JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

CIVIL AND ENVIRONMENTAL ENGINEERINGFUCULITY

ENVIRONMENTAL ENGINEERING CHAIR

SOLID WASTE LANDFILL SITE SUITABILITY ASSESSMENT USING GIS TOOLS: CASE STUDY OF JIMMA TOWN, ETHIOPIA

BY: MEKONNEN WOLDEMESKEL EDO

A THESISSUBMITTED TO ENVIRONMENTAL ENGINEERING CHAIR, CIVIL AND ENVIRONMENTAL ENGINEERING FUCULITY, JIMMA INISTITUTE OF TECHNOLOGY AND JIMMA UNIVERSITY FOR PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING.

OCTOBER, 2017

JIMMA, ETHIOPIA

JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

CIVIL AND ENVIRONMENTAL ENGINEERINGFUCULITY

ENVIRONMENTAL ENGINEERING CHAIR

SOLID WASTE LANDFILL SITE SUITABILITY ASSESSMENT USING GIS TOOL: CASE STUDY OF JIMMA TOWN, ETHIOPIA

BY: MEKONNEN WOLDEMESKEL EDO

ADIVISORS: 1. Dr.-Ing. FEKADU FUFA (PhD)

2. Mr. DIDA ABERA (PhD CANDIDATE)

OCTOBER, 2017

JIMMA, ETHIOPIA

Declaration

To the best of my knowledge the thesis work is my original work and has not been presented for the award of MSc degree either in Jimma institute of technology or any other university.

Mekonnen W/meskel Edo

Researcher Signature _________________ Date______________

This study has been submitted for examination with my approval as university supervisor.

Dr.-Ing. Fekadu Fufa (PhD)

Main Advisor Signature____________ Date_____________

Mr. Dida Abera (PhD Candidate)

Co-Advisor Signature ___________ Date____________

Acknowledgements

First of all, I would like to thank the Almighty GOD who made it possible, to begin and finished this work successfully. My gratitude and appreciation also goes to my advisor, Dr.-Ing.Fekadu Fufa (PhD) and Mr. Dida Abera (PhD Candidate), in addition to my friends and giving general constructive comment and suggestion to implement this study.

Moreover, I wish to express my deepest gratitude to my brother Tilahun Furgasa Edo for providing financial support and motivation to be successful in my study. In addition, my friend Abdo A/Fita and collogues thanks for your collaboration and motivation. Finally, my deepest gratitude and humble thanks go to my immediate parents particularly my lovely wife Yamrot Fikadu, my sisters and brothers for their never ending support, encouragement and motivation.

Abstract

Solid waste landfill site is a serious problem in the town because all solid wastes are not dumped in the suitable areas. The geographical information system (GIS) tools for selection of solid waste landfill site have become an advance. The study area has the problem of solid waste landfill site identification. Landfill sitting was determined for Jimma Town through the integration of geographic information system (GIS) tools, weighted linear combination (WLC) analysis, and remote sensing techniques. The main objective of this study is selection and management of prospective landfill sites using Geographic information system (GIS) tools for Jimma Town, which are environmentally suitable.

*The main data used for this study were a spatial resolution of (DEM 30 m *30m); ground control point (GCP) collected by ground point survey (GPS), geological map of the study area, protected area and shape files developed from structural map of the town. Also several parameters were collected from various sources in vector and raster GIS formats, and then, used within the GIS-based WLC analysis to select optimum solid waste landfill sites. Thematic maps as slope, protected area, agricultural lands, roads, river, soil map, historical site, geology, wet land, airport and built up area were considered in this research. Also, the trend of urban expansion within the study area was monitored using the master plan of the towns to support the selection process of landfill sites. After analysis of suitability of solid waste landfill site by using GIS tools and weighted analysis methods; The final result of solid waste landfill site suitability map was produced by overlay analyses system on GIS tools and ranked as the value given 1;unsuitable,2;less suitable,3;moderate suitable and 4;highly suitable sites of the town were determined. The results shows that 16.13% of the town covers unsuitable for municipal solid waste landfill site; 74.64% less suitable; 7.42% moderately suitable; and 2.02% most suitable. The most suitable site for solid waste landfill sites fall where free of environmental, social and health risks. The GIS tools analysis approach is appropriate for selection of municipal solid waste landfill site. Finally, three sites were suggested taking into the consideration the environmental, social and economic variables applied in the GIS-based WLC analysis.*

Keywords: *GIS, Land Use/ Land Cover, Municipal, Solid Waste Landfill, Multi Criteria.*

Table of Contents

List of Tables

Tables **Pages**

List of Figures

Acronyms

AG	Agriculture
AHP	Analytic Hierarch Processes
AI	Airport
BU	Built Up
CSA	Central Statistical Agency
CM	Conventional Method
DEM	Digital Elevation Model
DLSIC	Determine the Landfill Sitting InputCriteria
EMA	Ethiopia Metrological Agency
EPA	Environmental Protection Authority
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GEO	Geology
GPS	Global Positioning System
HI	Historical
LULC	Land Use/Land Cover
MC	Multi Criteria
MCDM	Multi Criteria Decision Making
MCE	Multi Criteria Evaluation
MSW	Municipal Solid Waste
MPCA	Minnesota Pollution Control Agency
QA	Quality Assurance
RI	River
RO	Road
SL	Slope
SO	Soil
SMVA	Spatial Multivariate Analysis
UNEP	United Nation Environmental Protection
UTM	Universal Transverse Mercator
WGS	World Geodetic System

WL	Wet Land
WLC	Weighted Linear Combination

CHAPTER ONE

INTRODUCTION

1.1 Back Ground

Solid waste is a global environmental problem in today's world both in less developing and developed countries. Increasing population, rapid economic growth and the rise in community living standards accelerate solid waste generation in the world (Ebistu & Minale, 2013).

Sanitary landfill is the most cost-effective system of solid waste disposal for most urban areas in developing countries. Recently, due to the growing urgency of urban 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. One of the major problems in waste management is concerned with the selection of the appropriate site for waste disposal (Nas*et al*., 2010).

Management of solid waste is one of the challenges facing urban areas in the world. This is because an aggregation of human settlements has the potential to produce a large amount of solid waste. Collection, transfer and disposal of such waste have been generally assumed by municipal governments in developed countries. The format varies, however, as in most urban areas, garbage is collected either by a governmental agency or private contractor, and this constitutes a basic and expected government function in such contexts. Municipal solid waste management has thus become a major issue of concern for many under developed nations, especially as populations increase (Oyinloye, 2013).

Selecting and managing appropriate solid waste dumping site is one of the challenging problems in developing countries, due to the lack of proper solid waste management system and the type of waste thrown to the environment. The practice of direct dumping of waste into water bodies, open and abandoned lands without proper treatment leads to serious environmental pollution and health-related problems. The rapid growth of the world population and the urbanization processes are making the nonrenewable resources to be in shortage and the disposal of effluent and toxic waste done indiscriminately. The current global trend of waste management problems stems from unsustainable methods of waste disposal, which is ultimately a result of inadequate planning and implementation (Mohammedshum*et al*.,2014).

Land and soil degradation processes can be seen in landfills. In developing countries it is necessary to develop efficient waste management systems due to increased waste production as a consequence of population growth. Despite developments that have improved waste management systems, the disposal of solid waste in landfills is still the most commonly used method in developing countries (Leao*et al*., 2004; Mahini and Gholamalifard, 2006; Sumathi*et al*., 2007; Donevska*et al.*, 2013). Sanitary land filling is one of the best ways to decrease the volume of waste products (Wang *et al*., 2009); nevertheless the lack of effective environmental laws and enough suitable land for landfill sites in most developing countries is a major issue that causes many problems (Hagerty*et al*., 1997).

An open dumpsite is an environmental hazard which causes natural resource (soil, water, air) degradation and environmental pollution. Previous works found that leachates from landfills contaminated groundwater (Mor*et al.*, 2006; Dimitrio*et al*., 2008; Nema*et al.*, 2009) and soil (Raman and Narayanan, 2008; Shaylor*et al.*, 2009; Hernandez *et al*., 1997). One of the main Problems with open dumping are open air burning due to gases emitted from waste degradation processes; some researchers have investigated the effects of fire on soil (Guenon *et al*., 2013; Leon *et al.*, 2014). The other serious threat to soil in landfill sites is salinity, which causes soil degradation and promotes groundwater salinization (Yazdani*et al*., 2015).

Effective solid waste management is a major challenge facing most African developing countries mainly due to lack of good governance, planning and inadequate technology. The challenge is more serious in Kenya’s urban centers where population growth and economic activities have led to an increase in solid waste generation rates. However, this increase has not been accompanied by an equivalent increase in the capacity of relevant authorities to deal with the problem. Nakuru town is the fourth largest urban centre in Kenya with an estimated population growth rate of 13% per year with waste generation rates of approximately 250 tons/day of which 45% is disposed off to at dumpsite, 19% of the total wastes is recycled or recovered by informal sectors and the remaining 36% is left unattended to and eventually deposited to the surrounding environment by storm water and wind (Kirimi and Waithaka, 2014).

In this research land use/land cover, soil, geology and slope of the study area were used as suitability factors. Moreover, proximity from road and proximity from rivers were also considered as constrains. All the factors and constrains were internally classified into five classes (very high, high, moderate, low and very low) with values ranging from 5 to 1, where the value of 5 denotes the most suitable and value 1 denotes the least suitable, for all factors and constrains considered. Weights for each class of criteria were derived using Analytic Hierarchy Processes (AHP) (Mohammedshum *et al*., 2014).

As a result of rapid population growth in the town, the solid wastes are increasing from time to time. The suitable site for these solid wastes is not selected due to this reasons the community of the town are dumping the waste anywhere and unsuitable area. The Solid waste landfill site suitability analysis using Geographic information system (GIS) tools is very important to solve that all problems discussed above. Even thought the problem is increasing, regarding to previous work there is no any research done on this area. So this study will fill gap to develop socio economic wellbeing of the community of the town.

1.2 Statement of the Problem

The population of Jimma Town is growing at an alarming rate. Moreover, currently in the town development activities are widely observed. As a result of fast population growth and development activities solid wastes are generated widely and the town is facing problem in their improper landfill site. It has direct effect in polluting the environment. Consequently, public health is also highly affected by the uncontrolled municipal solid waste disposal. Collection service coverage of less than 70% is not uncommon in developing countries. These inadequate municipal solid waste management systems cause environmental and public health problems (Lemma, 2007).

The same is true in Jimma town. Because of the inadequacy of proper collection and disposal of solid wastes in landfill, municipal and public health authorities and others concerned with disease prevention and control organizations in the town of Jimma are seriously confronted with the issue of improving the solid waste management system.

Application of the methodology is based on the collection of data related to the physical environment, state and characteristics of Landfill site. Data collection involved visiting the current landfill area as well as studying the existing library information. Thus, considering the solid waste landfill suitability in Jimma Town, this research was intended to assess the suitability of landfill site using GIS tools in Jimma Town. Therefore, this study will fill the gap and seek to validate the suitable site selection and the solutions of proper waste management by considering the sustainable development of the town.

1.3 Research Questions

1. What is suitability problem of landfill site in Jimma Town?
2. How suitable landfill site map is produced using GIS tools?
3. How the geographic boundary of suitable landfill site determined?

1.4 Objectives of the Study

1.4.1 General Objective

The general objective of this study is to assess solid waste landfill site suitability around Jimma Town using GIS tools.

1.4.2 Specific Objectives

1. To evaluate suitability of landfill site around the town.
2. To produce the suitable site map for landfill site.
3. To determine the geographic boundary of suitable landfill site.

1.5 Rational of the Study

Inadequate solid waste management in Jimma Town has resulted in the accumulation of waste on open lands, in drainage, near the road and in the residential areas, causing a nuisance and foul-smelling pools, environmental pollution through leachate from piles, visible burning of waste, clogging of drains and aesthetic problem. So this problem initiated me to study suitable solid waste landfill to solve the problem.

1.6 Scope of the Study

The study is limited to suitable solid waste disposal site selection in Jimma town. It focuses on some technical aspects of solid waste disposal site selection. The issues under consideration in this study are only solid wastes. The study is not included sanitary wastes area, engineering and design part of the construction. GIS and Remote Sensing based suitable site selection for solid waste disposal: A case study of Jimma Town, Oromia Regional State, Ethiopia.

1.7 Significance of the Study

The study of solid waste land fill site selection using GIS software is cost effective and environmentally sound. This study will alleviate water, air, and soil pollution due to unavailability of soil waste management system in the town.

This study expected to have practical utility in suitability of landfill in Jimma Town. It will help Jimma Town community and environmental authority office of the town to solve problem face with landfill suitability. Moreover, researcher can use the study as a spring board for further investigations.

1.8 Limitation of the Study

GIS is a suitable tool for site selection since it has the capability to manage large amount of spatial data that comes from various sources. Kao *et al.,* 1996 pointed out that large amount of spatial data can be processed using GIS. The limitation of the study is that ground water table suitability check was not considered due to lack of data and the time given for data collection was inadequate to analyze on the university schedule.

1.9 Organization of the Study

This study has five chapters. Chapter one is an introduction part which consists of the introduction, statement of the problem, research equations, the objectives, rational of the study, scope of the study, significance of the study and limitations of the study. The second chapter deals with review of related literature obtained from various published and unpublished reference materials. Chapter three describes the study area and the research methodology and materials. Chapter four contains the analysis, results and discussion parts of the study and the fifth chapter presents the conclusion and recommendations of the study.

CHAPTER TWO

REVIEWOF RELATTED LITERATURE

2.1 General Description of Landfill Suitability

Landfills are the physical facilities used for the disposal of residual solid wastes in the surface soils of the earth. In the past, the term sanitary landfill is used to describe a landfill in which the waste placed in the landfill was covered at the end of each day. Today, sanitary landfill refers to an engineered facility for the municipal solid waste designed and operated to minimize public health and environmental impacts (Allen, 2001).

The municipal solid waste landfill is defined as a method of disposing without creating any problem to public health or safety, by utilizing the principles of managing to confine the refuse to the smallest practical area, to reduce it to the smallest volume, and to cover it with a layer of earth with advisable covering layer at the conclusion of each day's operation, or at such more frequent intervals in every day activity. Therefore, the process of landfill sitting considers environmental, ecological, and technical parameters. The selected locations must also fulfill the necessities of existing legislative guidelines and reduce health and environmental expenses in the meantime. Furthermore, design considerations, area availability and prospects of development (Ahamad *et al*., 2016).

The process of searching for a new municipal waste disposal site is time consuming. The related procedures are extremely complex because its involve combination of several knowledge from diverse interesting areas, and numerous gatherings are in charge of or influenced by the outcomes. To properly identify and select appropriate landfill sites, systematic procedures was adopted and followed carefully stated that the determination of suitable landfill locations is a decision that requires extensive land evaluation.

2.2 Solid Waste Management

Solid waste management is defined as the process of controlling of waste generation, storage, collection, transporting and disposal of solid wastes. Integrated solid waste management includes the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals (Tchobanoglous and Kreith, 2002). Current solid waste management technologies can be summarized as: source reduction, recycling, waste transformation and landfill system.

Figure 2.1 Open Area Current Desposal Site (Photo by Mekonnen)

2.3Theoretical Review of Landfill Suitability

Open dump as the name implies, a disposal site where wastes are piled on the surface of the ground. There are generally no provisions for controlling vectors, littering due to wind action, or runoff to surface or ground waters. The Resources Conservation and Recovery Act of 1976 specifically prohibit open dumping, and most states also have existing regulations against open dumps. As enforcement becomes more complete, open dumps should be phased out of existence. The sanitary landfill is defined as "a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or at such more frequent intervals as may be necessary (ESAUK, 2016)

According to national environmental authority solid waste management encompasses generation, collection, transportation and disposal of wastes. Authorities have the responsibility to ensure safe, reliable and cost effective removal and disposal of solid waste. Waste management is undertaken mainly to minimize the effect of wastes on resource loss and conservation, health, environment, costs, and aesthetics. It incurs financial and social and other costs. The term includes the issue of regulation of the various aspects of management of wastes. Waste management is the process by which products and by products, generated by business and industry, are collected, stored, transported, treated, disposed off, recycled or reused in an effort to reduce their effects on human health. Therefore, a proper managed waste; that is well collected (NEPA, 2000).

2.4 Solid Waste Generation Rate

House hold generates 0.18 kg/day for low income families; whereas middle income and high income households generate 1.65 kg/day and 3.06 kg/day respectively. Similarly, per capita generation rate of a person is 0.20 kg/day, 0.48 kg/day and 0.93 kg/day for low, middle and high income, respectively in Jimma Town. This indicates that generation rate has direct relationship with income level (Tegeny, 2008).

As many researcher cited, population less than 200 P/Ha persons per hectare is highly suitable, population within 200 P/Ha to 400 P/Ha is moderately suitable, population between 400 P/Ha to 600 P/Ha is less suitable and more than 600 persons per hectare is unsuitable for waste dumping site (Jaybhaye *et al*., 2014)

2.5 Critique of the Existing Literature Relevant to the Study

General Types of Landfills although considerable variety exists for hazardous waste landfills, there is no uniformly used nomenclature in the field. Among the commonly encountered terms are open dump, sanitary landfill, and secure landfill. Other commonly used terms include: chemical landfill, industrial landfill, and hazardous waste landfill, general purpose for landfill, special purpose landfill, isolation burial, and environmental containment site.

Open dump as the name implies, an open dump is a disposal site where wastes are piled on the surface of the ground. There are generally no provisions for controlling vectors, littering due to wind action, or runoff to surface or ground waters. The resources conservation and recovery Act of 1976 specifically prohibit open dumping, and most states also have existing regulations against open dumps. As enforcement becomes more complete, open dumps should be phased out of existence sanitary landfill.

The earliest hedonic analysis of the disamenity impacts of landfill appears to be which, like almost all subsequent studies, uses distance to the nearest landfill as a proxy for the disamenity impact (Havlicek *et al*., 1985).

However, geographic information system is not comprehensive enough; it is mainly due to the fact that evaluation criteria produced ultimately weak evidence to support the selection. Thus, it leads to the need to develop a proper tool in the evaluation process for a site and ensure the criteria uses are fulfils sustainable concept landfill site selection criteria under department of Environment in Malaysia, prior for a landfill site to be selected, it has to fulfill a series of criteria listed out to reduce the impacts towards the environment to the minimum. In relation to this, Department of Environment has produce a guideline namely, Guidelines for development of solid wastes sanitary landfill. In this guideline, it stated six major criteria that should be taken into consideration when selecting a landfill site (Sin *et al*., 2016).

The process of searching for a new municipal waste disposal site is time consuming. The related procedures are extremely complex because its involve combination of several knowledge from diverse interesting areas, and numerous gatherings are in charge of or influenced by the outcomes. To properly identify and select appropriate landfill sites, systematic procedures must be adopted and followed carefully. Stated the determination of suitable landfill locations is a decision that requires extensive land evaluation. Therefore, the process of landfill sitting considers environmental, ecological, and technical parameters (Yahya *et al*., 2016).

The selected location also fulfils the necessities of existing legislative guidelines and reduces health and environmental expenses in the meantime. Furthermore, design considerations, area availability and prospects of development (Yahya *et al*., 2016).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Area

The study area is situated in the Oromia regional state located in the south western part of Ethiopia, 256km far from Addis Ababa, Jimma town is located on 740'0.012''N and 3649'59.880''E with an average elevation 1763 m. According to five years rainfall data obtained from the National Meteorological Agency of Jimma Substation, the annual rainfall of Jimma town varies from 1414.4mm to 2392.3mm with a mean annual value of 1769.7mm.

3.2 Population

The total population of the town is 206, 427 out of this 103,895 are male and 102,532 are female. The crude density is thus 382persons/km^{2}and therefore; the district is among the most densely populated area in Oromia Region (CSA, 2007).

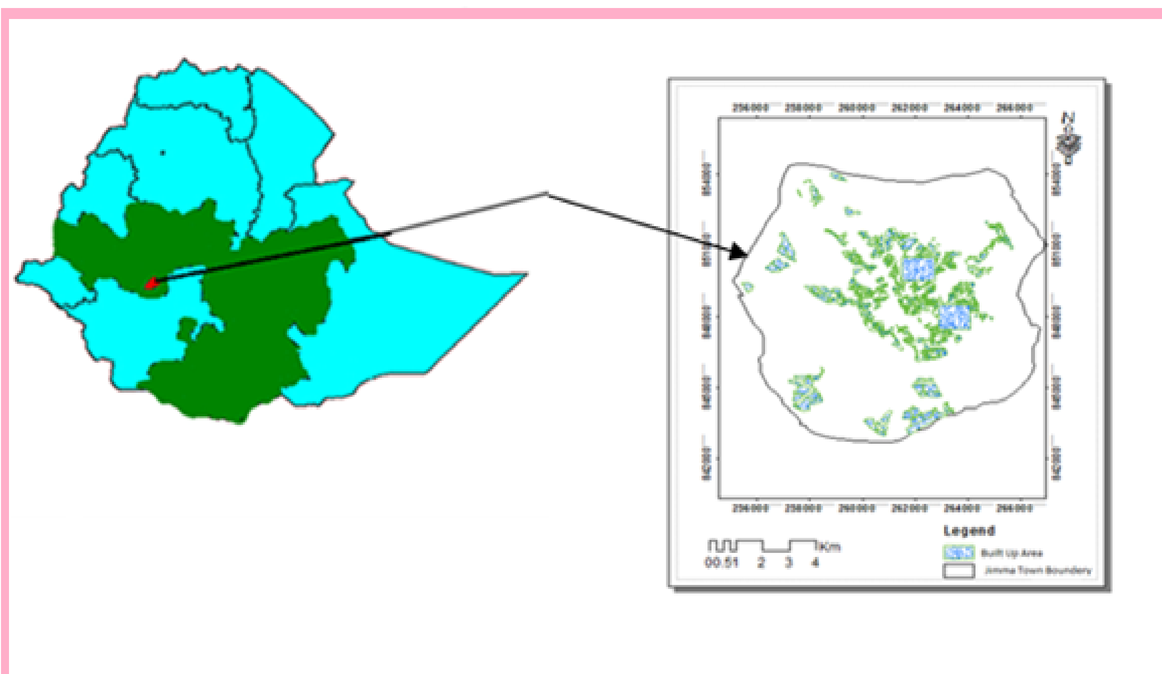

Figure: 3.1 Map of Study Area

3.3 Study Design

A site survey and using GIS tools were used to assess suitability of landfill site in Jimma Town. The method for data collection was using GIS tools, site observation. This approach is the most important approach for the data collection on this study, because the method costs less amount and address the aim of the study.

A number of criteria were applied for solid waste landfill site selection in this study; land use/land cover (LULC), soil type, geology and slope of the study area were used as suitability factors. Moreover, proximity from road and proximity from surface water, air port and historical site were considered as national and international Guidance of solid waste landfill site suitability analysis criteria. Also hydrologic criteria, geological criteria, and built up areas, difficult infrastructural provisions, protected area were considered.

3.4 Data collection and analysis

In the present study primary and secondary data were used. The primary data were collected from field surveys using GPS instrument to measure the coordinates of some location in the study area. Whereas, the secondary data for the study was acquired from governmental institutions, reports, journals and internet. The exact location of currently existed landfill and illegal waste disposal sites were collected by using global positioning system (GPS). Preparation of thematic maps includes the digitization of collected secondary data. Spatial data were generated using collected GPS data. An amount of secondary data about MSW management associating other relevant information was collected from various Government organizations.

The information of different types and forms has converted into the GIS database. GIS software (Arc GIS 10.3) with its tools was used to recommend landfill suitability analysis and for the preparation of final maps.

Methodologies were used normally based on a composite suitability analysis using map overlays (O' Leary *et al*., 1986) and their extension to include statistical analysis (Anderson and Greenberg, 1982). With the aid of this functionality, GIS *was* used to facilitate the process and decreases the cost of site selection for building sanitary landfills in the last few years (Siddiqui *et al*., 1996; Kao *et al*., 1997).

The slope of the land surface *was* calculated on the pixel basis using the Digital Elevation Model (DEM 30*30) of the study area, the land use types was grouped and ranked according to their suitability for a landfill site, the land use vector map was converted to a raster map. For all criteria, standard criteria for pollution control on the landfill sites were used.

3.5. Application of GIS Tools in Suitability Analysis

3.5.1. GIS- Based-Multi Criteria Evaluation

GIS-based multi-criteria decision analysis involves the utilization of geographical data, the decision maker's preferences and the combination of the data and preferences according to specified decision rules (Malczewski, 2006). Multi-criteria approaches have the potential to reduce the costs and time was involved in siting landfills by narrowing down the potential choices based on predefined criteria and weights. Weighted Linear Combination (WLC) and Analytic Hierarchy Processes (AHP) are the two most widely used Multi-Criteria Analysis methods that were used for this study (Carver, 1991).

3.5.1.1 Analytic Hierarchy Processes (AHP)

The Analytic Hierarchy Process is a decision making method for prioritizing alternatives when multiple criteria was considered. It offers a methodology to rank alternative courses of actions was based on the decision maker's judgments concerning the importance of the criteria and the extent to which they was met by each of the alternatives (Nydick and Hill, 1992). It provides a hierarchical structure by reducing multiple variable decisions into a series of paired comparisons and develops subjective priorities based upon user judgment. AHP was used in this study to derive weights for each criterion internally and externally (Ersoy and Bulut, 2009).

3.5.1.2 Weighted Linear Combination (WLC)

Weighted Linear Combination is a type of Multi Criteria Evaluation Method in GIS environment used to evaluate the suitability of a site for landfill. The WLC procedure is characterized by full tradeoff among all factors, average risk and offers more flexibility than the Boolean approaches in the decision making process. The approach allows the decision maker to assign weights according to the relative importance of each suitability map and combines the reclassified maps to obtain an overall suitability score (Malczewski, 2004).

In this study, GIS based Multi Criteria Evaluation Analysis was employed. This methodology is best suited for siting suitable landfills accurately in time and cost effective manner and hence it is used by many researchers. Because the technique can effectively be used for suitability analysis in GIS environment via criteria establishment, standardization factors, establishment of factor weights and finally WLC. Landfill site selection methodology is a two step process. The first step employs GIS to screen out unsuitable areas based on standards and criteria set by national and international environmental acts and rules was identify potential landfill sites. In the second step MCDM, was used for ranking the candidate sites and identify the best site based on the weights assigned to each criterion. AHP is a powerful MCDM tool to assign weights and rank the selected sites for selecting the best site among the competent. Generally, after finding out where the unacceptable areas are, the remaining areas were classified into classes of high and low priority for being used as waste disposal areas (Ersoy and Bulut, 2009).

This was done through two steps of weighting process. In the first step, each layer was internally weighted based on the minimum and maximum distances and/or requirements. Finally, the layers were standardized and thematic map of each criterion/layer was produced. In the second step, each layer was externally weighted based on the fact that how critical and important the data layer is to the waste disposal problem. After external weight was assigned to each layer, WLC techniques was applied to combine all the factors and prepare landfill suitability map.

After creating a final suitability map using GIS, the AHP process was applied again for comparing alternative landfill sites to each other against other criteria (size, distance from the center of the city and from nearby built up areas) in order to choose the most suitable landfill site among candidate sites.

3.5.1.3 Evaluation Criteria

Landfill site selection studies depend on the natural and legal condition of an area. In this regard the criteria and principles considered in this study was divided into three broad classes namely, physical, environmental and socio economic criteria. These criteria was contained their own components and were selected according to the guide directions and legislations of EPA of Ethiopia and International Guidelines. The pair wise comparisons associated with the analytical hierarchy process (AHP) the factors have been used to Weight the themes. Pair wise comparison matrix is created by setting out one row and one column for each factor in the problem. This matrix judgment was made about the relative importance of factors involved; judgment 9 point scaling system method was used.

The solid waste landfill site selection was done using multi criteria evaluation and creating layers to yield a single output map or index of evaluation. The weights were developed by providing a series of pair wise comparisons of the relative important factors to the suitability of pixels for the activity being evaluated.

The procedure by which the weights were produced follows the logic developed by Saaty, 1977;Lawal,2011under the analytical hierarchy process (AHP) which is utilized to determine the relative importance of the criteria in a specified decision making procedure. Linear distances were derived for each factor at maximum size for the purpose of classification. Classifications were done on various layers and the values were assigned ranging from most suitable to unsuitable. Whereas, reclassification of layers were classified into the 1, 2, 3 and 4 ranked system, where 1 represented unsuitable, 2 less suitable, 3 moderate suitable and 4 highly suitable after distance and suitability standards calculation was done, respectively. These criteria were developed by referring to different sources from the literature as indicated above. Then pair wise comparison of criteria was performed and results were put into a comparison matrix. The matrix is populated with values from 1 to 9 and fractions from 1/9 to ½ representing importance of one factor against another in the pair. The values in the matrix need to be consistent, which means that if x is compared to y, it receives a score of 5 (strong importance), y to x should score 1/5 (little importance). Something compared to itself gets the score of 1 (equal importance).

The weights calculated from each column were summed and every element in the matrix was divided by the sum of the respective column. The consistency ratio (CR) was calculated in order to ensure that the comparison of criteria made by decision makers was consistent. The rule is that a CR less than or equal to 0.10 signifies an acceptable reciprocal matrix, whereas greater than 0.10 is not acceptable. Weights obtained by this method are interpreted as average of all possible weights.

3.5.1.4 Thematic map preparation

Thematic maps are an important source of GIS tools information. These are tools to communicate geographical concepts in the form of map. The thematic maps such as surface water, soil type, land use land cover, geology, slop, wet land, road network, historical site, airport, agricultural area and built up area map were prepared for the present study and buffered with appropriate distance.

The spatial data are ratified to the same coordinate system (UTM, WGS 84). The attributes has been given and the layers are prepared in to layouts for the description of the study area. The vector layers are prepared for the overlay analysis to find out the appropriate sites for solid waste landfill site.

3.6Land Use/Land Cover Classification

Land use Land cover map was obtained from Jimma Town structural plan shape file to use for this study analysis. Sites with potential for higher value uses such as nature conservation, agriculture, residential development and institutions should not be used for landfill(Ekmekciogˇlu *et al*., 2010).

To identify suitable solid waste landfill site, it was consisted of open space, road network, agricultural area, wet land, built up area, airport and rivers, as attribute table of land use/land cover of Jimma Town in Arc map and it was the land use vector map is converted to a raster map, and then land use types was grouped and ranked according to their suitability for a solid waste landfill site.

The land cover and use is the natural and human landscape that may be exposed by the threats imposed because of landfill adjacency. By reviewing different literature, it was advisable to select land, which was occupied by bare and grass lands for solid waste disposal (Ebistu and Minale, 2013).

3.7 Parameters Used for the Evaluation of Suitability Analysis

Geology, soil, land use land cover, slope, surface water, wet land, agriculture, road, and historical site, and airport and built up area.

3.8 Study Variable

In this study there are two main types of variables were conducted, Independent variables; geology, soil, land use land cover, slope, elevation, hydrology, road, airport, protected areas and built up area .Al so dependent variable was solid waste landfill site suitability.

3.9 Data Processing and Analysis

The data was collected using the specific method of data collection is analyzed in detail and through manner. The method of analyzing was employed comparative analysis. The reason for choosing this method of data analyzing is that it was allow to describing, summarizing and presenting quantitative and qualitative data.

The presentation was in tables, figures and percentages and finally the analyzed data is presented in understandable way to draw conclusion and allow interpretation. From this analyzed data the researcher was able to know the conditions related to the statement of the problem and a conclusion was drawing regarding it. On the other hand, quantitatively data was analyzed by using GIS tools.

3.10 Dissemination of Findings

This is the final thesis for the holding of degree of Master of Science in environmental engineering from Jimma University Institute of Technology and giving to Environmental Engineering Chair and disseminate to Jimma University Institute of Technology library.

To Jimma Town Environmental Authority and other non-governmental organizations which will be disseminate the study findings. Publication in national and international journals will also be consider the research purposively corporate as much as possible.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Evaluated Factors Suitability of Landfill Site Around The Town.

4.1.1 Slope

The land with a slope <10 % is most suitable for solid waste landfill site. This is because of the areas with high slopes will have high risk of pollution and potentially not a good site for dumping. Taking this into consideration almost all of the study area falls under the slope 0-10 %, which has largest area covers of the total study area. This indicates most of the land is suitable for solid waste landfill site according to slope suitability. Even though the slope is very important, because of the area is more or less flat in its topography; it is not that mach significant for solid waste landfill site selection in Jimma town. Based on the slope amount, the study area can be divided into four slope classes, with slope 0- 10 % and slope > 20 % respectively.

According toSener *et al.*,2011the land with a slope 0-10 % highly suitable, 10–15 % moderately suitable,15–20 less suitable and >20 unsuitable. Land morphology is evaluated by slope that is defined in percent or degrees (Kontos *et al*., 2005).

The slope layer map was obtained from the study area of DEM map on the basis of pixel size in percentage. By considering the suggestions in the literature, slope map is classified into four groups. The groups and related rankings are shown in table 1 and the final map ready for analysis is shown in figure 1.In the study area, the slope is too steep are given less value 1 and if the slope is gentle have high value 4 (Allen *et al*., 2003).

Table: 4.1 Slope Categories and area coverage of the study area.

S.N.	Slope Class	Suitability	Rank	Area(Hac.)	Area(%)
1	>20	Unsuitable	1	2878	27.04
2	15-20	less suitable	2	1788.97	16.81
3	10-15	Moderately suitable	3	2357.75	22.16
4	0-10	Most suitable	4	3617.13	33.99
Total				10641.85	100.00

Table 1 shows that, 33.99 % of the study area had a slope of0-10 % it took the largest percentage and given more weight as most suitable, and 27.04 % of the study area had a slope of > 20 % is unsuitable for landfill site. Based on the fact that areas 0-10 % were more preferred than the other classified, more weight was given for less slope site and vice versa. Accordingly, the less suitable weight was given for areas within slope of 15-20 % and slope 10-15 % considered as moderately suitable for landfill site. The suitability and weight assigned to each buffer classes are summarized in table 4.1 and slope suitability map was shown in figure 2.

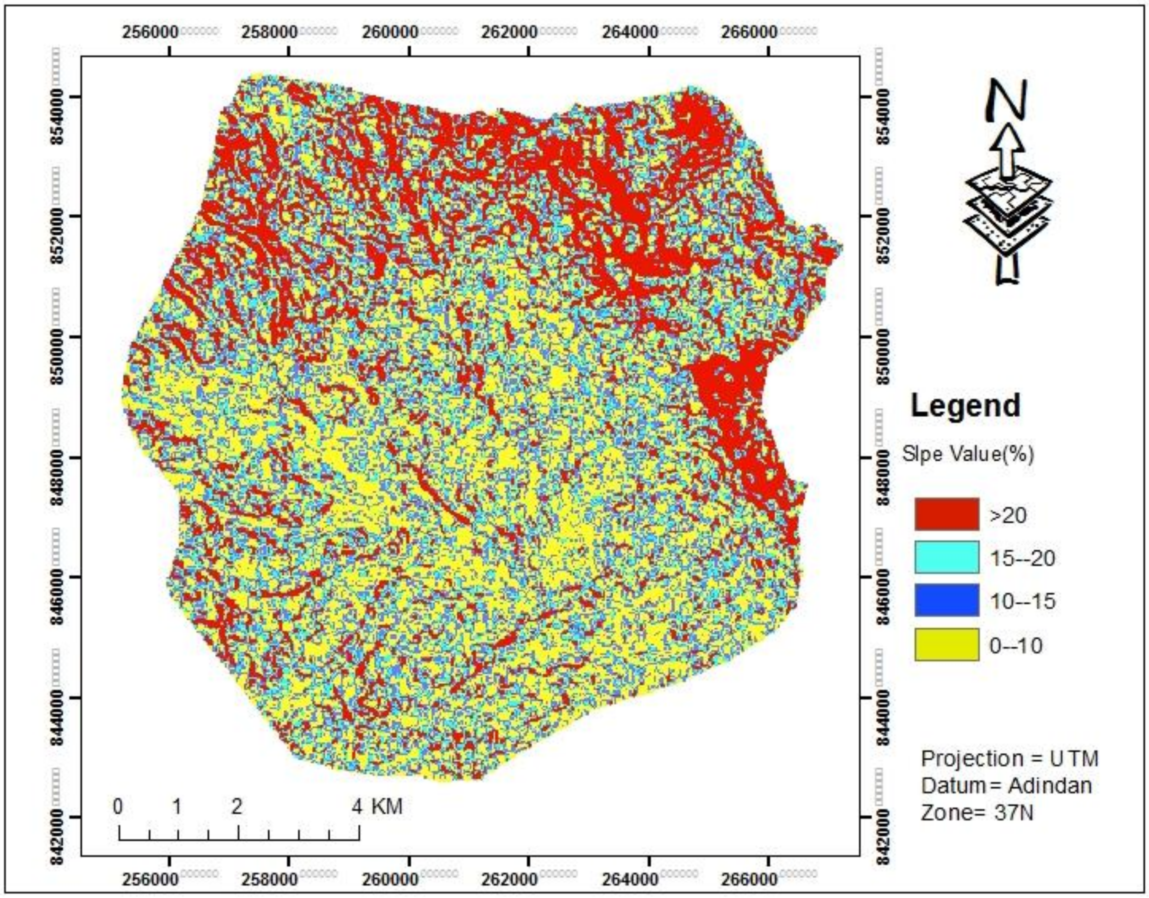

Figure 1: Reclassified Slope Categories map of the Study area.

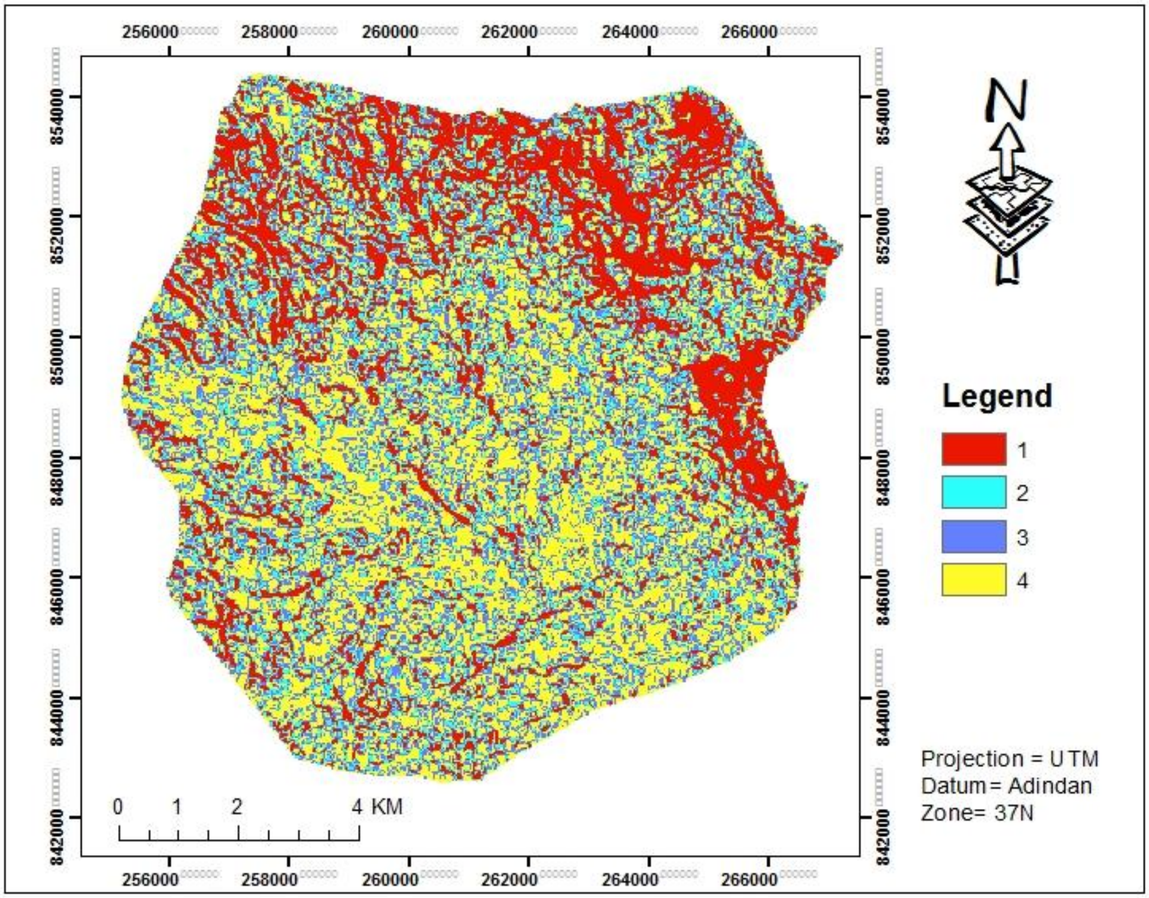

Figure 2: Ranked slope suitability map of the Study area.

4.1.2 Surface water

This criteria is important from the point view of both environmental and economic concerns, because in addition to causing pollution problems, it may require an efficient drainage system with high expenses and used minimum of 100 m buffer distance (Gemitzi *et al*., 2007).

Table 4.2 shows that, by following the rule of Sener *et al.*, 2011 the study was reclassified the distance between surface water and solid waste dumping site. Distance <1000 m covered56.77 %of the study area was unsuitable for landfill due to the vicinity to the streams and rivers and hence given a 1 value, the area covers 15.27 % of the study area is less suitable and given a 2 value, the area of 1000 m-1500 m and which cover 15.27 %of the study area is moderately suitable and given 3 value. An extent of>2000 m and area covers 19.42 %of the study area is most suitable for landfill siting because of the minimum effect on surface water due to the area is far from the river and given 4 value. The following map shows suitability level and weights, standardized thematic map of rivers/streams.

Table:4.2 proximity to rivers and streams suitability site and area caverage

S.N.	Distance from landfill site (m)	Suitability	Rank	Area (Hac.)	Area (%)
1	<1000	Unsuitable	1	6041.19	56.77
2	1000-1500	Less suitable	2	1625.35	15.27
3	1500-2000	Moderately suitable	3	908.35	8.54
4	>2000	Most suitable	4	2066.24	19.42
Total				10641.13	100.00

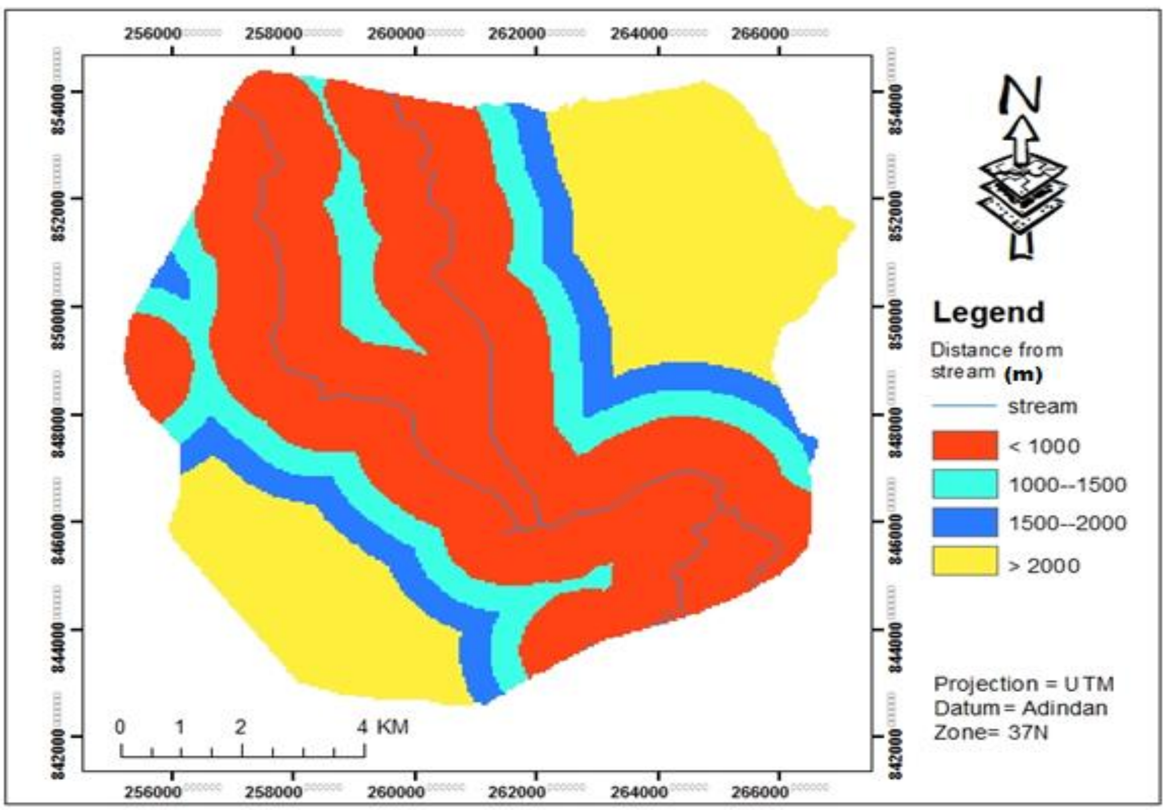

Figure 3: Landfill Site proximity to surface water map of the study area.

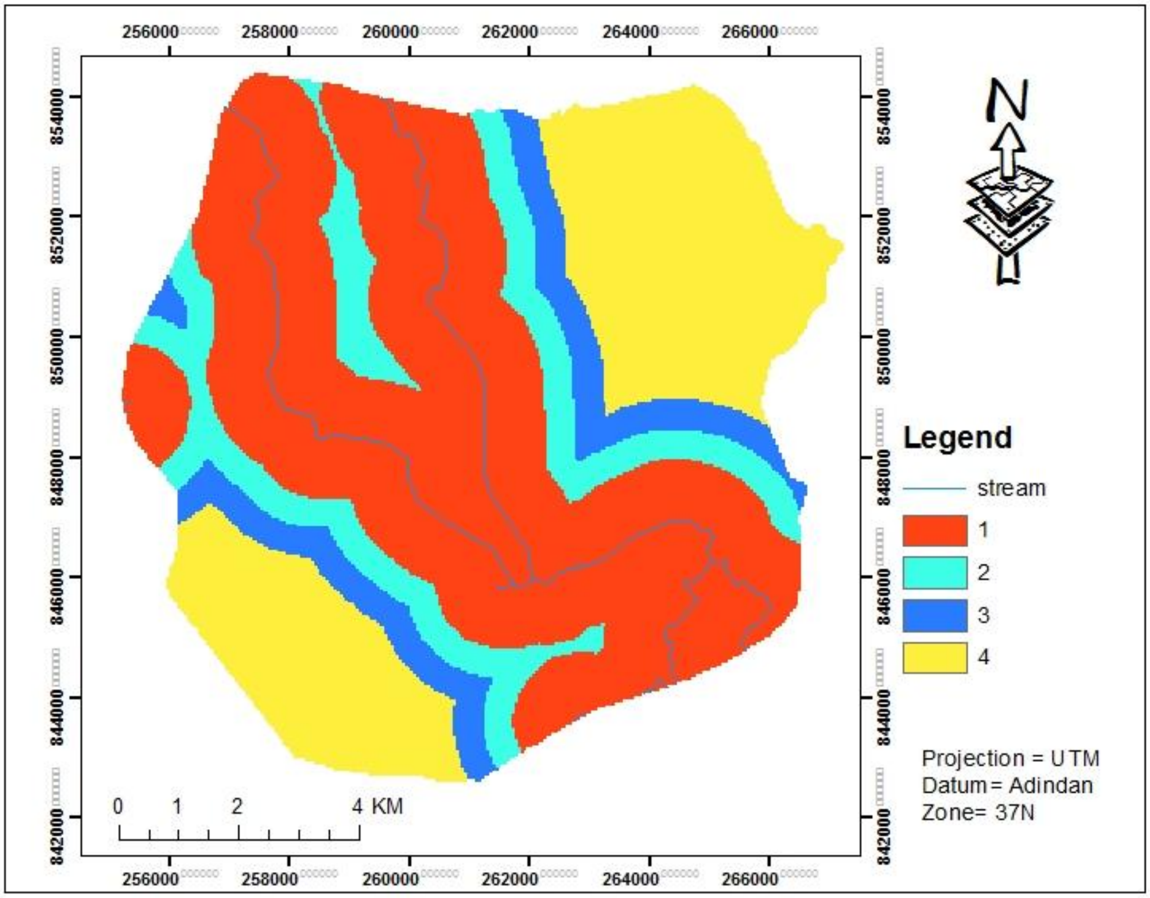

Figure 4: Ranked suitability to surface water map of the study area.

4.1.3 Soil permeability

According to Abdoli, 1993 the amount of soil permeability is increase, the suitability site will decrease because the very high permeable soil, the most probable the entrance of leachate into ground water and their pollution. Therefore 3.95 % of the study area is most suitable which is covered by chromic vertisol and a value given 4, 41.96 % of the study area is dystricniti sols which is moderate suitable for landfill site selection and a value given is 3.The remaining 1.51 % and 52.56 % of the study areas are less suitable and unsuitable for landfill site respectively and the value given were 2 and 1. The soil map was shown in figure 6.

Table: 4.3 Soil type and their permeability with area coverage.

S.N	Soil type	Permeability	Suitability	Rank	Area(hac)	Area(%)
1	Eutric fluvi sols	High	Un Suitable	1	5594.01	52.56
2	Dystric fluvi sols	Low	Less suitable	2	161.14	1.51
3	Dystric niti sols	Moderately low	Moderately suitable	3	4466.37	41.96
4	Chromic vertisol	Very low	Most suitable	4	420.88	3.95
	Total				10642.4	100

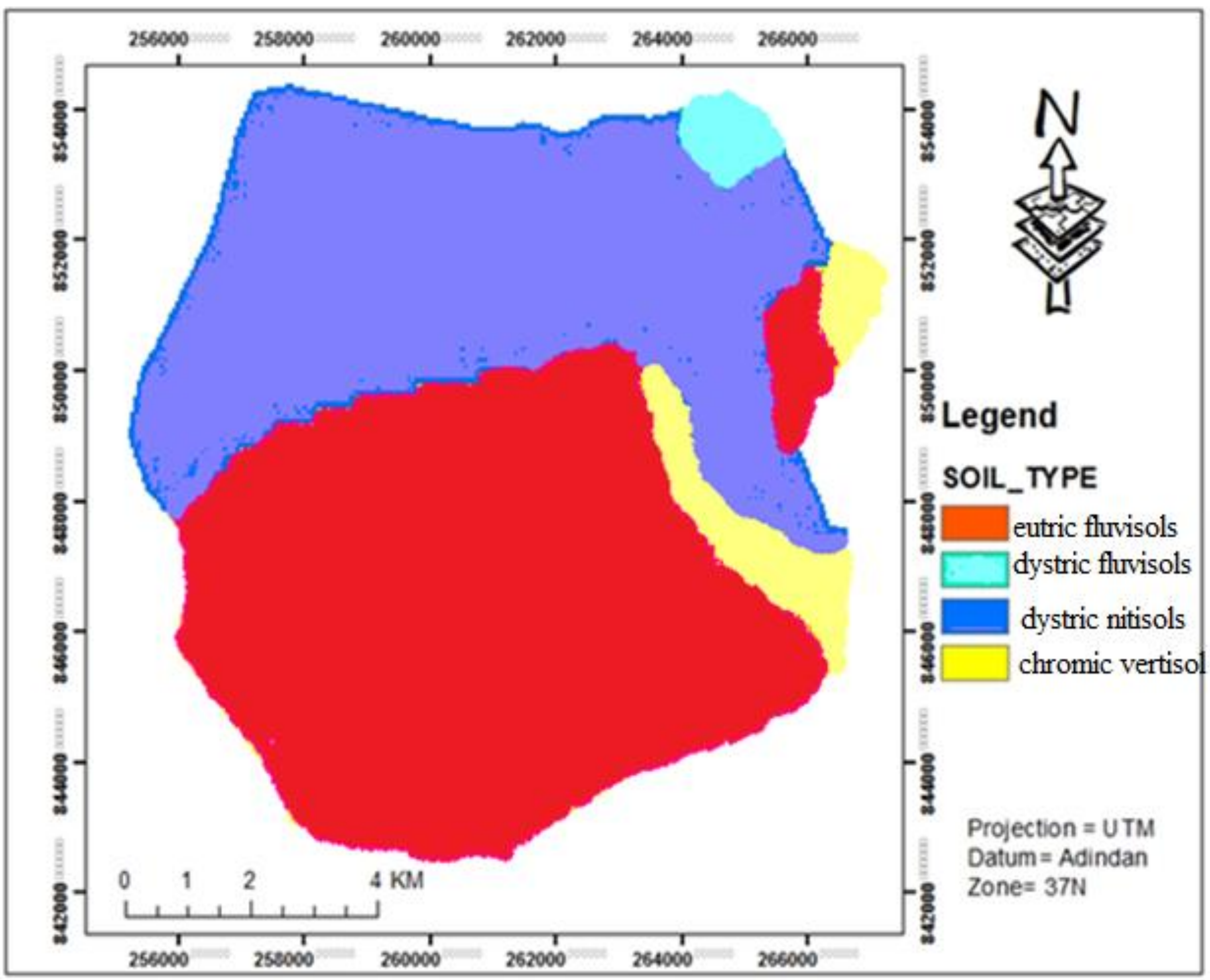

Figure: 5Map of soil type of study area

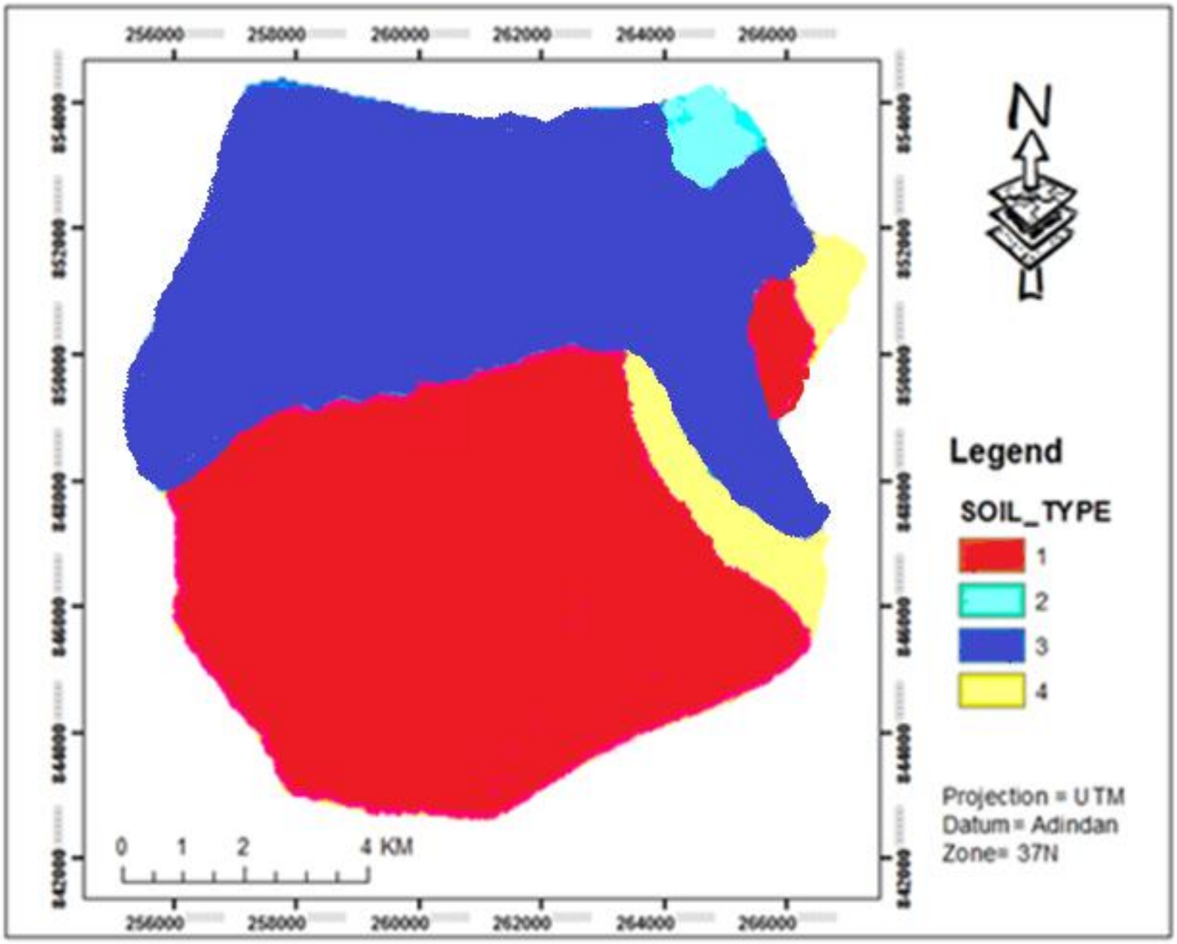

Figure: 6 Ranked soil suitability map of study area

4.1.4 Road network.

The selected site should be close to the high ways and main roads, because building roads for landfill access especially in long distances requires huge preliminary expenses (Abdoli, 1993). According to Al-Hanbali *et al*., 2011, 2000 m distance has been buffered. Al so based on the road network proximity standard Rafiee *et al*., 2011; EPA ,1995, areas found below 500 m and above 5000 m from a highway were considered as unsuitable.

In the present study by considering the two extreme, the suitability of road network classified as <500 m, 500-1000 m, 1000-1500 m, and >1500 m as shown in figure 7,the suitability is low vey near to the road and very far from it, because of traffic congestion and more transportation expense respectively.

Table: 4.4 Sites proximity to road network map of the study area.

S.N.	Distance from landfill site(m)	Suitability	Rank	Area (Hac.)	Area (%)
1	<500	Unsuitable	1	4846.59	45.55
2	500-1000	Less Suitable	2	3034.07	28.52
3	1000-1500	Moderately suitable	3	1761.94	16.56
4	>1500	Most suitable	4	996.7	9.37
Total				10639.3	100.00

Table 4.4 shows, 9.37%of the total areas is the most suitable while, 45.5 % of the study area is unsuitable for landfill. The remaining area 16.56 % and 28.52 % of the study areas are moderately suitable and less suitable for landfill siting respectively. The spatial distribution of road proximity suitability map is shown in Figure 8.

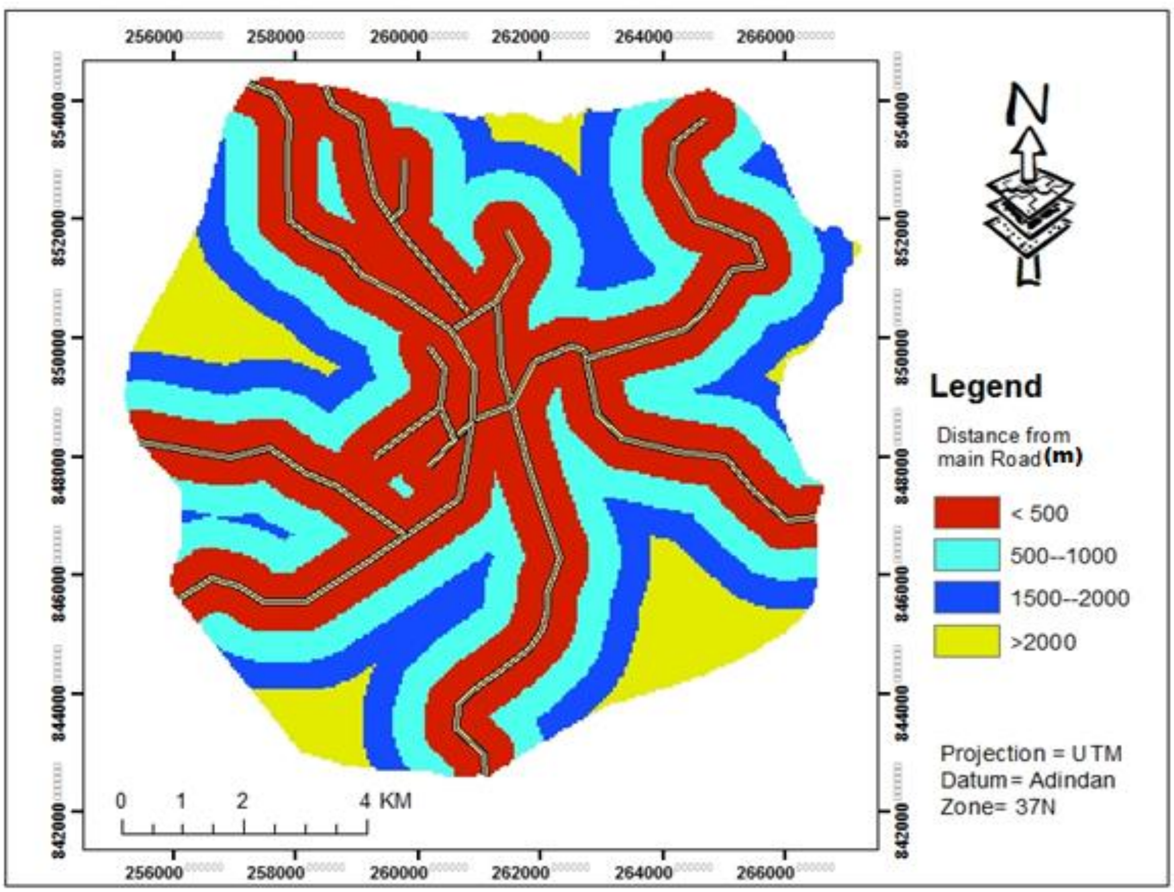

Figure 7 :Reclassified Sites proximity to road network map of the study area.

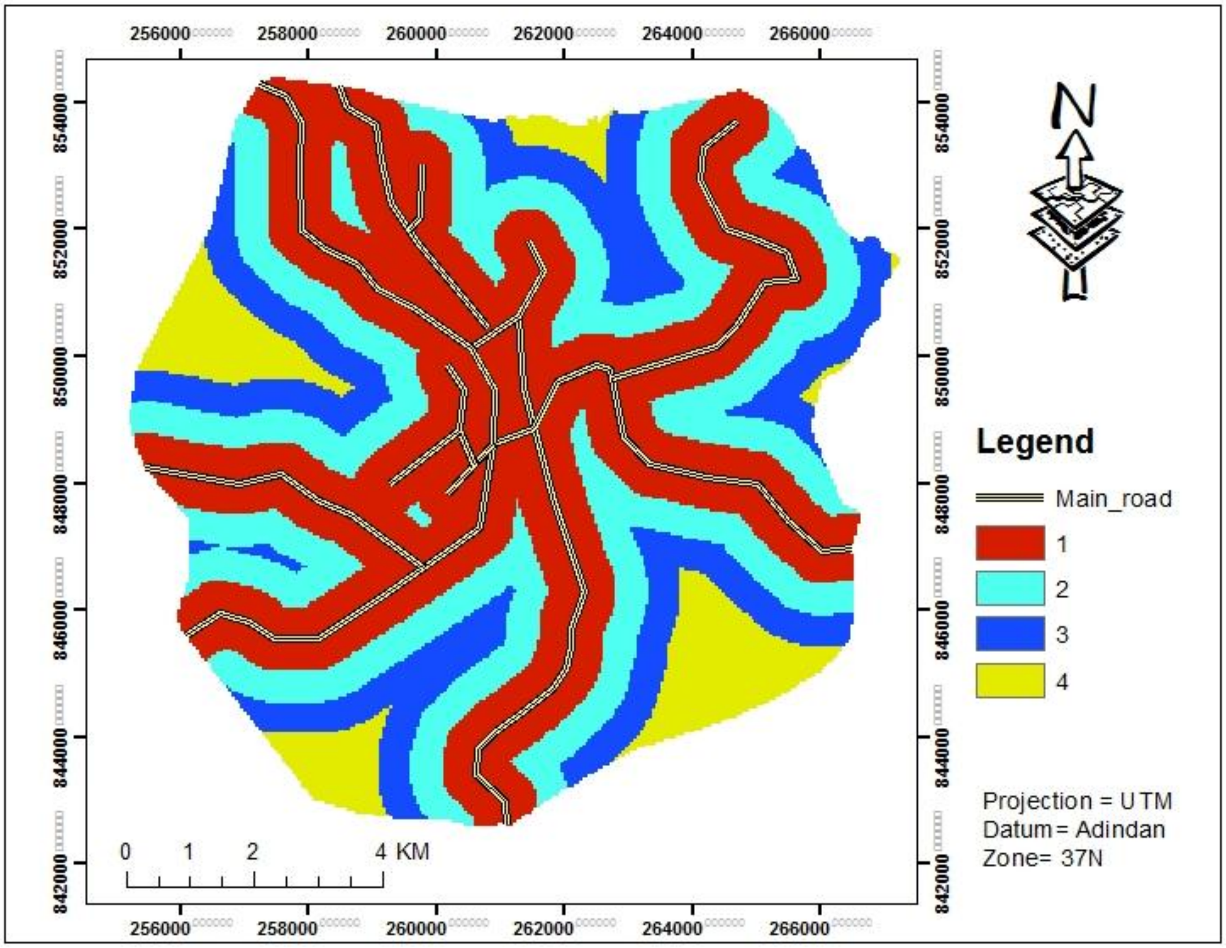

Figure 8: Sites suitability to road network map of the study area.

4.1.5 Airport

In different literature, there are different values related to the safe distances from airports like 3000 m according to Chalkias, 1997 and 3048m according to (Bagchi, 1994).By considering these suggested values, the safe distance for an airport was determined as a minimum of 2250 m far from landfill site. The layer of airport was classified as most suitable, moderately suitable, less suitable and unsuitable for a landfill site by assigning values 4, 3, 2 and 1 respectively.

Table: 4.5Siteproximity to airport and area coverage.

S.N.	**Distance from landfill site(m)**	**Suitability**	**Rank**	**Area (Hac.)**	**Area (%)**
1	<750	Unsuitable	1	1263.8	11.87
2	750-1500	Less Suitable	2	1255.28	11.79
3	1500-2250	Moderately suitable	3	1586.57	14.90
4	>2250	Most suitable	4	6539.8	61.43
Total				10645.45	100.00

Table 4.5 shows, 61.43 % of the study area had a distance of > 2250 m far from the airport which is more suitable and it took the largest percentage, and 11.87 % of the study area had a distance of < 750 m and it was the nearest area for Abba Jifar airport which is unsuitable. Based on the fact that areas far from airport were more preferred than near sites, more weight was given for far away site and vice versa. Accordingly, for areas >2250 m away from Abba Jifar airport was given more weight as very highly suitable. The least weight was given for areas within < 750 m radius and considered as unsuitable for landfill site. The suitability and weight assigned to each buffer classes are summarized in table 4.5. According to their weight, airport proximity map of the study area was standardized and suitability map was prepared in figure 10.

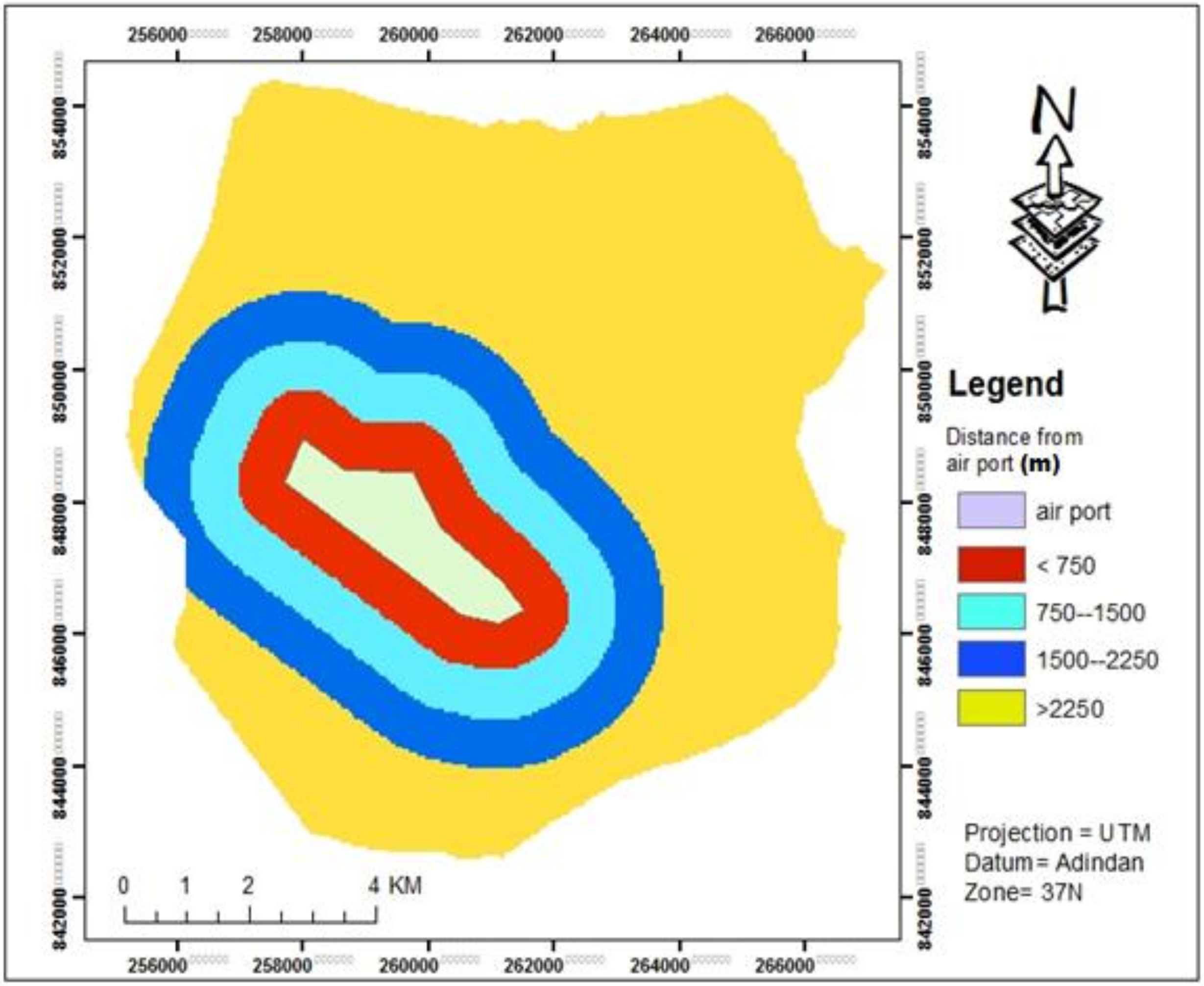

Figure 9: Reclassified Sites proximity to airport map of the study area.

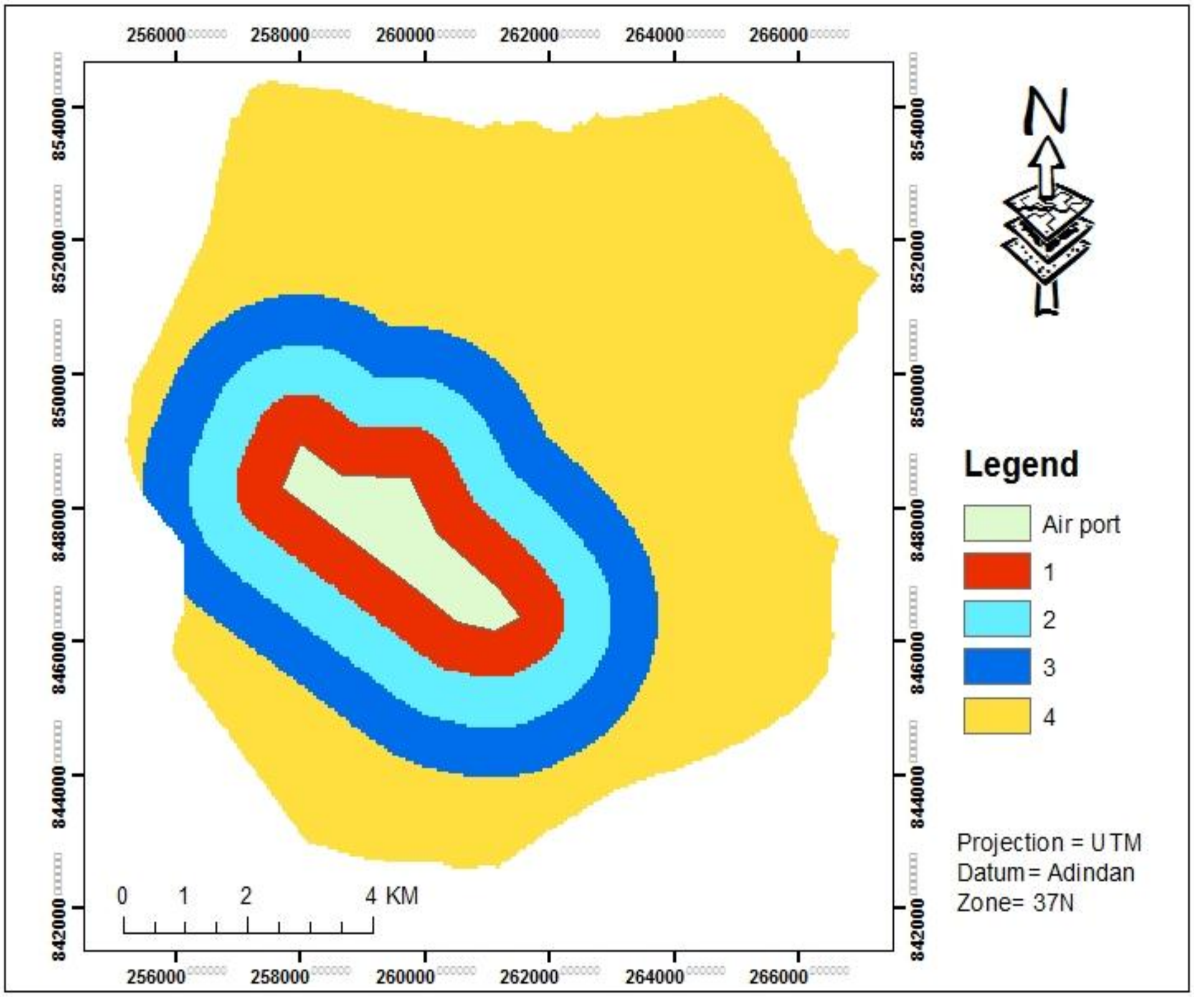

Figure 10: Sites suitability to airport proximity map of the study area.

4.1.6 Suitability with Regards to Wetlands

Distance from water bodies (lake, wetlands, rivers and streams) buffered 300-500 m Hasan *et al*., 2009;UNEP,2005 ; EPA , 1995.Boyye wetland is sensitive areas that are protected by the town due to their unique environmental and social function. It would be ideal for the new municipal solid waste landfill to be located at least 2,250 meters away.

Figure11 illustrates that landfill sites are located in areas which are classified as optimum for landfill development in relation to wetlands preservation. Landfill sites are positioned >2250 meters away from the wetland were most suitable. The suitability of wetland classified as < 750 m, 750-1500 m, 1500-2250 m, and > 2250 m, the suitability is low if the distance very near to the wetland and more suitable if the distance very far from wetland.

Table: 4. 6 Suitability with Regards to Wetland and area coverage

S.N.	Distance from landfill site(m)	Suitability	Rank	Area (Hac.)	Area (%)
1	<750	Unsuitable	1	530.22	4.98
2	750-1500	Less Suitable	2	1061.87	9.97
3	1500-2250	Moderately suitable	3	1299.48	12.21
4	>2250	Most suitable	4	7749	72.82
Total				10640.57	100

Table 4.6 shows that, the study was reclassified the distance between wetland and solid waste dumping site. Area <750 m covered 4.98%of the study area which is unsuitable for landfill due to closely near to the wetland and hence given a 1 value, distance from 750-1500 m and the area covers 9.97% of the study area is less suitable and given a 2 value, the distance 1500-2250 m and area covers 12.21%of the study area is moderately suitable and given 3 value. An extent of >2250 m 72.82%of the area which is the most suitable for landfill siting because of no effects on Study area wetlands do to the area is far from the wetlands and given a 4 value. The following map shows suitability level and ranked map of wetlands.

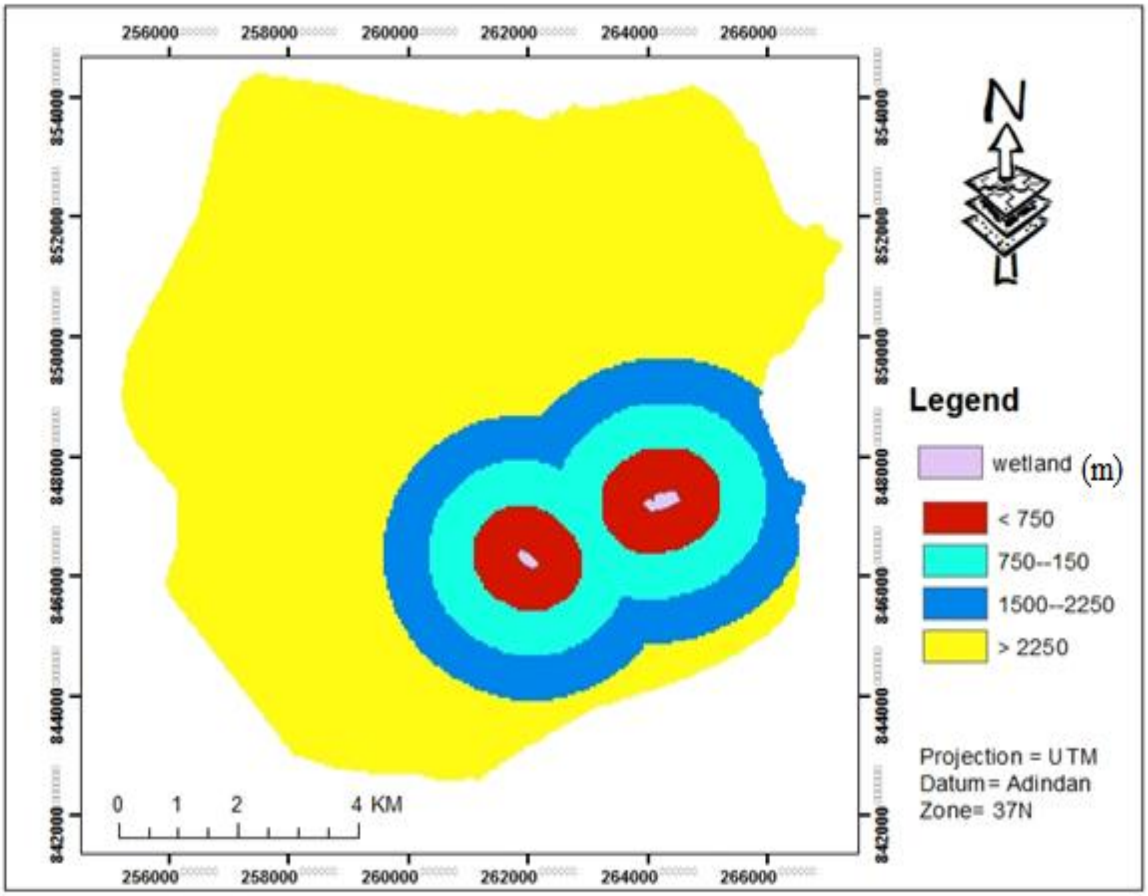

Figure 11: Reclassified Wetland Suitability Map of study area

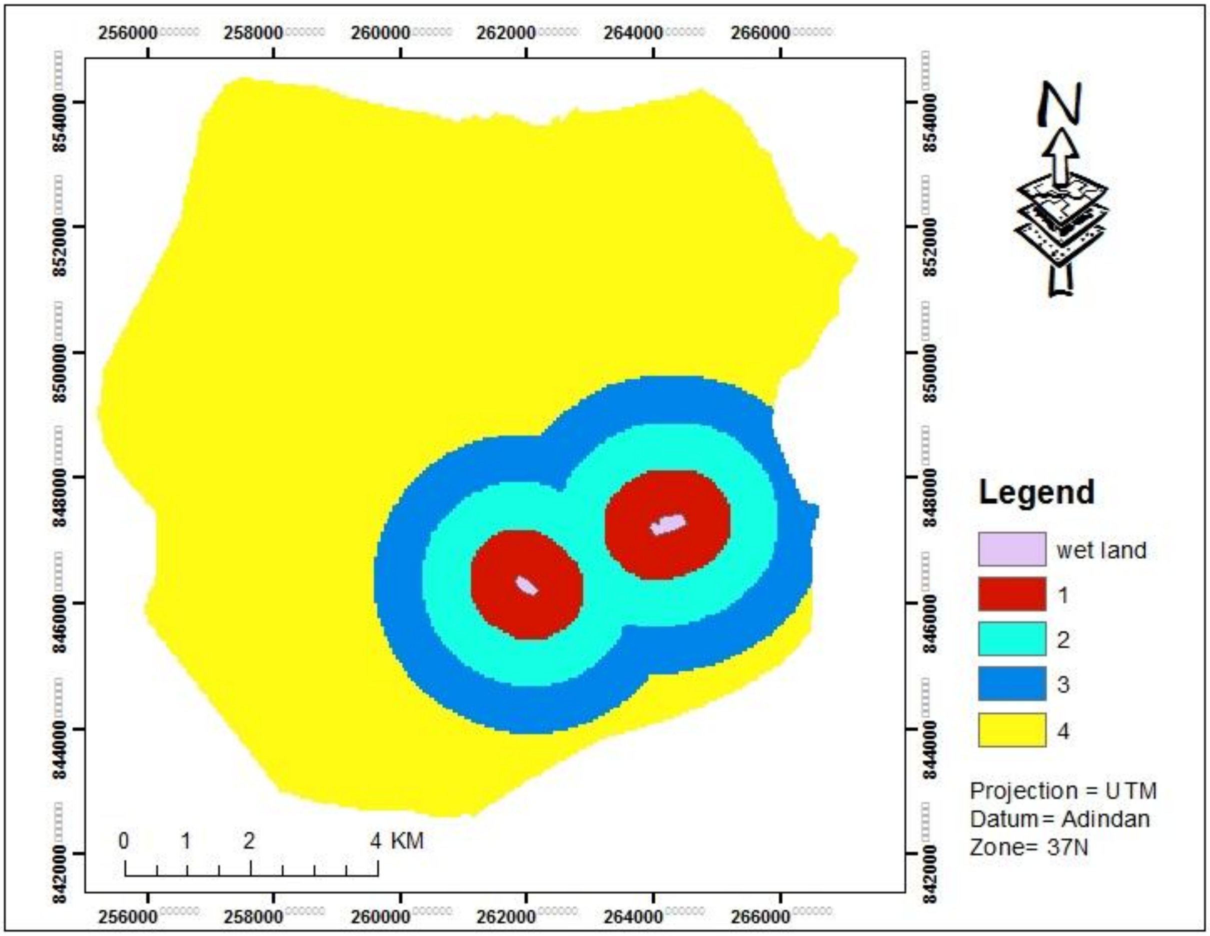

Figure 12: Ranked Suitability with Regards to Wetland

4.1.7 Built up Area

Landfill site should be located far from populated centers of the city. Otherwise it causes decreasing the aesthetic and land value of the surrounding area and bad odors (Chang *et al.*, 2008). By considering sufficient landfill capacity for the city long term requirements, landfill site should not be affected by the development plans of the city (Abdoli, 1993).

The greater the distance from residential areas the more suitable for landfill site selection. According to Allen,2000, it should be located at least 5 km distance from urban centers. By considering all the suggested safe distances in the literature, minimum distances for the study area were determined as 5 km for urban centers. According Hasan *et al.*, 2009, set built up with distance 500m-2000m as best site for solid waste disposal. These distances were classified as < 500 m, 500-1000 m, 1000-1500m, and > 1500m according to their suitability by ranking with the help of literature review.

Table: 4.7 Proximity to built up and area coverage of the study area.

S.N.	Distance from landfill site(m)	Suitability	Rank	Area (Hac.)	Area (%)
1	<500	Unsuitable	1	5871.88	55.17
2	500-1000	Less Suitable	2	1464.33	13.75
3	1000-1500	Moderately suitable	3	2209.25	20.75
4	>1500	Most suitable	4	1100.27	10.33
Total				10642.46	100

Table 4.7 shows that, 10.33 % of the total area was given more weight as most suitability for landfill site. However 55.17 % of the total area was unsuitable as very near to landfill site. Generally, suitability level and weights were decreased as very far away from the built up area and very close to the built up area. As a result, 20.75 % and 13.75 % of the total area were moderately suitable and less suitable respectively. According to their weight, built up proximity map of the study area was standardized and suitability map was prepared as figure 14.

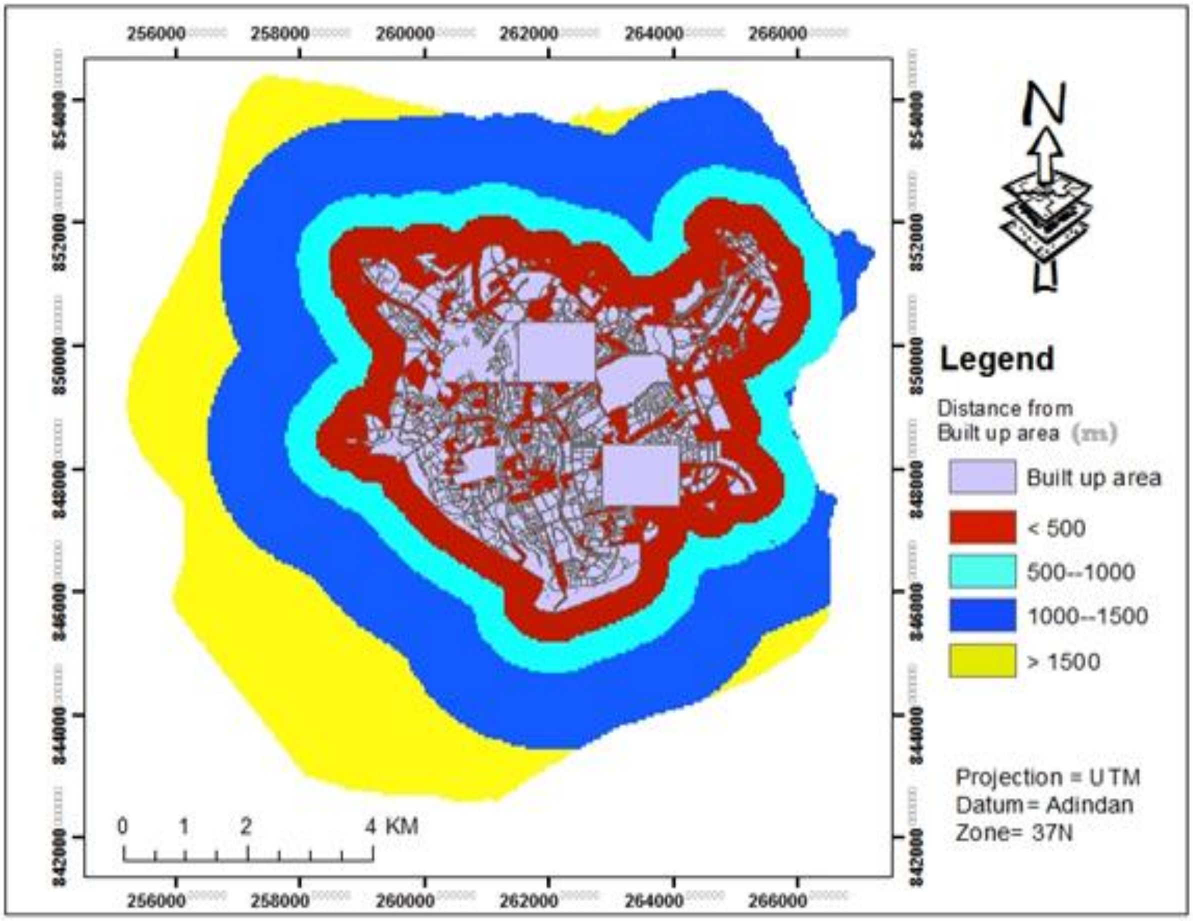

Figure 13: Reclassified site proximity to built up map of the study area.

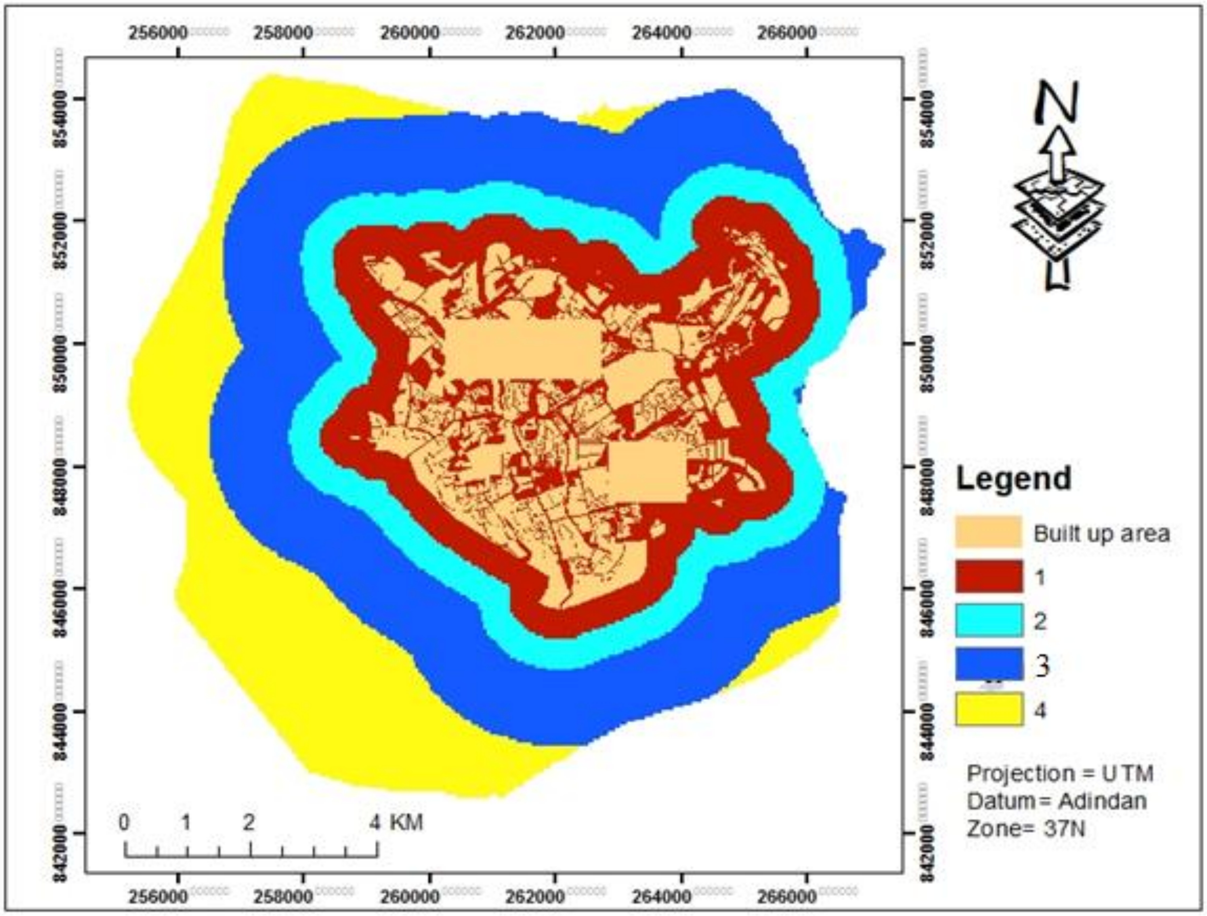

Figure 14: Ranked suitability of built up map of the study area.

4.1.8 Proximity to Agriculture Areas

Sites with potential for higher value uses such as nature conservation, agriculture, residential development and institutions should not be used for landfill (Ekmekcioglu *et al*., 2010)

Table: 4.8 Proximity to agriculture and area coverage of the study area.

S.N.	Distance from landfill site (m)	Suitability	Rank	Area (Hac.)	Area (%)
1	<500	Unsuitable	1	1278.11	12.01
2	500-1000	Poorly Suitable	2	1572.93	14.78
3	1000-1500	Moderately suitable	3	4226.88	39.72
4	>1500	Most suitable	4	3563	33.48
Total				10640.92	100

Table 4.8 shows that, reclassified distance between agricultural site and solid waste landfill site. Area < 500 m covered 12.01%of the study area which is unsuitable for landfill due to closely near to the agricultural site and hence given a 1 value, distance from 500-1000 m and the area covers 14.78% of the study area is less suitable and given a 2 value, the distance 1000-1500 m and area covers 39.72%of the study area is moderately suitable and given 3 value. An extent of >1500 m 33.48%of the area which is the most suitable for landfill siting because of no effects on study area agricultural site due to the area is far from the agricultural site and given a 4 value. The following map shows suitability level and ranked map of agricultural site.

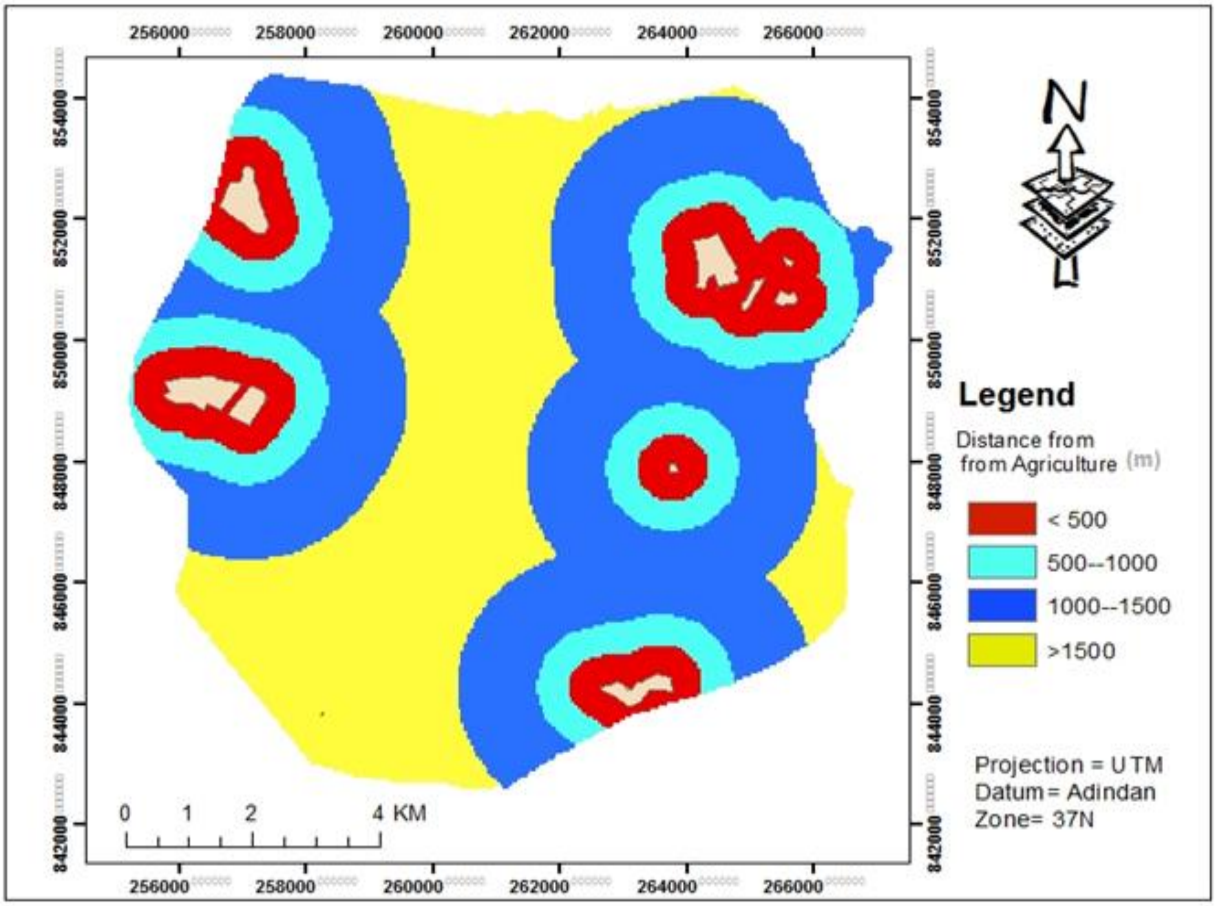

Figure 15: Proximity to agriculture areasmap of the study area.

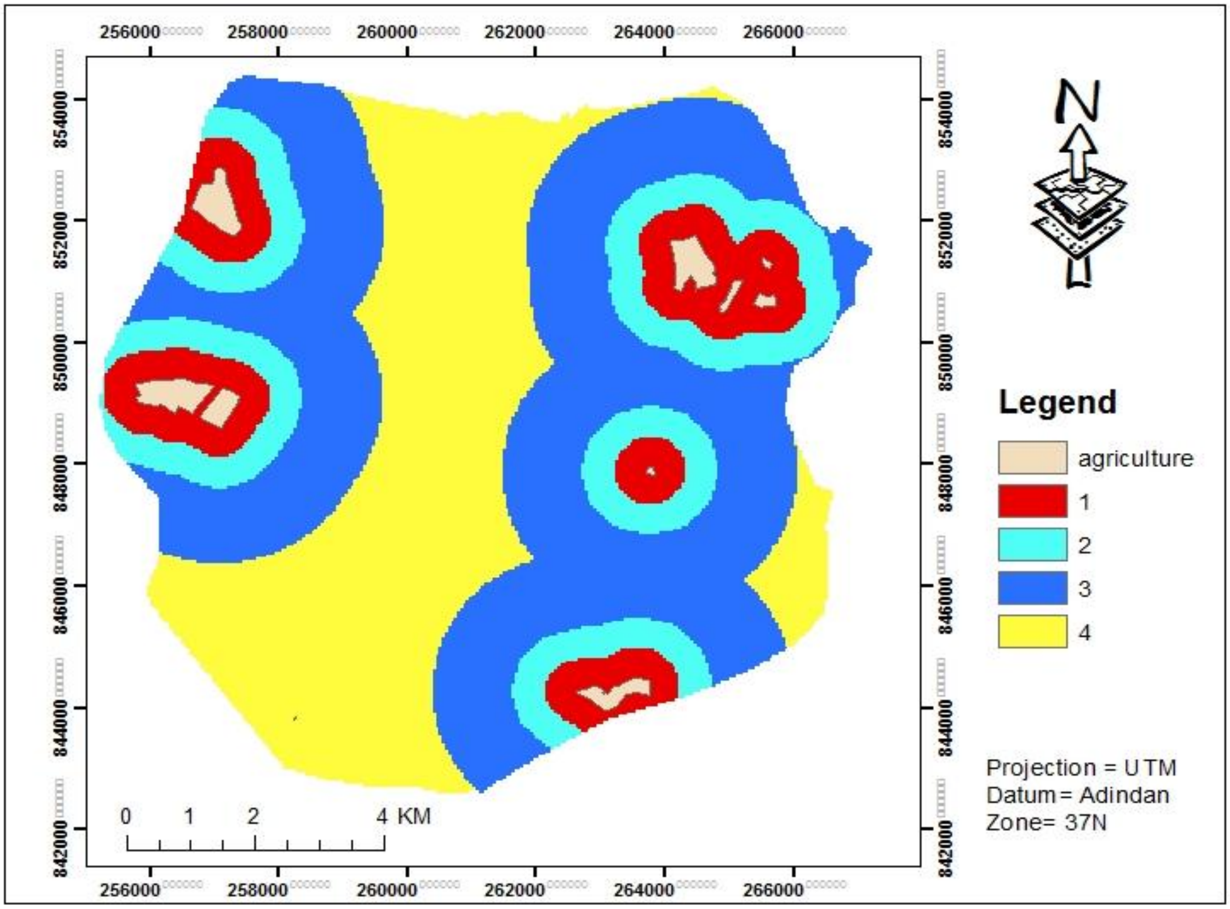

Figure 16: Agricultural area suitability map of the study area.

4.1.9 Proximity to Historical Site

Protected historical site of study area is Aba Jifar Palace. The landfill should not be located in or close proximity to historical site, to limit this minimum of 1000 m buffer surrounding. When the distance increases the suitability also increases. According to criteria of Ersoy and Bulut, 2009; Babalola and Busu, 2010, the area located at the distance greater than 3000 m from sensitive area were selected as highly suitable for solid waste dumping site.

Generally the area was classified in to four classes as shown in figure 18; 2.93 % of the area distance is less than 1000 m then the area were unsuitable for landfill site. In this study, about 83.08 % from the total area were located at distance of>3000 m from historically sensitive area, this was the most suitable area for landfill site.

Table: 4.9Proximity to Historical Site

S.N.	Distance from landfill site (m)	Suitability	Rank	Area (Hac)	Area (%)
1	<1000	Unsuitable	1	312	2.93
2	1000-2000	Less Suitable	2	733.78	6.89
3	2000-3000	Moderately suitable	3	753.68	7.08
4	>3000	Most suitable	4	8840.83	83.08
Total				10640.29	100

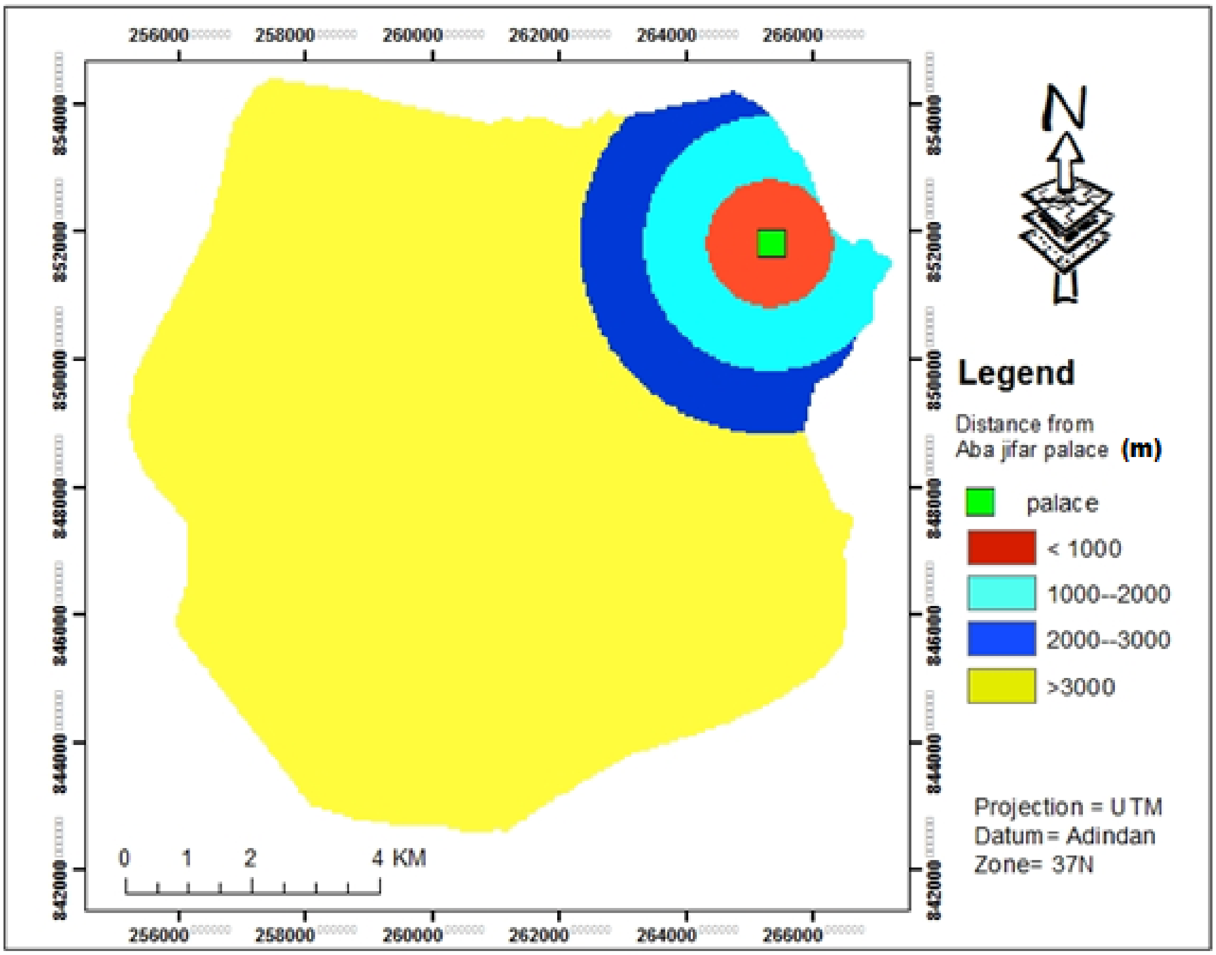

Figure17: Reclassified Historical Site

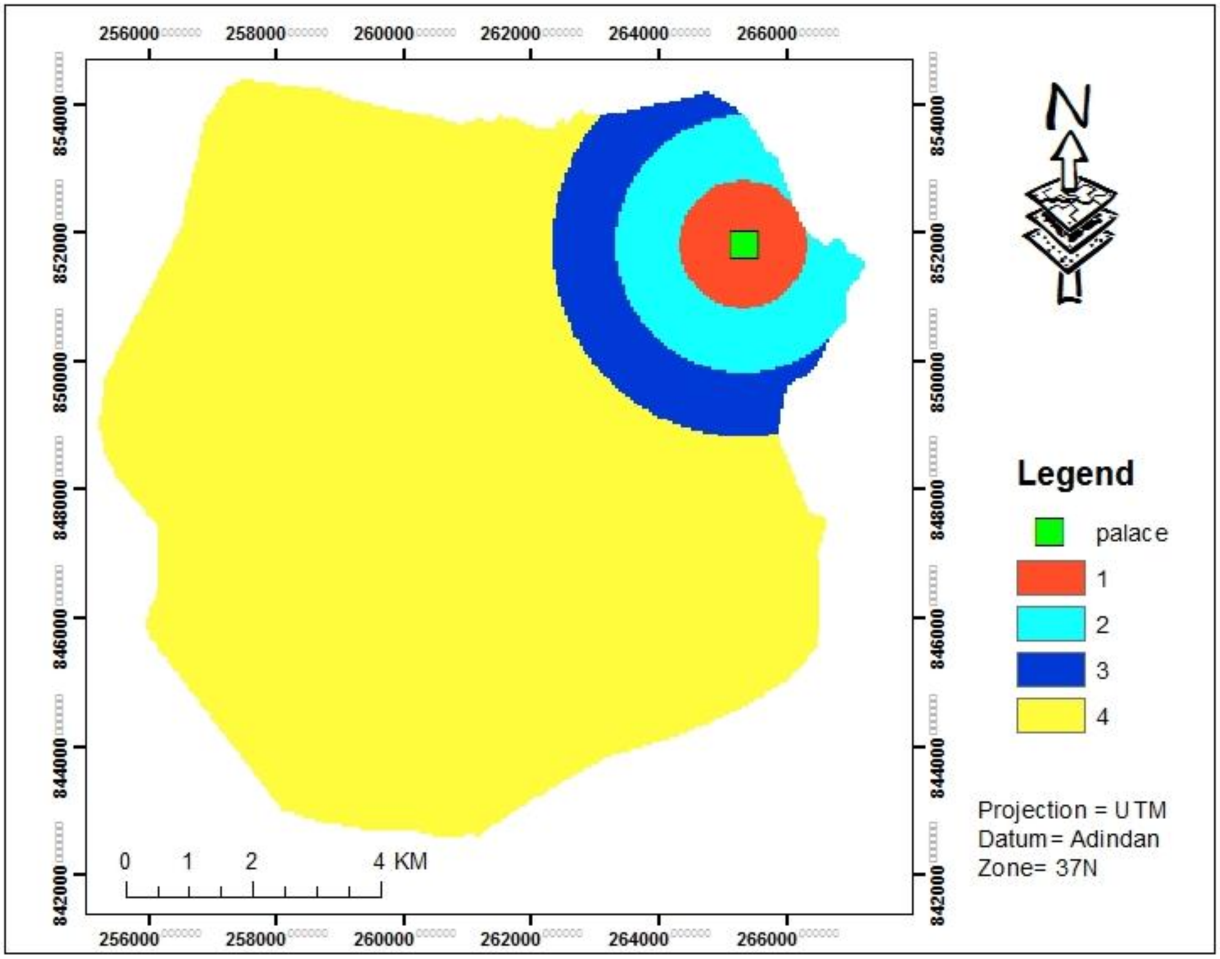

Figure: 18 Ranked Protected Historical Site

4.1.10 Geological Suitability

The geological map of the study area was obtained from Ethiopian geological map and digitized. A database description was created and attached to the map. In the study area, there were two main geological types in the GIS environment and mainly grouped in two category, [Jimma Volcanics (upper part) Rhyolite and Trachyte flows and tuff with minor basalt] and [Nazret series: Ignimbrites] were grouped according to their suitability for a landfill site which is given in Table 4.10.

The vector map of geology was converted to a raster map to be finalized for analysis. The raster map is shown in Figure 19. Geology is one of the important environmental factors that should be considered during landfill site selection processes. Impermeable strata and consolidated material are suitable for landfill site as they do not allow movement of leachate and hence minimize the risk of groundwater contamination from landfill leachate (Ersoy and Bulut, 2009).

In the study area, Volcanics (upper part) Rhyolite, Minor Basalts and Trachyte are permeable due to high degree of weathering and fractures and thus are less suitable for landfill site. However, Ignimbrites are very low permeable due to less degree of weathering and fracture, siting landfill in such areas is the best option to protect ground water from pollution. Therefore, based on the nature of rock, degree of weathering and fracture the study area were categories in to two main geological coded class of Ethiopia as Table 4.10 shows as, most parts of study area (60%) is covered by Nazret series Ignimbrites and the value given was most suitable.

The second most dominant geologic unit in the study area is Jimma Volcanics (upper part) Rhyolite and Trachyte flows and tuff with minor basalt which covers 40 % of the total area. It is characterized by high degree of weathering and fractures hence, described as high permeable rock, do to this character it is less suitable for solid west landfill site siting.

Table: 4. 10 Area coverage and Geologic suitability

S.N	Types of Geology	Suitability	Code	Area (hac)	Area (%)
1	Jimma Volcanics (upper part) Rhyolite and Trachyte flows and tuff with minor basalt	Less suitable	Pjr	3789.45	40
2	Nazret series: Ignimbrites, un weldedtuffs, as hflows, chyolitic flows, domes and trachyte	More suitable	Nn	6852.71	60
Total				10642.16	100

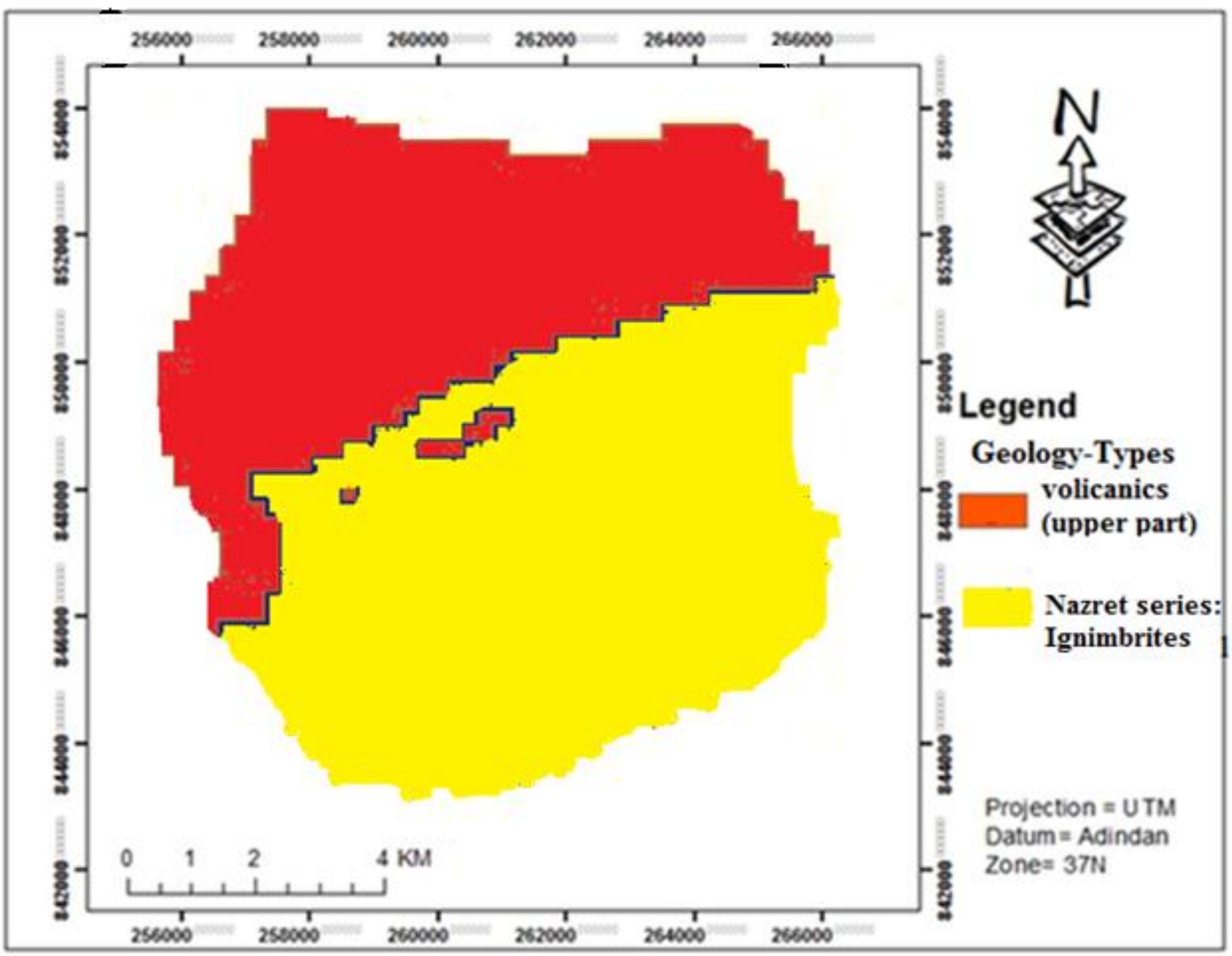

Figure: 19 Geological Map of Study Area

4.1.11 Land use/Land cover

Land use map was obtained from Jimma town municipality for this analysis, and seven different land use types were included in this study as shown in figure 20. This criterion is not on the basis of specific directions and may alter according to the study area (Kontos *et al*., 2005). From the stand point of economy it is better to choose open space which can be used after landfill site completion or can be sold (Abdoli, 1993). Sites with potential for higher value uses such as nature conservation, agriculture, residential development and institutions should not be used for landfill (Ekmekcioglu *et al*., 2010).

The identified uses in the study area are consisted of open space, road network, and agricultural area and built up area, wet land, air port and rivers (source, digitized structural map of study area land use/land cover in Arc map). The land use structural plan of the town digitized and then converted to a raster map, and then land use types was grouped and ranked according to their suitability for a landfill site.

Land use/land cover of the study area large part covered by built up area which accounts74.64 %, (Road net work, historical site, rivers ,wet land and airport), agricultural and open space area which covered 16.13 %,7.42 %, and 2.02% of the total study area, area in that order.

Table: 4. 11 Area coverage and Land use/land cover suitability

S.N.	Distance from landfill site (m)	Suitability	Rank	Area (hac)	Area (%)
1	Road net work, historical site, rivers ,wet land and airport	Unsuitable	1	1717	16.13
2	Built up area	Less Suitable	2	7943.55	74.64
3	Agricultural area	Moderately suitable	3	790	7.42
4	Open space	Most suitable	4	215.61	2.02
Total				10642.16	100

Based on the above land use suitability of table 4.11, from the land use suitability point of view the largest part of the study area 74.64 % was found as less suitable for solid waste disposal sites whereas, 16.13% and 7.42 % of the area were unsuitable and moderately suitable, respectively. The remaining 2.02 % of the study area was found most suitable for solid waste disposal site. Land use/land cover of the study area and suitability ranked were shown in figure 20.

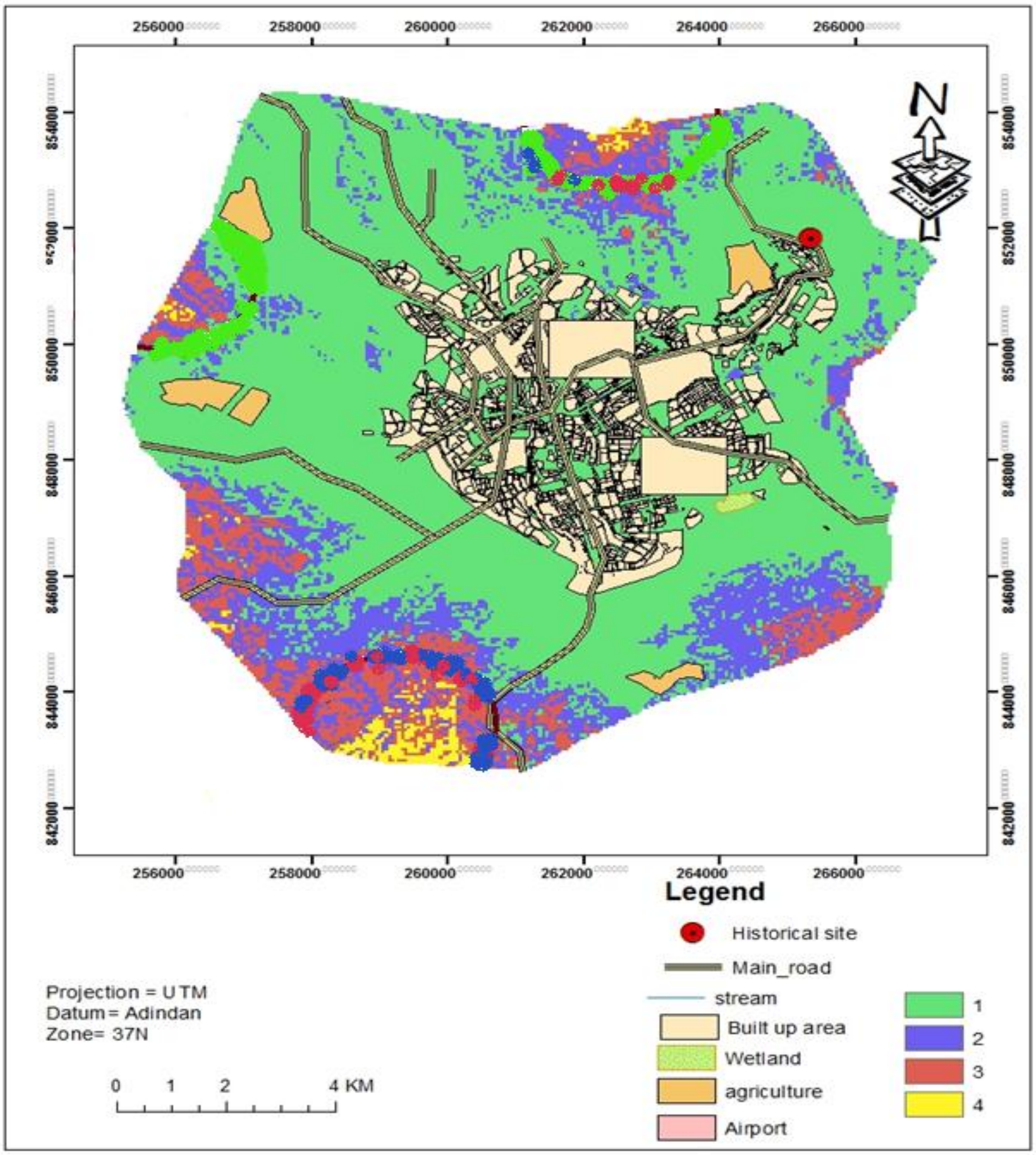

Figure 20: Land use/Land cover map of Jimma Town.

4.2 Result of Weight Criteria's

The factors and their resulting weights were used as input for the multi criteria evaluation (MCE) module for weighted linear combination of overlay analysis. According to Lawal *et al*.,2011, if the consistency ratio is less than or equal to 0.1, it signifies acceptable reciprocal matrix.

The consistency ratio of this study indicated that 0.002 was acceptable as table 4.12 was shows. In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 (value 1 = unsuitable, value 2 = less suitable, value 3 = moderately suitable, value 4 = most suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map. The factors, their values and weights are summarized in table 4.12. According to the degree of importance, they have the role of selecting suitable solid waste dumping site. After the overlay analysis of the given factors the following suitable solid waste landfill site map was produced as shown in figure 21.

Table: 4.12 Weights of the criteria using pair wise comparison matrices

Factors	**LU/LC**	**BU**	**SL**	**SO**	**GEO**	**RI**	**AI**	**RO**	**HI**	**WL**	**AG**	**N[th] Root product**	**Criteria weight**	**Weight (%)**	**AVR**
LU/LC	1	2	3	3	3	5	5	5	7	7	7	2.689	0.244	24.4	11.02
BU	½	1	2	3	3	3	5	5	5	7	7	2.095	0.19	19	11.04
SL	1/3	½	1	1	2	3	3	3	5	5	5	1.314	0.119	11.9	11.05
SO	1/3	1/3	1/1	1	2	3	3	3	5	5	5	1.283	0.117	11.7	10.97
GEO	1/3	1/3	½	1/2	1	3	3	3	3	5	5	1.045	0.095	9.5	11.01
RI	1/5	1/3	1/3	1/3	1/3	1	2	2	3	3	5	0.688	0.063	6.3	10.94
AI	1/5	1/5	1/3	1/3	1/3	½	1	2	3	3	5	0.596	0.054	5.4	11.06
RO	1/5	1/5	1/3	1/3	1/3	½	1/2	1	3	3	3	0.494	0.045	4.5	10.98
HI	1/7	1/5	1/5	1/5	1/3	1/3	1/3	1/3	1	2	3	0.327	0.03	3	10.90
WL	1/7	1/7	1/5	1/5	1/5	1/3	1/3	1/3	1/2	1	3	0.268	0.024	2.4	11.21
AG	1/7	1/7	1/5	1/5	1/5	1/5	1/3	1/3	1/3	1/3	1	0.200	0.018	1.8	11.11
												11.000	1.000	100	121.28

$\lambda max = 121.28/11 = 11.02563$

$CI = (\lambda max - n)/(n-1) = (11.02563 - 11)/(11-1) = 0.02563/10 = 0.002563 = 0.003$

$CR = CI / RI = 0.003/1.51 = 0.002$

Consistency Ratio = 0.002< 0.1 acceptable

LU/LC=Landuse/Landcover,Bu=Builtup,SL=Slope,SO=Soil,RI=River,AI=Airport,RO=Road,HI=Historical site, WL=Wet land, AG=Agriculture, GEO=Geology

4.3 FinalMap for Suitable Landfill Site.

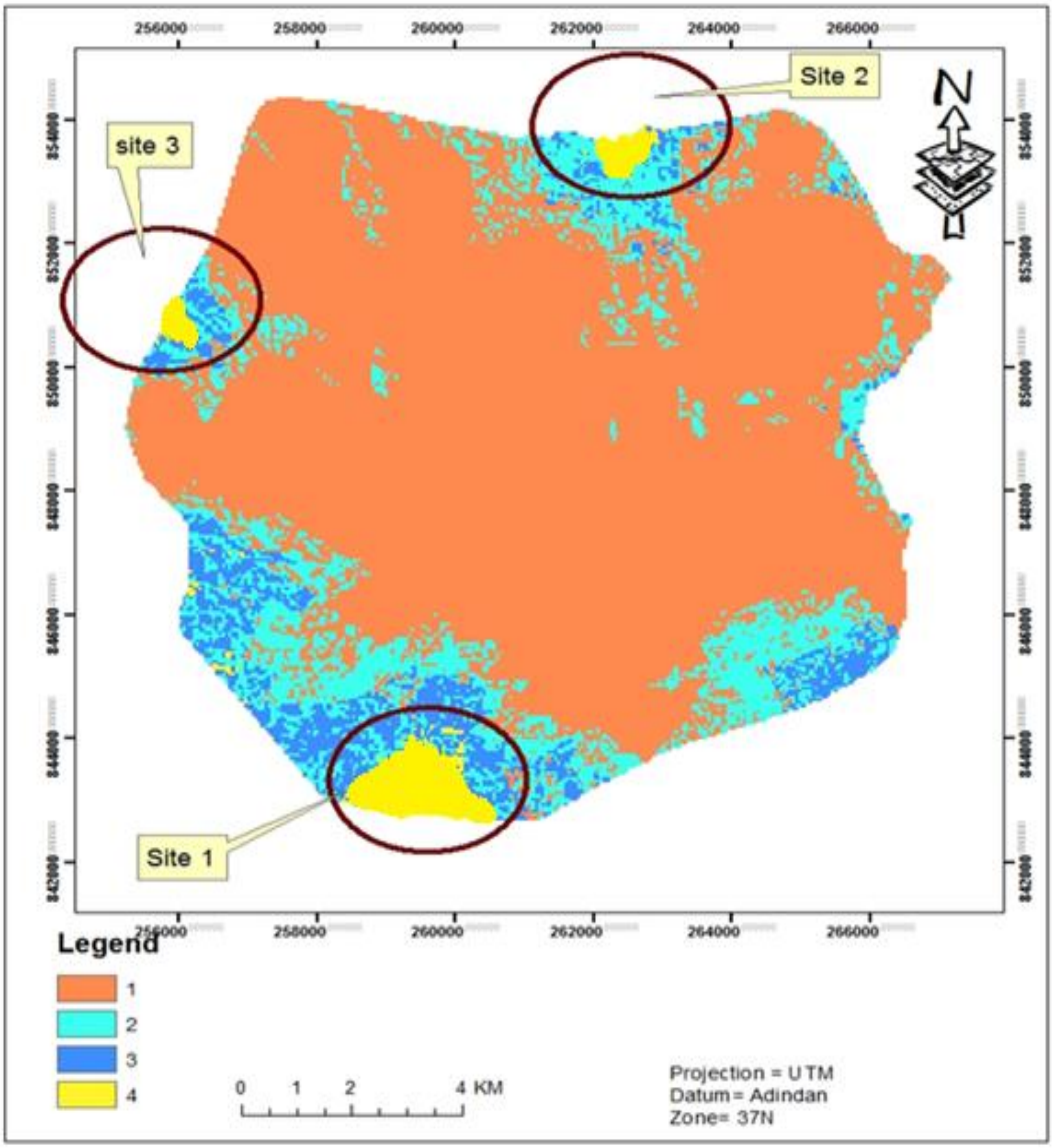

Figure 21**:** Final Suitability Map of Solid Waste landfill Site

4.4 Geographic Boundary of Suitable Landfill Site

Table: 4.4.1Geographic boundary of potential suitable landfill site

Sr.No.	Potential Landfill sites	Area (Hac)	Area (%)
Site 1	Kofe beside of Bore	160.7	74.53
Site 2	Around Mandera Kochi	36.53	16.94
Site 3	Around Bosa kito	18.38	8.52
Total		215.61	100

Table: 4.4.2 Level of Suitability and Percentage of Total Area Coverage

Sr. No.	Suitability	Area (Hac.)	Area (%)
1	Unsuitable	7943.55	74.64
2	Less suitable	1717	16.13
3	Moderate suitable	790	7.42
4	Most suitable	215.61	2.02
Total		10642.16	100

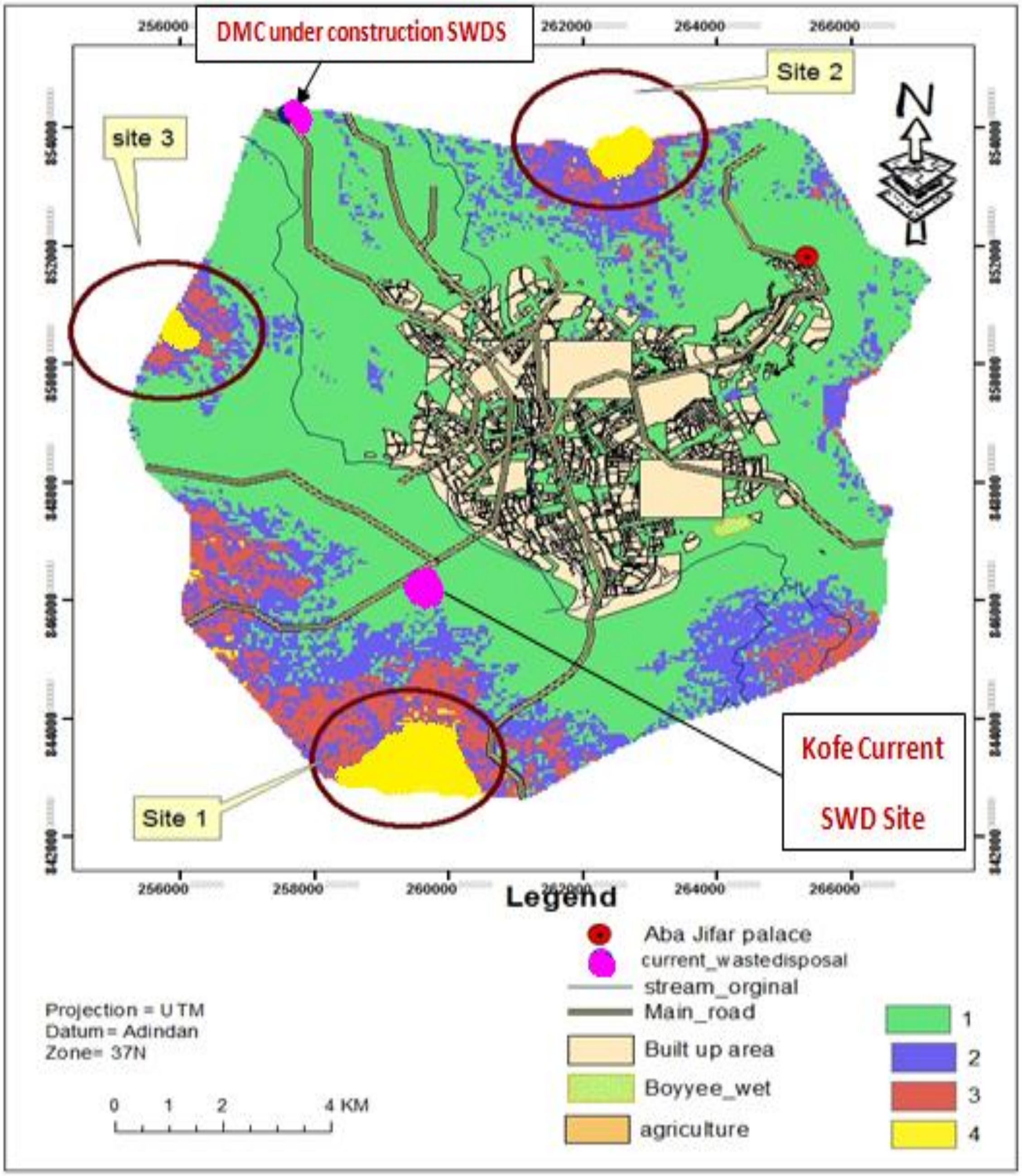

Figure: 22 Current Waste Disposal Site and Under Construction Landfill Site siting Point.

CHAPTER FIVE

CONCLUSIONS and RECOMENDETIONS

5.1 Conclusion

To identify Jimma town solid waste landfill site there are eleven parameters, different siting criteria, various referenced materials and sources are used. The overlay analysis of the given factors using raster calculator in Arc GIS software produced the suitable solid waste dumping site as shown in figure 21.The final solid waste dumping site suitability map was divided into four categories: unsuitable, less suitable, moderate suitable and most suitable.

1. The result indicate that 16.13 % of the study area is unsuitable, 74.64 % area is less suitable, 7.42 % is moderate suitable and 2.02 % of the study area is most suitable for landfill site. The results have shown that three sites were selected as the most suitable. The sites are easy to access; manage for disposal of solid wastes. These places are far away from any water sources and other variables put into analysis. Out of them there is no existing waste dumping site. These sites are suggested to solid waste land fill site as shown in table 4.4.1.
2. By using the stated criteria, the suitable areas for solid waste landfill site fall on the North West, western and southern direction from the town. The areas were more suitable for solid waste landfill site suggested that selecting the optimum site for solid waste dumping may facilitate transportation and reduce the cost of transport. Moreover, suitability, for slope analyses had shown that slope 0-10 % is more suitable in order to minimize environmental impacts. The total areas of the three most appropriate sites are 215.61hac out of total areas. The areas of the potential sites are site 1 kofe Beside Bore being the largest site with area covered 160.7 hac; site 2 around Mendera Kochi near Bebela with area covered 36.53 hac and site 3 around BosaKito with area covered 18.38 hectors respectively.
3. Kofe beside Bore site which is indigenous residential area located far away from any resource of economical/ecological value can be described as one of the most appropriate site and it will be considered as more than 10 years services do to large area coverage.

5.2 Recommendations

Owning to adverse effect of the existing dump sites, the researchers strongly recommend the administrative body of Jimma Town Municipality to put the finding of this study into effect as soon as possible. The site selected as the best landfill is expected to serve the purpose for longer than 10 years in order to reduce the cost of landfill sites selection and construction of another site over and again. Therefore, the volume of solid waste generated from the municipality should carefully be determined to further decide the dimension of the landfill site during construction.

1. To protect downstream surface water pollution, runoff must not flow into and out of the municipal solid waste landfill site. Hence, drainage system should be constructed around the landfill. The selected landfill site was only for non-hazardous solid waste. Therefore, hazardous wastes should not be dumped into this site. Hazardous wastes from industries, health institutions or house-holds should be separated from non-hazardous solid waste before disposal. Hence, separate landfill should be selected for such hazardous solid waste as siting parameters and construction of landfill for hazardous solid waste is quite different from that of non-hazardous waste.
2. The present study considered a few of environmental, social and economic factors for landfill site selection. However, other factors such as ground water table depth were not incorporate as evaluation criteria in GIS analysis, partly because of the data needed not found for GIS impute. Hence, further study should fill this research gap by including these layers as evaluating criteria. Currently illegal disposing site around kofe is not suitable, because this site is beside main road across to Mizan, the site is near closely with Air port with in 200m radius from its compound and near to community settlement and surface water and industry zone, due to this problem Jimma Town Municipality take action to solve this problem by stop disposing.

3. Currently under constricting landfill site around DMC al so not suitable for municipal landfill site, because as the researcher take x y coordination with GPS and check the point of the site on GIS tool, this landfill site is unsuitable because of the site close to main road across to Aggaro, Gambella, Mattu, Nekemt etc. Near to built up area in general this site is far from candidate new suitable landfill site as shown in figure 22.

References

Abdoli, M. A. (1993).Municipal Solid waste management system and its control methods. Organization of Recycling and conversion of material of Tehran Municipality, 142-154.

Abujayyab, S. K. M.,Ahamad,M. S. S.,Yahya, A. S.,Bashir, M.J. K.,&Aziz, H. A. (2016). GIS modelling for new landfill sites: critical review of employed criteria and methods of selection criteria.IOP Conference Series: Earth and Environmental Science,37,012053.https://doi.org/10.1088/1755-1315/37/1/012053.

Al-Hanbali A, Alsaaideh B, Kondoh A (2011).Using GIS-based weighted linear combination analysis and remote sensing techniques to select optimum solid waste disposal sites within Mafraq City, Jordan. J. Geogr. Inf. Sys. 3(2): 267-278.

Allen, A., Brito, G., Caetano, P., Costa, C., Cummins, V.,Donnelly, J., et al. (2003). The development of a GISmodel for the location of landfill sites in Ireland andPortugal, Atlantic area. INTERREG-IIC Programmed, Final Project Report, Project Ref. No. EA-B1IRENo2.15.

Babalola A, Busu I (2010). Selection of landfill sites for solid waste treatment in Damaturu Town-Using GIS Techniques. University Technology Malaysia, Johor state, Malaysia.

Bagchi, A., (1994). Design, Construction and Monitoring of Landfills. 2nd ed., John Wiley and Sons. Inc., New York

Chalkias, C.N. and Stournaras, G., (1997) GIS application for the selection of sanitary waste disposal landfills and quarry sites in major Sparti area, Greece. Engineering Geology and the Environment.Marinos, Koukis, Tsiambaos, Stournaras (eds).

Chang, N., Parvathinathan, G. and Breeden, B. J. (2008). Combining GIS with fuzzy multi - Criteria decision making for landfill sitting in a fat growing urban region, Journal of Environmental management. 87(1): 139-153.

Ebistu, T., & Minale, A. (2013). Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia. African Journal of Environmental Science (November), 976–989.

Ekmekcioglu,M.,Kaya, T.and Kahraman, C., (2010). Fuzzy Multi criteria disposal method and site selection for municipal solid waste, waste management,30:1729-1736.

EPA,(1995). Decision Maker's Guide to Solid Waste Management, Volume II, pp58.

EPA,(2008). Environmental management of landfill facilities (municipal solid waste and commercial and industrial general waste), EPA Guidelines.

Ersoy,H. and Bulut,F. (2009). Spatial and multi-criteria decision analysis-based methodology for landfill site selection in growing urban regions, Waste Management & Research ,00:1-12.

ESAUK. (2016). Landfill & Disposal. Esa, 27(December), 309–316.

Gemitzi, A., Tsihrintzis, V.A., Voudrias, E., Petalas, C. and Stravodimos, G., (2007). Combining geographic information system, multicriteria evaluation techniques and fuzzy logic in siting MSW landfills. Environ Geol, 51: 797-811.

Ham,Y.J.,Maddison,D.J., &Elliott, R.J.R. (2013).The valuation of landfill disamenities in Birmingham.EcologicalEconomics,85,116129.https://doi.org/10.1016/j.ecolecon.2012.09.006

Hasan, R.M., Tetsuo, K. and Islam, A.S. (2009). Landfill demand and allocation for municipal solid waste disposal in Dhake city-an assessment in a GIS environmental, Journal of civil Engineering Dhake University, Dhake. 37:2, 133-149.

Jimma Structural Plan, Oromia Urban Planning Institute, November 2008.

Jimma Sanitary Landfill Environmental and Social Impact Assessment Report February, 2013.

Kirimi, F. K., & Waithaka, E. H. (2014). Determination of Suitable Landfill Site Using Geospatial Techniques and Multi-Criteria Decision Analysis : A Case Study of Nakuru Town , Kenya, 3(11), 500–505.

Kontos, T.D., Komilis, D.P. and Halvadakis, C.P. (2005). Sitting MSW landfill with a spatial Multiple criteria analysis methodology. Waste Management, 25(8):818-833.

Lawal DU, Matori A-N, Balogun A-L (2011). A Geographic Information System and multi-criteria decision analysis in proposing new recreational park sites in Universiti Teknologi Malaysia. Mod. Appl. Sci. 5(3):79-86.

Malczewski, J., (1997). Propogation of errors in multicriteria location analysis: A case study, In Fandel, G., Gal, T. (eds.) Multiple Criteria Decision Making, Springer-

Verlag, Berlin, 154-155.

Mohammedshum, A. A., Gebresilassie, M. A., Rulinda, C. M., Kahsay, G. H., & Tesfay, M. S. (2014). Application of geographic information system and remotesensing in effective solid waste disposal sites selection in Wukro Town, Tigray, Ethiopia. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 40(2), 115–119.

Nas,B.,Cay,T., Iscan, F., & Berktay, A. (2010). Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. Environmental Monitoring and Assessment, 160(1-4), 491–500. O‟Leary,P. R.,Canter,L. and Robinson, W.D., (1986). Land disposal. In: Robinson, W.D. (Ed.). The Solid Waste Handbook: A Practical Guide. Wiley, NY, USA p. 271.

Oyinloye, M. A. (2013). Using GIS and Remote Sensing in Urban Waste Disposal and Management: A Focus on Owo L.G.A, Ondo State, Nigeria. European International Journal of Science and Technology, 2(7), 106–118.

Rafiee, R., Syed, E., H., Afshin, D. and Nematolah, K. (2011). Siting transfer stations for Municipal solid waste using a spatial multi-criteria analysis. Environmental and Engineering Geo-Science, 17(2): 143-154.

Saaty TL (1977). A scaling method for priorities in hierarchical structures. J. Math. Psycho. 15:231-281.

Sener S, Sener E, Nas B (2011). Selection of landfill site using GIS and multicriteria decision analysis for Beysehir Lake Catchment Area Konya, Turkey. J. Eng. Sci. Des.1(3):134-144.

Siddiqui,M.Z.,(1996).Landfill siting using geographic information systems:a demonstration.Journal of Environmental Engineering,122-6, 515-523.

Sin,T.J.,Chen,G.K.,and Hwang, G. H. (2016). Challenges in Selecting a Sustainable LandfillSiteinMalaysia.MATECWebofConferences,47,0502 .https://doi.org/10.1051 matecconf/20164705021.Solid, G. (n.d.). Chapter 5 Site Suitability Analysis Using Gis & Riam, 149–177.

Tchobanoglous, G., Kreith, F.,(2002). Handbook of Solid Waste Management, McGraw-Hill, New York

UNEP,(2005).Solid Waste Management,Volume II:Regional Overviews and Information

Sources. USA, New York, pp334.

Wastes,H.,&Disposal,T.(n.d.).Basel Convention Technical Guidelines on Specially Engineered.

Yazdani,M.,Monavari,S.M.,Omrani,G.A., Shariat, M., & Hosseini, S. M. (2015). Landfill site suitability assessment by means of geographic information system analysis. Solid Earth, 6(3), 945–956.

Annex 1.Site Survey

Table: 14Factors Considered for Solid Waste Landfill Site Suitability

Category	Layer	Meter/Appropriate Unit	Remark
Land use/cover	Distance from Agriculture		
	Distance from Built up area		
	Distance from Air port		
	Distance from Cultural site		
Topography	Slope		
Soil	Soil type		
Geology	Geology		
Hydrology	Rivers, wet land		
Access	Distance from Roads		