas with steep slope are covered with redness color while relatively gentle slope areas are covered with light green color. The most steepness for solid waste landfill site suitability analysis on this thesis is chosen 5-10 percent and areas with performance value of larger than 20 percent are rejected and regarded as overpriced for construction, expansion and managing of a solid waste landfill site while those deceitful on steepness but 10 percent are favored for concern.

Soil type

Soil characteristics endorse a secure and more economically feasible operation and process of a solid waste dump site. Permeability, actual porosity, and workability are important soil features which were considered for solid waste dump site selection. Within the present study area, there have been two classes of soil types used for solid waste disposal site selection analysis. These are orthicon solonchaks and lithosol soils were classified (Mohammed *et al.*, 2009).

According to the Environment Protection Agency solid waste Landfill site Manual 2006, areas covered with Nitosols are most fitted for solid waste disposal, vertisols are moderate suitable, solonchaks are less suitable and xerosols are unsuitable for solid waste dumping.

Table. 8 Soil Type

Soil type	Level of suitability	Value	Area (km) ²	Percent of total area (%)
mollicandosols	high suitable	5	31.3701	56.1
vitric andosols	Moderate suitable	3	24.6538	44.1
Total			56	100

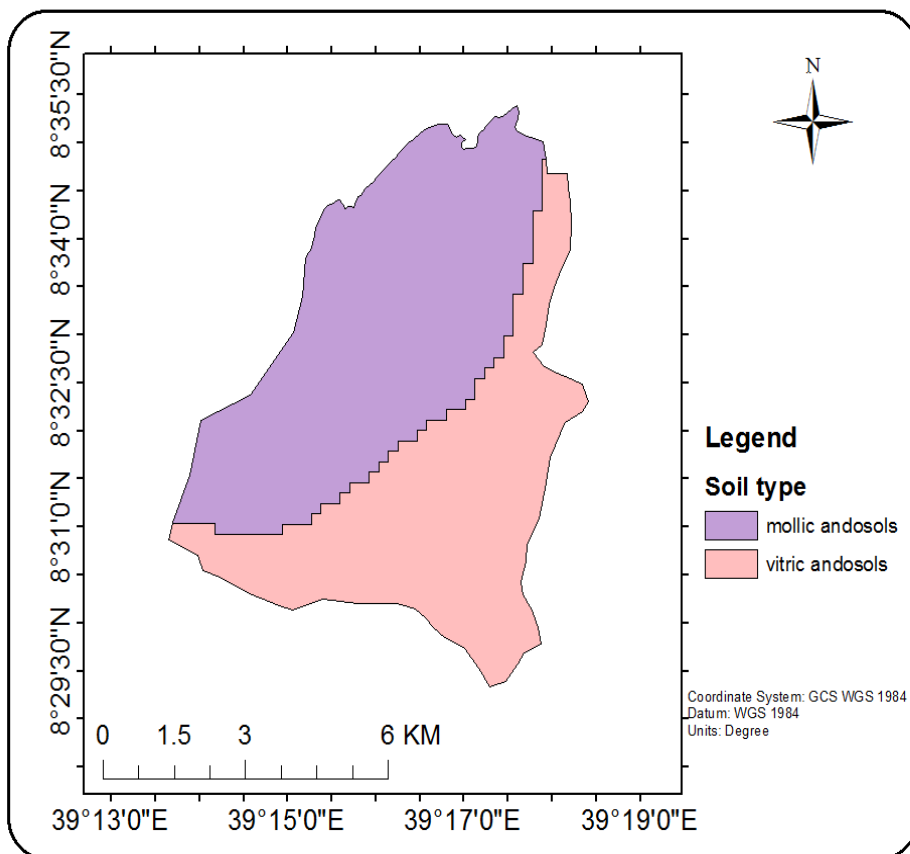


Figure.6 Soil type map of the study area

Land use/ land cover

LULC of the study area reflected together contribution issue during this particular study for the evaluation of landfill determination for solid waste dumping site within the study area. The problem consequent from remote sensing imagery (Land sat 8 MT+) the imagery data captured in 7/2020 during January with 30m resolution. So as to assess ground truth of land use and land cover the references data were obtained from Google earth addition to intensive prior ground truth knowledge of the investigator (signature representative points). This study employed supervised image classification procedure to categorize the image in to different land use/ land cover classes betting on cluster pixels which consistent to user defined exercise site. This classification type necessitates selecting training areas to be used because the basis for arrangement. The foremost common supervised classification method which is that the maximum Possibility classifier was also used.

Accordingly, about 174 representative points are collected from the world to represent the several land use and land cover classes were marked using GARMIN GPS 72 during the sector survey for the accessible residences. These points were accustomed sample representative signatures for the several land use and land cover types identified during the sphere appointment. Subsequent this, supervised image classification has been dole out using ERDAS Imagine software from Land sat image of 2019. Accordingly, four (4) land use / land cover types were identified. These are farmland, settlement, Vegetation, and bare land. From this point, the larger a part of the study area is settlement (which accounts about 53%).

Accuracy assessment

The Classified of LULC maps from remote sensed imageries may contain some errors. Therefore, accuracy assessment was employed to go looking out those errors so on ensure dependability of the produced LULC maps. The classified maps were evaluated and related to a referenced data and ground truth employing a slip-up matrix. Generally, since image classification without accuracy assessment is incomplete (Lillesand et al, 2004), the accuracy assessment for the images is finished.

Prior to analyze the land use/land cover change, user's, producers and overall accuracy of the land cover change area and confidence level should be estimated (Olofsson et al. 2013). To

keeping with GFOI (2013) the sample based estimator for the globe proportion (p_{ij}), where i denotes the row and j denotes the column within the error matrix, is calculated because the subsequence equation:

$$p_{ij} = w_i * \frac{n_{ij}}{n_i} \quad (1)$$

Where w_i is that the ratio of m_i/m_t ; m_i is that the mapped area of land use class i ; m_t is that the total area of the map, n_{ij} is that the cell value at row i and column j ; n_i . Is that the full sample count of land use class i . After this the realm of each land use/cover class is estimated supported on the reference classification, which can be calculated using the equation proposed by Olofsson et al. (2013) as follows:

$$p_j = \sum_{i=1}^n w_i * \frac{n_{ij}}{n_i} \quad (2)$$

p_j is category/land use class j supported the reference data. Then a confidence interval for the estimated area of every land use class is estimated after the quality error of every land use class is calculated. The estimated standard error (SE) of the estimated area proportion (the column total) of every land use class is estimated as:

$$SE(p_j) = \sqrt{\sum_{i=1}^n w_i^2 \frac{\frac{n_{ij}}{n_i} (1 - \frac{n_{ij}}{n_i})}{n_i - 1}} \quad (3)$$

The standard error for estimated area of every land use class was calculated by multiplying the proportion area of a given class by the inter map area as proposed by Olofsson et al. (2013)

Different others principles, whose suitability is set supported some normally accepted distance to the possible solid waste landfill site, here the natural value of a land plays an significant role in determining a solid waste dumping site. The lower the natural worth of a given land use what so ever style of use being serving would be given more importance to be chosen as a solid waste landfill site. This criteria appears a gain subjective than the others.

In generating a restriction map shown issues associated with environment, population, sanitary and charge of construction and management a number of the importance criteria to classify a given land use/land cover type as a constraint. As a result, suitability of web sites for a solid waste landfill site within the city are considered and rejected supported on subjects mentioned above as criteria. Therefore suitable land use/land cover should be situated aloof from settlement (built up areas), within the low-density population areas, near agricultural, bush land /or forestland and on open areas. Land use types contains of commercial areas, built up areas and current residence and are rejected from analysis while open places, forest and agricultural and green areas are considered as suitable site for analysis.

Table .9 Error matrixes of sample counts.

Classified samples	Reference Samples								
		BL	CL	S	VE	FL	Total	Mapped area(km2)	Wi
BL		128	2	0	0		133	4.6377	0.9
CL		1	92	0	2		95	14.7934	0
S		0	0	3	0		3	29.7061	0.1
VE		0	2	0	2		4	6.86799	0
Total		129	96	4	4		240	56.00519	1

Note: BL=Bare land, CL= Cultivated land, S=Settlement, VE=vegetation

Table.10 Error matrix of the estimated area proportion

Reference Sample								
CULC type	Vegetation	Cultivated land	Bare land	Settlement	Row Total	PA	UA	
VE	1	0	0	0	1	100%	100%	
CL	0	3	3	0	6	50.00%	100.00%	
BL	0	0	19	0	19	100.00%	79.20%	
S	0	0	2	12	14	92.31%	92.31%	
Total column	1	3	24	12	40			

Note: BL=Bare land, CL= Cultivated land, S=Settlement, VE=vegetation

Table. 11 Estimated LULC and confidence interval

	Proportion area		adjusted area(km ²)	Estimated Area(km ²)	Mapped Area(km ²)	Interval Area(km ²)	Confidence Interval(km ²)	
	Pj	SE (Pj)					Upper limit	Lower limit
BL	0.82	0.02	4.4	4.6377		9	188	179
CL	0.065	0.03	6.55	14.7934		12.8	26.8	1.21
S	0.056	0.006	1.3	29.7061		1.96	14.73	9.73
VE	0.02	0.008	1.82	6.86799		3.6	8	0.07
Total				56.00519				

Note: BL=Bare land, CL= Cultivated land, S=Settlement, VE=vegetation

To accept or reject the omission or commission error, the standard error and confidence interval of each land use class must be projected. Therefore, the standard error of each land use class, SE (Pj), was calculated using and presented in Table 11. A 95% confidence interval ($Z = 1.96$) was used to assess the accuracy of each land use class.

The result realized from accuracy assessment is an overall accuracy obtained from random sampling procedure for image classification is about 87.50%. User's accuracy ranged from 79.20% to 100% while producer's accuracy ranged from 50 % to 100%. As well as 78.49% kappa statistics was calculated.

Table.12 Description of Adama city LULC classification

S/N	Major LULC	Description
1	Cultivated land	Areas of land important for solid waste disposal. This category includes areas currently under farmland and land under farmer.
2	Settlement	Areas occupied by residential, commercial center and government institutions.
3	vegetation	Areas dominated by natural high vegetation, which are relatively dense collection of trees and also closed cover and eucalyptus plantation
4	Bare land	Areas that have little or no vegetation cover mainly include degraded land, gorges and exposed big rocks

Table.13 Area coverage of LULC map of the study area

N/L	LULC classes	Area(km2)	Area(%)
1	Bare land	4.6377	8.26
2	Cultivated land	14.7934	26.42
3	Settlement	29.7061	53
4	Vegetation	6.86799	12.25
5	Total	56.00519	100

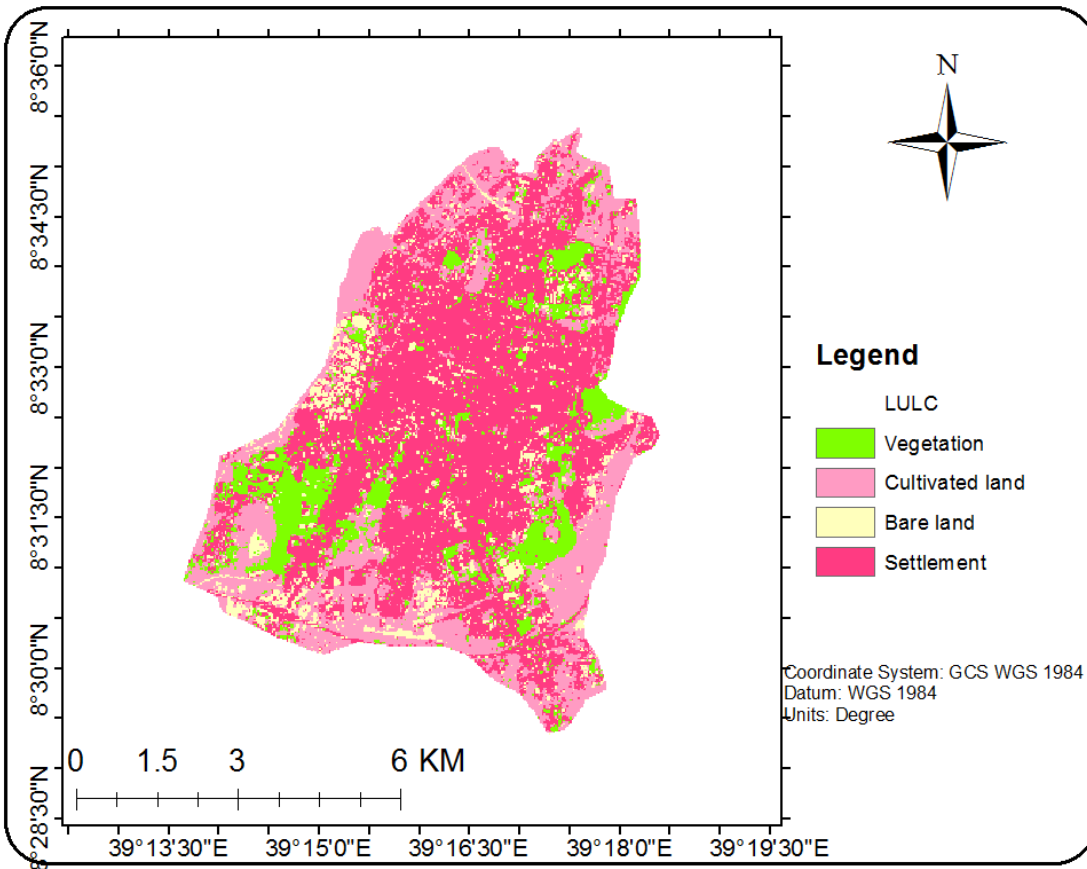


Fig.7 LULC map of the study area.

4.4 Criteria Standardization

The process of setting the relative importance of each criterion is known as the standardization of the criteria (Staay, 1980). The certain criteria needed for maps and use diverse components. For executing WOA for solid waste landfill suitability site, the criteria maps need to be converted into a similar scale through standardization techniques. Standardization techniques convert the measurements in each criteria map into uniform measurement scale so that the resulting maps lose their dimension along with their measurement unit (Reshmidevi et al. 2009). This process eventually will assure the positive correlation between factors of suitability mapping.

There are a number of methods that can be used to make the attribute map layers comparable. Linear scale transformation is the most frequently used GIS-based approach for criteria standardization (Malczewski,2003). Thus, criteria have been consistent for this study, by using reclassify spatial analyst tool, to make assured that every criterion had an equivalent

measurement foundation. Concurrently during reclassification, factor ratings were also allocated for suitability analysis

Before merging datasets, first they need to be resampled at 30m *30m resolution and set to a collective measurement scale, such as 1 to 5, 1 to 9. That common measurement scale is what regulates how suitable a particular site each cell for solid waste dumping site. Higher values specify more suitable cells for solid waste dumping site.

A combination of solid waste disposal site supplies that were selected for this evaluation was identified and factor rating for solid waste landfill site are decided. Issue ratings are sets of values which indicate how well each factor / criterion is satisfied by particular situations of the consistent solid waste landfill site determination. Factor ratings are usually made in terms of five classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2) (FAO, 1985; 1993).

4.4.1 Assigning Criterion Weights

Spatial decision problems typically involve criteria of different importance to the decision maker's (Malczewski, 2000). Therefore, information about the relation criteria and importance of the criteria is compulsory. The derivation of weights is a central step in provoking/eliciting the decision maker's preferences. In the procedure for MCE, weights can be derived by taking the principal eigenvector of a square reciprocal matrix of pair wise comparisons between the criteria (Malczewski, 2003; Eastman, 2006).

The purpose of weighting is consequently to express the importance or favorite of each issue relative to other issue. In the procedure for MCE using weighted linear combination, it is necessary that the weights sum to 1. The MCE method used (weighted linear combination) needs that all factors must be standardized or transformed into components that can subsequently be compared. During assigning values in the matrix, the upper triangle (above diagonal) holds the position equal of a row variable as associated to the column. Lower triangle is the reciprocal of the higher one.

To this conclusion, after discussion and careful analysis of the set of evaluation criteria with experts, all the Pair Wise Comparisons for the set of the considered conditions were ended. After

all possible combinations of two issues are associated; the next responsibilities will be calculating a set of weights and consistency ratio. This ratio specifies any inconsistencies that might occur during the pair wise comparison process. For this particular study in the process of comparing two variables at a time, value from 1 to 5 will be assigned based on relative importance for the intended purpose.

Using Pair Wise Comparison Matrix, factor weights are calculated by comparing two factors at a time using a scale with values from 5 to 1/5 introduced by Saaty (1980).

Table .14 AHP Scale of Relative Importance

Intensity of importance	Definition	Description
1	Equally important	Two variables are required equally to the intended objective
2	Weak or slight	Intermediate scale between the two adjacent comparisons
3	Moderate importance	One variable is slightly important over the other variable being compared
4	Moderate plus	Intermediate values between the two adjacent judgments
5	Strong importance	One variable is strongly important over the other variable being compared
6	Strong plus	Intermediate scale between the two adjacent comparisons
7	Very strong or demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice.
8	Very strong or demonstrated importance	One variable is very strongly important over the other variable being compared
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible instruction of declaration

4.4.2 Pairwise Comparison Matrix

In addition to reviewed literature and different guidelines references made the experts' opinions were used in order to decide the ranks of influencing criteria used to determine the weights. Pair Wise Comparison Matrix (PCM) required for AHP procedure based on forming judgments between two criteria and attempting prioritizing entire list of parameters (Saaty, 1997). The Pairwise Comparison Matrix analysis helps for decision makers to assign different levels of importance of factors involved in land suitability analysis (Elaalem, 2012). The advantage of this method is that all alternatives are contributed in land suitability analysis (Rabia and Terribile, 2013). Therefore, at the first PCM was prepared in excel and computed further more in Idrisi 17.0 software to determine the weights of parameters and consistency ratio according to the AHP. Ranks indicate strength and dominance of criterion. Using Pair Wise Comparison Matrix, factor weights are calculated by comparing two factors at a time using a scale with values from 5 to 1/5 introduced by (Saaty, 1980). A rating of 5 indicates that in relation to the column factor, the row factor is more important. On the other hand, a rating of 1/5 indicates that relative to the column factor, the row factor is less important (Mustafa *et al.*, 2011). In cases where the column and row factors are equally important, they have a rating value of 1. Using Pair Wise Comparison Matrix, factor weights are calculated by comparing two factors at a time using a scale with values from 5 to 1/5 introduced by Saaty (1980).

Table.15 Pair Wise Comparison Matrix

	LULC	Road	Stream	Soil	Slope
LULC	1	2	3	4	5
Road	1/2	1	1/3	1/4	1/5
Stream	1/3	1/2	1	1/3	1/5
Soil Type	1/4	1/3	1/2	1	1/5
Slope	1/5	1/4	1/3	1/2	1
Total	2.61	4.41	5.82	6.41	6.6

4.4.3 Weight Normalized

The normalization of criteria values allows for the direct comparison of criteria when calculating suitability and reflects the conceptual relationship between the criteria value and a suitability score (Jiang & Eastman, 2000). Priority vector is also called weight normalized principal Eigen vector. To normalize the values, divided the cell value by its column total and calculated the priority vector or weight by determining the mean value of the rows (Saaty, 1980)

Tabl.16 Weight Normalize

	LULC	D-Road	D-Stream	Slope	Soil Type	Weight
LULC	0.38	0.45	0.35	0.62	0.76	27
D-Road	0.19	0.23	0.12	0.05	0.03	24
D-Stream	0.26	0.12	0.17	0.11	0.03	19
Slope	0.09	0.15	0.08	0.15	0.03	17
Soil Type	0.08	0.05	0.16	0.07	0.15	13
Total	1	1	1	1	1	100

4.4.4 Aggregating the Criterion Weights and the Standardized Criterion Maps

The weighted linear combination (WLC) aggregation method multiplies each standardized factor map (i.e., each raster cell within each map) by its factor weight and then sums the results using spatial analyst in GIS by calculating sum to one, the resulting appropriateness map will have the same range of values as the consistent factor maps that were used. This result was then multiplied by each of the constraints in turn to "mask out" unsuitable areas (Ronald Eastman J., 2001).

In the context of GIS, three decision rules i.e. Boolean overlay, weighted overlay and ordered weighted averaging are common for MCE (Jiang and Eastman, 2000; Malczewski, 2000; Malczewski, 2003). The present study, however, adopts only the weighted overlay technique for deriving composite suitability maps.

In this technique, eleven important factors were taken in consideration and reclassified in to five classes. These were highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2)

In this particular study, Multi-Criteria Evaluation (MCE) approaches for the chosen solid waste disposal were employed and Weight Overlay Analysis (WOA) module which resulted in numerous classes of suitability level. Before executing overall weight overlay analysis at the primary level, each suitability criterion was categorized in to 1 to five common measurement scales. Supported their respective weight has been given for all individual suitability parameters careful during this study, comparing one factor with another has been held reckoning on their relative importance. Finally, a collective suitability criteria maps displayed four classes of suitability points. These are; highly suitable, moderately suitable, marginally suitable and currently not suitable. Though, there's no solid waste landfill site that's classified as forever not suitable for the chosen solid waste disposal site within the study area. During analyzing, settlement and vegetation cover areas are treated as 'unavailable' or as a constraint for solid waste landfill site suitability.

The area attention of every suitability class for every main solid waste dumping site under this study was considered after changing the raster output of the weighted overlay to a polygon feature and dissolving grid code result lead to an Arc GIS environment. Table 18 shows the output of the analysis. The key component in GIS work is that the design of the database. Among the databases utilized in Esri's ArcGIS program, Personal Geodatabase has been chosen as an appropriate geodatabase for this exact research work. Geodatabase could be a vessel, associated with folder, which is employed to input, store, manage feature datasets, and feature classes. The database is planned to hide of complete information includes data associated with road network, GPS readings of sample sites, accessibility maps stream data, and reservoirs data, border map, map of sub cities, land use map as fine as data in raster formats like Digital Elevation Model (DEM) Slope data used during the analysis process DEM. Maps in vector and raster formats are used for the analysis. When solid waste landfill site suitability is evaluated during a raster GIS environment, each land unit within the database is valued consistent with its priority in solid waste landfill site selection and every thematic layer signifies it's unique within the evaluation procedure. Next the privet Geodatabase formation, feature dataset is additionally created to carry the feature classes like land use map, road map, slope map et al with the identical stages surveyed in feature dataset creation. Taking complete feature class construction, area and topology are adjusted the feature classes and pointing to topology and area respectively. In instruction to assign suitable site for the chosen solid waste dumping site in study area, the result

displays that for every of the chosen solid waste landfill site for the nominated solid waste dumping site were veiled out during weight overlay analysis. So that, during this analysis all classes of suitability levels were attributed additionally to restricted/no data value except permanently not suitable.

Table.17 Criteria accepted for dump site selection suitability and their rank

Parameter	Parameter (m)	Suitability class	Rank	Weight	Area (Km ²)	Area (%)
Road	0-500	Unsuitable	1	0.45	19.9	35.5
	501-1000	Suitable	4	0.23	16	28.57
	1001-1500	Highly suitable	5	0.12	8.9	15.8
	1501-2000	Moderately suitable	3	0.15	11.3	20.125
	>2000	Less suitable	2	0.05	0	0
River/stream	0-500	Unsuitable	1	0.35	27.22	48.6
	501-1000	Suitable	4	0.12	8.42	15
	1001-1500	Highly suitable	5	0.17	9.93	17.7
	1501-2000	Moderately suitable	3	0.08	10.45	18.7
	>2000	Less suitable	2	0.16	0	0
LU/LC	Bare land	Highly suitable	5	0.38	4.6377	8.26
	Cultivated land	Suitable	4	0.19	14.7934	26.42
	Settlement	Less suitable	2	0.26	29.7061	53
	Vegetation	Unsuitable	1	0.09	6.86799	12.25
Soil type	mollicandosols	high suitable	5	0.76	31.3701	56.1
	vitric andosols	Moderate suitable	4	0.15	24.6538	44.1
percent of slop	0-5	highly suitable	5	0.62	20.01	35.73
	5_10	Suitable	4	0.05	19.13	34.16
	10_15	Moderately suitable	3	0.11	7.1	12.7
	>20	Less suitable	2	0.15	10.013	17.9

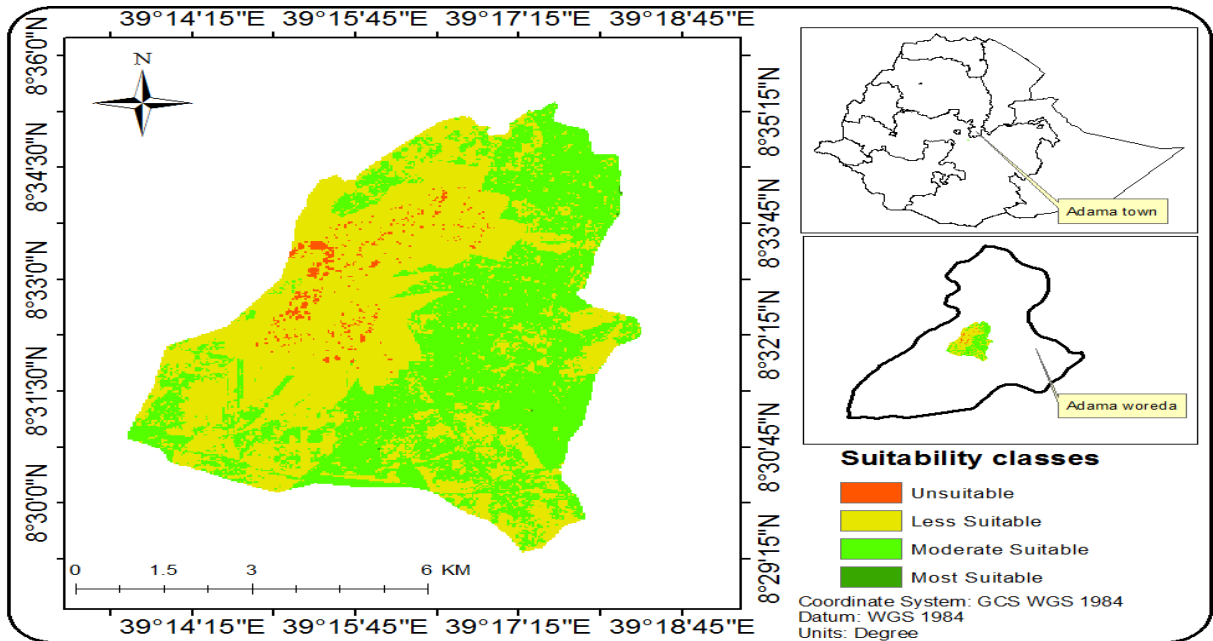


Figure.8 Final suitable site allocated map

As it is displayed above on figure suitability of a land rises with the worth. The upper the value the extra the suitability for a landfill site growth during this thesis analysis. Therefore smallest and no suitable areas are shaded with a red color and are given low suitability balances whereas suitable areas are given higher suitability scale and shaded with green colors. Extremely suitable areas for a landfill site expansion cover high area and are signified by a dark green color on a final suitability map. They're located along the margins of the town, constituting approximately 0.87% of the whole area of the town while unsuitable areas protection the central and broader area of town of Adama establishing nearly half the city's areal attention. Central parts of the town where there exist constructed up and services facilities areas are exposed as unsuitable for a landfill site growth. Because of some constraints, the realm that lies on marketable and residential land uses are made restricted during the weighted overlay process.

Table.18 Proportion respective area coverage for solid waste landfill

level of suitability	area (km²)	area %
S1	0.99	1.77
S2	25.00	44.64
S3	29.14	52.04
N1	0.87	1.55
Total	56.00	100.00

4.5 Proportion by Area of Suitable Sites

According to GIS and RS based MCA, 0.99km² and 25km² are highly suitable and moderately suitable for solid waste landfill site respectively.

Whereas, large area is marginally suitable which cover 52.04 % (29.14km²) of an area for solid waste landfill site? The remaining 52.04 % (29.14) and 1.55% (0.87km²) are currently unsuitable and permanently unsuitable for solid waste landfill site development respectively.

4.5.1 Allocation for the Solid Waste Dumping Site

Land-use distribution is a process of allocating different activities or uses to specific components of area in a geospatial context, to maximize a spectrum of social, economic, and ecological benefits Shaowen W, Hui L (2011). Suitable solid waste landfill site allocation is the result of interaction between solid waste landfill site suitability and unsuitable solid waste landfill site in an environment affected maybe by environmental, socio-economic, political and administrative rules areas.

General solid waste landfill site suitability analysis specifies the overall suitability of the solid waste landfill site for each LUTs. It also shows which LUTs contend for a parcel of land at the same level of suitability class. Overall solid waste landfill site suitability analysis is a revealing of suitable solid waste landfill site allocation. Hence, the total solid waste landfill site suitability analysis is achieved for the LUTs considered in the study area.

In mandate to compute the overall site suitability analysis for all land operation types, raster data formats should be transformed in to vector data format. The analysis is performed in a vector overlay analysis in a GIS environment using Analysis Implement.

CHAPTER FIVE

5. Conclusion and Recommendations

5.1 Conclusion

Landfills suitable sites are an environmentally acceptable dumping of solid waste on the ground. The main purpose of founding landfills suitable sites is to protect the safety of the environment by reducing effects on resources and community health. Similarly the main purpose of this study was finding suitable sites selection for landfills using GIS and remote sensing technologies.

As the study displays GIS requires collecting different data from different sources with different formats and the data must be updated to show the current information of the study area. Remote sensing also helps in taking information about the study area through satellite images.

The findings have shown the ability of GIS and remote sensing as a veritable tool for analyzing the criteria for decision making. The analysis has taken important issues to minimize the negative impacts of solid waste landfill site. The parameters which were used for the evaluation of landfill suitability for major solid waste dumping in the study area are: topography (elevation and slope), distance from main road, Soil type, LULC and distance from river/stream as determining factor in order to find appropriate site for solid waste dumping site selection. The results have shown that two sites were north and south suggested as highly suitable for solid waste landfills. The sites were easy to access and managing for landfill of solid wastes. Hence, the capacity to use AHP with GIS and RS technology for identification of suitable solid waste dumping site will minimize the environmental risk and human health problems.

5.2 Recommendations

Among the fast growing towns and cities, Adama is maybe the prominent one. As results of increment solid waste generation within the town has been increasing and becomes complex. In other hand, the town doesn't have solid waste disposal suitable sites selection. Multi criteria evaluation technique is incredibly important technique for dump site selection, therefor the researcher will use this method is utilized to contemplate different criteria from different points of view. The chosen solid waste dumping sites during this study are only for solid wastes landfill suitable site. In step with the results the highly suitable area is far from settlement, therefor, the govt. Should put waste collection bins during a special a component of the cities and arrange the transportation with appropriate vehicles; similarly, the system are visiting be proper management. Decentralization of the system and dealing in closer with the local administration office (kebeles) and right right to down to community and household level is crucial to unravel the problem of improper collection and solid waste landfill site practices. Individual consciousness and participation, as number of the core principles of integrated solid waste landfill suitable site selection system. This is often actually because lack of individual awareness and improper solid waste dumping practices are among the foremost challenges the residents are complaining. Each households because the pillars of the large community must be give much attention and focus during all points of solid waste dumping site processes starting from solid wastes collection ,sorting conduct and final solid waste dumping site selection. It's also should be public awareness in several ways like media, school symposium, workshops seminars which explored by the government and participation within the design and implementation of solid waste landfill suitable site selection. The concerned body should formulate solid waste landfill suitable sites by considering social, economic and environmental aspects to spice up the status of the town. The GIS can be strong tool for identifying suitable solid waste dumping sites selection.

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Appendixes

1. Appendixes

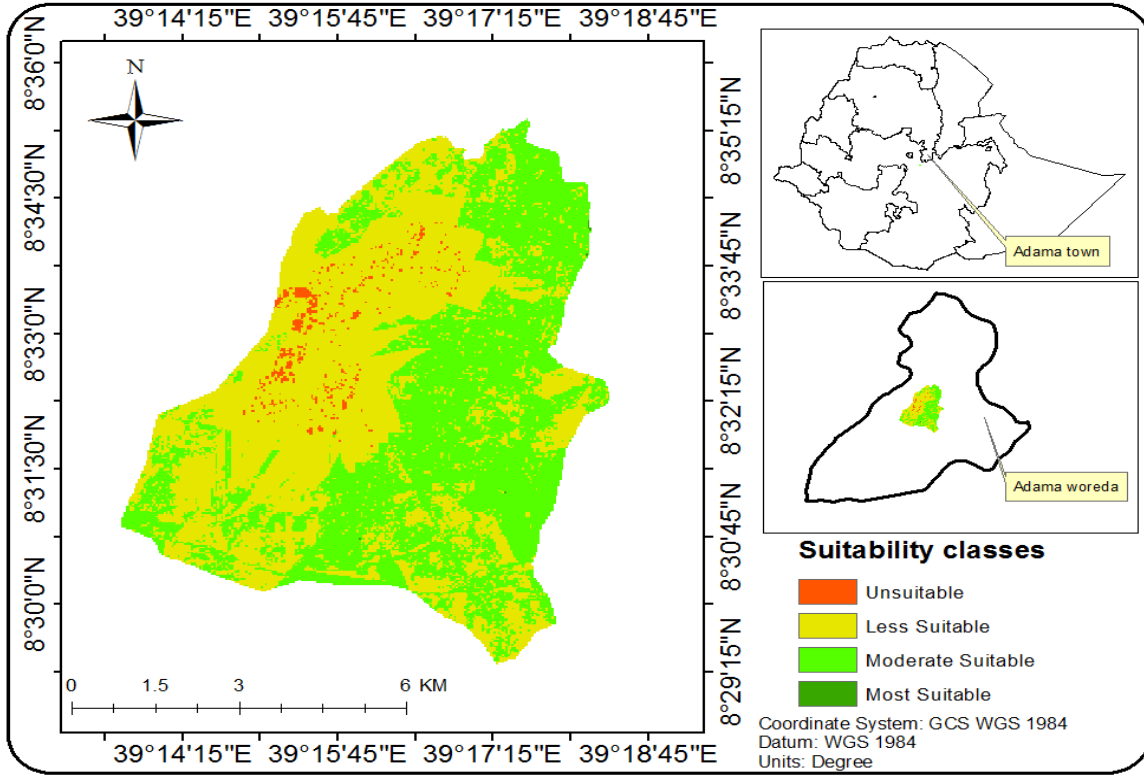
1.1 Pair wise comparison matrix for

	LULC	Road	Stream	Soil	Slope
LULC	1	2	3	4	5
Road	1/2	1	1/3	1/4	1/5
Stream	1/3	1/2	1	1/3	1/5
Soil Type	1/4	1/3	1/2	1	1/5
Slope	1/5	1/4	1/3	1/2	1
Total	2.61	4.41	5.82	6.41	6.6

1.1 Weight Normalize

	LULC	D-Road	D-Stream	Slope	Soil Type	Weight
LULC	0.38	0.45	0.35	0.62	0.76	27
D-Road	0.19	0.23	0.12	0.05	0.03	24
D-Stream	0.26	0.12	0.17	0.11	0.03	19
Slope	0.09	0.15	0.08	0.15	0.03	17
Soil Type	0.08	0.05	0.16	0.07	0.15	13
Total	1	1	1	1	1	100

Final suitable site allocated map



wey points	lat	long	LULC Types
1	8.56877	39.2924	VEGETATION
2	8.56644	39.2897	VEGETATION
4	8.56109	39.2907	VEGETATION
5	8.55951	39.2811	VEGETATION
6	8.55831	39.2841	VEGETATION
7	8.56019	39.2842	VEGETATION
8	8.56477	39.2838	SETTLEMENT
9	8.55888	39.2744	SETTLEMENT
10	8.55915	39.2703	SETTLEMENT
11	8.55586	39.2729	SETTLEMENT
12	8.55477	39.2925	SETTLEMENT
13	8.55352	39.2774	SETTLEMENT
14	8.55131	39.2904	SETTLEMENT
15	8.55056	39.2667	SETTLEMENT
16	8.5483	39.2838	SETTLEMENT
17	8.5503	39.2937	SETTLEMENT
18	8.56081	39.262	SETTLEMENT
19	8.57046	39.2854	SETTLEMENT
20	8.57141	39.2904	SETTLEMENT
21	8.57094	39.2816	SETTLEMENT
22	8.5516	39.2885	SETTLEMENT
23	8.57972	39.2967	CULTIVATED LAND
24	8.573	39.2979	CULTIVATED LAND
25	8.57391	39.3018	CULTIVATED LAND
26	8.58444	39.2785	CULTIVATED LAND
27	8.58008	39.2776	CULTIVATED LAND
28	8.57812	39.2764	CULTIVATED LAND
29	8.50542	39.2682	BARE LAND
30	8.50822	39.2685	BARE LAND
31	8.51087	39.2685	BARE LAND
32	8.51531	39.2823	BARE LAND
33	8.51096	39.2442	BARE LAND
34	8.52001	39.2391	BARE LAND
-	-	-	-
174	-	-	-

