ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

Department of Geodesy and Geomatic Engineering

SUITABLE SOLID WASTE DISPOSAL SITE SELECTION USING GEOGRAPHIC INFORMATION SYSTEM AND MULTI-CRITERIA APPROACH: CASE AMBO TOWN

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Thesis submitted to the School of Civil Engineering and Architecture, in partial fulfillment of the requirements for the degree of Master of Science in Geodesy and Geomatic Engineering

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Adama, Ethiopia

DEDICATION

Dedication for the memory of all OROMOS killed on IRREECHAA celebration at BISHOFTU October 2, 2016 G.C

DECLARATION

The thesis paper attached here to, entitled "*Suitable solid waste disposal site selection using analytical hierarchical process and multi-criteria approach: case Ambo town*" prepared and Submitted by *Hailu Zewde* to the School of Civil Engineering and Architecture in partial fulfillments of the requirements for the award of the degree master of science in Geodesy and Geometics Engineering ,Adama Science and Technology University authentic record of my own work carried out during the year 2014-2017 under supervision of Dr. Tilahun Erduno (major advisor) and Mr. Dejene Tesema (co-advisor).

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct and to the best of our knowledge and believe. This has been submitted for the examination with our approval.

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BOARD OF EXAMINERS APPROVAL

The undersigned certify that they have read and hereby recommend to the Adama Science and Technology University to accept the Thesis submitted by *Hailu Zewde*, and entitled "*Suitable solid waste disposal site selection using analytical hierarchical process and multi-criteria approach: case Ambo town*", in partial fulfillment of the requirements for the award of a Degree of Masters of Science in Geodesy and Geomatics Engineering.

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LISTS OF ABBREVIATIONS AND ACRONYMS

AHP	Analytic Hierarchy Process
amsl	Above mean sea level
CAD	Computer Assisted Drafting
CSA	Central Statics Authority
DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis System
ETM	Enhanced Thematic Mapper
GIS	Geographic Information System
GPS	Global Positioning System
ISWM	Integrated Solid Waste Management
LULC	Land Use Land Cover
MSWM	Municipal Solid Waste Management
MCDA	Multi Criteria Decision Analysis
MCE	Multi Criteria Evaluation
MOA	Ministry of Agriculture
MUDC	Ministry of Urban Development and Construction
UTM	Universal Transverse Mercator
WLC	Weight Linear Combination

ABSTRACT

Solid waste management system is the most difficult task that many countries, both developing and developed, are facing. Site selection method is one of the easy and cheap management systems which are always needed for sustainable management of solid waste. The main objective of the study was to select waste disposal site for the town that is environmentally sound, socially acceptable and economically feasible in Ambo town. To achieve the objectives, the present study was conducted by Analytical Hierarchical Process and Multi-criteria Approach for selecting suitable waste disposal sites. The data used for the study include digital elevation model (DEM), Ground control point (GCP) collected by Global position system (GPS),Soil, Geology, Topography map, and Structural plan as well as interviews and field observations. All the factor maps were reclassified and standardized in GIS environment followed by preparation of their suitability map. Analytical Hierarchy Processes pair-wise comparison module was used to derive weights for all factor parameters. Accordingly, 34.49km^2(45%) of the study area is unsuitable, 26.93km^2(34%) less suitable, 12.18 km^2 (15%) is suitable and 3.95km^2(6%) is more suitable for waste disposal. The proposed more suitable areas for solid waste dumping sites fall on south, south-west and east part of the town where there are least environmental and health risks. The study revealed that Geographic Information System (GIS) techniques are helpful tools for solid waste disposal site selection. The finding of the study shows that 6 candidate dumping sites in relation to those evaluating criteria. Waste disposal site 1, 2 and 3 have been chosen as the most suitable site. Therefore, waste disposal sites 4, 5 and 6 are ranked from 1 to 3 based on their area and distance from the center and nearby settlements due to their minimum environmental and social negative effects compared to the other sites. In general, waste disposal site selection has been required appropriate consideration from stakeholders and other concerned bodies.

Key Word: *AHP, Multi-criteria approach, Geographic Information System*

1. INTRODUCTION

1.1. Background

Solid wastes could be defined as non-liquid and non-gaseous products of human activities, regarded as being useless. Its origin is mainly from households, municipal and construction (Munier, 2005). The generation and management of solid wastes are the problems facing both developing and developed countries. Generation of solid waste has become an increasing environmental and public health problem everywhere in the world, particularly in developing countries. Fast expansion of urban, agricultural and industrial activities spurred by rapid population growth has produced vast amounts of solid waste disposal. In many countries with increase in population and the rising demand for food and other essentials, there has been a rise in the amount of solid waste being generated making its management and disposal problematic. Solid waste management has long been a worldwide environmental problem. This is because of the rapid growth of population and urbanization that decreases the non-renewable resources and disposal of waste and toxic waste arbitrarily, as a result of this major environmental issues posing stress to the arrival of human being (Munier, 2005).The management of solid waste in Africa is often weak due to lack of appropriate planning, inadequate governance, poor technology, weak enforcement of existing legislation and the absence of economic and fiscal incentives to promote environmentally sound development. The current practice of solid waste management system in Africa is open dumps without leachate and gas management over ecologically or hydro-logically sensitive areas (UNEP, 2005).

The most common problems associated with inappropriate management of solid waste include transmission diseases, fire hazards, foul odour, atmospheric and water pollution, aesthetic pain and economic victims. Urban solid waste management is considered as one of the most urgent and serious environmental problems facing municipality authorities in developing countries particularly in Africa. According to Bjerkli (2005), the insufficient handling of solid waste represents a source of water, land and air pollution affecting the urban environment and the health of the people living in the cities and towns is one of the most critical environmental problems that facing today in Africa.

Therefore, solid waste management is becoming a major public health and environmental concern in urban areas of many African countries like in Ethiopia, especially in Ambo town. General awareness of our environmental problems has led to the development of pollution control technologies, more rigorous legislation, strategies on waste handling and disposal to minimize the environmental impact associated with solid waste. Waste disposal is an important part of waste management system, which requires much attention to avoid environmental pollution. Based on this it is convincing that waste management will be effective if a suitable site is identified and properly utilized. There are various techniques that are currently being used for solid waste management; these include thermal treatment, biological treatment, land filling and recycling However, in today's society, finding a suitable site is becoming a significant problem(UNEP, 2005).

A suitable disposal site must have environmental safety criteria and attributes that will enable the waste to be isolated, so that there is no unacceptable risk to people or the environment while it is operating. Criteria for site selection will include natural physical characteristics as well as socio- economic, ecological and land-use factors. Preferable selection of suitable site for waste disposal has been normally carried by traditional approaches i.e. throwing it at all types of free land in or around the city (Md.Mujibor, et. al., 2008). The uncontrolled and improper solid waste management in the city is polluting the environment and affecting public health. As indicated by UNEP (2005), improper solid waste management leads to substantial negative environmental impacts such as air, soil and water pollution, flooding due to the blockage of drainage system and generation of greenhouse gases .

Furthermore, it will result in health and safety problems like diseases spread by vectors such as insects and rodents attracted by garbage heaps, and diseases associated with different forms of pollution. Therefore, for sustainable environmental and public health protection, solid waste should be disposed in environmentally sound and socially acceptable sites. Hence, environmental protection and public health considerations should be the principal concerns in site selection. This is because selection of an appropriate site will minimize potential environmental impacts and provide a sound basis for effective management (Zain, 2009).

Sound practice in siting of solid waste disposal can highly reduce the risk of environmental pollution and public health imposed by improper system which is common in developing countries. However, selecting safe site for solid waste disposal is not an easy task. It is tedious and costly requiring multiple criteria that are difficult to handle. Moreover, Biotto et.al (2009) describes identification of waste disposal sites as a complex spatial problem, involving multiple criteria and objectives which require the use of spatial analysis models for its solution. Nevertheless, integrating Geographic Information System (GIS) and Remote Sensing is the best tool in selecting environmentally sound and socially acceptable disposal sites with accurate precision, cost and time effectively.

The development of GIS coupled with availability of digital data from Remote Sensing technology made solid waste disposal site selection easy. Because it's unique capabilities. The distinguishing feature of GIS capability to perform an integrated analysis of spatial and attributes data and it can be used not only for automatically producing maps, but it is unique in its capacity for integration and spatial analysis of multisource datasets (Malczewski, 2004).

Moreover, GIS is used to perform a screening process that led to identification of a couple of suitable candidate sites based on given criteria. The suitability criteria are defined with the focus to minimize any potential health risk from direct or indirect contamination due to the proximity of a disposal site with respect to key geographic features. Thus, the first-stage analysis using GIS is essential for the initial identification of a couple of suitable solid waste disposal sites prior to undertaking further analyses or field investigations (Chang et al., 2007). This screening will minimize the cost and time of site selection processes.

The general workflow of this study includes four major steps. The first was identifying factors to be used for identify best location for waste disposal and producing maps for each. Secondly, assigning weight for the selected factors. The third was overlaying and generating waste disposal suitability map and finally, determining suitable areas.

1.2. Statement of the problem and Justification

Waste management is a major issue of the global environmental agenda. As population and consumption grow result in increasing quantities of waste. In developing countries, the population of towns is increasing due to both natural increase and migration from rural areas. This high population growth and the activities of development result in the generation of large amount of solid waste which faces problem of their disposal and have potential effect to pollute the environment like water, soil and air. The pollution of these and other resources of the environment affects public health. In Ethiopia, most of the diseases are related to environmental sanitation and water contamination and Ambo town affected by this problems (Malczewski, 2004).

As the town is becoming an increasing population, the municipality did not give medal attention to sustainable solid waste disposal and management system. Solid waste management is currently receiving wide attention in many towns of Ethiopia, especially in the study area where solid wastes are from abattoir, from settlement, hospital and hotels; because solid waste disposal that are generated in most towns of Ethiopia are not appropriately handled and managed. However, it is possible to minimize and solve these problems through planning and implementing different municipal solid waste management components. Unsuitable and not manageable site of waste disposal lead to serious contamination to the environment, for instance surface water and air pollution, which have negative effect and considered as threat to residents in the study area (Soto, 2001).

Identifying solid waste disposal site selection and management is considered as one of the most serious environmental and social problem challenging task to municipal authorities in Ambo town. One of this impacts raise from location of dumping site in unsuitable areas. The existing site for Ambo town is not sufficient in its capacity and it is damaging the environment due to its location and the type of waste dumped, while the surrounding area is being river, residential and public services area. Due to the swift expansion and urbanization development in ambo town, it badly needs to develop controlled solid waste dumping site to prevent several contamination problems. The solid waste disposal system should be in an environmentally sound and socially acceptable way so as to protect the environment and safe-guard public health.

However, the manual method used to select suitable solid waste disposal site selection is, tedious, time consuming and costly. Because they don't fully utilize GIS and remote sensing technology and were unable to consider many of these factors. As a result, update geographic data such as land use /land cover, and urbanization were not included in their existing sites. Furthermore, the current waste disposal system of the town is open dump. It causing social and environmental problems. When the site was selected, there were no evaluation of the underlying soil structure, topography, surface water and geological condition of the area. The study focused on integrating GIS and remote sensing techniques to provide appropriate information about geographic data to assist in selecting potential solid waste disposal site using different constraints and factors. Moreover, GIS is capable of integrating geospatial data from different sources and thus help decision makers in environmental and public health protection (Soto, 2001).

Hence, the present study employs GIS and remote sensing techniques for appropriate solid waste disposal site selection for ambo town.

1.3. Objective of the study

1.3.1. General

The general objective of this study is to select suitable solid waste disposal site for Ambo town using Geographic Information System (GIS) and Multi- criteria approach.

1.3.2. Specific

Having the above general objective, the study was geared to attain the following specific.

- To identify factors for solid waste disposal site selection
- To evaluate existing solid waste disposal site in terms of selected factors
- To identify potential sites suitable for solid waste disposal
- To verify and prioritize potential site

1.4. Research question

So as to achieve the intended objectives stated above, the following questions were formulated.

- What are factors influence solid waste disposal site selection?
- What is the level of suitability of existing solid waste disposal site in ambo town?
- What are the factors that are necessary in waste disposal suitable site selection?
- How does potential sites suitable for solid waste disposal can be identified?
- How does best suitable site can be determined from identified potential sites?

1.5. Significance of the study

This study is expected to select and map suitable solid waste disposal sites to protect the environmental safety of Ambo town. Since unsuitable solid waste disposal sites affect the social and economic activities of communities as well as the health of resources of the study area, like water, the final result of this project will help the town to solve the problems.

This study may have two main significances. First it may give some guide line information to policy makers, solid waste managers and environmental protection agencies about existing situation municipal solid waste management problem of ambo town.

Secondly the study may also be important in putting base line information to the next work of those who would like to conduct detailed and comprehensive studies either in ambo or other areas. In addition, the study is also expected to give an insight about the application of GIS and Remote Sensing technologies for the selection of suitable solid waste disposal sites.

1.6. Scope of the study

The scope of the study is confined to suitable solid waste disposal site selection in ambo town. It focuses on technical aspects of solid waste disposal site selection. The issues under consideration in the study are only solid wastes. Sanitary wastes area, engineering and design part of the construction are not included.

1.7. Limitations of the Study

In addition to financial limitation, the study is constrained by the following limitations:

- Lack of organized secondary data due to the absence of documentation and organized database system in the study area.
- The data collected at national levels are in collected as small sample in a very wide range of area, so that the data lack well representation of the area.
- The resolution of the recent satellite imagery data were the major problem to deal the current land use condition of the town; So that, the writer was used master plan of the town to obtain the current land use condition.

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

1.8. Organization of the Thesis

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

2. LITERATURE REVIEW

2.1. Municipal Solid Waste Management System

Waste is generated universally and it is a direct consequence of all human activities. Wastes are generally classified into solid, liquid and gaseous. The subject of this study, are mainly waste disposal of site selection using analytical hierarchical process and multi-criteria approach, because it is the simplest, cheapest and most cost -effective method of disposing of waste. These wastes can be generated by the full extent of human activities that range from relatively innocuous substances such as food and paper waste to toxic substances such as paint, batteries, asbestos, healthcare waste, sewage sludge derived from wastewater treatment and as an extreme example, high-level (radioactive) waste in the form of spent nuclear fuel rods. Numerous classifications of solid wastes have been proposed and the following represents a simple classification of waste into broad categories according to its origin and risk to human and environmental health (Malczewski, 2004). These includes: household waste, municipal waste, commercial and non- hazardous industrial wastes, hazardous (toxic) industrial wastes, construction and demolition waste, health care wastes generated in health care facilities e.g. hospitals, medical research facilities), human and animal wastes and Incinerator wastes.

Household waste represents waste generated at home and collected by municipal waste collection services. It includes this plus shop and office waste, food waste from restaurants, etc., also collected by municipal waste collection systems, plus waste derived from street cleaning, and green (organic) waste generated in parks and gardens. Municipal solid waste management (MSWM) encompasses the functions of collection, transfer, resource recovery, recycling and treatment. The primary target of MSWM is to protect the health of the population, promote environmental quality, develop sustainability and provide support to economic productivity. Waste management is a problem for most countries around the world because of the increasing volume of waste material and the paucity of places to deposit. It has been a threat to environment and public health. However, proper waste management helps protect human health and the environment, as well preserve natural resources (Soto, 2001).

Solid waste should be managed through a number of activities such as waste prevention, recycling, composting, controlled burning in the order of preference.

Combination of these activities in a way that best protect the community and the local environments is referred to as integrated solid waste management (ISWM). A sustainable waste management philosophy should encompass the following basic principles of solid waste management hierarchy which includes reduction in the generation of waste, waste streaming at source, recycling and reuse, pre-treatment of waste to minimize quantity and volume of residual waste. The hierarchy ranks those waste management operations according to their environmental or energy benefit and the purpose is to make waste management practices as environmentally sound as possible (UNEP, 2005).

2.1.1. Solid Waste Management System in Low Income Countries

The open dump approach is the primitive stage of development and remains the predominant waste disposal option in most of Africa countries including Ethiopia. It is a strategy for municipal solid waste management which involve indiscriminate disposal of waste and limited measures to control operations, including those related to the environmental effects of surroundings. An operated or semi-controlled dump is often the first stage in a country's efforts to upgrade use modeling (Soto, 2001).

Controlled dumps operate with some form of inspection and recording of incoming wastes, practice extensive compaction of waste, and control the tipping front and the application of soil cover. Operated dumps, however, implement only limited measures to mitigate other environmental impacts. Operated dumps still practice unmanaged contaminant release and do not take into account environmental cautionary measures such as leachate and gas management (Soto, 2001). But as cities grow and produce more waste and their solid waste collection systems become more efficient, the environmental impact from open dumps becomes increasingly intolerable.

Generally, in most countries of Ethiopia, particular Ambo town the environmental impacts and economic damages of poor solid waste management practices on groundwater and receiving surface waters are becoming a serious issue. This study is also because of the environmental impacts of surface waters and other resources like crops of the study area. Municipal solid waste management system is either not efficient or as such solid waste generated has become a threat to the environment. The growth in population, urbanization, industrialization and waste generation in Ethiopia calls for proper solid waste management as it has become a necessity for environmental conservation and sustainability.

For a sustainable solid waste management system policies and techniques such as waste recycling, reuse, waste reduction, thermal treatment, and biological treatment must be in place. The waste disposal site selection method has been widely recognized as the most used of all waste management techniques. However, the communities of small towns and villages in Ethiopia usually cannot afford disposal design, construction and operation standards equal to those applied in large cities, and in many cases, large cities cannot afford to apply standards equal to those of high-income countries. Perhaps the first question to be addressed when sitting a disposal is: What constitutes an appropriate level of environmental protection for the community? This will differ from community to community and will depend on the climate in the area as well as the available resources for construction and operation of the disposal. Often, construction and operation resources are limited and this must be reflected in the sitting process. In line with the internationally recognized waste management hierarchy, the first priority should be given to waste minimization (reduction at source). It should be followed by recycling, treatment and land disposal in this order (WHO, 1996).

2.2. The role of GIS and Remote Sensing for waste disposal Site Selection

2.2.1. Application of Remote Sensing in Site Selection

Remote sensing is defined as the science or art of obtaining information about an object, area or phenomenon through the analysis of the data acquired by a device that is not in contact with the object, area or phenomenon under investigation. Remote sensing serves as a tool for environmental resources assessment and monitoring. Nishanth et al. (2010) also states remote sensing as one of the excellent tools for inventory and analysis of environment and its resources, owing to its unique ability of providing the synoptic view of a large area of the earth surface and its capacity of repetitive coverage. With the availability of remotely sensed data from different sensors of various platforms with a wide range of spatio temporal, radiometric and spectral resolutions has made remote sensing as one of the best source of data for large scale applications and study. The use of remote sensing is becoming increasingly frequent in environmental studies. In the recent years, no serious research of the environment performed without advanced image processing and analysis.

One of the most important applications of remote sensing can be found in the case of solid waste disposal site selection where remote sensing data (satellite images) are used for extracting most of the site selection criteria used for siting disposal (Oštir et al.,2003) (example, mapping land use/land cover, geology and surface water), time and cost effectively. Moreover remote sensing can provide digital data as an input for GIS.

2.2.2. Application of GIS for waste disposal Site Selection

Technological development in computer science has introduced Geographic Information System (GIS) as an innovative tool in disposal process (Oštir et al., 2003). GIS combines spatial data (maps, GPS data, aerial photographs, satellite images) with the other quantitative, qualitative and descriptive information databases. This technology offers an analytical frame work for data synthesis that combines a system capable of data capture, storage, management, retrieval, analysis and display. When remotely sensed data are combined with other landscape variables organized with in a GIS environment provide an excellent frame work for data capture, storage, synthesis, measurement and analysis. For assessing a site as a possible location for solid waste disposal, several environmental and political factors and legislations should be considered. The GIS aided methodology presented here utilizes to create the digital geo-database as a spatial clustering process and easily understood way for site selection process. Moreover, waste disposal siting is a complicated process requiring a detailed assessment over a vast area to identify suitable location for constructing a subject to many different criteria (Chang et al., 2007). GIS application can help in determining the disposal location in accordance with the technical requirements, with weight overlay the thematic map to get an appropriate (Akbari et al, 2008).

GIS is a tool that not only reduces time and cost of the site selection but also provides digital data bank for future monitoring program of the site. The procedure followed under the GIS framework rejects the unacceptable sites considering environmental factors exclusively, other than economic and political issues, contained in the form of multiple layers of attribute information to select the candidate sites for disposal waste through an weight overlay analysis performed by GIS software. Therefore, the GIS offers the spatial analytical capabilities to quickly eliminate parcel of land unsuitable for disposal site (Chang et al.2007) and hence reduce cost and time of siting processes.

2.3. Criteria used for waste disposal site selection

The criteria used in site selection include environmental, economic and socio-political, some of which may contradict to each other. With increase environmental awareness, new rules and criteria developments are emerged over time. The waste disposal site selection process has become much more complicated, as new procedures and tools have been created. By considering this and other factors I would like to review waste disposal site selection criteria used by different researchers in different countries.

2.3.1. Waste disposal site selection criteria used case of Uganda

Several countries like Australia, Malaysia, Niger, North Dakota, Philippines, Uganda, and United States among others have put in place rules and regulations to follow when selecting suitable sites for sanitary design. These guidelines are used the primary mechanism used to protect the host community and the environment at large.

The following are the factors that several researchers have used to determine the appropriateness of a site to be used for waste disposal (North Dakota Department of Health, 2002; and Yaw et al, 2006).

I. *Site capacity:* a site should be capable of providing at least ten years of use in order to minimize costs for site establishment and operation.

II. *Land cover:* buffer zones should be provided between the waste disposal and sensitive areas or other land uses. For example at least 100 meters from public roads, at least 200 meters from industrial developments, at least 500 meters from urban residential or economic area, at least 1000 meter from rural residential areas.

III. *Airports:* the distance between an airport and a waste disposal should be a minimum of three kilometres, there is a clear demonstration of bird control measures.

IV. *Surface water*: the distance between the waste disposal and the nearest surface water should be a minimum of 100 meters, or 200 meter to minimize the risk of polluting water with leachate. However, North Dakota Department of Health (2002) uses a minimum distance of 60 meter to the nearest surface water.

V. *Ground water:* an extremely deep water table region is suitable so that underground water is not contaminated by the leachate of the waste.

According to North Dakota Department of Health (2002) and Yaw et al, 2006), the bottom of disposal drain should be at least four feet above the water table.

VI. *Local topography:* land forms located in flat or undulating land, in an empty extracts are suitable for waste disposal. Must not be sited in hill areas, those with ground slopes nominally greater than ten percent. However, North Dakota Department of Health (2002) recommends that 15 % slope or less.

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

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

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

X. *Infrastructure:* Should have suitable transport accesses, with power and water available, they should not be located within 100 meter of any major highways, city streets or other transportation routes. Yaw et al, (2006) recommended that 300 meter.

XI. *Local Flora and Fauna:* sites that contain protected or endangered fauna and flora, or sensitive ecosystems are unsuitable for waste disposal facilities.

XII. *Distance from environmentally protected areas:* Must not be located in close proximity to sensitive areas such as fish sanctuaries, mangrove areas and areas for special protection would be excluded. Therefore a 3,000 meter buffer is necessary to surround an environmentally sensitive area.

XIII. *Distance from urban areas:* Should not be placed too close to high-density urban areas in order to mitigate conflicts. Development of landfills should be prohibited within 3000 meter from village or rural settlements Yaw et al. 2006, and a distance of 4000 meter from a town.

XIV. *Population:* Yaw et al, (2006), recommend that areas with a population density less than 200 persons were regarded as suitable.

2.3.2. Criteria used in West Bandug Regency

I. *Geology:* bedrock in areas of potential disposal is very significant in minimizing the spread of leachate naturally, both at the time of moving into ground water or when moving laterally along the ground water. Therefore, required selection demands that do not have bedrock with the formation of sandstone, limestone or hollow rock.

The other geological areas which are important to be evaluated are the potential for earthquakes, the active volcanic zones and land slide areas. The area around the volcano and areas for potential earthquake is geological-prone areas that are not encouraged to become candidate sites. High soil movement is not considered suitable candidates (Akbari, 2008).

II. ***Hydrogeology:*** Hydro-geological information is needed to determine the presence of ground water, soil impermeability detection, the location of rivers or reservoirs or surface water and drinking water sources used by the residents around. Soil with rapid permeability assessed to have a low value to a potential site because it provides small protection against ground water and require special additional technology. Soil type also affects the permeability of water into the ground. Site cannot be selected on the type of sandy soil because it has a high porosity so that the graduation rate in the ground water will be relatively high so that it can interfere with ground water quality. The ability of permeability of soil to absorb water is fast, good, medium and slow. Rapid permeable soil (coarse sand), is classified the rate and permeability which is 3.6-36 cm per hour; permeability of the medium, i.e. 2.0-3.6 cm per hour; whereas the slow permeability below 2.0 cm per hour (Akbari, 2008).

III.Topography: Should not be located on a hill with an unstable slope. An area is preferable if located on the sloping area with high topography. The best slope should be modest slopes, which enable easier storm water control, leachate control and site stability measures, as well as facilitating the operation of the site. Different researchers set different slope criteria for site selection. For example, Hasan et al. (2009) set areas with slope <15-20% as the best site, while Change et al. (2007) describe slope <12% as the best site and slope >12% unsuitable.

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

Multi-criteria analysis is a set of mathematical tools and methods allowing the comparison of different alternatives according to many criteria, often conflicting, to guide the decision maker towards a judicious choice (Chakhar and Mousseau, 2008).

MCDA consists of a series of techniques such as weighted summation or concordance analysis that permit a range of criteria relating to a particular issue to be scored, weighted and then ranked by, for example, experts, interest groups and/or stakeholders according to their degree of suitability or importance for locating/sitting a particular facility/service (Malczewski, 2004) .

Analytic Hierarchy Process (AHP) is one of the most commonly used MCDA tools. This tool is applied in site selection processes as it assists the decision making process by allowing decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model (Eldrandaly et al., 2005). Hence, multi-criteria techniques could be particularly useful in situations where there are a large number of alternative sites for a development, where there are large number of potential criteria to be taken into consideration or where subjective judgments by different stakeholders of the different alternatives is needed to try to reach an objective consensus in the final decision- making process or to make these processes more open and accountable (Higgs, 2006).

A solid waste management program often involves conflicting economical, environmental, and socio-ecological impacts. For example, locating a new site for development at minimal cost is feasible, but the tradeoff could be the likelihood of groundwater pollution. Moreover, site selection by GIS is a multi-criteria evaluation (MCE) and generally has four steps criterion establishment, standardization of factors, establishment of factors weight and weighted linear combination. With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of results to yield a suitability map (Hasan et al., 2009).

2.4.1. Multi-criteria Decision Making (MCDM)

GIS-based multi-criteria decision analysis involves the utilization of geographical data, the decision maker's preferences and the combination of the data and preferences according to specified decision rules (Malczewski, 2006. MCDM is a set of mathematical tools and methods, like weighing, to compare different alternatives according to the criteria. The main components for MCDM are human value judgment and assessment of criteria, to rank potential disposal sites using different criteria. Multi-criteria approaches have the potential to reduce the costs and time involved in siting disposal by narrowing down the potential choices based on predefined criteria and weights.

Weighted Linear Combination (WLC) and Analytic Hierarchy Processes (AHP) are the two most known Multi-Criteria Analysis methods that were used for this study.

2.4.2. Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by (Saaty, 2008). The Analytic Hierarchy Process is a decision making method for prioritizing alternatives when multiple criteria must be considered. It offers a methodology to rank alternative courses of actions based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each of the alternatives (Nydick and Hill, 1992). AHP is a powerful and flexible decision-making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. It provides a hierarchical structure by reducing multiple variable decisions into a series of pairwise comparisons and develops subjective priorities based upon user judgment. AHP is a decision support tool which can be used to solve complex decision problems.

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

2.4.3. Weighted Linear Combination (WLC)

WLC is a type of multi-criteria evaluation method in GIS environment used to evaluate the suitability of a region for waste disposal. The WLC procedure is characterized by full tradeoff among all factors, average risk and offers much flexibility than the Boolean approaches in the decision making process. The approach allows the decision maker to assign weights according to the relative importance of each suitability map and combines the reclassified maps to obtain an overall suitability score (Malczewski, 2004).

In this particular research, GIS-based Multi-Criteria Evaluation methodology was followed. This methodology is best suited for siting disposal accurately in time and cost effective manner, hence used by many researchers. Because the technique can effectively be used for suitability analysis in GIS environment via criteria establishment, standardization of factors, establishment of factor weights and finally weighted linear combination. Waste disposal site selection methodology is a two-step processes. The first step employs GIS to screen out unsuitable areas based on standards and criteria set by national and international environmental acts and rules and identify potential candidate sites. In the second step MCDM, is used for ranking the candidate sites and identify the best site/s based on the weights assigned to each criterion. AHP is a powerful MCDM tool to assign weights and rank the candidate sites for selecting the best site among the candidates. Generally, after finding out where the unacceptable areas are, the remaining areas should be classified into classes of high and low priority for being used as waste disposal areas (Soto, 2001).

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

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Geographic location

Ambo area is known for its different natural resources including the abundant resources and attractive scenery. Its perennial rivers including huluka (which is originated in dandi destrict at a place called danbal), taltale, boji,burka-tiko (chopho) etc. are of crucial importance. The geographical location of ambo town is between$8^0$36'30'' N-$8^0$59'30'' N latitude and between 37^{0}47'30''E-37^{0}55'15''E longitude and an elevation of 2101 meters. . It is located in the western shoa zone of the oromiya regional state. Relatively ambo town is located 114kms faraway west of Ethiopian capital city (addis abeba), 60kms north west of weliso town and 12kms east of guder town.

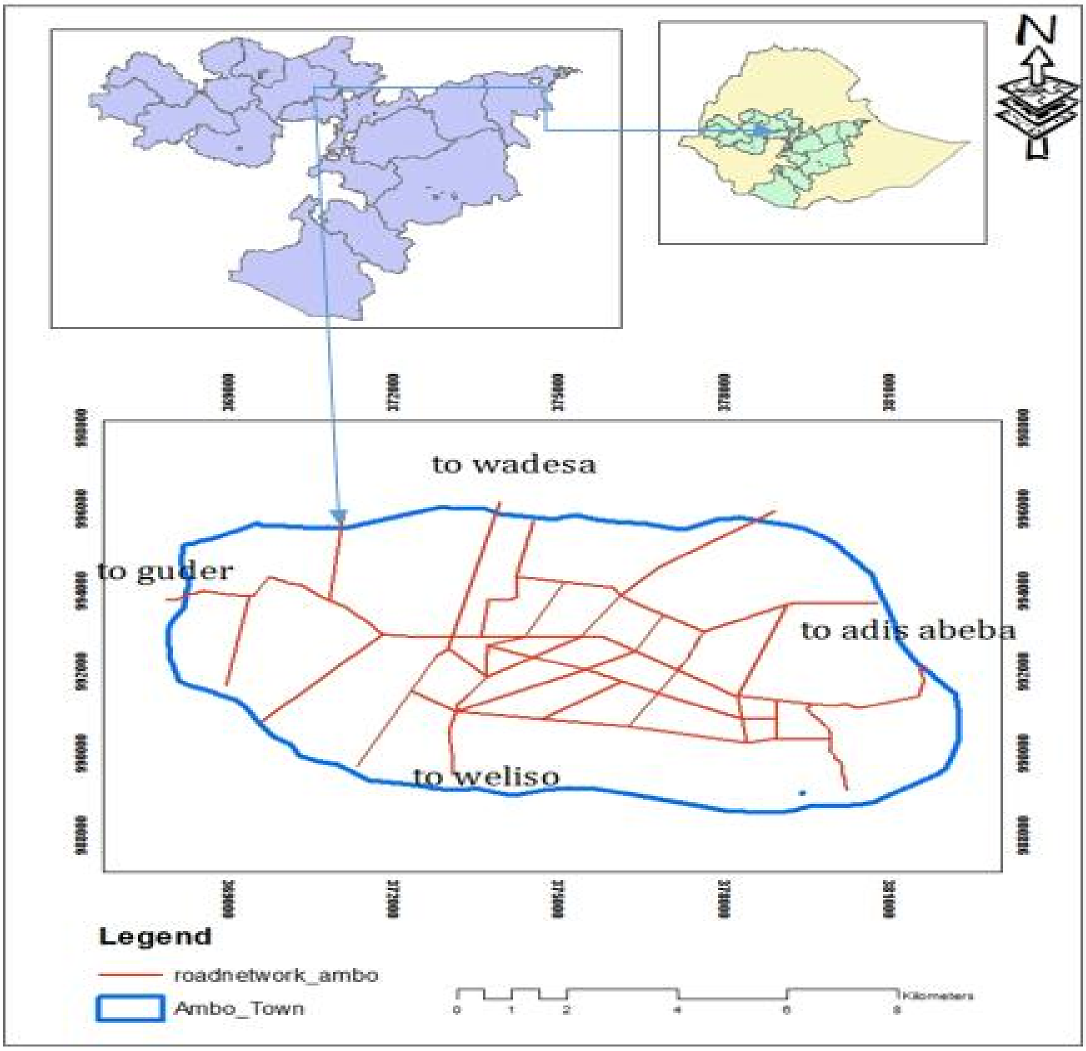

Fig 3.1: Location map of the study area, 2017

3.1.2. Climate

The study area is mainly arid and semi-arid with hot temperature for most of the year. The climate of Ambo town is characterized by four distinct seasons. The main wet season extends from June to August, short rainy season locally known as tsedey extends from September to November, Dry season locally known as bega extends from December to February and a little rainy season locally known as belg extends from March to May. Generally, according to the traditional climate zone classification Ambo town is grouped under Woina dega climatic zone. According to the meteorological data, the mean monthly temperature of the town for the last 30 years (1981-2010) is about 18.64^0c and the mean monthly rain fall is about 968.9mm. As the data shows December and January are driest months while July, August and September are the wettest months. The highest concentration occurs from June to September.

3.1.3. Topography

Topography shows the patterns of land features of the area. Most of the existing built up areas of the town are almost gentle slope and undulated while some hill slope and mountain are also seen in the town. For example, along the course of the rivers and streams, steep slope and gullies are also observed. Most of the proposed expansion areas are characterized by flat, gentle slopes and undulated plains towards Awaro and lamu Muja in the eastern direction, Odo Liban Kisose in the Northern and Gosu Kora in the southern. But some of the slopes in the Sankale Farisi in Western direction have higher slopes and also has human induced barriers such as Ambo Mineral Water Factory, Sankale Police Training Centre and Sankale GypsumFactory (Ambo Town Administration Office, 2013). The topography of Ambo town is characterized by plain surface with an elevation ranging from 1872 m to 2362m amsl. Ambo town has an elongated shape that extends from west to east. Elevation is the criteria that show topography of the area. The elevation of Ambo town in this study was generated from DEM of the town, using Spatial Analyst tool of Surface extension.

3.1.4. Socio-economic characteristics

I. Population: Over the past few years the human population of Ambo town has been growing rapidly. According to CSA, 2007, the total population of the town was 50,267 with the growth rate of 2.5%.

The current population size of Ambo town is expected to reach more than 100,000 by 2020 with an average growth rate of 5%. The poor quality of housing and inability of the administration to increase supply could be taken as key indicators that a wide reform is necessary for Ambo town.

II. Economic Characteristics: Economically most of the residents in Ambo town are engaged in trade activities and as employees of industries and government office. Agriculture and handcrafting are also economic sources for some residents. Ambo town is accessible with different infrastructures like road, water and electricity supply, education, bank, health services and telephone services. Transportation service in the town is highly accessible for neighboring towns. The major road networks connect to with Addis Ababa city and the eastern wollega zone passing through it and in North West direction road connect to weliso town.

3.2. Sources of Data

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

3.2.1. Primary Data

Ground control points were used in this study. During field survey points to identify public facilities like schools and health centers as well as protected areas like churches and mosques were collected using GPS. In addition some sample points from different land use/ cover types were also collected to update the current land use/ cover type of the study area. Field observations were also used to show the existing waste disposal site. The primary data types are used to show the character of study area. Interviews with experts of environmental protection officers and residents who are near to the existing were waste disposal made to get more information. The results from interviews were used to identify the problem of existing waste disposal in the study area.

3.2.2. Secondary Data

Different factor and constraint maps that help to select suitable waste disposal site were used. These includes: road network, soil, settlement and DEM also helped to derive the slope, elevation ,stream, and geology of the study area which are very important for further analysis to select suitable site.

Table 3.1. Summary of data and Data Source

Data types	**Description**	**Data source**
Boundary town	Structural plan of Ambo 2010	Ambo municipality
Land use land cover types	Landsat OLI imagery 2016, pixel 30mx30m Resolution	Ethiopia mapping agency
Geology layer	Geology map, scale 1:250,000	Ethiopia geologic survey
Soil layer	Soil map, scale 1:250,000	Ministry of agriculture
Slope, stream and elevation	Aster DEM 30mx30m resolution	Ethiopia mapping agency
Road network and settlement	Topographic map, scale 1:250,000	Ethiopia mapping agency
Bore hole and protected area	Collected by GPS	Ambo municipality

3.3 .Methods

There are different methods of GIS operation for suitability analysis; such as digitizing, spatial analysis, buffering, weight overlay and AHP were the major ones used in this study to select suitable waste disposal sites.

3.3.1. Digitizing

This function of GIS converts the base map of the area into digital map to use in GIS environment. This is done by using on- screen digitizing by encoding the spatial coordinates of the features on the map. It was used to digitize boundaries town, Roadnetwork, and settlement that exist in the study area from the structural plan.

3.3.2. Buffering

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

3.3.3. Weight Overlay

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

3.3.4. Assigning Criteria Weights

One of the components of GIS-Based MCE methodology is assigning criteria weights for each factor maps. The purpose of weighting in waste disposal site selection process is to express the importance or preference of each factor relative to other factor effect on dumping siting. A number of criterion-weighting procedures based on the judgments of decision makers have been proposed in the multi-criteria decision literature. The procedures include ranking, rating, pair-wise comparison, and trade-off analysis.

They differ in terms of their accuracy, degree of easiness to use and understanding on the part of the decision makers, and in the theoretical foundation (Hasan et al.2009). Accordingly, one of the most promising is pair-wise comparison developed in context of a decision making process is known as the AHP. In MCE using a weighted linear combination, it is necessary that the weights sum to 1. Accordingly, in IDRISI, the weight module utilizes the pair-wise comparison technique to help develop a set of factor weights that will sum to 1.0 (Table 4-11). In AHP, weight can be derived by taking the principal eigenvector of a square reciprocal matrix of pair-wise comparisons between the criteria.

The comparisons concern the relative importance of the two criteria involved at a time, in determining suitability for the stated objective. Accordingly, all possible combinations of two factors were compared based on expert judgment to prepare a pair-wise comparison matrix from which the module calculates a set of weights and consistency ratio. This ratio is very import as it shows any inconsistencies that may have arisen during the pair-wise comparison process.

3.3.5. Aggregating the Criteria Weights and Standardized Factor Maps

The distinguishing feature of GIS is its capacity for integration and spatial analysis of multisource datasets. The data are manipulated and analyzed to obtain information useful for a particular application such as suitability analysis. Waste disposal site selection by GIS is a MCE, which involves aggregation of factors in a systematic way. Once the factor maps are prepared, the last step in suitability analysis is to evaluate the criterion so as to combine the information from the various factors. The present study employs, MCE method to combine all the fact maps considered for site selection. Among MCE procedures WLC is flexible, easy to use and frequently for factors aggregation (Malczewski, 2006).

3.4. Material used (hardware and software)

The materials used in this study for data analysis include computer hardware and software. The hardware used in this study includes PC, color printer, scanner, Sony trace digital camera and GPS. The software for preparing and analysis of the data include MS word 2013 for editing purpose, MS excel 2013 to store attribute information collected during field survey, Arc GIS 10.3 for digitizing, buffering, overlaying, intersect, data analysis including spatial analysis and suitability model, ERDAS imagine 2014 was used for georeferencing and to weigh each class of criteria were derived in IDRISI3.2 software using AHP methods.

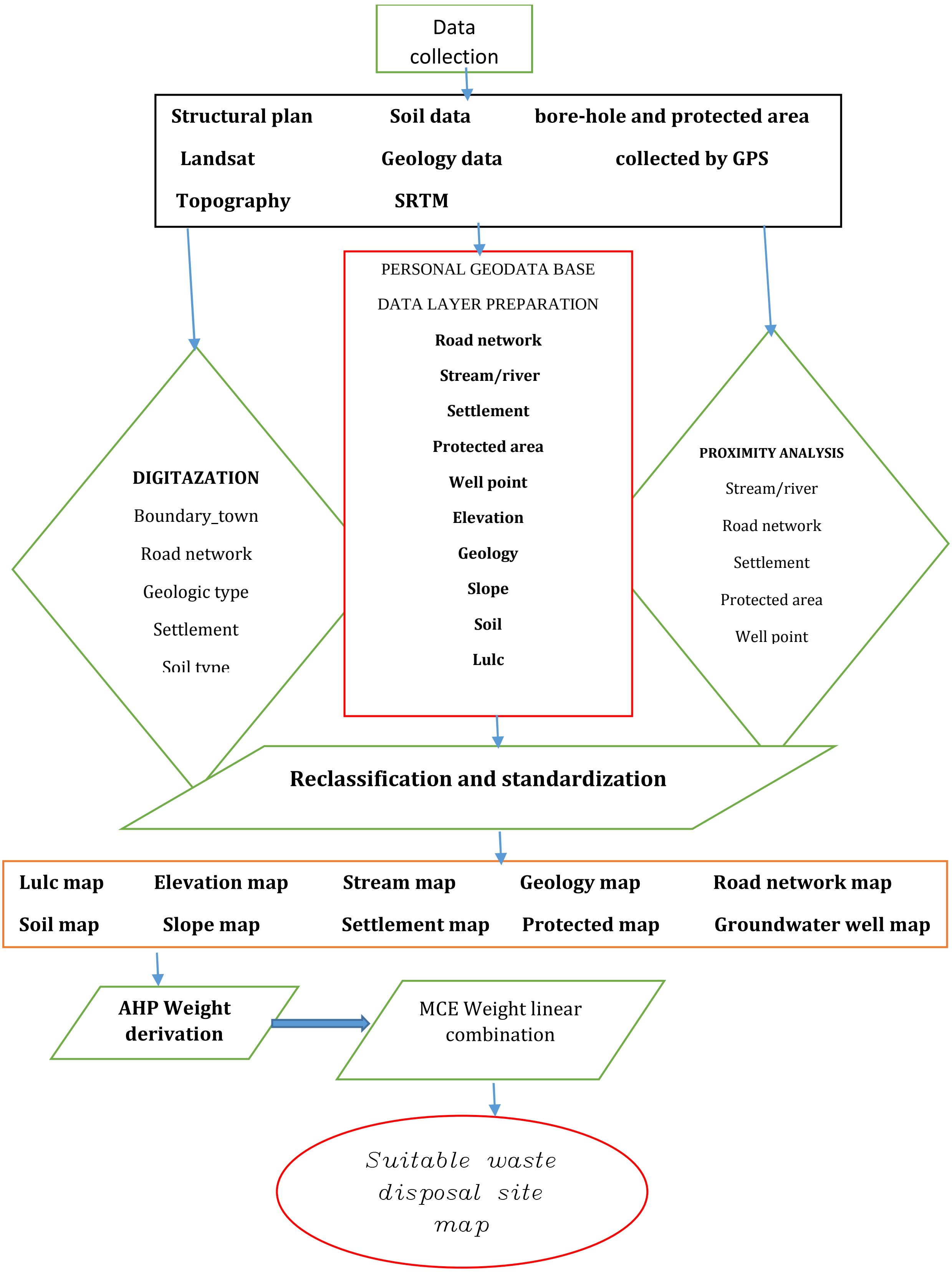

Fig 3.2: Technological Scheme of solid waste disposal site selection

4. DATA ANALYSIS, RESULT AND DISCUSSION

This part discusses the analysis and presentation of different data sets that were used to select suitable solid waste disposal sites. In this study, suitable sites were determined by using the GIS capability and weighting product of AHP method. Waste disposal must be situated and designed so as to meet the necessary conditions for preventing pollution of the groundwater and other resources. Similarly, site should be kept as far away as possible from population density, for reducing impact on public health. On the other hand, the site should be placed not much far from existing roads for saving road development, transportation, and collection costs. Furthermore, difficult or steep terrains are not appropriate for hosting waste disposal.

For this study ten (10) suitability criteria includes: distance from settlement, protected areas, roads network, Groundwater well, stream/river, soil type, geology, elevation, urban land use type and slope were used based on the relevant Ethiopian Environmental Protection Regulations, in addition to international practices that account for environmental, economic and social factors. Maps were created for each suitability criterion and the final composite map was finally produced by simple overlaying of the individual maps. The layers, buffering zones used, rankings and weights were summarized using tables. The weights were assessed by taking into account the possibility of modifying the natural conditions of the sites so as to increase their suitability**.**

4.1. Solid Waste Management System in Ambo Town

The first objective of the thesis was to assess the present waste management strategies in Ambo town. This objective was achieved through field observation and interview with experts of Environmental Protection department of Ambo town. The result showed that the municipal of the town together with the land administration office selected and prepared the existing open dumping site not based on the criteria of distance from river, well point, road, settlement and protected area of the town. According to the observation and interview, the existing solid waste disposal system is not satisfactory, because the existing site does not consider major environmental and health factors, like distance from water bodies, agricultural fields and settlement.

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

a) Illegal Solid Waste Disposals along road, house and fence from field survey

4.2. Suitable site screening and identification of each criterion

The first step waste disposal sitting process is identifying site requirements or criteria. Since the main objective of this study is selecting suitable site, criteria used should minimize surrounding environmental, economic and social impacts.

4.2.1. Slope Factor

Slope refers to the slants of downward or upward of ground. In other words, the slope classification of Ambo town is largely dominated by terrain with flat to undulating and steep slopes. Slope is an important factor in suitability site selection process because it governs the amount of surface runoff produced the precipitation rate and displacement velocity of water to the potential site in addition to the construction cost. It means that when the slope is gentle it decrease the construction cost as compared to the sharp slope area (Tsegaye, 2006).

As described in the above section, slope is one of the key criteria to be considered in waste disposal site selection. This is because site topography can reduce or increase adverse effects on the environment (Centre for Advanced Engineering, 2000). Moreover, steep slope is either not best option for solid disposal because of the difficulty posed in construction or leveling, which incur additional cost. Moreover, high topography areas reduces the stability of the side slopes (increased risk of landslides) and increase leachate movement. Therefore, the best slope for solid waste disposal should be modest slopes, which enable easier storm water control, leachate control and site stability measures, as well as facilitating the operation of the site. Different researchers set different slope criteria for waste disposal site selection.

For example, Hasan et al. (2009) set areas with slope <15-20% as the best site for waste disposal, while Change et al. (2007) describe slope <12% as the best site and slope >12% unsuitable for landfill. Moreover, Ersoy and Bulul (2009) state that areas with slope<20% is optimum site for waste disposal. According to Tirusew et al., (2013); the type of slope for waste disposal site should be gently, less than 10%.

In this study, slope of the study area was generated from DEM using Arc-GIS spatial analyst extension of surface tool. This study considered the lower slope more highly suitable than the land with higher slope. As the slope becomes steeper the area should be considered as least suitable. Areas with high slopes will have high risk of pollution and potentially not a good site for disposal.

Table 4.1: weight assignment for different range of slope in Suitability level

Slope Class	**Level of Suitability**	**Relative weight**	**Area (km²)**	**% of total area**
<10%	More suitable	4	61.91	78
10-13%	Suitable	3	10.23	13
13- 16%	Less Suitable	2	5.67	6
>16%	Unsuitable	1	2	3
Total			79.29	100

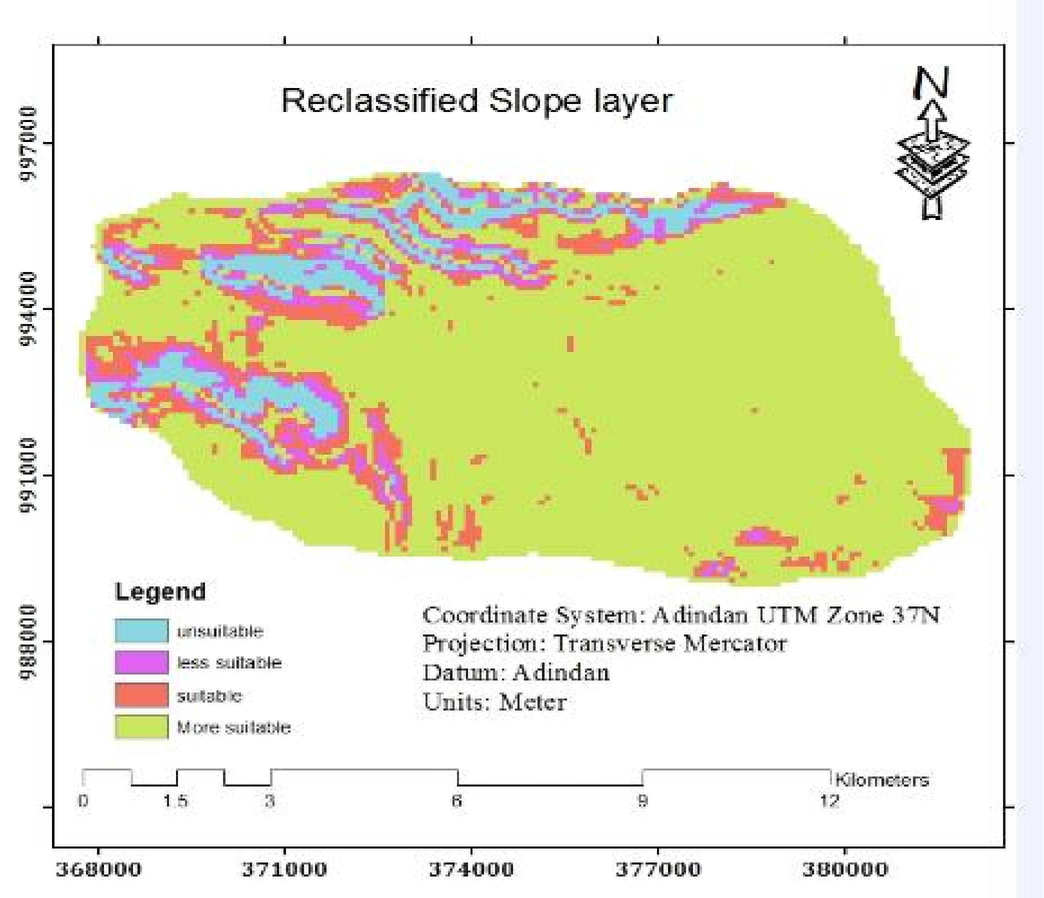

Fig 4.1: Reclassified Slope layer generated new pixel value estimated relative weight

The reclassified slope was ranked from 1 to 4, as 4 is highly suitable and 1 is for unsuitable for site selection. The majority of the study area falls under the slope class of 0-10%, covering 78.36% of the total study area, which is more suitable for solid waste disposal.

Whereas 12.69%, 6.42% and 2.53% of the study area was covered by slope classes 10-13, 13-16 and >16% respectively. This means that the town is more or less flat in its topography.

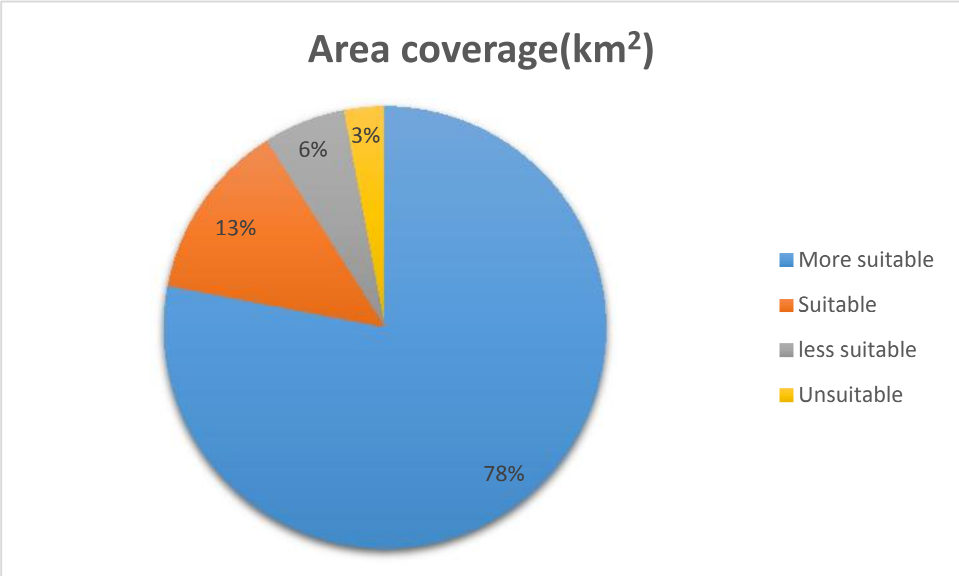

Fig 4.2: Spatial coverage of relative slope range computed from reclassified slope layer

4.2.2. Proximity from road

Proximity from roads is one of the criteria that should be considered from economic and social Point of views during solid waste disposal site selection processes. Because siting waste disposal very close to roads may have public health problem as disposal pose hazardous effect to health. Moreover, waste disposal site very far from road network is also not recommended due to high transportation cost. Therefore, to minimize such problems, it must not be sited very close to and far from roads. Minimum and maximum distance from road network of the study area was set after summarizing different literatures. MUDC,2012 set 400m buffer, Chang et al. (2007) set 100m buffer while Hasan et al. (2009) uses 100-300m buffer from road as a minimum distance within which landfill should not be located. However, 300m buffer distance is mentioned as the safest distance (Map Asia, 2004;Zain, 2009; Yahaya, 2010; Ersoy and Bulut, 2009; EPA, 1995).

According to the ministry of urban development and construction 2012, the waste disposal shall not be located within 400 meter of any major highways, city streets or other transportation routes. For this work, areas within 400-2000m away from roads were analyzed as best site for waste disposal.

Therefore, Multiple Ring Buffer tools were used to create buffer classes around the roads with 0-400m, 400-1000m, 1000-1500m,1500-2000m and >2000m distance ranges. Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation In this study existing roads were digitized from structural plan 2010, of the town, which was accessed from Ambo Municipality.

Table 4.2: Weight assignment for proximity road of Suitability class

Distance from Road(m)	**Level of Suitability**	**Relative weight**	**Area (ha)**	**% of total area**
>1500	More suitable	4	8.23	11
800- 1500	Suitable	3	13.84	19
400-800	Less suitable	2	27.15	37
0-400	Unsuitable	1	25.01	33
Total			74.19	100

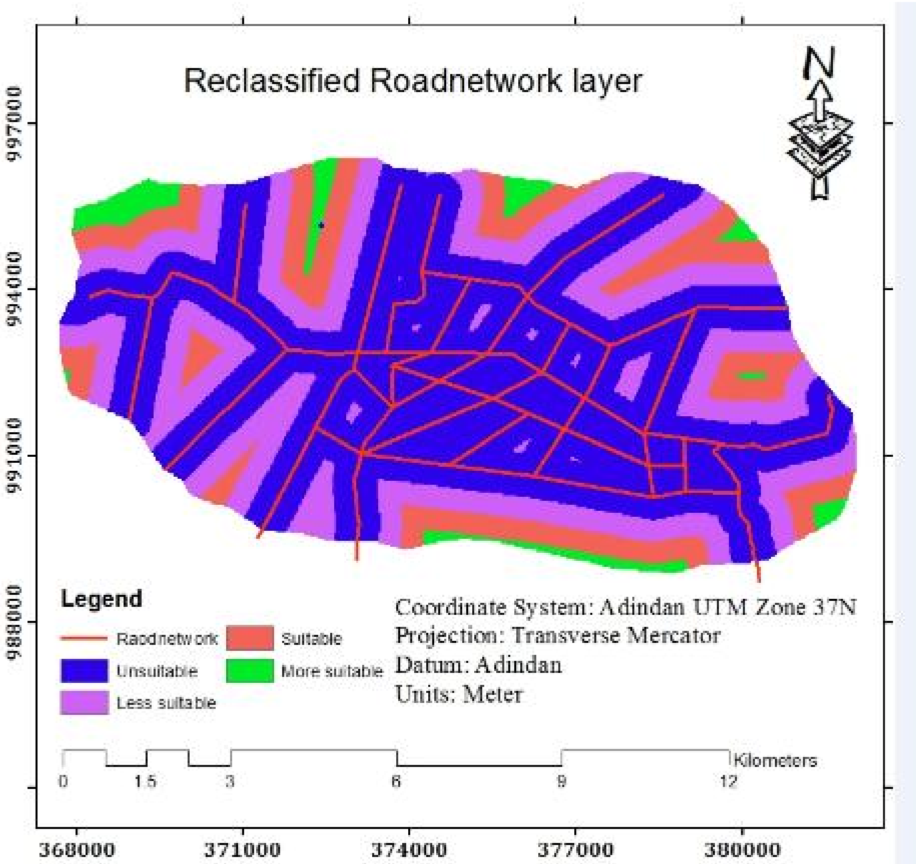

Fig 4.3: Reclassified Road Suitability layer of the study area

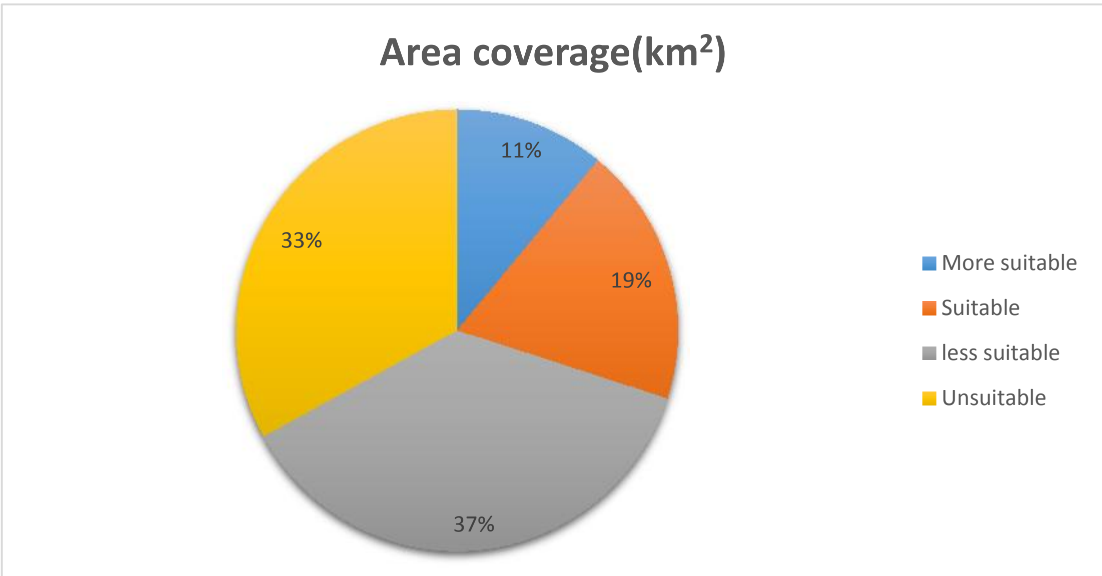

Fig 4.4: Spatial coverage of relative road range computed from reclassified road layer

4.2.3. Surface Water

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

Table 4.3: Weight assign proximity of Stream/river suitability class

Distance from Stream(m)	**Level of Suitability**	**Relative weight**	**Area (km^2)**	**% of total area**
>1500	More suitable	4	5.04	6
1000m- 1500	Suitable	3	12.48	15
500m- 1000	Less suitable	2	25.05	31
<500	Unsuitable	1	39.69	48
Total			82.17	100

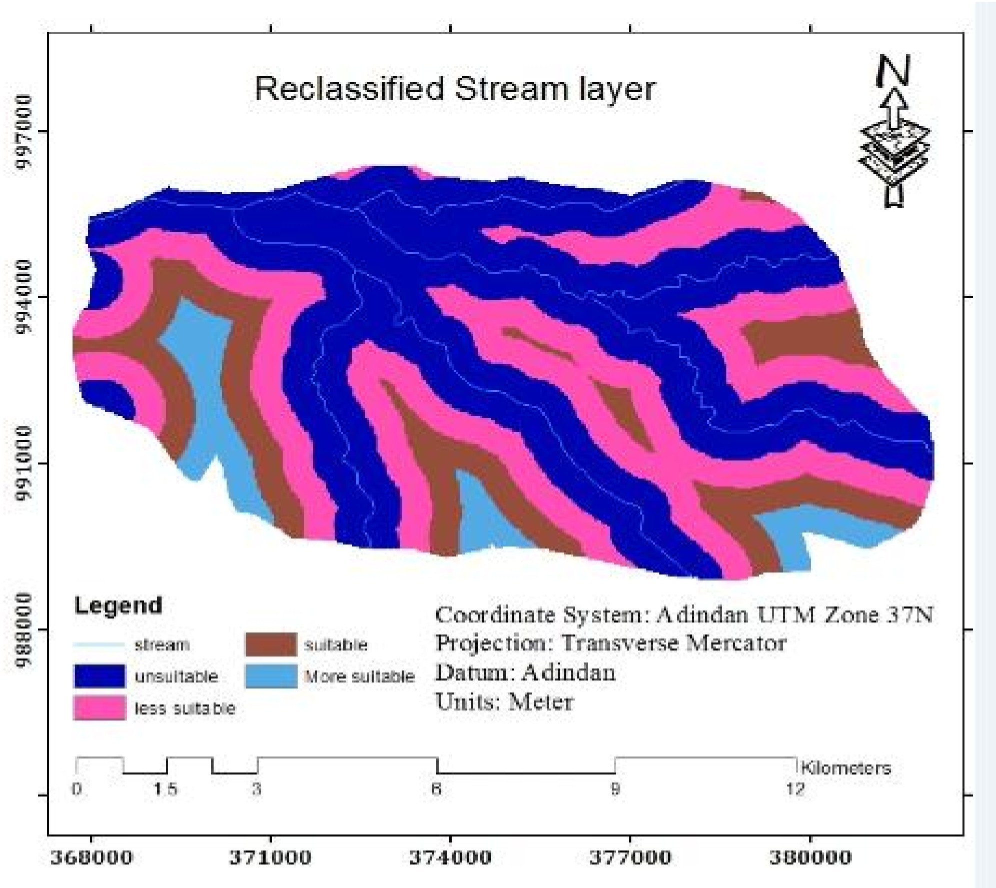

Fig 4.5: Reclassified Steam layer of the study area

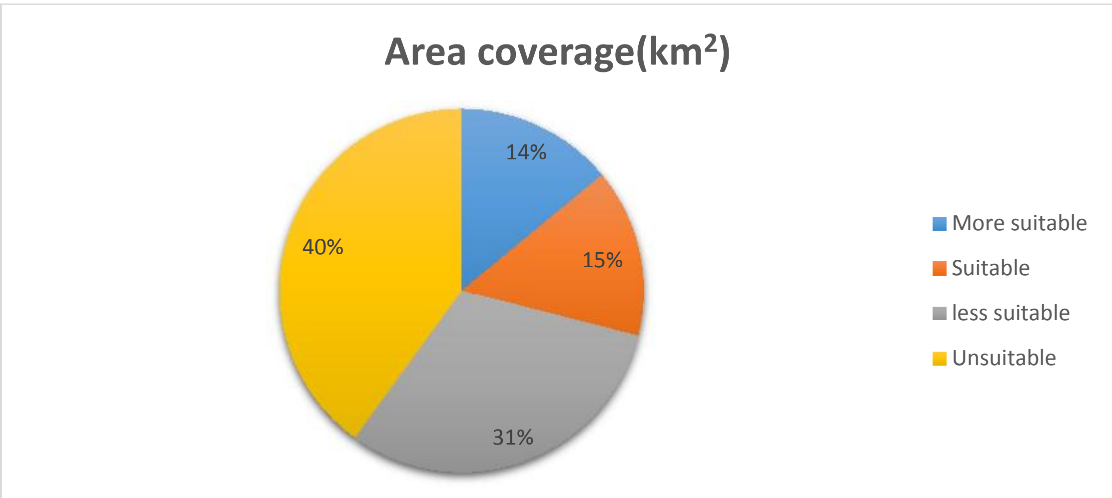

Fig 4.6: Spatial coverage of relative range computed from reclassified stream layer

4.2.4. Soil criterion characteristics

The five soil forming factors namely climate (temperature and rainfall), topography, parent material, biological activities (flora and fauna) and time determine the types of soil that are formed at a particular area. As a result, soil can vary from place to place.

The difference in the nature of soil results in the difference in water infiltration and holding capacity. The permeability and porosity of a given soil control the vertical as well as horizontal movement of contamination (Tsegaye, 2006). According to soil classification of MOA, three type of soil that exists in Ambo town is eutric Fluvisols, Pellic vertisols and haplic Leptosols. Pellic vertisols the dominant exists of major soil in Ambo town. Soil formation of the study area is directly related with weathering of the parent materials or rocks that exist in the area. The nature of the soil is varying from area to area in depth and content. The permeability and infiltration of each soil depends on its textural composition. The soil classes in the study area with different characteristics as follow.

1. Eutric Fluvisols

The reference soil group of the Fluvisols accommodates genetically young, a zonal soils in alluvial deposits. The name Fluvisols is a misleading in the sense that these soils are not confined to river sediments (Fluvius means ' river') but occur also in lacustrine and marine deposits. It is a soil having a thickness of 25cm or more and fluvic soil material starting with in 50cm from the soil surface. It contains sand and clay with high porosity in nature. The permeability of eutric Fluvisols is moderate as its texture is generally characterized as moderately fine size textured as and with relatively less clay content than Vertisols (GSE, 2011).

2. Pellic Vertisols

They are important agricultural soils. They have high clay content and consequently a high moisture storage capacity. The PH is slightly acidic to neutral. These soils have high yield potential, but require proper fertility management. Vertisols are naturally fertile soils, but poor drainage and difficult workability because of limited nutrient availability. The most important characteristic of Vertisols is their high water holding capacity, a consequence of the deep profile and high content of clay. Because of its low porosity in nature it is very important to located waste disposal with a thickness of more than 109 cm and it is characterized by fine textured soil with >60% clay in composition. As a result, the porosity of such soil is very fine making the movement of material difficult within the soil (GSE, 2011).

3. **Haplic Leptosols**

Haplic Leptosols in the FAO world reference base for soil resources is a very shallow soil over hard rock or highly calcareous materials or a deeper soil that is extremely gravelly or stony. It is very shallow, less than 10 cm deep (GSE, 2011). This type of soil is found in the western part of the study area. From its characteristics, this type of soil is not suitable for location of waste disposal due to its shallow depth underlined by hard rock and with less developed soil.

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

This is due to availability of lining material and permeability depends on depth and texture soil, respectively. Clay textured soil is more preferred for dumping site as it is impermeable to leachate and also used for lining the base of sanitary design. Moreover, area with deep soil is preferred as it provides soil for covering solid waste after each disposal to minimize air pollution from the site. In this study, Pellic Vertisols identified as highly suitable soil for waste disposal due to its clay dominated (60%) and very deep soil (Gizachew, 2011). Haplic Leptosols were identified as unsuitable soil types due to coarser texture and shallow soil depth (Gizachew, 2011). The other soil type of the study area fall in between these extremities due to moderate depth and fine texture (GSE, 2011).

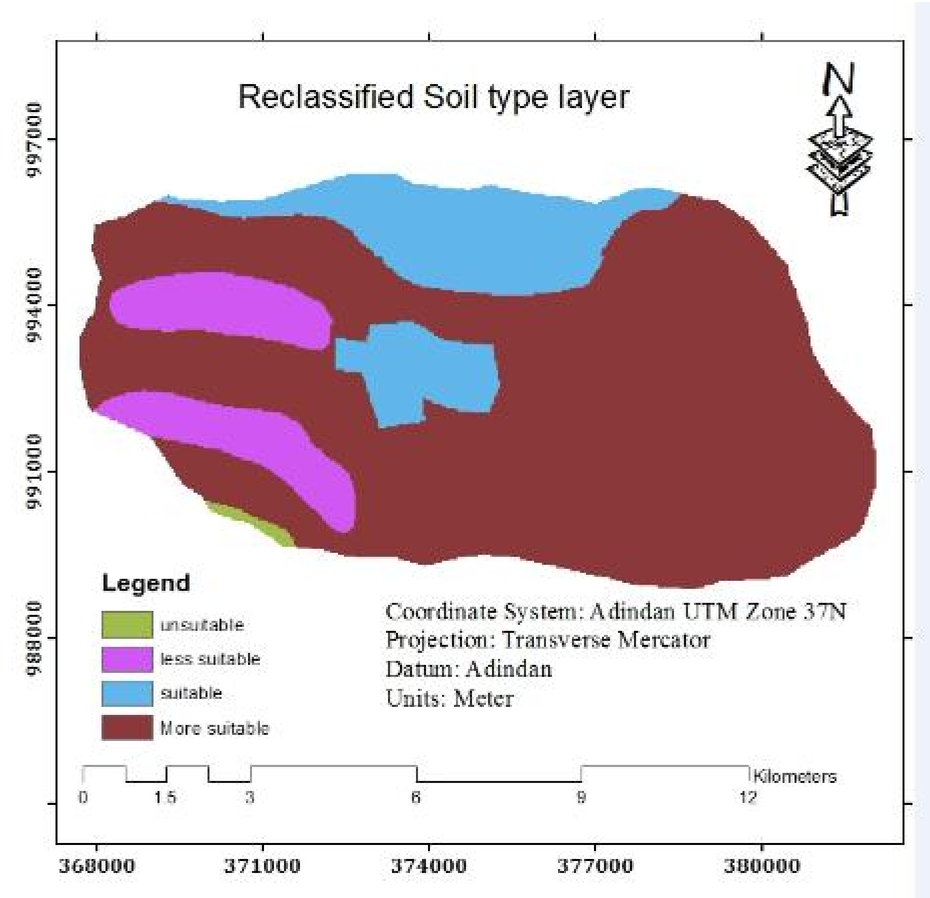

Fig 4.7: Reclassified Soil types layer of the study area

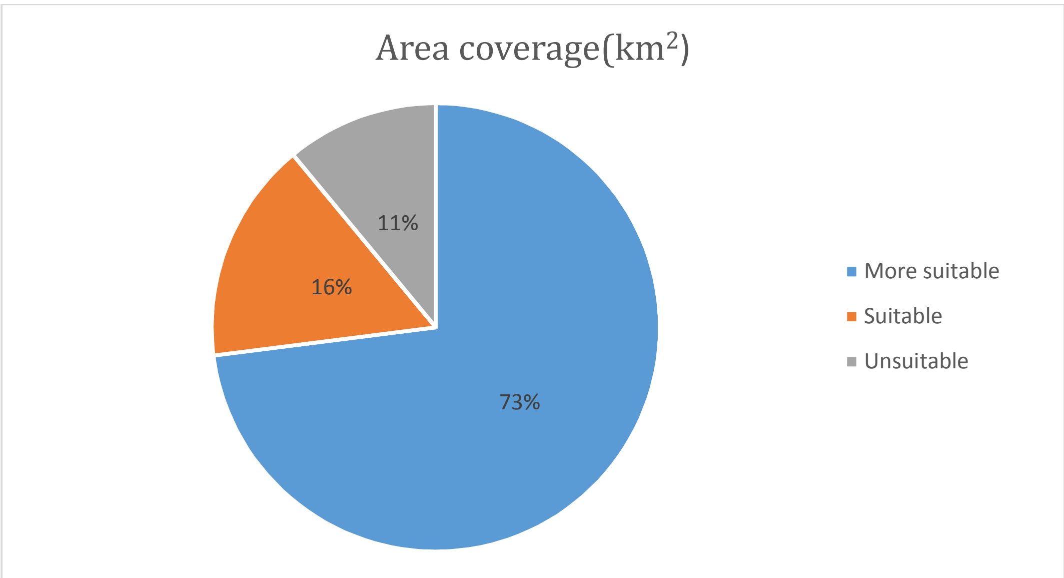

Fig 4.8: Spatial coverage of relative soil range computed from reclassified soil layer

As shown in Fig 4.7, most part of the study area is safe for waste disposal sitting due to low permeability. But for high permeability area, lining the base of waste disposal will be required to protect ground water from leachate contamination. From the above soil map of the study area the next map is produced based on the criteria given by the municipality that states the site must be on a suitable soil with 104 cm depth and cannot be easily penetrate by water. Accordingly, about 73 % of the total area is more suitable, 16% suitable and 11 % Unsuitable for dumping site.

Table 4.4: Weight assign for Soil criterion of suitability class

Soil Type	**Suitability class**	**Area cover(km^2)**	**%of total area**	**Relative weight**
Pellic Vertisols	More Suitable	61.93	73	4
Eutric Fluvisols	Suitable	13.51	16	3
Haplic Leptosols	Unsuitable	8.36	11	1
total		83.80	100	

4.2.5. Distance from Protected Area

The protected area in this study includes the Ambo churches, mosques, schools, industry, administrational zone and health centers. The waste disposal should not be located in close proximity to sensitive areas listed above to a minimum limit of 1,000 meter buffering surrounding. When the distance increases from these areas suitability also increases. In this study the X, Y coordinates for the above listed protected areas were gathered using GPS during the field survey and buffering using the standards of MUDC, 2012, to locate suitable site. Accordingly, four different zones were specified; in which far buffering from protected areas are more suitable while near are less suitable for waste disposal sitting. The study considered the reclassified distance as unsuitable from 0 - 1000meter, less suitable from 1000-1500m, suitable from 1500-2000m and highly suitable above 2000meter.

Table 4.5: Weight assignment of distance from Protected Area in Suitability Class

Distance from protected	Level of Suitability	Relative weight	Area (km^2)	% of total area
>2000	More suitable	4	4.37	6
1500- 2000	Suitable	3	11.63	14
1000m- 1500	Less suitable	2	18.77	23
<1000	Unsuitable	1	47.66	57
Total			82.42	100

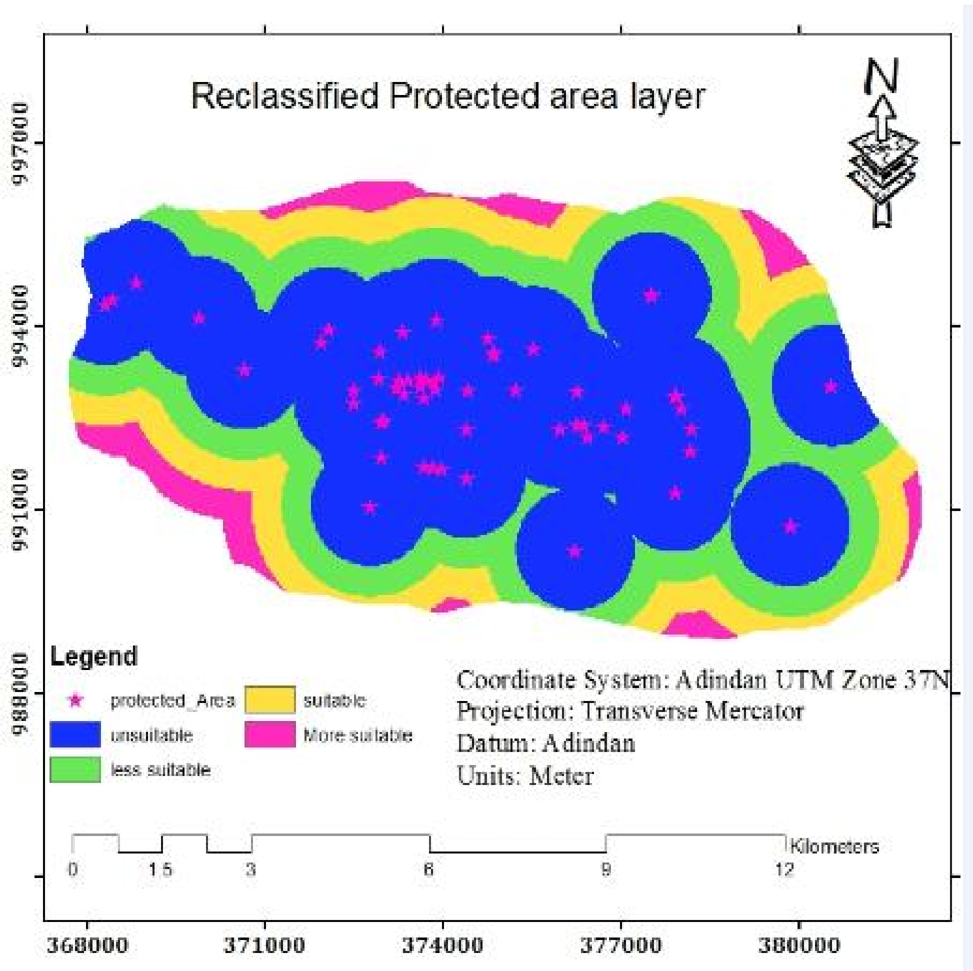

Fig 4.9: Reclassified layer of Protected Area

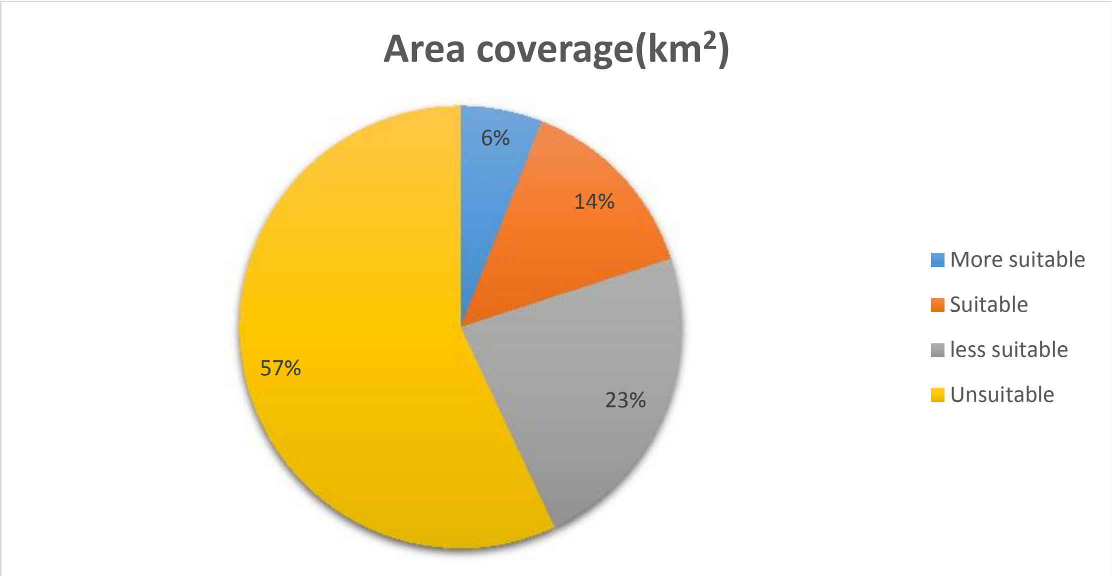

Fig 4.10: Spatial coverage of relative range computed from reclassified protected area layer

4.2.6. Distance from Settlement

The waste disposal sites should not be sited or located near to populated areas. The extent of the residential areas were derived by digitization from structural plan of the town, and distance of 2500 m and above are considered as suitable while 1000m and below were considered unsuitable. Hence the land suitability for waste disposal increases with the increase in distance from the residential areas (MUDC, 2012).

Table 4.6: Weight assign for proximity of Settlement

Distance from Settlement(m)	**Level of Suitability**	**Relative weight**	**Area (km^2)**	**% of total area**
>2000	More suitable	4	7.66	9
1500- 2000	Suitable	3	10.94	14
1000m- 1500	Less suitable	2	19.42	25
<1000	Unsuitable	1	40.68	52
Total			78.68	100

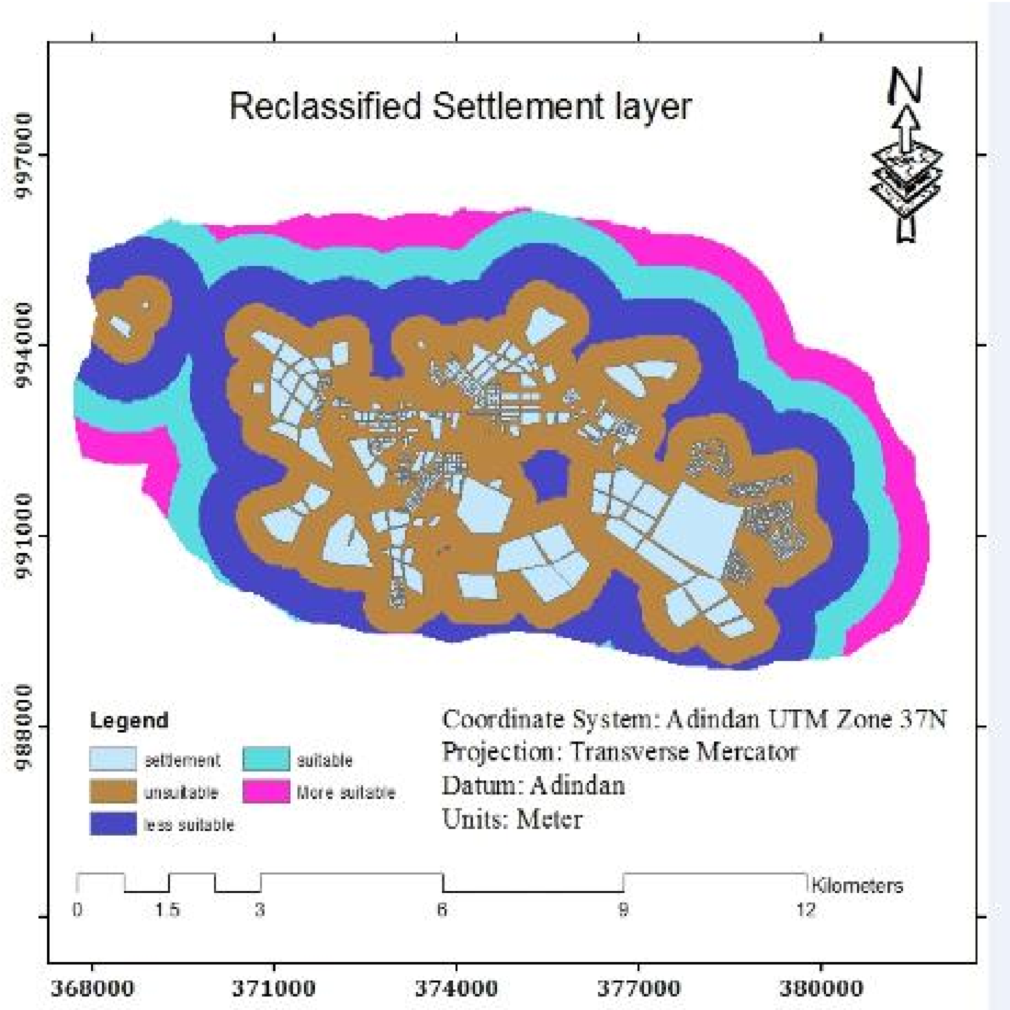

Fig 4-11: Reclassified layer of Settlement

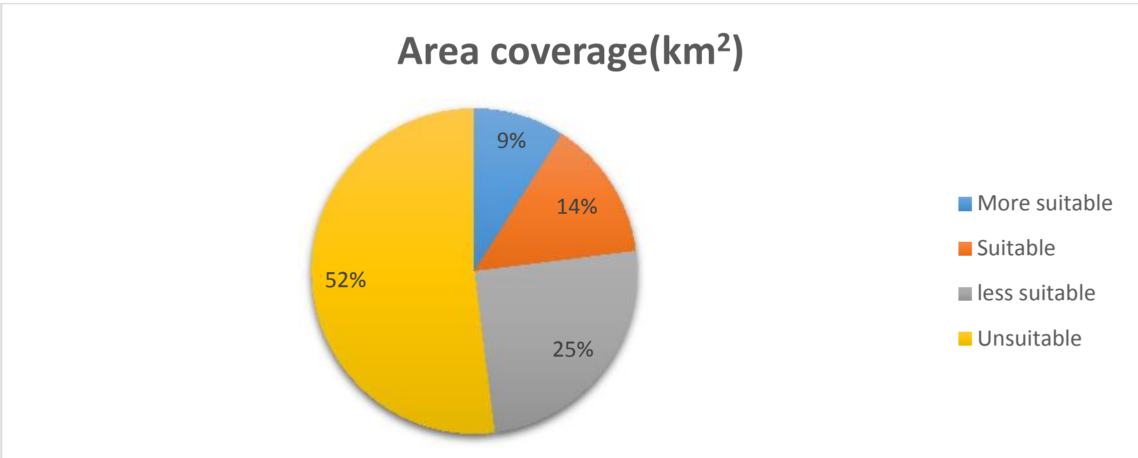

Fig 4.12: Spatial coverage of relative range computed from reclassified settlement layer

4.2.7. Geological Characteristics

It is essential to have an accurate understanding of the local geological setting in order to evaluate suitable waste disposal site and to control the site from contamination.

This will include the type of rocks existing, details of the structure and characteristics of the rocks, composition and distribution of the subsoil, distribution and characteristics of the geology (Basak, 2004).The rationale to study about the geology is to know the solid strata of the study area, which includes the type of rock, the state of weathering, the extent and distribution of structural features such as faults, joints, and bedding planes, the effect of leaches and the permeability of the strata. In addition to the geological information, it is important to know about the subsoil of the strata like its composition, the lateral and vertical continuity of the strata, the permeability, resistance to erosion and the stress of deformation behavior (Gizachew, 2011).When we talk the geology of a given area, it is important to know geologically unstable or unsuitable areas of a given site. Geologically unstable areas are defined as locations where natural or manmade features create a considerable risk to the reliability of the waste disposal located (Tsegaye, 2006).

Generally, geological faults are areas most dangerous site; even though it is difficult to avoid being on or close geological faults. Because as majority of the faults increase the permeability of the bedrocks in the fault zone it would normally not be appropriate to roll out or down grade a site because of the presence of an absolute assurance that a site is geologically suitable. Because fault zones in permeable rocks are usually more significant than in low permeability rocks (Tsegaye, 2006).Geology affects the located waste disposal activity and how it can be suitable. Let's us see the geological condition of the study area and examine how it can be suitable for this project site. The geology of Ambo town and its surroundings has been studied by researchers at the regional scale. In 1970, Levitte studied the geology of Ambo (western part of Ethiopia) and he divided the rocks in the area into three major units: Mesozoic Sedimentary sequence, Nazret pyroclastic and Tarmaber-Megezez Formation of the Ethiopian.

1. Nazreth pyroclastic rocks

It is widespread over all of the study area covering most extensive regional exposure of the northern and western parts of the study area. The upper part of it is characterized by clayish sediment and black soil this corresponds to its low resistivity nature. The thickness of this sediment is more than 700 meters (Geological Survey of Ethiopia, 2011).

It is light to dark-grey in fresh sample and reddish yellow to pink up on weathering. The weathering activity changes the light to dark-grey color to reddish yellow to pink (Geological Survey of Ethiopia, 2011).

2. Mesozoic Sedimentary sequence

It is exposed in the form of unevenly distributed small dome and gently circular to elliptical hills. It has a characteristic color light grey to pink in fresh ample (Efrem, 2010) identified an intercalation of ash and tuff locally.

3. Tarmaber-Megezez formation

This lithological unit crops out in the central, west to east and southern part of the study area. It forms most flat and extensive geomorphology. The constituents of these rocks type are predominantly sand, clay and gravel. Gravel formations are shown in to lower parts of the cross section, the upper part is clay, and sandy predominate. The thickness of the sediments in the region varies from 0-25 meters and their thickness is high in the western part of the town (Geological Survey of Ethiopia, 2011).The geology map of the town was obtained from Geologic Survey of Ethiopia (GSE) in soft copy. The map was geo-referenced and then digitalized in GIS environment to utilize the raw data as information. Accordingly, three (3) different geologic units of the study area were digitized and their thematic map was prepared. The geology type of the town as stated above Nazareth pyroclastic rocks, Mesozoic Sedimentary sequence and Tarmaber-Megezez Formation with the area coverage of 65.73%, 16.16% and 18.11% respectively.

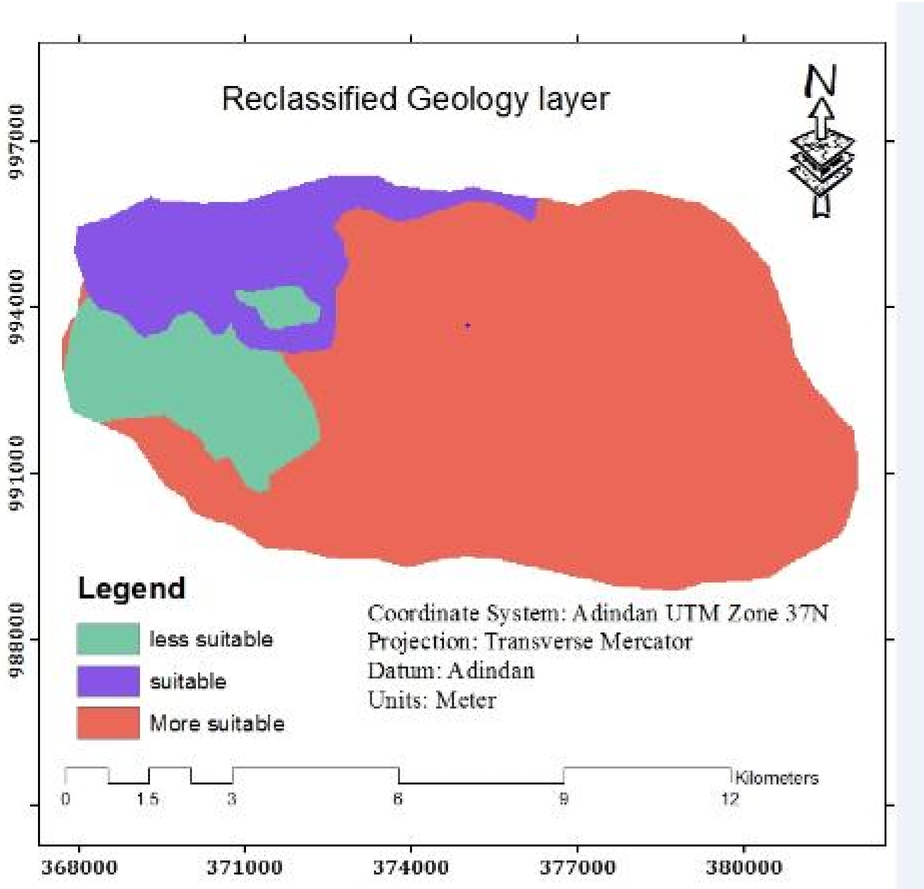

Fig 4.13: Reclassified of Geological layer of the study area

Geology is one of the important environmental factors that should be considered during waste disposal site selection processes. Impermeable strata and consolidated material are suitable for site as they do not allow movement of leachate and hence to minimize the risk of groundwater contamination from disposal leachate (Centre for Advanced Engineering, 2000). For this study, the degree of porosity, thickness of the rocks and the presence of fracture are the factors or criteria to select the suitable rock type. The more weathered and fracture, the more permeable and instable the rocks will be (Tameru et al., 2003). Hence, such formations are not suitable for solid waste disposal sitting; because of the high probability of the underground water to be contaminated. To select the rock type that fulfill this criteria spatial analysis operation of GIS with extraction specifically selection is used. Nazret pyroclastic rock is very suitable for waste disposal site; because it has no porosity in addition to its thickness greater than 700 meters with less transitivity (Geological Survey of Ethiopia, 2011).

Table 4.7: Weight assign for geology type of suitability class

Geology Type	**Suitability class**	**Area cover(ha)**	**Area Cover (%)**	**Relative Weight**
Nazreth pyroclastic rock	More suitable	62.18	74	4
Mesozoic sedimentary	Suitable	12.08	14	3
Tarmaber-megezez	Unsuitable	9.55	12	1
total		83.80	100	

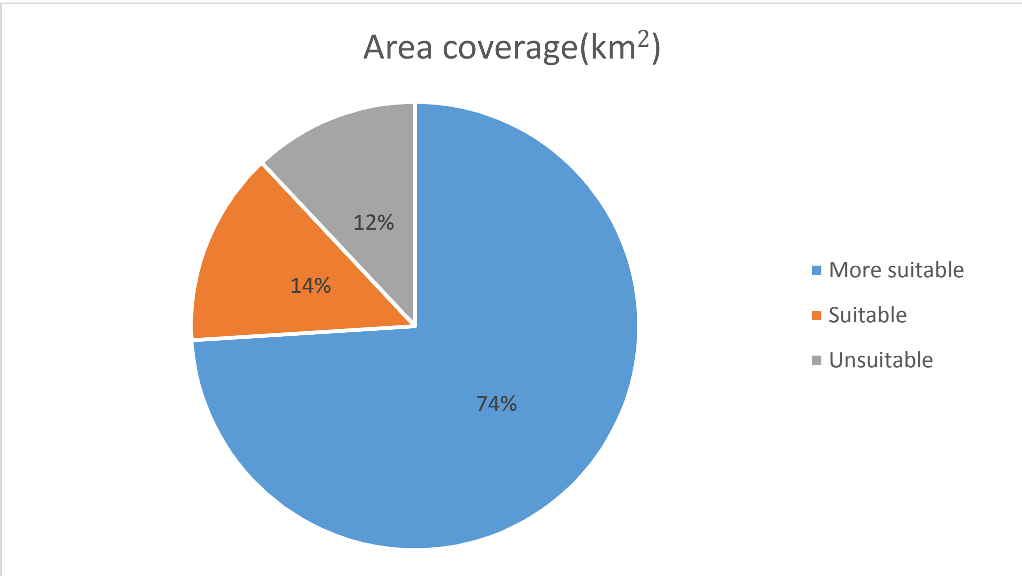

Fig.4.14: Spatial coverage of relative geology range computed from reclassified geology layer

4.2.8. Proximity from Groundwater well

Proximity of waste disposal to a groundwater well is an important environmental criterion in the site selection; so that wells may be protected from the runoff and leaching of the site. Hence, solid waste disposal should be placed away from water wells. Otherwise, it can have irretrievable human and environmental effects. As a result, proximity from groundwater well was considered as an important criterion for this research. Accordingly, 4 ground water well points that are currently functional and other not functional were obtained from Ambo Water and Sewerage Authority (AWSA) and Multiple Ring Buffer tools were used to prepare buffering zones around each well.

Waste disposal should not be sited within 500m buffer distance from water wells. However, Hasan et al. (2009) used 500- 1000m and use700m as a minimum distance which can be safely sited. For this work, 1000m buffer distance was used. Moreover, additional buffering was performed around the wells in order to identify the best site for waste disposal. Buffer distance of 0-1000m, 1000-1500m, 1500-2000, and >2000m were prepared around each and every well points (Fig. 4-15).

Different buffering was used to identify and rank according to their preference. Waste disposal very far from water well will have minimum effect and the vice versa. Generally, the more closely, the more probable for ground water to be contaminated. Areas with >2000m buffer distance were very highly suitable and areas with 0-1000m is the least. Weights were calculated for each class based on the suitability level. More weight was assigned to more suitable areas, and vice versa (Table 4.8).

Table 4.8: Weight assign of proximity of groundwater well

Distance from Well (m)	**Level of Suitability**	**Relative weight**	**Area (km^2)**	**% of total area**
>2000	More suitable	4	11.83	27
1500- 2000	Suitable	3	12.06	28
1000-1500	Less suitable	2	15.13	23
<1000	Unsuitable	1	14.02	22
Total			53.03	100

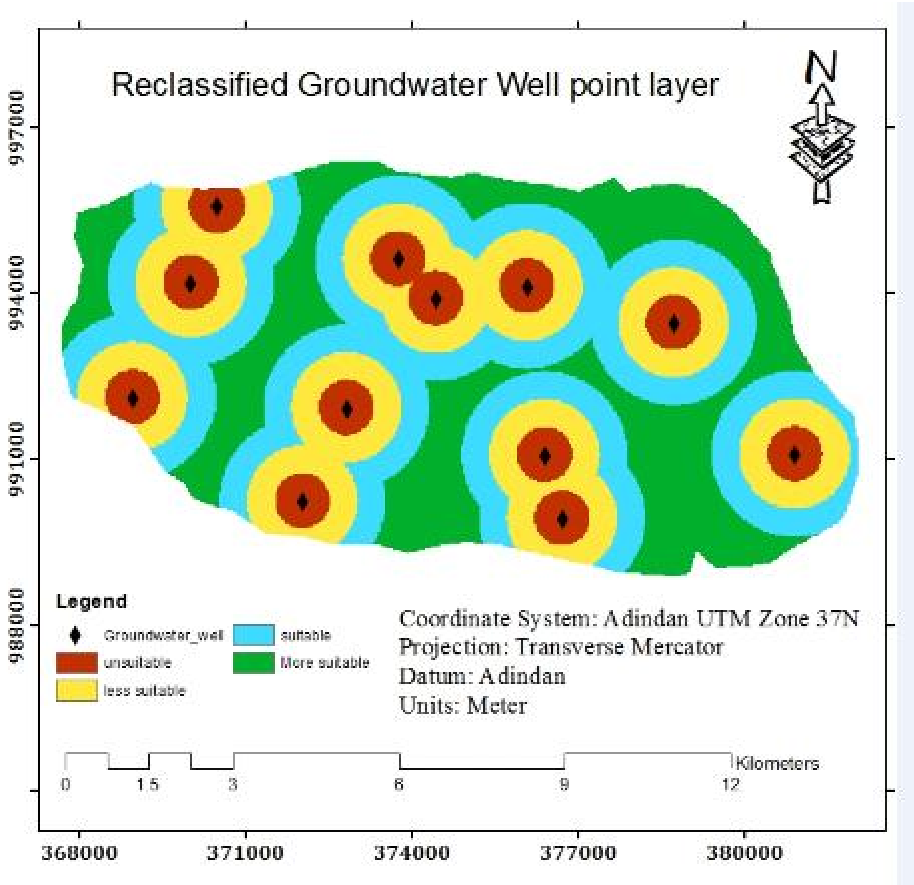

Fig 4.15: Reclassified for groundwater well layer suitability class

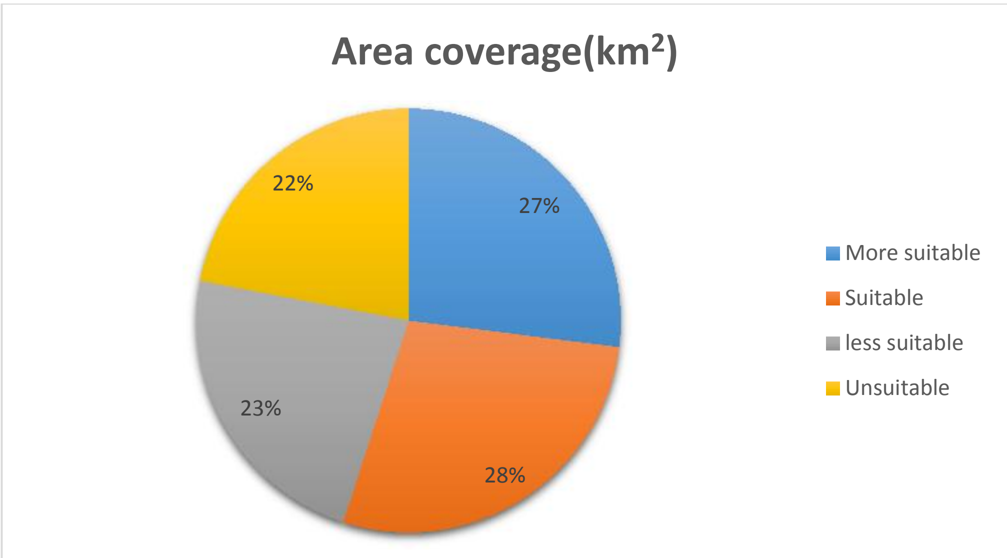

Fig 4.16: Spatial coverage of relative range computed from reclassified groundwater Well layer

4.2.9 Land Use/land cover types

The land cover types of the town was analyzed from Landsat OLI acquired in 2016. The image was georeferenced to a projection of Universal Transverse Mercator, Grid of UTM Z 37N and datum with Adindan. Master plan of Ambo town was also used as auxiliary information during image classification. The image was undertaken under supervised classification with the help of 50ground control points that were collected during the field survey, to update the information. Classified pixels were clustered into six general categories as: built up area, urban agriculture, water bodies, open forest, cover forest and bare/open land (fig. 4.17). Accordingly, the land use types were ranked based on their importance to evaluate suitable site to locate landfills. These are; bare/open land are ranked as highly suitable, urban agriculture as moderately suitable, open/cover forest as less suitable and areas near to water bodies and urban infrastructures(built up) as unsuitable were identified (Table 4.9).

Accordingly, master plan of the study area was used as a guidance to identify representative land cover classes. This was used for solving the problems of identifying features of similar reflectance like green area with forest, open land and agricultural, open land with agricultural land. Finally, supervised classification has been carried out using ERDAS Imagine software from the images of Landsat 2016. Large parts of the study area are covered by built up area and Water bodies and least area cover open forest Land use/land cover of the study area is shown below.

Table 4.9: Weight assign for Land Use in Suitability Classes

Land Use Categories	**Level of Suitability**	**Relative weight**	**Area (km^2)**	**% of total area**
Bare/open land	More suitable	4	41.62	48
Agricultural land	Suitable	3	18.07	21
Open/cover forest	Less suitable	2	10.83	13
Built up ,Water bodies	Unsuitable	1	13.58	18
Total			84.10	100

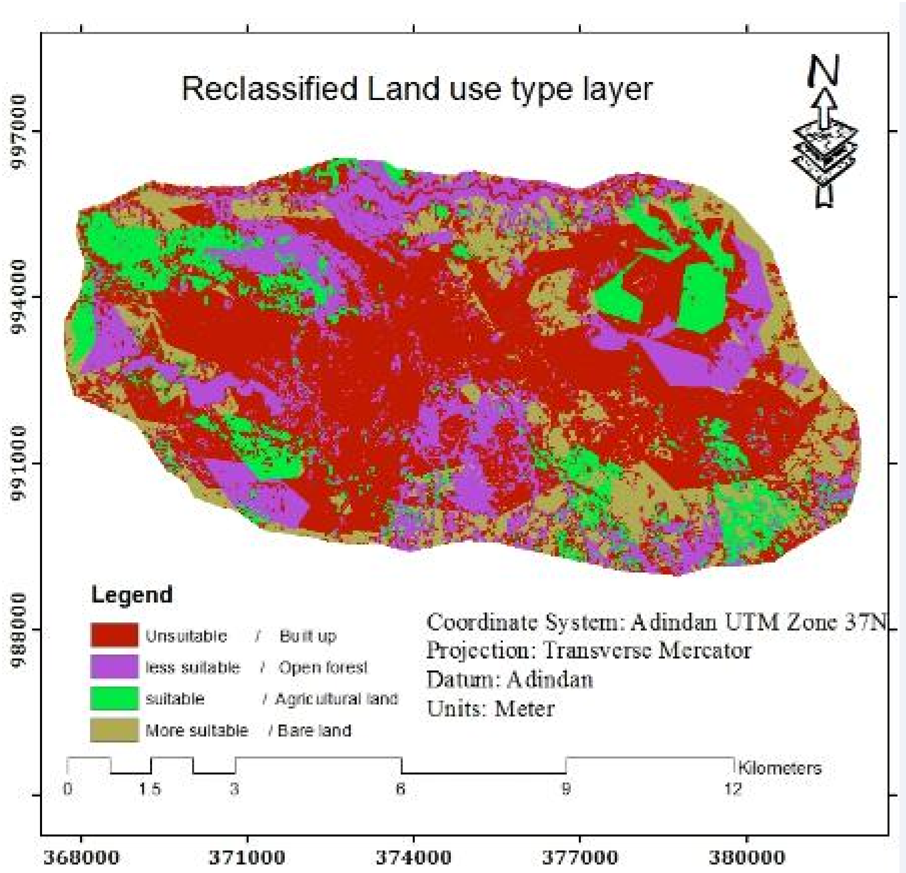

Fig 4.17: Reclassified Land Use types Categories layer of the study area

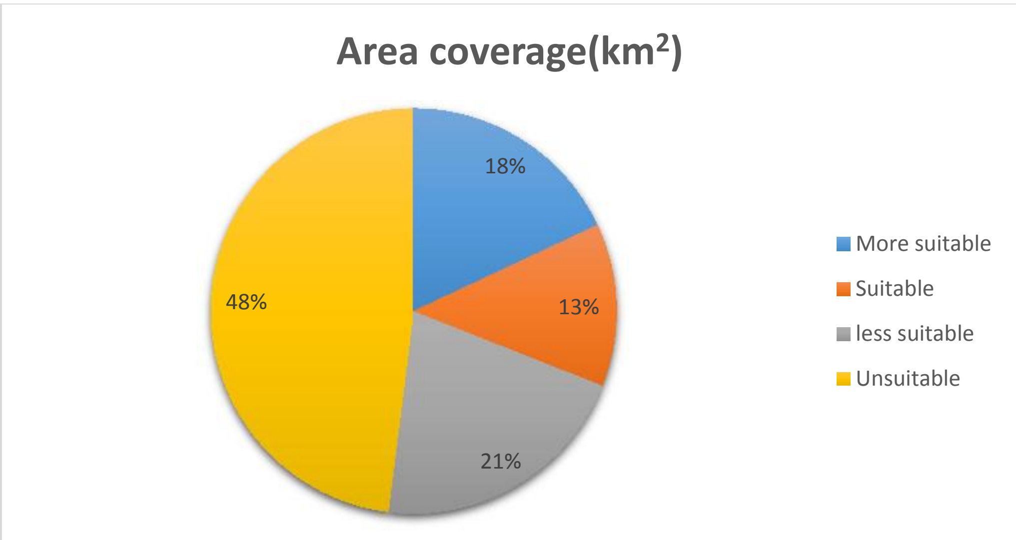

Fig 4.18: Spatial coverage of relative range computed from reclassified land use layer

4.2.10. Elevation factor

Waste disposal site selection tends to at lower topography rather than the higher topography. Higher the elevation less waste disposal site and vice versa (Gedebo, 2005), for the present study elevation data having 30x30 meter spatial resolution has been created based on the ASTER DEM. The study area's elevation ranges between 1872 meters to 2352 meters from the mean sea level, this values have been classified equally into four classes and high weight is assigned for lower elevation areas as compared to higher elevations. Weightage for each class have been assigned (Table 4.10 and Fig 4.19).

Table 4.10: Weight assignment for different range elevation class

Elevation Class(m)	**Level of Suitability**	**Relative weight**	**Area (km^2)**	**% of total area**
<500	More suitable	4	8.82	11
500-1000	Suitable	3	19.51	24
1000-2000	Less suitable	2	46.93	55
>2000	Unsuitable	1	8.62	10
Total			83.88	100

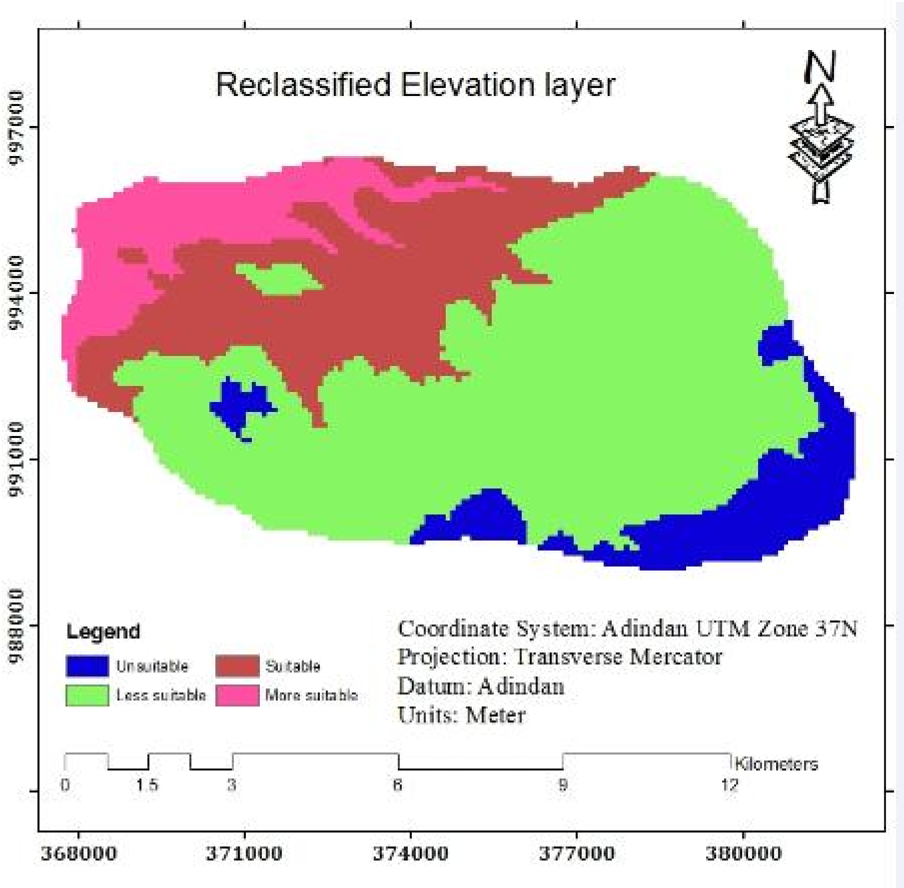

Fig 4.19: Reclassified elevation layer of different range class

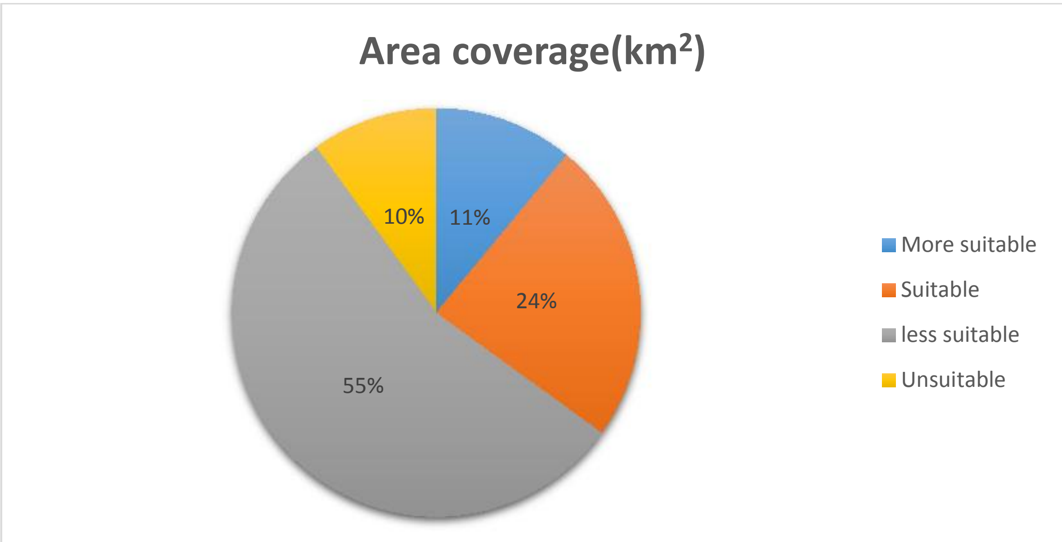

Fig 4.20: Spatial coverage of Elevation range computed from reclassified elevation layer

Based on this AHP weight derivation module, the following eigenvectors of weights for all factors considered for waste disposal site selection are generated. Table 4-11 shows that proximity from streams/rivers, and proximity from ground water well are more important than other factors for waste disposal site selection. The main reason for this is to protect groundwater from leachate contamination from dumping site.

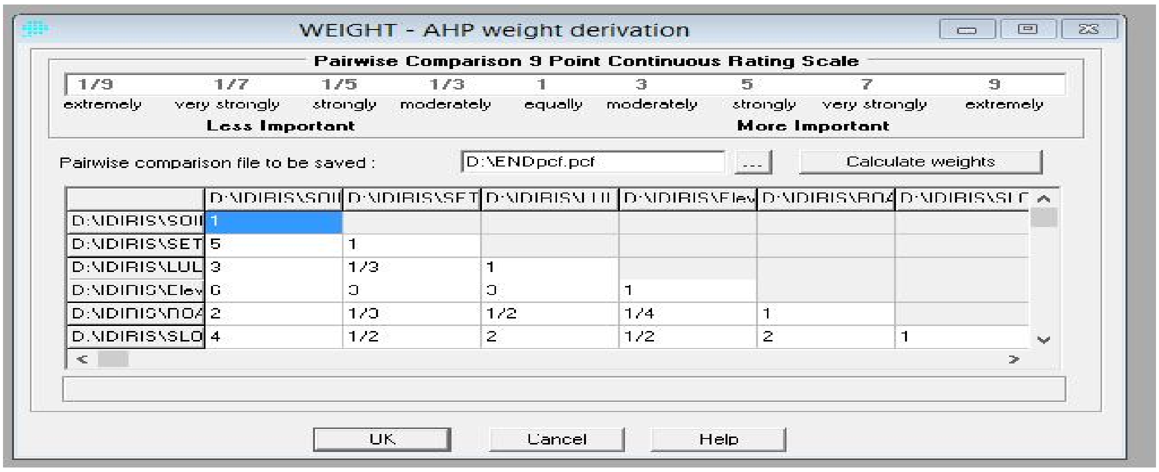

Fig 4.21: AHP weight derivation method considering all factors for waste disposal site selection.

Table 4-11: weight derivation for each candidate dumping sites with each of criteria

	ST	SE	LUC	E	PR	S	PS	PPA	PW	G	Weight	Weight
ST	1										0.0195	3
SE	5	1									0.0916	9
LUC	3	1/3	1								0.0438	5
E	6	3	3	1							0.1318	13
PR	2	1/3	½	1/4	1						0.0315	4
S	4	1/2	2	1/2	2	1					0.0610	6
PS	7	2	4	2	5	3	1				0.1771	17
PPA	7	2	4	2	5	3	1	1			0.1771	17
PW	7	2	4	2	5	3	1	1	1		0.1771	17
G	5	1	2	1/2	3	2	1/2	1/2	1/2	1	0.0895	9
Total											**1.00**	**100.0**

Consistency Ratio = 0.02<<0.1 == acceptable

(Note: ST= Soil Type, SE= Settlement, LUC= Land use/Land cover, E=Elevation, PR=Proximity from Roads, S=Slope, PS= Proximity from Streams/Rivers, PPA= Proximity from Protected Area, PW= Proximity from Well and G=Geology).

4.3. Waste disposal Suitability Analysis Results

The importance's of environmental factors like geology and soil permeability, hydrological factors such as proximity from groundwater well and streams/rivers and topographic factors such as slope and land uses, for determining waste disposal sites are not the same. The analysis of the weight assignment shows that ground and surface water related factors like soil permeability, proximity from wells and streams/rivers are more influential than the other factors, as they are very important to protect water pollution from dumping leachate. Weighted Linear Combination result showed four classes of suitability levels. These are unsuitable, less suitable, suitable and more suitable. As the overall suitability result shows; there is no area that fulfills the more suitable criteria. This indicates that there is no very highly suitable in all the ten (10) criteria considered.

The unsuitable area includes built up and vegetation cover, steep slope (>16%), area close to road, groundwater well and rivers/streams. The main purpose is to protect human health and environment from potential effects of dumping site, to minimize the location sites and waste transportation. However, 3.95km^2 (6%) of the area satisfies the environmental, social and economical criteria set in the previous section and hence identified as more suitable. These areas are preferable for dumping site cover because of their minimum effect on environment, public health and cost effective than other parts of the area. 12.18km^2 (15%) of the study area is suitable, 26.93km^2 (34%) less suitable and 34.49km^2(45%) Unsuitable area coverage. The suitable areas can be used with some careful management system such as lining the base of waste disposal so as to minimize their negative effects on the environment and public health. Most of the suitable waste disposal sites were identified in the south, south-west and eastern part of the study area of the town (Fig.4.22). Moreover, the central and northern part of the town is believed to be the potential source of ground water for the town and the surrounding, hence not allowed for waste disposal site. Therefore, the northern and central parts of the town are excluded to protect water pollution.

Table 4.12: Spatial coverage of Suitability level in the percent of total area

Level of Suitability	Relative weight	Area (km²)	% of total area
More suitable	4 (Black)	3.95	6
Suitable	3 (Green)	12.18	15
Less suitable	2 (Blue)	26.93	34
Unsuitable	1 (Red)	34.49	45
Total		77.55	100

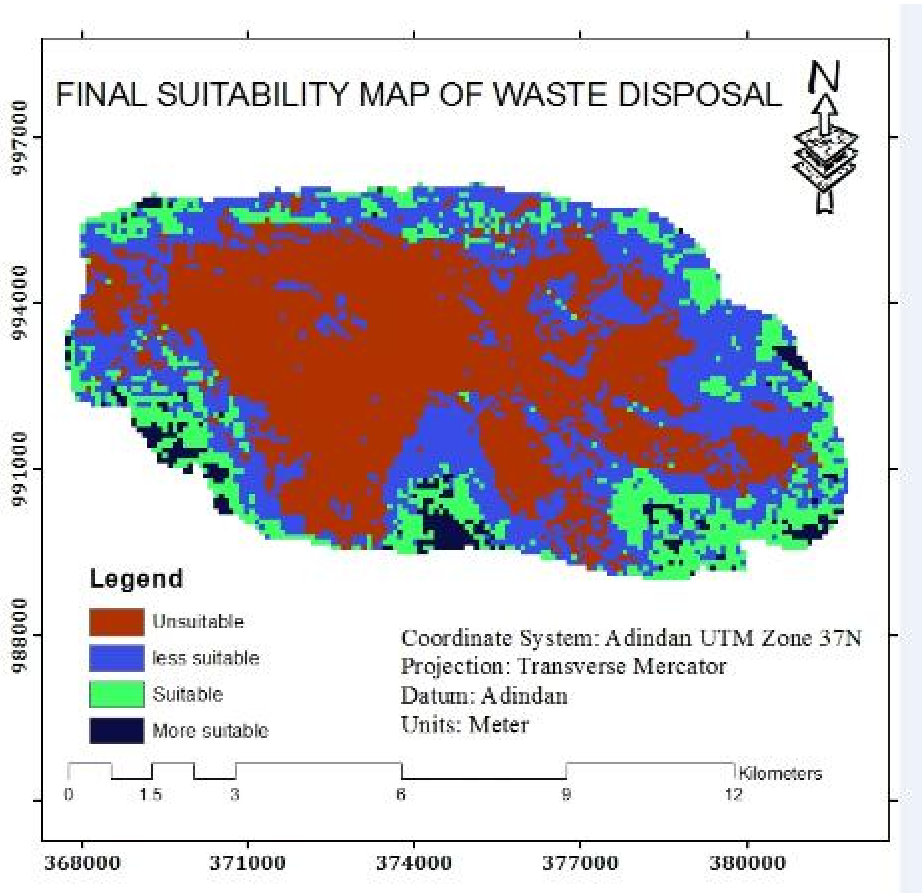

Fig 4.22: overall suitability map derived from each weightage criteria

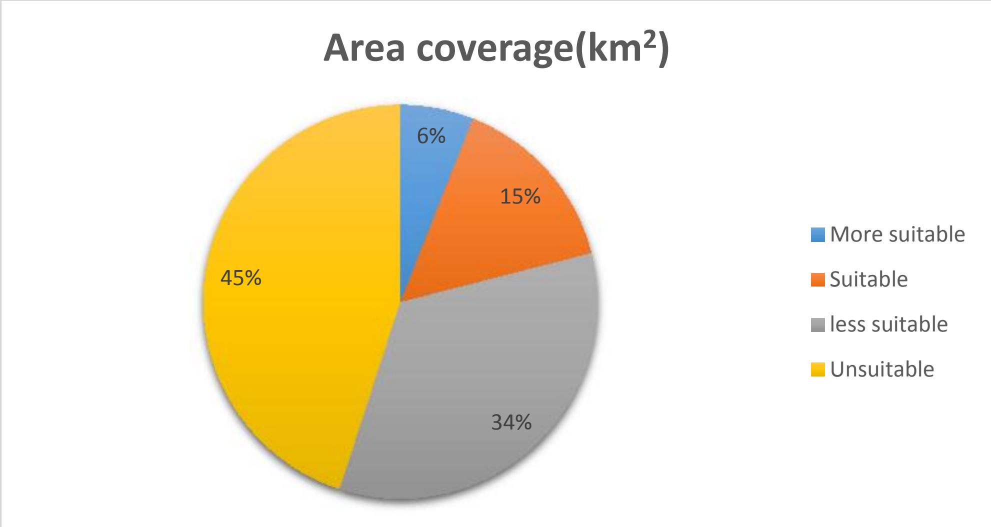

Fig 4.23: Spatial coverage of final value computed from suitability criteria layer

With a weighted linear combination, factors were combined by applying a weight to each followed by a summation and waste disposal suitability map that shows suitable sites within the region. Suitable sites were evaluated against other criteria like size of the site and distance from the center to select the best suitable sites for waste disposal. Therefore, area, distance from center and distance from nearby settlements were determined for each candidate sites in GIS environment.

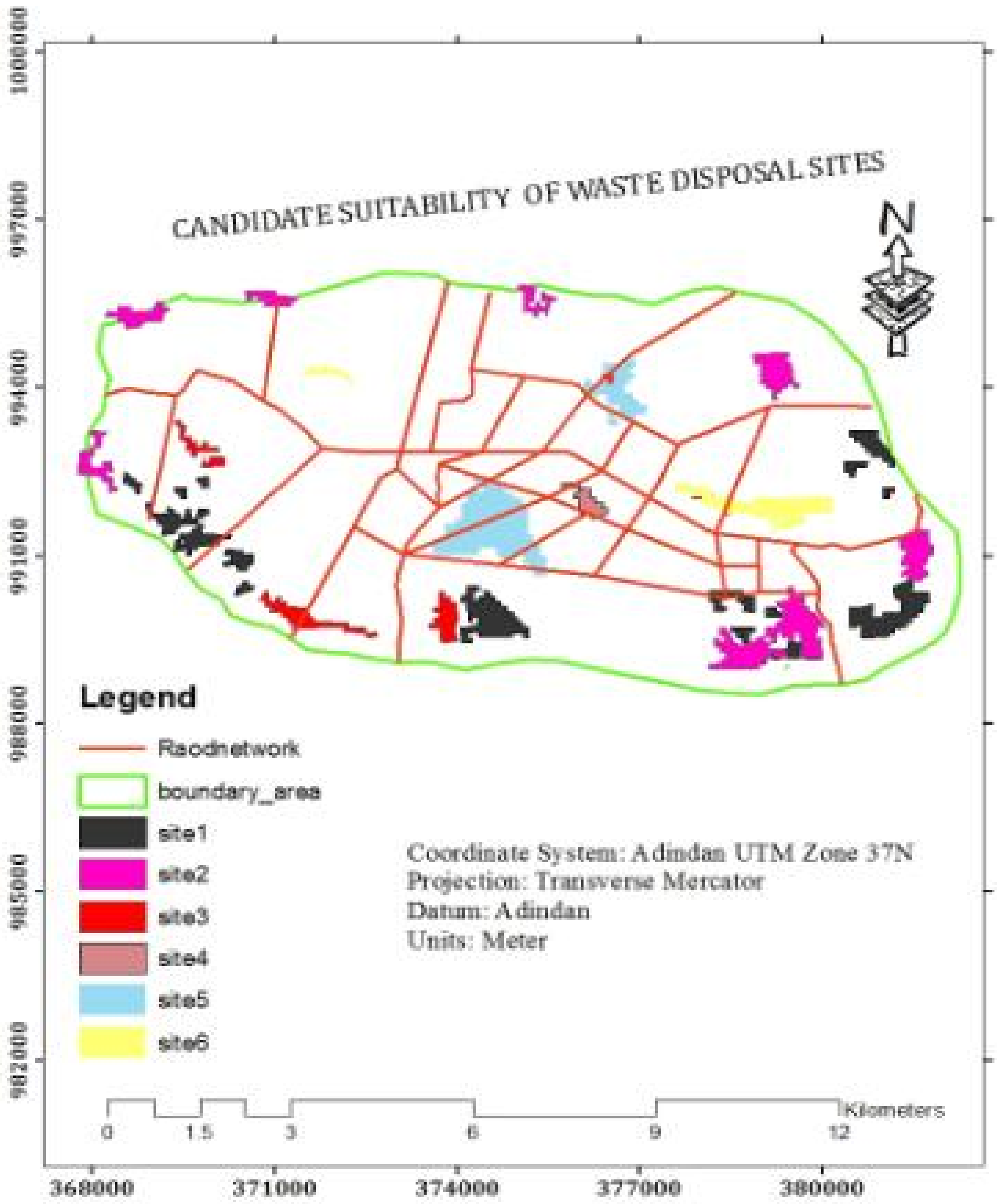

Fig 4.24: waste disposal site suitability map

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Solid waste disposal system in Ambo is open dumping. As a result there are environmental and social problems resulted from the dumping site. All types of solid wastes from hospitals, industries, domestic, market and commercial are dumped, which may contain leachable toxic compounds that are harmful to the environment and human health, at the site without any treatment and separation. Moreover, the disposal site is very close to the main road and surrounded by residential houses and institutions hence resulted in societal problems like nuisance, hazard health and disturbances due to large number of waste pickers continuously working each day at the site. Furthermore, suitability map shows that, the dumping site is located at environmentally and socially unsuitable area that does not satisfy the unacceptable.

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 factors to minimize the negative impacts of waste disposal. These are land use type, slope, water sources, protected areas, settlement, type of soil, elevation, road, ground water and geology as determining factor in order to find appropriate site for solid waste dumping site. Integrating AHP with GIS for spatial decision making process is a worthwhile technique to handle large and conflicting criteria in waste disposal site selection processes. Accordingly, suitability map for each of the factors were prepared in GIS environment. Determine the weight derivation of AHP by pair wise comparison in idiris 32 software. The factor maps were combined according to their importance. The results of the final suitability sites have shown that 1, 2 and 3) of the study area were proposed as more suitable; 4, 5 and site 6 of the total area is suitable area. This sites are easy to access and manage. These places are based on the criterion of the study area and other variables put into analysis. They are located in south, south-west and east peripheries of the town with the selection area of green spaces and urban agricultural land with less than 10% slope.

5.2. Recommendations

- The selected sites by this study are only for non-hazardous solid wastes. Since the criteria for hazardous wastes are different from non-hazardous wastes, separate dumping site should be selected; because chemical, soil and toxic chemical test should be needed.
- To protect downstream surface water pollution, runoff must not flow into and out of the sanitary dumping site. Hence, the municipality should not construct drainage system passes into the waste disposal.
- Detailed hydrological and geological studies for the selected site should be further investigated.
- Further studies are necessary for the design and construction of dumping site.
- However, the negative impacts from waste disposal can be minimized through selecting an appropriate site, which minimize potential environmental impact; GIS and RS techniques are effective for the purpose.

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