GIS−Based Solid waste landfill site selection in Dukem Municipality, Ethiopia

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This is to certify that the thesis prepared by MEGERSA BULTOSA FUFA, entitled: GIS–BASED SOLID WASTE LANDFILL SITE SELECTION IN DUKEM MUNICIPALITY, ETHIOPIA and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Remote Sensing and GIS complies with the regulations of the university and meets the accepted standards with respect to the originality and quality.

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DECLARATION

I hereby declare that the dissertation entitled "GIS−Based Solid waste landfill site selection**;** A case of Dukem, Ethiopia" has been carried out by me under the supervision of Dr. K.V.Suryabhagavan and Dr. Mekuria Argaw, School of Earth Sciences and Environmental Science, respectively, Addis Ababa University during the year 2013−2015 as a part of Master of Science program in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

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ACRONYMS

GIS	Geographical information system
MCDA	Multi criteria decision analysis
GPS	Global positioning system
RS	Remote sensing
MSW	Municipal solid waste
WHO	World health organization
AFDB	African development bank
ENDA	Environment development action
NGO	Non government organization
OUPI	Oromia urban planning institution
TIN	Terrain irregular network
AHP	Analytical hierarch process
USGS	United state geological survey
DEM	Digital elevation model

Abstract

One of the growing potential problems of increased consumption is an escalation in the quantities of municipal solid wastes produced. Land filling is now accepted as the most widely used method for environmentally safe disposal of solid waste. However, appropriate site selection for waste disposal is one of the major problems in waste management. Selection of suitable landfills can be extremely complex mainly due to the fact that the selection process involves many factors, criteria and regulations. In this study, attempts have been made to determine sites that are suitable for landfill siting in the Dukem municipalities. Geographical Information System (GIS) based methodology was applied in order to identify and select potential suitable sites. Suitability classes for landfill site are categorized into four classes with their respective area coverage are unsuitable/restricted area (8.8 km^2), less suitable (3 km^2), moderately suitable (21 km^2) and highly suitable area (3 km^2). Most of the highly suitable landfill sites were identified in the southern and northern part of the study area. For this purpose, different criteria were used in relation to landfill site selection. The initial step of the methodology comprises a GIS based operation and analysis that exclude all areas unsuitable for any waste disposal facility. Criteria were mapped using the GIS technique and spatial analytic tools, then different factor map layers were overlaid to obtain a potential suitability map. The final map produced show areas that are suitable for landfill siting.

Keywords: Landfill, GIS, Remote sensing, municipal solid wastes, suitability.

CHAPTER I

INTRODUCTION

Our Environment is facing potential threat from unsustainable waste disposal practices prevailing in almost all the urban centers in the country. Vast quantities of waste generation by the cities are one of the serious outcomes of unplanned development (Weigand *et al.*, 2003). Due to the increasing population and industrialization, large quantities of wastes are being generated in different forms such as solid, liquid and gases. Each city produces tones of solid waste daily from the household, hospitals, industries, agricultural fields, market centers etc. Solid wastes are directly thrown away on to the street roads, water bodies, vacant places, sewerage systems, city garbage collection sites etc (Hadjibiros and Dermatas, 2007).

In earlier days, waste disposal did not pose problem due to negligible quantity of waste and now a days due to the lack of public awareness and erratic disposal and dumping methods problems has risen (Gizachew Kabite *et al.,* 2011). Due to rapid urbanization and increase in domestic and industrial sectors, solid waste generation has been observed in the cities. The management of this enormous waste in terms of collection, handling and disposal with conventional methods has become increasingly difficult.

The proper and scientific solid waste disposal necessitates the selection of proper site, which is dependent upon several issues that have impact for the site selection. Broadly, they are divided into three categories i.e., economic, social, and environmental. The factors parameters involved in this project are slope, road, land use land cover, drainage; soil type and underground water table are selected.

Generally, the study was aimed at providing suitable solid waste disposal sites by using GIS techniques in order to minimize the risk to human health problem in Dukem municipality. The present study will also be helpful to set appropriate selection criteria for the identification of new solid waste dumping sites through scientific methods. Source reduction, recycling and waste transformation methods are widely used to manage solid waste, however in all of these methods there is always residual matter even after the recovery process to disposal (Kao et al., 1996).The necessity of getting rid of these waste yields in an economic approach which is called as landfilling. However, municipal landfill siting is becoming increasingly difficult due to growing environmental awareness, decreased government and municipal funding and extreme political and social opposition (Siddiqui *et al*., 1996).

The increasing population densities, public health concerns, and less land available for landfill construction are also the difficulties to overcome (Kao et al., 1996). Landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. Environmental factors are very important because the landfill may affect the surrounding biophysical environment and the ecology of the area. Economic factors must be considered in the siting of landfills as well. It is evident that, many factors must be incorporated into landfill siting decisions GIS is ideal for this kind of preliminary studies due to its ability to manage large volumes of spatial data from a variety of sources. It efficiently stores, retrieves, analyzes and displays information according to user defined specifications. Multicriteria Decision Analysis (MCDA) is used to deal with the difficulties that decision-makers encounter in handling large amounts of complex information (Siddiqui *et al*., 1996).

The principle of the method is to divide the decision problems into smaller more understandable parts, analyze each part separately and then integrate the parts in a logical manner (Malczewski, 1999). The integration of GIS and MCDA is a powerful tool to solve the landfill site selection problem, because GIS provides efficient manipulation and presentation of the data and MCDA supplies consistent ranking of the potential landfill areas based on a variety of criteria. These data are usually organized into thematic layers in the form of digital maps. The combined use of GIS with advanced related technologies (e.g., Global Positioning System – GPS and Remote Sensing - RS) assists in the recording of spatial data and the direct use of these data for analysis and cartographic representation. GIS have been successfully used in a wide variety of applications, such as urban utilities planning, transportation, natural resources protection and management, health sciences, forestry, geology, natural disasters prevention and relief, and various aspects of environmental modeling and engineering (Daneshvar *et al.*, 2005).

The most widespread application of GIS supported modeling on waste management lies in the areas of landfill sites and optimization of waste collection and transport. GIS-based Multi-Criteria Evaluation methodology was employed to perform the spatial decision making process for total study area was found to be highly, moderately, marginally and un- suitable for landfill, in that order, by considering suitable solid waste disposal sites with the least negative effects on environment as well as public health have been identified with first, second and third order suitability ranks.

The role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations. In this manner, aspects such as customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill, are important. GIS is a tool that not only reduces time and cost of site selection, but also provides a digital data bank for future monitoring programme of the site.

GIS is a suitable tool for site selection since it has the capability to manage large amount of spatial data that comes from various sources. (Kao *et al.,* 1996) pointed out that large amount of spatial data can be processed using GIS. It potentially saves time that would normally be spent in selecting an appropriate site. While Daneshvar *et al.,* (2005) claimed that GIS is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analyzes and displays information according to user-defined specification. However, GIS can be limited by the existing sources of data needed in siting analysis.

1.1 Problem Statement

As one of the main town in Ethiopia, Dukem municipality is dealing with solid waste management challenges. The increasing population and economic development lead has to solid waste management problems, such as high urban waste generation, lack of coverage areas and lack of landfills. There has to be an appropriate planning for proper waste management by means of analyzing the waste situation of the area. Protection of the environment from solid waste hazards is becoming a serious problem.

The effect of solid land fill in countries like Ethiopia with limited financial and natural resources and high population growth rate is more severe. It is need of time to shift on usage of emerging technology in planning, management and decision making. So far study has been conducted to identify suitable landfills site using emerging technology like GIS and RS in Dukem. To overcome these difficulties, prudent management system for solid waste is required. Furthermore, solid waste disposal site should be selected using scientific criteria to prevent any harmful effect on local communities and the environment.

GIS thematic maps would ease the decision makers while routing waste disposal towards recommended landfill sites with environmentally suitable approach. GIS spatial analysis and GIS thematic maps could be used as a tool for future disposal of solid waste, recommended landfill sites would also comply environmental protection criterion. Therefore, the siting of landfills has become a necessary issue for waste management in growing and developing areas of this country. This project was therefore motivated by the need to find potential suitable landfill sites that would ensure that collected Municipal solid waste can be properly disposed of into designated areas with the idea of incorporating sustainability into the project to reduce footprint of land area.

1.2 Significance of the study

The study will provide GIS techniques for the selection of suitable sites for the disposal of municipal solid wastes with a minimum or no risk for the environment. It is anticipated that the findings from this study will be a significant basis for application in other municipalities, which may lead to environmental sustainability in Municipal solid waste management.

Theoretically, the study is expected to contribute to the development of scientific thought, particularly in sustainable community solid waste management at neighborhood level.

Practically, this research is expected to provide inputs for stakeholders, particularly local governments in formulating policies and appropriate methods to promote sustainable community Solid waste management system.

1.3 Objectives of the study

1.3.1 General Objective

The general objective of the present study is to determine suitable site for solid waste landfill site through integrating GIS and remote sensing that are environmentally sound, to protecting the environment and public health.

1.3.2. Specific Objectives

- ✓ To produce thematic maps of social and economic factors of the area.
- ✓ To produce thematic map showing potential sites that are environmentally sound, economically feasible and socially acceptable for solid waste landfill.
- ✓ To prioritize and rank the identified suitable landfill sites according to their suitability.

CHAPTER II

LITERATURE REVIEW

2. 1 Waste

Waste or garbage is any material generated by human activity that is considered to be useless, superfluous, valueless or unwanted and is disposed of in the environment Hadjibiros and Dermatas, 2007). After collection, this waste may be dumped into landfill sites or destined for composting, incineration or recycling (Weigand *et al*, 2003).

2.1.1 Solid waste

Solid waste is usually used to describe non-liquid materials from domestic, trade, commercial, agricultural and industrial activities, and from public services. It consists of both solid and liquid waste but not waste water. Solid waste consists of any refuse, sludge, discarded materials, small amount of liquid, semi –solid (Hadjibiros and Dermatas, 2007).

In many of the developing countries, the generation of solid waste has become part of daily living, and the countries are faced with the problem of solid waste generation in an almost endless fashion. The implication is serious taking into account the inefficient disposal system in many of these countries, which could eventually cause health problems and environmental degradation (Hadjibiros and Dermatas, 2007). Solid waste generation has been of great concern in developing localities of Ethiopia and of the different types of waste, solid waste has been difficult to manage. The rates of solid waste generation have increased at an alarming rate over the years with lack of management system, especially the collection and disposal functions (Hadjibiros and Dermatas, 2007).

2.1.2 Municipal solid waste

Municipal solid waste (MSW) refers to the material discarded for which municipalities are usually held responsible for collection, transportation and final disposal. MSW encompasses household refuse, institutional, commercial and industrial waste that is neither waste water discharge nor atmospheric emission (Gizachew Kabite *et al.*, 2011).

The composition of municipal solid waste is a heterogeneous mixture of different types of discarded wastes. This implies that municipal solid waste often includes food waste, garden waste ,paper, dry refuse, kitchen waste, discarded clothing, which are biodegradable and other fractions of non- biodegradable material such as furnishing , glass, plastics and other furnishing household material recycling (Weigand *et al*, 2003) .

At present, in some developing districts in Ethiopia, MSW is collected in mixed state and is being dumped in environmentally very sensitive places like road sides, forests, wildlife areas, water courses, etc., causing numerous negative environmental impacts (Gizachew Kabite *et al.*, 2011).

2.1.3 Classification of municipal waste management

Municipal Solid Waste is classified as hazardous and non-hazardous. Hazardous waste is any waste, excluding domestic and radioactive wastes, which, because of the physical, chemical or infectious characteristics, can cause significant hazards to human health or the environment when improperly treated, stored, transported or disposed of (WHO, 1996).

2.1.4 Municipal waste generation

In general, the level of economic activity as reflected in the gross domestic product of any country determines the rate of solid waste generation, because the higher the rate of production and consumption, the more waste is generated(Gizachew Kabite *et al.*, 2011).

In developing countries, the generation of waste ranges from 0.3 to 0.5 kg/person/day, while in developed countries it ranges from 1.6 to 2.0 kg/person/day (Filemon and Uriate, 2008). In Ethiopia, the accelerated growth of population, increasing economic activities and change in consumption behavior has resulted in a quantum jump in solid waste generation (Gizachew Kabite *et al.*, 2011).

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2.1.5 Waste composition

MSW consists of different category and types of material. The level of income largely determines the content of material in the waste composition, e.g. high income countries consume more of packaged products, which results to higher percentage of combustible materials and more inorganic material in their waste such as textile, plastics, etc, while low income areas have a higher percentage of materials suitable for compositing. Also the composition of waste varies depending on the source, life style, climate, market size for waste material, population size, reuse and reduction policy and effectiveness of recycling(Abul,2010).

2.1.6 Waste handling practices

2.1.6.1 Waste reuse

In many of the developing municipalities in Africa, such as Abuja, the rate of reuse of waste is high due to the fact many households save and reuse materials such as plastic bags, bottles, paper for domestic purposes until it is no longer fit for reuse (Al-Yousfi, 2004).

2.1.6.2 Waste recovery and recycling

Recycling is an important factor in helping to reduce the demand for resources. In many of the African countries, waste recycling is often used to supplement income or when non- waste resources are unaffordable. Materials (empty bottles, plastic containers etc) from domestic use are kept away from the waste of the household, while commercial and industrial wastes, such as metal, glass, and paper, are recycled by industrial (Leao *et al.,* 2004). Recovery and recycling of waste practices is used for conserving finite resources and reducing the amount of waste require disposal by land filling. Despite these benefits, many of the African cities still have poor institutional framework for waste recycling, reuse and recovery. As a result waste management problems still prevail in these cities (Leao *et al.,* 2004).

2.1.6.3 Waste collection and waste transfer

Waste management infrastructure is largely non-existent in many cities in Sub Sahara Africa. Of concern is the poor state of infrastructure, constraints and inadequate waste management facilities for various waste streams. Currently, the MSW management situation is characterized by these concerns and has resulted in refuse being dumped in any open space. At present in Ethiopia, waste collection and transportation is limited by inadequate equipment, personnel and financial resources (Gizachew kabite et al.,2011)

Across many cities, where collection service is limited, it is largely performed by non-mechanical means, which is often carried out by individuals and the community. However, the recent implementation of public private partnership in refuse clearing, collection and its disposal at designated landfill is gradually improving the efficiency of Municipal solid waste, thereby resulting in affordable waste collection and disposal service (AFDB, 2002). Finally, across the cities transfer stations are not common with regard to Municipal solid waste management rather the collection vehicle goes directly from their pickup points to the disposal site.

2.1.6.4 Collection

The term collection includes not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied (Tchobanoglous *et al.,* 1993). Solid waste can be collected from door to door or by using communal containers. Collection in many developing countries is done by using communal containers in which containers are placed at a place where the residents of the area are required to bring their refuse and dump in.

According to Addis Ababa city municipality (2010), municipal waste collection in Addis Ababa is handled in three ways:

- ✓ door-to-door collection, for households located along accessible streets
- ✓ block collection, for clients (large hotels, enterprises and institutions) requesting the municipality to provide them with refuse containers (charged service);
- ✓ Container system, which expects residents to carry and dump their waste in $8m^3$ refuse containers placed at supposedly accessible sites.

2.1.6.5 Transfer

Waste collected from an area may be directly transported to the disposal site or it may be transferred to another type or size of equipment for hauling .In addition, transfer takes place from relatively small pieces of equipment to large pieces of equipment.

For instance, refuse may be collected by pushcarts and brought to a neighborhood transfer depot, where the waste is then dumped to a tipping truck, and then the tipping truck brings the waste to an area wide transfer station, where it is dumped into a container which is finally transported by large trailer trucks (Dereje Tadesse, 2001). The designing of transfer stations may be based on the economically viable radius of transport for each collection equipment.

2.1.6.6 Composting

Composting is a purposeful recycling or conversion of organic biodegradable waste materials. Basically, it considerably reduces the volume of wastes to be transported to sites designated for disposal, and increases the recovery rate of recyclable materials(Dereje Tadesse, 2001).

Across many African cities, the waste transported to a composting facility is with mixed municipal waste, which consists of plastics, glass, metals, and other household materials, instead of waste consisting primarily of organic matter. This has resulted in mechanical breakdowns and end products of poor quality. Apresent, many composting facilities have failed as a result of technical, financial, and institutional problems (AFDB, 2002).

In most municipalities throughout Africa such as Abuja, small-scale composting practices are being promoted by NGOs and community based organizations. The compost produced is largely for self-consumption or for sale to households (AFDB, 2002).

2.1.7 Municipal solid waste management in developing countries

Globally, waste generation has been increasing with increasing wealth and economic growth. In developing countries, the waste generation is growing rapidly and may keep increasing in quantum as a result of improvement in standard of living, economic activities and population growth (UN-Habitat, 2010).

In most of these nations, the issues of Municipal Solid Waste Management are of immediate concern, and problematic. For example, in some African countries, one to two thirds of the solid waste generated is not collected. As a result, the uncollected waste, usually end up in the surrounding environment or drainage or open dump.

They are confronted with many aspects of problems such as, inadequate service coverage and operational inefficiencies of services, limited utilization of recycling activities and inadequate landfill disposals (UN-Habitat, 2010).

2.1.8 Waste Disposal and Management in Dukem

There is waste disposal site in Dukam town near the abattoir of the town at the distance of not more than 50 m from the main asphalt road and the health Centre. The solid waste thrown to this part of the town is burned at the municipality waste disposal site. The waste disposal site of the town is found at the edge of Dukam River. Therefore the decomposed matter from the solid wastes enters the river in the form of seepage during the rainy season because of the steeper slope where the solid is thrown. This pollutes the water of the river and creates a serious downstream pollution (OUPI, 2000).

The types of wastes generated in the town are more of organic in origin. These include residue of chat, dry grass and leaves of false banana which is used to wrap chat. There are also inorganic wastes generated in the town. These include broken glass, cans of bottles, and plastic bottles and bags. These inorganic and organic wastes are in large concentration mainly along the main road. This especially is true of the high way ditch which is almost filled by these wastes. The wastes along the main road are burned in the ditch especially in the morning. This is hazardous for health because the smoke of the burned materials is mixed with carbon monoxide which is released from vehicles crossing the town.

The burning of solid wastes in the ditch also affects the proper flow of liquid wastes which is easily blocked by the ash which has clayey nature. Therefore when the solid waste does not get a proper canal, the waste creates flooding problem along the main road. Bad smell also affects the residents living by the side of the high way because of the chemical reaction that takes place when the wastes decompose. However why do people burn solid wastes along the high way and or in the ditch? This is because of the absence of organized people working on the solid waste. The low perception of people towards the hazardous effect of wastes also let the people pile the solid waste up in the ditch. People with low perception about the effect of wastes also lead the people to have very low sense of belongingness. That is why they throw wastes in the ditch and burn the waste in it. The average solid waste generated in Dukam town is greater than 2kg/day according to information obtained from the municipality's social affair. The amount of solid waste generated in the town in a year is calculated as:

24,222 × 2 kg/day × 365.25 = (176942 quintals) (OUPI, 2000).

In some areas especially around Oda Nabe School the solid waste is piled up and this has created a bad smell on the surrounding residents and the people by passing in that road. At this site, any sort of solid waste like ash, dried glass, and house hold wastes, are thrown and piled up here affecting the health of the residents and the community living and working around this site.

The solid waste disposal site of the town is incompatibly located because of:

Its short distance from the only high way that crosses the town has created rather a filthy condition in the area.

- ✓ Its central location as the waste disposal site is almost surrounded by residential quarters and the abattoir of the town has made this site the dirtiest part of the town.
- ✓ Its location along the edge of Dukam River. This has created seepage of liquid waste due to the chemical reaction taking place as a result of decomposition. The solid matter is gradually moves to the river because of the piling up of solid wastes which accelerates the down movement of solid wastes to the course of the river.
- ✓ Vultures and dogs feeding on the wastes and leftovers of slaughtered animals found adjacent to the waste disposal site are creating unsecured situation especially on the children of the surrounding.
- ✓ Its location disregarding wind direction which blows from southeast to northwest to the abattoir of the town, the surrounding residents, and the health centre of the town which is found at short distance from the waste disposal site.

Because of the above problems created by the unsuitable location of the waste disposal site of the town, the site should be relocated by considering the following.

a. Using GIS and Remote sensing techniques to find best solid waste landfill of the town to minimize and avoid the impact of solid wastes on the environment and the surrounding population.
b. To increase the awareness to the people about the impact of solid and liquid wastes especially on those who are involved in commercial activities along the shops of the main road. The municipality and or any interested groups should buy and establish solid waste containers to minimize the impacts of solid wastes on the quality of the natural environment and the residents of the town. Conditions of Waste Disposal sites in Dukem town as shown in (plate 2.1).

plate 2.1 Conditions of waste disposal sites in Dukem town.

2.1.8.1 Land filling

Landfill is a system for solid waste disposal onto or into land, taking social, economic and environmental matters into account. There are two extremes in waste disposal – crude or open dumping and sanitary land filling; however there are also intermediate dumping which is referred to controlled dumping and engineered land filling (Hadjibiros and Dermatas, 2007).

Land filling includes monitoring of the incoming waste stream, placement and the compaction of waste, and installation of landfill environmental monitoring as well as control facilities. In developing countries, the implementation of improved land disposal practices is gradually progressing. At present, the accelerated population growth and the need to ensure environmental sustainability are forcing municipalities to plan towards better waste disposal practices. This implementation is largely dependent on the available resources and institutional framework for regulating solid waste management (Tchobanoglous et al., 1993). Of concern is the location of landfill, considering that closeness of site to residential, river, water channel or other fragile ecosystem could lead to adverse environmental pollution and degradation as well as health hazards.

The placement of solid waste in landfills is probably the oldest and definitely the most prevalent form of ultimate garbage disposal. From the outset, it must be recognized that many "landfills" are nothing more than open, sometimes controlled, dumps. The difference between landfills and dumps is the level of engineering, planning, and administration involved. Open dumps are characterized by the lack of engineering measures, no leachate management, no consideration of landfill gas management. Thurgood (1997) stated that as a minimum, four basic conditions should be met by any site design and operation before it can be regarded as a landfill:

- ✓ Full or partial hydro geological isolation

If a site cannot be located on land which naturally contains leachate securely, additional lining materials should be brought to the site to reduce leakage from the base of the site (leachate) and help reduce contamination of groundwater and surrounding soil.

- ✓ Formal engineering preparations

Designs should be developed from local geological and hydro geological investigations. A waste tipping plan and a final restoration plan should also be developed.

✓ Permanent control

Trained staff should be based at the landfill to supervise site preparation and construction, the depositing of waste and the regular operation and maintenance. Land filling is the oldest and most widely practiced method for disposing of solid waste.

Properly constructed and operated landfill sites offer a safe disposal way for municipal (and industrial) solid wastes, typically at the lowest cost compared to other disposal options. Should the financial resources be limited (as this is the case in many developing countries), it may not be necessary from health and/or environmental viewpoints to invest in other disposal methods given that suitable sites are available for landfills (Al-Yousfi, 2004).

In other words, sanitary landfills can be "stand alone" facilities under constrained conditions. Landfills however, form the basis of every integrated solid waste management plan. There are a number of complementary (or alternative) treatment options for waste, e.g., incineration, composting…etc., but none of these treatment options can function alone. All require landfill as a final stage: all other waste management options, such as recycling and incineration, rely on landfills for disposing of unsuitable refuse or inert residues, respectively. Therefore availability of some landfill space is essential for every region, and will continue to be so in the future in spite of technological advancements Michael at al., (1993).

Cheremisinoff (2003) stated that the advantages of land filling as a waste disposal option include:

• It costs less than other disposal options.
• A wide variety of wastes are suitable for landfill.
• It frequently offers the only final disposal route for residues arising from end-of-pipe treatment technologies and other waste management options, such as incineration.
• Landfill gas can be collected and utilized for heat and as a low-polluting fuel for energy generation.
• Restored land can provide valuable space for wildlife habitat or leisure use.

In the other hand, the disadvantages of land filling include:

• Older sites, constructed before the impacts of leachate and landfill gas were realized, are now sources of pollution with uncontrolled leakages.

• There is continued risk of contamination from operational landfill sites.

• Some parts of the world are experiencing shortages of suitable landfill sites close to the source of waste generation.

• Land filling achieves a lower conversion of wastes into energy than other solid waste management strategies.

• Land filling may produce contaminated land that is unsuitable for some future uses.

2.1.8.2 Site Selection Criteria for Landfills

Several countries (like Australia, Malaysia, Niger, Philippines, Uganda, and United States among others) have put in place rules to follow when selecting suitable sites for landfills. These guidelines act as the primary mechanism used to protect the host community and the environment at large. Below are the factors that several researchers (Lin and Kao, 1999; Bagchi, 2004; Gaim, 2004; Twumasi *et al.,* 2006; Despotakis and Economopoulos, 2007; Chang *et al.,* 2008) have used to determine the appropriateness of a site to be used as a sanitary landfill.

(i**)** ***Site Capacity****:* A site should be capable of providing at least 10 years of use in order to; minimize costs for site establishment and closure, smooth running of operations, and provision of adequate time for acquiring the next site.

(ii) ***Land cover:*** Location of a landfill facility should not endanger any environmentally sensitive areas or have a negative impact on existing or future land uses. Risks to public health and impacts on the areas surrounding the landfill can be limited by providing buffer zones between the landfill and sensitive areas. Several researchers have recommended appropriate buffer distances between a landfill facility and other land uses. For example; at least 100 m from public roads, and at least 200 m from industrial developments. For the case of Malaysia (Gaim, 2004), land use types such as grassland, forests and cultivated land were considered appropriate for dumping except marshland and swamp type. For this study, grassland and bush land areas were considered appropriate for a landfill site.

(iii) ***Airports****:* The distance between an airport and a landfill should be a minimum of 3km, unless there is a clear demonstration of bird control measures at the landfill.

(iv) ***Surface Water****:* The distance between the areas dedicated for waste disposal and the nearest surface water (permanent or intermittent) or the 100 year flood plain should be a minimum of 100 m. Sites that contain, or are located within 100 m of; water supply catchments or ground water recharge areas, coastal areas, are subject to tidal inundation or storm surge, wetlands, areas that may be seasonally inundated, or are likely to be flooded in a major rain event, water bodies (watercourses or open drains). Depending on the circumstances, high water Table conditions may also render a site unsuitable for use as a landfill facility. This minimizes the risk of polluting water with leachate. However, North Dakotta Department of Health (2009) recommended a minimum distance of 200 feet (equivalent to about 60 meters) to the nearest surface water. However Bagchi (1994) stated that a landfill should not be located within 100 feet (30.48 m) of any non meandering stream or river, and at least 300 feet (91.44 m) from any meandering stream or river.

(v) ***Groundwater****:* An extremely deep water table region is suitable so that underground water is not contaminated by the leach ate of the waste. According to North Dakota Department of Health (2009), the bottom of disposal trench should be at least four feet above the water table.

(vi) ***Local Topography****:* landforms located in flat or undulating land, in a disused quarry are suitable for waste disposal. Major landfills must not be sited in hilly areas, those with ground slopes nominally greater than 10%. However, EPA (2003) recommends a slope less than 5 %, and North Dakota Department of Health (2009), 15% slope or less.

(vii) ***Soils****:* Soil structure should be suitable for construction of landfill cells and drainage works. The soil should also be of sufficiently low permeability to significantly slow the passage of leachate from the site. Sites in clay-rich environments are preferable, due to the low permeability, good workability and superior leachate retaining characteristics of these soils. Sufficient soil should be available to provide adequate covering for wastes (Lin and Kao, 1999).

(viii) ***Climate****:* areas with heavy rainfall need extra care to avoid side effects of drainage and erosion; sites with prevailing winds require extra efforts to control litter and dust (Lin and Kao, 1999)

(ix) ***Unstable Areas: Major*** Landfills must not be located within 100 meters of an unstable area. Unstable areas can include poor foundation conditions, areas susceptible to mass movement, soft sandy and collapsible soils, and Karst terrains. North Dakota Department of Health (2009) supplemented that environmentally sensitive or unstable areas do not provide safe, long-term waste disposal. Such areas include; wetlands, gravel pits, flood plains, and shallow water Table areas. All these are environmentally sensitive to surface water and groundwater pollution. Ravines, woody draws, and steeply sloping terrains are unstable areas subject to accelerated erosion, which may expose the waste.

(x) ***Infrastructure****:* Although landfills should have suitable transport access, with power and water available, they should not be located within 100 m of any major highways, city streets or other transportation routes. Twumasi et al. (2006) recommends 300 m. It would be more cost efficient for landfills not to be located so far away in order to avoid high transportation costs. For this study, at least 100 m were considered appropriate for a landfill site.

(xi) ***Local Flora and Fauna****:* Sites that contain protected or endangered fauna and/or flora, or sensitive ecosystems are unsuitable for landfill facilities (Lin and Kao, 1999).

(xii) ***Distance from environmentally sensitive or protected areas****:* A landfill must not be located in close proximity to sensitive areas such as fish sanctuaries; mangrove areas and areas gazette for special protection would be excluded. Therefore, a 3,000 m buffer is necessary to surround an environmentally sensitive area. EPA (1998) recommends a buffer of at least 500 m. For this study, at least a 2000 m buffer was considered appropriate for a landfill site.

(xiii) ***Distance from urban areas****:* the landfill should be situated at a significant distance away from urban residential areas due to public concerns, such as aesthetics, odor , noise, decrease in property value and health concerns, which may avoid contamination of freshwater aquifers through leaching. Urban buffers may range from 150 meters to 5 km (Zeiss and Lefsrud, 1995; Lin and Kao, 1999).

(xiv) ***Population:*** Gaim (2004) recommended that areas with a population density less than 200 were regarded as suitable for landfills.

2.1.8.3 Open dumping

Open dumping is the disposal of solid waste at any location other than a facility permitted by the regulatory body. Although it is the most common disposal method in many countries it causes many problems that are detrimental to humans and the environment (Zeiss and Lefsrud, 1995). For example, in most developing countries open dumping and open burning have been practiced. Many of these open refuse dumps have consistently been emitting smoke due to fires set on them with the result that the environment is polluted and the leach ate flows into streams and groundwater resources, contaminating water supplies North Dakota Department of Health (2009).

No dump can be regarded as controlled unless it is run according to rules and regulation laid down by the relevant authority. It involves adequate sealing of the refuse with inert material. The first step in controlling a dumpsite is to stop burning the refuse on the site. The next step might be to improve access to the site by developing or upgrading the site. Roads and subsequently use inert materials to cover the waste in order to stem water population and other effects (UN-Habitat, 2010).

2.1.8.4 Sanitary land filling

Sanitary land filling is the technique of disposing of refuse on land creating no nuisance or danger to public health or safety by applying the principles of engineering to restrict the refuse within a smallest practical volume and to cover it with a layer of earth at more frequent periods as may be required. In many developing countries such as Nigeria, open or controlled dumping is largely used as the disposal method. The benefit of sanitary landfill over the other approaches or methods cannot be overemphasized because it is pollution-free and prevents water infiltration. Thus, it eliminates any health or environmental risk that may result from solid waste disposal (UN-Habitat, 2010).

Siting a sanitary or ordinary landfill requires an evaluation process in order to identify a potential suitable location. This location must comply with stipulated environmental regulations, and at the same time it must minimize economic and social costs (UN-Habitat, 2010).

2.1.9 Conceptual background of geographic information systems (GIS)

2.1.9.1 Geographic Information System (GIS)

Geographical information systems evolved from the collection and compilation of spatial data, and through its functionalities it can consistently and intelligently coalesce into a final geo -product. This final information product is interactive and offers organizations, institutions and individual users a host of capabilities for analysis (Burrough and McDonnel (1998).

Traditionally, GIS use was associated with static data, longer time and involved only a few specialized users. Today that is all changing. GIS can now be associate and utilization of relatively dynamic data, short time, and involve many users. Geographic information can facilitate decision support system and can even solve a variety of complex problems. The spatial output obtained from a GIS is virtually boundless, limited only by the adeptness of the user and data availability (Burrough and McDonnel (1998).

2.1.9.2 Remote sensing definition

The Definition of **Remote Sensing** In the broadest sense, the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study; e.g., the utilization at a distance (as from aircraft, spacecraft, or ship) of any device and its attendant display for gathering information pertinent to the environment, such as measurements of force fields, electromagnetic radiation, or acoustic energy. The technique employs such devices as the camera, lasers, and radio frequency receivers, radar systems, sonar, seismographs, gravimeters, magnetometers, and scintillation counters (Burrough and McDonnell, 1998).

The practice of data collection in within the wavelengths from ultraviolet to radio regions. This restricted sense is the practical outgrowth from airborne photography. Remote Sensing is preferred and thus includes regions of the EM spectrum as well as techniques traditionally considered as belonging to conventional geophysics (Burrough and McDonnel ,1998).

As humans, we are intimately familiar with remote sensing in that we rely on visual perception to provide us with much of the information about our surroundings. As sensors, however, our eyes are greatly limited by 1) sensitivity to only the visible range of electromagnetic energy; 2) viewing perspectives dictated by the location of our bodies; and 3) the inability to form a lasting record of what we view. Because of these limitations, humans have continuously sought to develop the technological means to increase our ability to see and record the physical properties of our environment (Burrough and McDonnel ,1998).

Beginning with the early use of aerial photography, remote sensing has been recognized as a valuable tool for viewing, analyzing, characterizing, and making decisions about our environment. In the past few decades, remote sensing technology has advanced on three fronts: 1) from predominantly military uses to a variety of environmental analysis applications that relate to land, ocean, and atmosphere issues;
2) From (analog) photographic systems to sensors that convert energy from many parts of the electromagnetic spectrum to electronic signals; and 3) from aircraft to satellite platforms. Today, we define satellite remote sensing as the use of satellite-borne sensors to observe, measure, and record the electromagnetic radiation reflected or emitted by the Earth and its environment for subsequent analysis and extraction of information (Burrough and McDonnel ,1998).

Remote sensing refers to the activities of recording/observing/perceiving (sensing) objects or events at far away (remote) places. In remote sensing, the sensors are not in direct contact with the objects or events being observed. The information needs a physical carrier to travel from the objects/events to the sensors through an intervening medium. The electromagnetic radiation is normally used as an information carrier in remote sensing. The output of a remote sensing system is usually an image representing the scene being observed (Burrough and Mc Donnel ,1998).

2.1.9.2 Data representation by Vector and Raster Models

GIS can create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas, and develop effective solutions. GIS works with two fundamentally different types of geographic models, the "vector" model and the "raster" model. The vector data structure organizes spatial feature by the set of vectors, which are specified by starting point coordinates, while raster organizes spatial features in regular spaced grid of pixels (Burrough and McDonnel ,1998).

2.1.9.3 Database of GIS

Geographic data collections can be represented as feature classes and raster-based datasets in a GIS database. Many themes are represented by a single collection of homogeneous features such as a feature class of soil type polygons and a point feature class of well locations. Other themes, such as a transportation framework, are represented by multiple datasets (such as a set of spatially related feature classes for streets, intersections, bridges, and highway, and so on) (Burrough and McDonnel ,1998).

Raster datasets are used to represent continuous surfaces, such as elevation, slope, and aspect, as well as to hold satellite imagery, aerial photography, and other gridded datasets (such as land cover and vegetation types). Both the intended use and existing data sources influence spatial representations in a GIS. When designing a GIS database, users have a set of applications in mind. They understand what questions will be asked of the GIS. Defining these uses helps to determine the content specification for each theme and how each is to be represented geographically. For example, there are numerous alternatives for representing surface elevation: as contour lines and spot height locations (such as hilltops, peaks), as a continuous terrain surface (a TIN), or as shaded relief. Any or all of these may be relevant for each particular GIS database design. The intended uses of the data will help to determine which of these representations will be required. Frequently, the geographic representations will be predetermined to some degree by the available data sources for the theme. If a preexisting data source was collected at a particular scale and representation, it will often be necessary to adapt your design to use it (Burrough and McDonnell, 1998).

Basically there are two types of data in a GIS input.

I. Spatial data

ii. Non Spatial data or attribute data

Spatial data includes information such as latitude and longitude for geo-referencing, the features on a map like soil units, administrative districts etc. Analog maps of topography, land use map, soil profile map, geology etc. are the main building units of the input. Other spatial data include aerial photos and satellite images. Non Spatial or Attribute data involves information of agriculture, industry, economy, population etc.

2.1.9.4 GIS capabilities

The main purpose of a geographic information system is to process spatial information, which is then designed for data mapping, management and analysis. Moreover, it can be used to assist decision-making process. The processing functions consist of three functional areas: computer mapping, spatial database management and cartographic modeling. And with these functions, tremendous volumes of data are handled. The strength and power of GIS lie in: ability to integrate large spatial information and display the output (Burrough and Mc Donnel ,1998).

- ✓ Manipulate data and present them in digital form
- ✓ ability to connect all activities to spatial entity, and
- ✓ Allow for access to administrative data.

In GIS, the spatial element is seen as more important than the spatial element and this is one of the key features which differentiate GIS from other information systems (Michael, 1993).

2.1.9.5 Remote Sensing *vs* GIS

GIS (Geographic Information System) is a kind of software that enables:

The collection of spatial data from different sources (Remote Sensing being one of them).

· Relating spatial and tabular data.

· Performing tabular and spatial analysis.
· Symbolize and design the layout of a map.

A GIS software can handle both vector and raster data (some handle only one of them). Remote Sensing data belongs to the raster type, and usually requires special data manipulation procedures that regular GIS do not offer. However, after a Remote Sensing analysis has been done, its results are usually combined within a GIS or into database of an area, for further analysis (overlaying with other layers, etc). In the last years, more and more vector capabilities are being added to Remote Sensing software, and some Remote Sensing functions are inserted into GIS modules.

2.1.10 Use of GIS in waste management

GIS can function as a decision support tool for municipal solid waste management. In general, the use of GIS in waste management can be cumbersome and large, considering that its application with regard to operations and planning is largely dependent on spatial data. There is a lot of planning and management aspects in waste management which GIS can be used to store data concerning waste producers, amounts and types of waste produced, planning waste collection points, optimal transporting route, optimal locations for transfer stations, and for selection of areas suitable for waste disposal and locating new landfills Twumasi et al. (2006) .

In addition, GIS can be used to monitor existing status of waste implication on the environment since it can combine different datasets ranging from land use, topography, hydrographic network, environmental protection zones, soil types, population, etc. GIS can add value to waste management applications by providing outputs for decision support and analysis of waste management databases (Basagaoglu et al., 1997)

2.1.10.1 Landfill site selection

One of the most critical needs that GIS can serve in solid waste management is siting landfills. With increasing land use pressure and impacts of landfill on the environment, finding potential sites for landfills can be complex and time consuming. Before the advent and widespread application of GIS in waste management, such as landfill siting, a special committee of professionals that consist of municipal planners, environmentalists, developers, public and other municipal board officials were mandated to investigate and find potential sites suitable for waste disposal. Many a time, the work has been cumbersome and time consuming due to conflict of needs within the large committee of legislated mandates (Thurgood, 1997and Ayo and Ibrahim,2010).

As a result, the outcome of the task may not be accepted by key groups in the approval process, thereby resulting in waste of money and time in investigating suitable sites for waste disposal. With the application of GIS, the task of finding potential sites can be done efficiently and effectively. It also reduces time and costs and improves timelines of information. In locating a disposal facility, the process of selecting a site for landfill entails three major issues: data collection, criteria for location of disposal facility, and public participation (Thurgood, 1997).

In general, GIS is ideal for preliminary site selection because it can manage large volumes of spatially distributed data from a variety of sources, store, retrieve, analyze and display information for decision making. Therefore, the major goal of landfill site selection is to ensure that a disposal facility is located at a potential site with minimal environmental and social impact (Bagchi, 2004).

2.1.10.2 Use of GIS to Select Landfill Sites

According to Burrough and McDonnel (1998), a GIS is defined as a powerful set of tools for collecting, storing, retrieving, at will, displaying, and transforming spatial data. The ability of GIS to incorporate data of large geo spatial entities to multilayered models has endeared it to many subject areas including geology and seismology. Likewise, site selection procedures in solid waste management have also used GIS technology Twumasi et al. (2006).

Usually in such instances initially a number of spatial data sets each siting criterion such as topography, settlements, roads, railways, airport, wetlands, infrastructures, slope, geology, land use, floodplains, aquifers and surface water are generated from conventional and remote sensing sources. After acquiring the necessary data, they are distributed into layers according to geo spatial characteristics they share with the aid of digitizing techniques like scanning and geo coding. Then, buffer zones for each layer of data are identified using the limitations identified as inherent of the concerning geo spatial characteristics. For example, a buffer zone in the slope layer map generated from a contour map or digital elevation model indicate the areas that have steep slopes which should be avoided in selecting a landfill sites. Individual raster maps are created for each layer after signifying a class per each layer using buffer zones (Bagchi, 2004).

The role of GIS tools in waste management planning is dominant in landfill site selection process. In addition, GIS tools are also used for distribution and identification of locations for other elements of waste management system such as transfer station network, waste selection and processing centers, for defining transportation corridors, etc. The method of multi criteria analyses and evaluation is used for identifying locations of elements of a waste management system in the GIS. This approach is inevitable in locating Sustainable Development – Authoritative and Leading Edge Content for Environmental Management complex objects, such as, for example, regional municipal solid waste landfills. Its complexity is reflected both in the size and function of objects, as well as in relation to various possible spatial impacts, also in negative context Twumasi et al. (2006).

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The use of GIS in defining strategies, analyses and visualization of solutions and alternatives helps us consider and clearly represent various scenarios, as well as select the most suitable solutions through a prism of different relevant criteria (spatial, ecological, hydro-geological criteria, etc.). Therefore, in using the GIS in the selection of the most suitable landfill sites, two things of key importance are:

1. Analysis of space, i.e. all of its physical-geographical characteristics. It is necessary to comprehensively consider the space on which the problem is to be solved or which can be useful for problem solving. In this process, because of social sensitivity associated with this issue, it is necessary to be impartial in considering a possible landfill site. This can only be achieved if the entire space is considered to the same level of detail and in the same manner Twumasi et al. (2006).

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2. Visualization of space and its characteristics and impacts. This is necessary so that all participants in the project could have equal chance to perceive and understand the subject problem area. This enables active participation in searching for solutions to an

acceptable compromise. All participants must consider the space, as well as its advantages and disadvantages for landfill site selection. This is precisely one of the most important advantages of using GIS tools in landfill site selection, as well as of choosing other elements of a waste management system Twumasi et al. (2006).

Defining landfill site selection criteria is the main step in landfill site selection process. In the first phase, based on exclusiveness, the sites which do not satisfy these criteria are ranked accordingly their suitability for final results. Positive areas within which it is possible to search for the most suitable solutions are the result of this process. This phase represents an activity of micro zoning. Using GIS tools, through overlapping cartographic presentations of a certain space carried out based on criteria. After ranking the suitable landfill sites, the attention is dedicated to the nomination of Landfill sites best suitable zones. In this process, local governments and professional institutions can and must be of great importance Twumasi et al. (2006).

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Through nominating potential landfill sites, preconditions for the selection of the most suitable landfill site are created, which is followed by multi criteria analysis and evaluation of candidate sites. Site selection criteria are entered into tables and weighted for each candidate site based on the entered value scale. In this way, the evaluation process using GIS tools is carried out in an efficient manner and in a short period of time.

The role of GIS tools in the landfill site selection process is in that it enables faster singling out and clearer presentation of suitable and unsuitable sites based on previously given criteria. In this context, it is evident that selection criteria and value scale for evaluation of candidate landfill sites are of key importance in this process, while GIS tools represent a powerful means which to a great extent facilitate and speed up the process. This refers not only to the landfill site selection process, but also to defining the spatial organization of the entire waste management system, as well as defining the transfer station network (UN-Habitat, 2010).

2.1.10.3 Multi Criteria Decision Analysis (MCDA)

Decision Analysis is a set of systematic procedures for analyzing complex decision problems. These procedures include dividing the decision problems into smaller more understandable parts; analyzing each part; and integrating the parts in a logical manner to produce a meaningful solution (Malczewski, 1999).

MCDA has undergone an impressive development during the last 30 years, in part because it is amenable to handling today's complex problems, in which the level of conflict between multiple evaluation axes is such that intuitive solutions are not satisfactory. MCDA is not a tool providing the 'right' solution in a decision problem, since no such solution exists. The solution provided might be considered best only for the stakeholders who provided their values in the form of weighting factors, while other stakeholders' values may indicate another alternative solution. Instead, it is an aid to decision-making that helps stakeholders organize available information, think on the consequences, explore their own wishes and tolerances and minimize the possibility for a post-decision disappointment (Malczewski, 1999).

2.1.10.4. Steps of Multi Criteria Decision Analysis

Decision making about proposals for future action should normally follow the sequence below stated below. The following process might apply to the development of a policy, a program or a project.

- Identification of decision makers (DMs), actors, and stakeholders.
- Identification of criteria.
- Identification of alternatives and options for achieving the objectives.
- Assignment of criteria performance values.
- Weighting the criteria.
- Ranking the alternatives.
- Sensitivity Analysis.
- Making a decision.

2.1.10.5. Methods of Multi Criteria Decision Analysis

This chapter gives a broad overview of the full range of MCDA techniques currently available. However, it is neither necessary nor desirable to explore all these techniques in detail. Some are oriented towards issues which public sector decision makers are unlikely to encounter; some are complex and untested in practice; others lack sound theoretical foundations. All MCDA approaches make the options and their contribution to the different criteria explicit, and all require the exercise of judgment. They differ however in how they combine the data. Formal MCDA techniques usually provide an explicit relative weighting system for the different criteria (Malczewski, 1999).

The main role of the techniques is to deal with the difficulties that human decision-makers have been shown to have in handling large amounts of complex information in a consistent way. MCDA techniques can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities (Malczewski, 1999).

2.1.10.6. Analytical Hierarchy Process (AHP)

The AHP developed by Saaty (1980) is a technique for analyzing and supporting decisions in which multiple and competing objectives are involved and multiple alternatives are available. The method is based on three principles: decomposition, comparative judgment and synthesis of priorities.

AHP is a well-known technique that breaks down a decision-making problem into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationships between levels. The top level of the hierarchy is the main goal of the decision problem. The lower levels are the tangible and/or intangible criteria and sub-criteria that contribute to the goal. The bottom level is formed by the alternatives to evaluate in terms of the criteria. AHP uses pair wise comparison to allocate weights to the elements of each level, measuring their relative importance with Saaty’s 1-to-9 scale, and finally calculates overall weights for evaluation at the bottom level.

CHAPTER III

MATERIALS AND METHODS

3.1 Description of the Study area

Dukem town is located at 37 km South East of Addis Ababa along the main road to Adama. Geographically located between $8^o45'25''N-8^o50'30''N$ latitudes and $38^o51'55''E-38^o56'5''E$ longitudes, total area covering 35.84 km^2 (Fig 3.1) and is one of the towns of oromia special zone which is found between Gelan and Bishoftu towns. In the Northwest: the town administration of Galan, in the southeast: the town administration of Bishoftu. In northeast: peasant associations of Tadacha Yatu, in southwest: Peasant associations of Wajitu Dibdibe and Bishoftu and in the west the peasant association of Gogecha. Progresses have been seen in the town since a number of houses, manufacturing, service sector and institutions have been constructed. The population is also rapidly growing because of its nearness to Finfinne and economic importance.

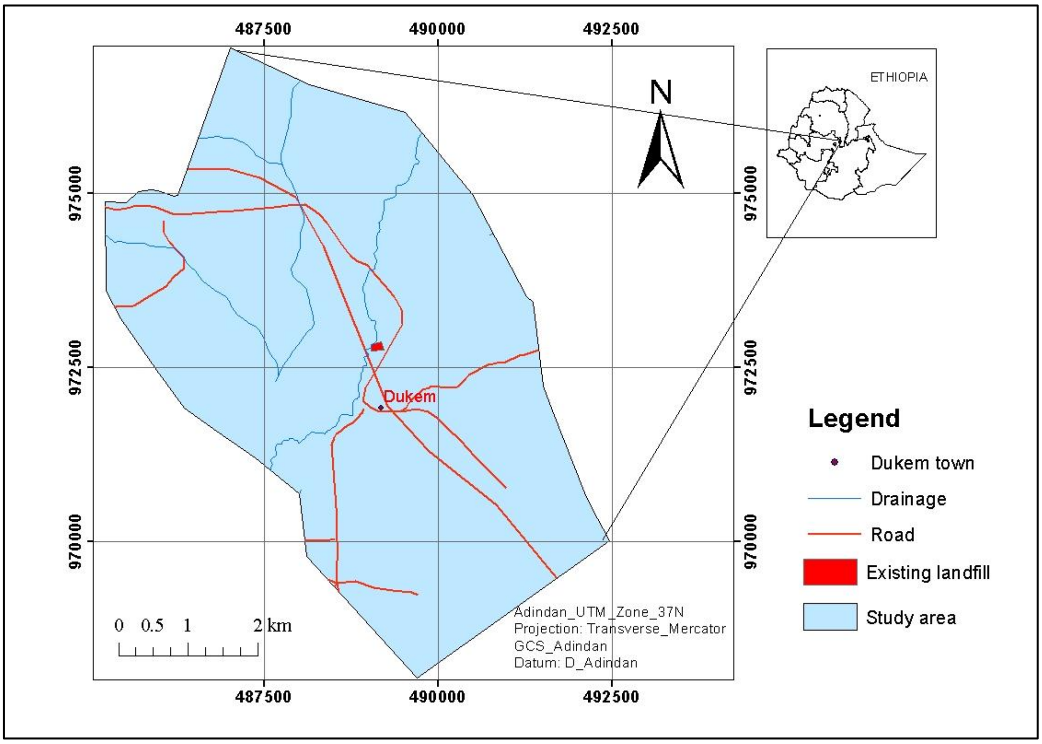

Figure 3.1 Location map of the study area

3.1.2 Topography

The relief of Dukem town is not uniform. There are many ups and downs especially in the northeastern and northwestern extremes of the town. Dukem is almost surrounded with chains of hills like Tedecha and Gimashe in the northeast and steeper slopes towards Oda Nabe cultural centre. The relief of Dukem town and its immediate borders in the north east gradually declines from northeast to south west. That means the highest altitude in this part of the bordering peasant association rises a little more than 2100 m above sea level. This declines to lower than 1800 m above sea level in the southern and southwestern direction. This indicates that the altitudinal range from the northwest extreme to southwestern part of the town is 300 m over a distance of about 10 km. The steepest gradient of the town is found in the northwestern part of the town where the gradient is greater than 41%. This is especially the case of hills found in the western, north western and in the pocket areas of the town. It is from these parts of the town that smaller streams and Dukem River originate and flow towards the southwest direction or towards Dukem town. The rain collected from the roofs and asphalt road of the town mixed with these streams and Dukem River have a serious flooding impact on the town especially during the rainy season. Therefore, there should be appropriate drainage system both along the highway and also along the feeder roads to minimize the impact of flooding in the town because the flooding of the high way has an impact both on humans and vehicles as a result of the slippery nature of soil eroded .The southern part of the town on the other hand has lower gradient which is less than 5%. This area should properly be managed so as to minimize flood hazards because of improper flood management system in the town during the rainy season (OUPI, 2000).

3.1.3 Soil

The soil of Dukam town is almost black vertisol. This type of soil forms deep cracks during the dry season but logs water during the rainy season. The cracking of the soil during the dry season facilitates the rate of soil erosion. As a result, there are deep gorges in different parts of the town especially along the courses of seasonal streams and Dukam river valley because of the very nature of the soil. The activities of people also facilitate the rate of soil erosion in the town. Activities like quarrying and also extraction of soil and also sand from the valleys of streams and Dukam River play their greatest contribution towards deep river gorges in different parts of the town.

People dig out soil and also stones from the banks of Dukam River to provide soil for the construction of mud houses. In the future these areas can be seriously affected by land slide and also can be hindrance for the construction and any development activities along the river valley. Therefore, appropriate environmental protection and management should be under taken by the concerned bodies and the municipality. In some parts of the town especially in the southern and in pocket areas the color of the soil is gray and reddish brown. This is mainly because of the impact of erosion from the surrounding highlands with the same color. This type of soil is nitosol which has an advantage for the cultivation of different vegetables and nurseries. Reddish brown soil mainly along river valleys and seasonal streams is source of raw material for constructing mud houses. It is also source of soil for those who cultivate seedlings and source of sand for construction (OUPI,2000).

A) ***Cambisols*** have limited agricultural value as they occur dominantly on slopes, are often shallow or have many stones or rock outcrops. Where cambisols are deep and not stony they are good for agriculture but available P content can be low. Cambisols have a strong brown or red color (OUPI,2000).

B) Luvisols

Luvisols have a distinct clay accumulation horizon. Most Luvisols are well-drained but Luvisols in depression areas with shallow groundwater may develop gleyic soil properties in and below the argic horizon. Stagnant properties are found where a dense illuvial horizon obstructs downward percolation and the surface soil becomes saturated with water for extended periods of time (OUPI, 2000).

C) **Vertisols**

Vertisols are heavy clay soils in flat areas that have a pronounced dry season during which they shrink and have large deep cracks in a polygonal pattern. During the wet season the clay swells and causes pressure in the subsoil. Vertisols have a fairly good but limited agricultural potential because the land is rather difficult to prepare. Dry soils are hard and wet soils are sticky. There is only a short period when moisture conditions of the surface layer are favorable to prepare land (OUPI, 2000).

Another difficulty is that the drainage of the subsoil is very low, because of the swelling clay. Very often the soils are flooded or have stagnant water during the wet season. The organic matter content in vertisols is often not more than 1 %. The soil has high water retention, but a relatively small amount of water is available for plant growth. Rooting might be restricted because of the swelling and shrinking properties of the soil (OUPI, 2000).

D) **Fluvisols:** Young soil in alluvial (floodplain), lacustrine (lake) and marine deposits (from the Latin, fluvius, meaning river). Fluvisols are common in periodically flooded areas such as alluvial plains, river fans, valleys and tidal marshes, on all continents and in all climate zones. Fluvisols show layering of the sediments rather than pedogenic horizons. Their characteristics and fertility depend on the nature and sequence of the sediments and length of periods of soil formation after or between flood events (OUPI, 2000).

E) **Leptosols:** Shallow soil over hard rock or gravelly material (from the Greek, leptos, meaning thin). Leptosols are shallow over hard rock and comprise of very gravelly or highly calcareous material. They are found mainly in mountainous regions and in areas where the soil has been eroded to the extent that hard rock comes near to the surface. Because of limited pedogenic development, Leptosols do not have much structure. The permeability and infiltration of each soil depends on its textural composition (Gizachew Kabite *et al.,* 2011).

3.1.4 Geology

Dukem is found in the main Ethiopian rift valley near the western escarpment. Volcanic rock materials of various compositions cover the area. Due to weathering of the rock, and subsequent erosion and deposition, thick residual clay and silty clay soil covered most part of the plain topographic landforms. The volcanic rocks found exposed along Dukem stream, Mandalo stream, Gogecha stream, rigs and slopes. According to the litho logical log of existing borehole, near Dukem stream, (488800 m E, 972368 m N), that was drilled in December 2002 the area can be depicted by alternating layers of ignimbrite, scoracious Basalt, aphanitic Basalt, scoria and clay.

Litho logical log of the newly drilled borehole in September 2005 for Bishoftu town, in the plain land of Garbi Ballo, at the distance of 5km from Dukem, located at the geographic grid coordinate 969255 m N and 492816 m E, shows from top to bottom, the area formed from thick clay deposit, scoriacious basalt flow (14meters), and reworked pyroclastic deposits of different size, fine to medium grained sand of different composition, and medium to fine gravel of different rock type. Due to the location of the study area in the main Ethiopian rift valley near the western escarpment parallel faults and step faults are prevalent in the area, which are governing ground water flow directions at depth and the flow of drainage pattern. A ridge extends northeast and southwest to Yerer Mountain in the north east and to Guji and Bilbilo Mountain in the southwest demarcated the western escarpment of the rift (OUPI, 2000).

3.1.5 Climate

There is strong relationship between altitude and climate in tropical countries. The altitude range of Dukam town ranges from 1800 m to 2100 m. From the altitudinal ranges the climatic zone of the town can be semi temperate because the altitudinal ranges of semi temperate in Ethiopian context is from 1500 m to 2500 m. The temperature of the town based on this altitudinal range is from 15 to 20(OUPI, 2000). But because of the impact of humans on the natural environment and a continuous deforestation, the temperature of the town is greater than the amount expected. In fact, the pressure of population on the natural forests to secure their agricultural land reduced the natural forest cover (OUPI, 2000).

Table 3.1: Monthly Rainfall of Bishoftu Meteorological Station

Year	**Ja**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**No**	**De**	**Annual Average**
1987	0	61.4	138.:	90.1	154	65	83.3	155.9	80.9	4.6	0	0	69.5
1988	8	15.9	6	44.7	36.8	100.7	146	236.8	121.	16.7	0	0	61.1
1989	0.6	12.2	35.1	47	0.4	59.1	183.7	171.5	135.	21.2	0	3.3	55.8
1990	0	123.	58.2	86.4	36.6	76	224	173.2	102.	0	0	0	73.3
1994	0	0.0	29.2	19.5	19.6	74.5	232.8	187.3	108.	0	10.	0	56.8

1995	0	2.4	7.8	34	5.5	92.5	188.4	169.6	75.1	0	0	11.	48.9
1996	16.	0.0	103.	55.3	105.4	261.5	164.1	275.6	90	0.1	5.9	0	89.8
1997	27.	0.0	26.7	74.8	13.6	121.7	235.8	171.8	71.4	99.9	10.	0	71.2
1998	32	51.4	13.9	77.2	41.8	77.7	206.3	293.5	97.6	93.3	0	0	82.1
1999	0.5	0.0	36.6	0	10	176.9	298.7	258.6	48.7	90.9	0	0	76.7
2000	0	0.0	8.6	50.4	65.4	77.4	244.3	181.4	139.	40	23.	3.4	69.5
2001	0	4.6	166.	21.8	104	79.5	242.3	143.4	64.3	38.2	0	0	72.0
2002	8.6	0.0	48	34.6	11	109.1	179.3	178	58.4	0	0	21.	54.0
2003	38.	55.4	64.4	100.3	21.1	81.4	277.9	285.5	120	6	3.6	35.	90.8
2004	0	0	68.1	119.9	2	133.5	172.5	209.1	79.6	22.6	10.	0	68.1
2005	21.	225.	122.	77.3	86.5	96.7	168	185.7	153.	0	2.9	0	95.0
2006	5	108.	0	52.2	32.2	108.2	329	141.4	122.	78.3	5.2	16.	83.3
2007	5.8	0.0	0	57.9	92	77.4	326.8	155.1	123.	50	8	0	74.7
Montl Avera	9.7	38.9	51.8	58.0	46.6	103.8	216.8	198.5	99.6	31.2	4.5	5.4	72.1

Source: National Metrological Agency of Ethiopia, 2008

As it is observed in the above table, the rainy season of Dukem town and its surroundings start in the summer of the northern hemisphere associated with the position of the overhead sun. But little rainfall is also expected as of spring season. The maximum amount of rain fall occurs in the months of June, July and August. This is the wettest season of the town and its environs. Therefore, it is very important to minimize flood hazards of the town by properly designing drainage canals along the roads of the town. Besides, it is necessary to remove wastes from the existing drainage canals before the onset of the rainy season (OUPI, 2000).

3.2 Source of data

Data acquisition in terms of data availability is considered as it is of prime importance when using GIS. The technical approach was also employed to produce suitability maps emphasizing "suitable" geographic areas resulting from weighted and combined map layers based on established criteria. Finally, the model flow chart and justification with respect to the application of the model constructed were also confirmed (Hadjibiros and Dermatas, 2007) observes that numerous criteria must be taken into consideration when prospective sites for landfills are being studied.

One of these is the need to evaluate large amounts of data as quickly as possible. In this study, the GIS-based landfill site selection approach combines the spatial analysis tools provided by GIS to integrate and evaluate different datasets based on certain evaluation criteria in order to determine potential landfill sites. The digitized datasets were interpolated with Arc GIS (Software) to generate operation of different dataset layers. Spatial analysis was carried out to identify potential sites. A final composite map was then produced, which presents all areas suitable for waste land filling.

Both spatial and non spatial data were sourced from government and private agencies. Analogue/digital maps of the study area were obtained from the Dukem municipalities planning office and other sources of secondary showing in (Table 3.1). The secondary data for the study was acquired from

- ✓ Internet
- ✓ Reports
- ✓ Books,
- ✓ Journals
- ✓ Governmental institutions and other documents.

Table 3. 2 Data and equipment used to execute the present study.

No.	Type	Description	Source
1	Map	Administrative boundary/master plan shape file	Oromia urban plan institute
	Map	Digital Soil map	Ministry of irrigation and energy
2	Map	Road dataset shape file	Dukem road authority
3	Map	Land use land cover shape file	Dukem municipality
4	Row data	well data	Dukem water and sewerage authority
5	Row data	STRM(30*30) resolution	USGS
6	Equipment	GPS and digital camera	Oromia road authority

3.3 Data acquisition and method

Data acquisition is the process or method of acquiring the data required for the study area. It involves both geometric and attributes data. The data acquisition represents elementary properties of entities and relationships. Comprehensive information was collected and produced in a digital format and the research methodology given in (Fig 3.2).

Software used for this project

- ✓ ArcGIS 10 version developed by ESRI
- ✓ ERDAS Imagine 2011 version
- ✓ Microsoft office 2007
- ✓ Microsoft vision 2007

3.4 Technical approach

GIS-based analyses were conducted using ArcGIS software, Spatial Analyst. Spatial Analyst, surface analyst, interpolation, reclassification, weighted overlay. It was used to produce suitability maps highlighting "suitable" geographic areas derived from weighted and combined map layers based on established criteria.

3.4.1 Analyzing maps

Analyzing maps essentially involves setting the study area boundary, making slope map, buffer zone maps, find distance, reclassified maps and suitability maps are produced. The non-suitable areas are known as buffers (Kontos *et al.,* 2003). Thematic maps include the surface water, rivers, roads, and land-use and etc. They will also be used as factor maps representing areas that range from low suitability to high suitability.

3.4.2 Study area boundary

Since all analyses over layers have to be limited to the extent of the study area, a boundary map (base map) is generated and was for future calculations.

3.4.3 Slope map

According to the criteria, a slope map is needed due to the fact that slope is a relevant factor in siting the landfill, given that an area is an important consideration for excavation. The landfill site should have a moderate slope to assist in controlling drainage.

3.4.4 Distance/Buffering

Depending on the criterion, it is preferable that the landfill be built near or away from a particular source. Proximity maps are to be made using "Spatial Analyst - Distance" option for layers associated with criteria which could be ranked based on their distance from the nearest source. The source may be anything such as a road, a stream, and so on.

3.4.5 Clip/extract by mask

Clip uses the clipping region; only those input coverage features that are within the clipping region are stored in the output coverage. This process helped in obtaining study area maps of all the parameters.

3.4.6 Reclassified map

Each map layer is to be ranked by how suitable it is as a location for a new landfill.

The parameters are reclassified for this study as unsuitable, low suitable, moderately suitable and highly suitable.

3.4.7 Weight and combine data sets.

The final step in suitability modeling is to determine the relative importance of each data set, weight them accordingly and then combine the data sets to produce a suitability map. Weighting the data sets define the extent to which each data set will influence the model results.

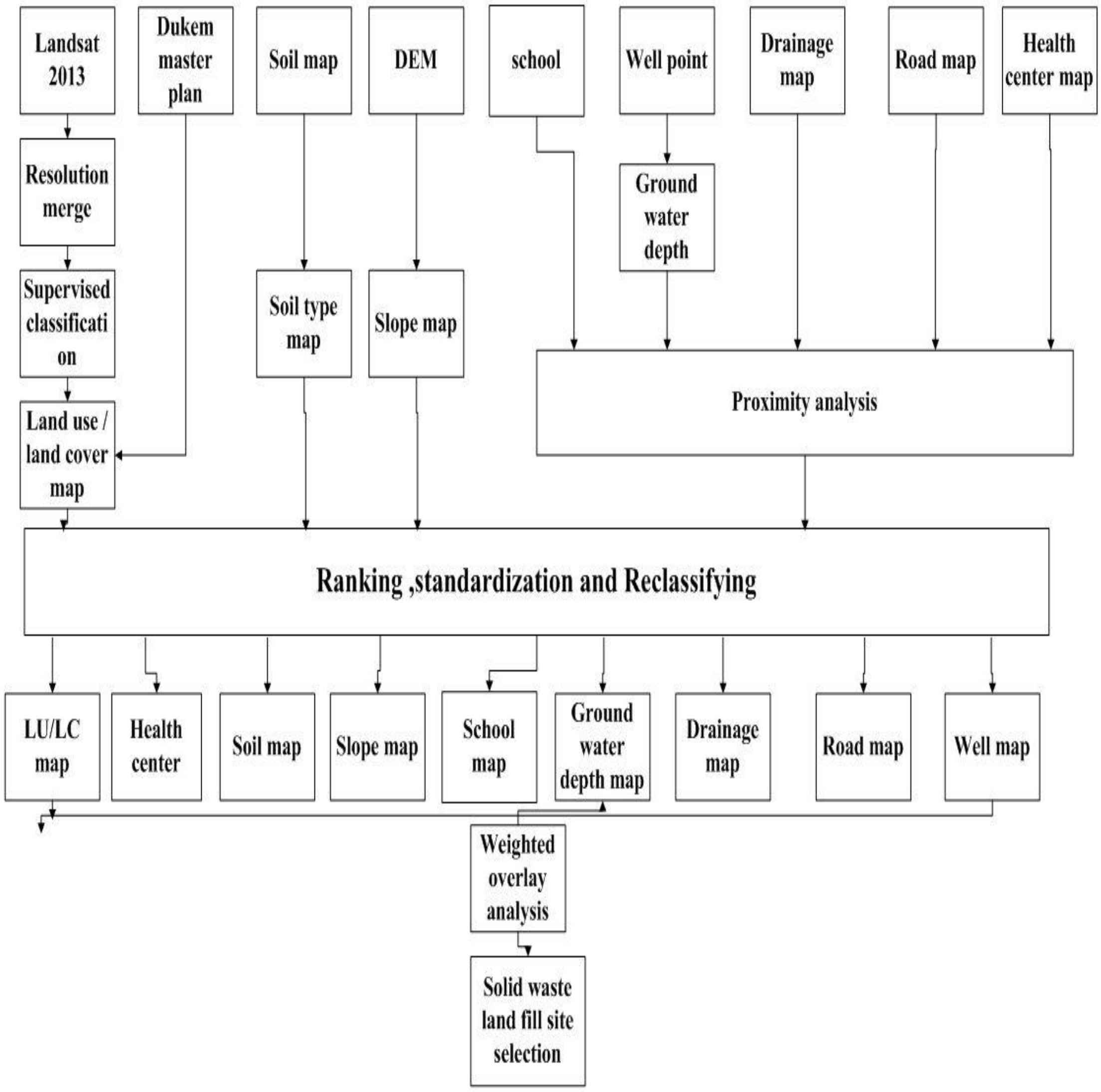

Figure 3.2 **Methodology**

3.5 Data analysis

In many Ethiopian urban areas, MSW is disposed on lands with water near surface, or open burning dumps. The waste is burned to reduce volume, but refuse does not burn well. The burnt refuse produces clouds of smoke and creates breeding grounds for rodents. Landfilling is thought as a means of dumping waste on unutilized land. Landfills are not a favorable usage of land. Finding sustainable suitable sites for MSW waste disposal is becoming increasingly difficult and poses important challenges as result of land availability, developmental changes and population growth together with important factors such as environmental, economic and other social concerns.

Of these, environmental concerns are perhaps the most important issues to be addressed during site selection. Thus, the process of siting a waste disposal facility should explicitly address the issues of the community. Therefore, the use of a GIS as Decision Support Tool for Landfill Siting can be incredibly useful in locating potential sites for a landfill. GIS can use integration of spatial information to ensure the quality of location selected. Using GIS for landfill site selection is a cost-effective and time-saving tool compared to conventional methods Daneshvar et al., (2005).

3.5.1 Criteria

In finding a potential suitable site, a number of variables were taken into consideration, which includes environmentally sensitive areas, exclusive protected area distance to streams, distance to water body, proximity to settlement, and proximity to infrastructure provision and the distance from transportation routes .To arrive at the selection criteria for potential sites for landfill, relevant literature and opinion were sought from relevant local municipal offices Daneshvar et al., (2005).

3.5.2 Analysis

The capabilities of GIS for generating a set of alternative decisions are mainly based on the spatial relationships principles of connectivity, contiguity, and proximity and overlay methods. For example, overlay operations are often used for identifying suitable areas for proposed or new facilities, waste disposal, etc. Having acquired the datasets necessary for landfill siting, spatial analyses were carried out to locate potential sites Daneshvar et al., (2005).

SOIL

The development of soils is mainly dependent on the type of rock from which they are derived and the condition of the depositions directed by climate and geomorphologic position (Gizachew Kabite *et al*., 2011). According to the soil map provided by the Ministry of Agriculture, the study area is mainly covered by five main soil types such as vertisols, luvisol, leptosol, cambisol and fluvisol (Fig 3.3) and the reclassified soil map (Fig 3.4).

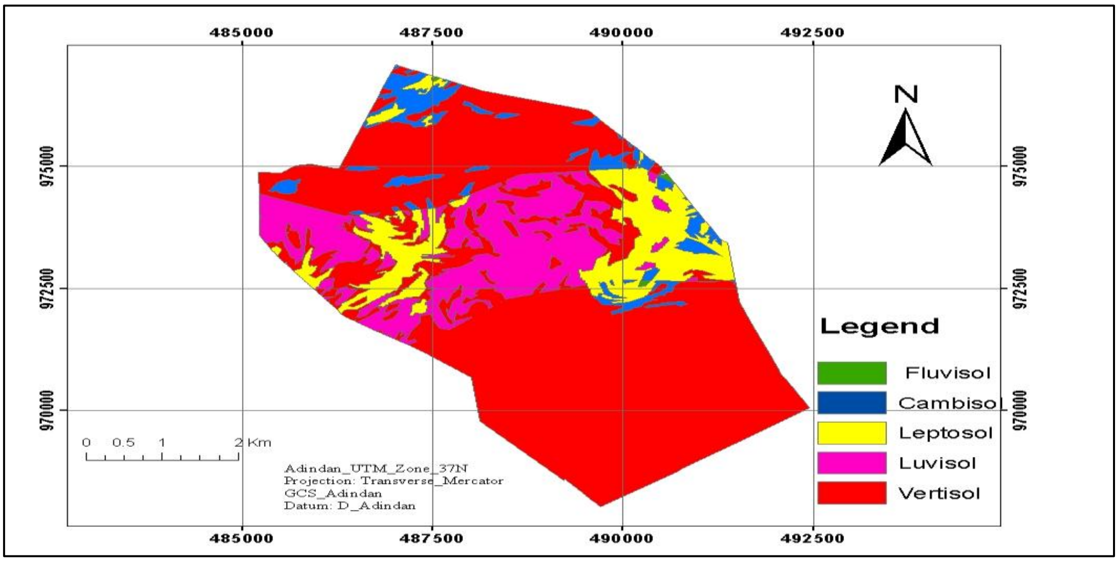

Figure 3.3 Soil map

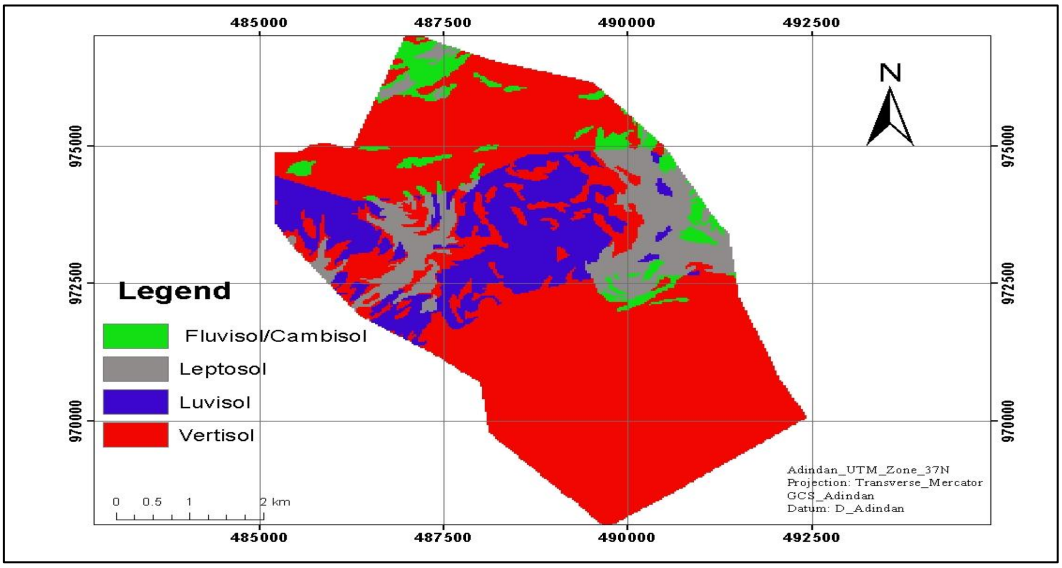

Figure 3.4 Reclassified Soil map

Proximity to road

Locating the landfill close to a road would help reduce costs related to transportation and Road network map of study area (Fig 3.5). To accomplish this, the major road layer and a buffer zone around the major roads were created. Landfills shall not be located within 100 m of any major highways, city streets or other transportation routes. The 100 meters was chosen based on accessibility of sites and options sought.

There are many suggested buffer zone distances. Minimum distance from the network is imported in order to avoid visual impact and other nuisances. Roads plus 300 m buffer areas from both sides should be applied. On the other hand, the landfill site should not be placed too far away from existing road networks to avoid the expensive cost of constructing connecting roads. Distance from main access roads should be smaller than 3 km and between 0.3 km and 2 km of a major road. The study preferred a buffer of 300 m distance from main roads by referring to different sources Sener et al. (2011). It was reclassified as unsuitable road within 300 m, low suitable between distances from 300 to 600 m. The distance starting from 600 up to 1000 was considered as moderate suitable and highly suitable is distance between 1000−2000 m (Fig 3.6).

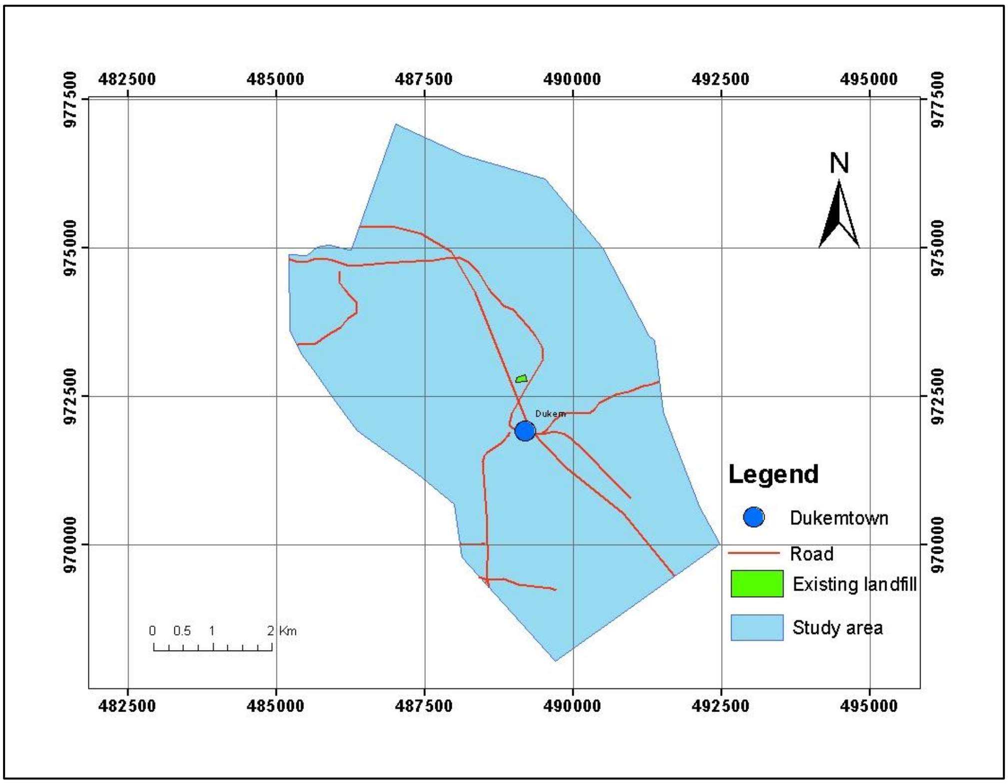

Figure 3.5 Road network map of study area (source: Dukem road authority)

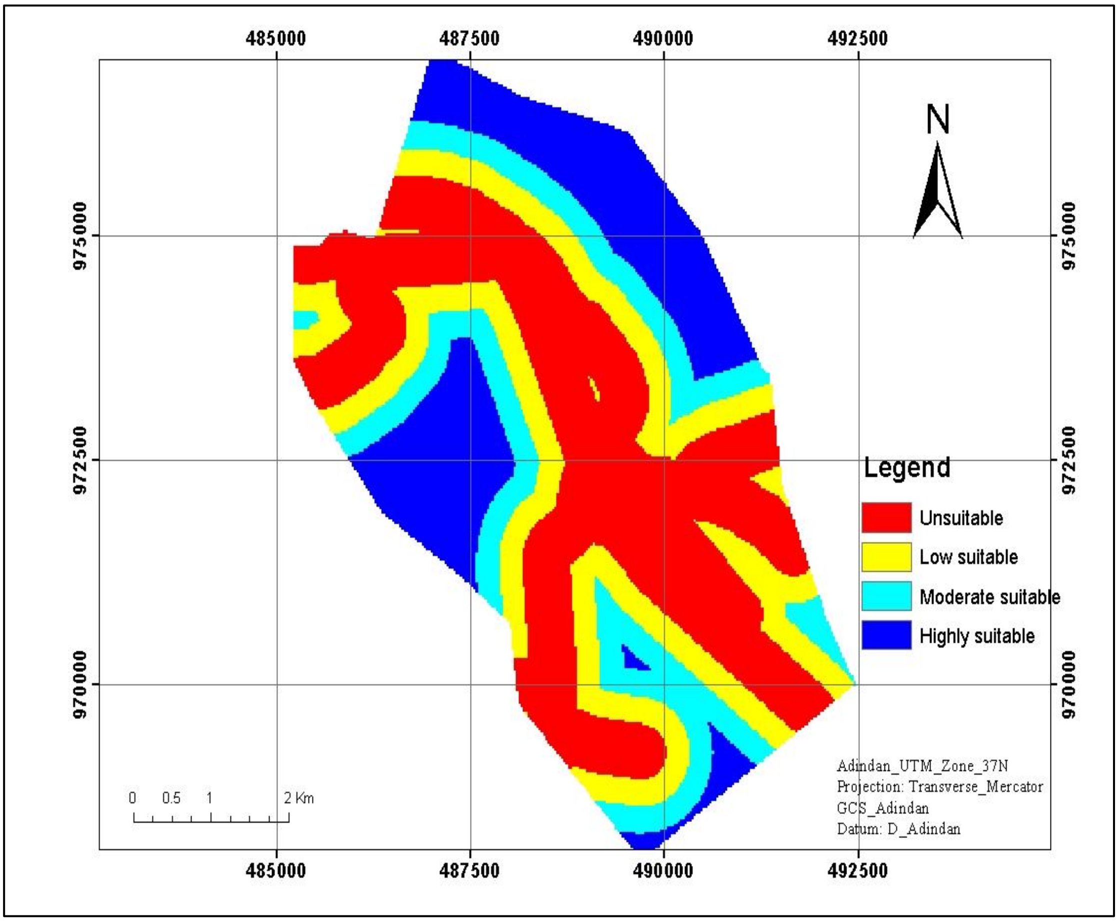

Figure 3.6 Reclassified road map

Proximity to drainage system

Landfills should not be placed too close to streams and rivers that constitute the drainage system of an area in order to mitigate conflicts relating to the contamination of sources of water supply and Drainage map of study area (Fig 3.7). This becomes imperative in order to guard against health problems, noise complaints, odor complaints, decreased property values and animal – perpetrated mischief due to scavenging creatures. To accomplish this, the drainage layer and a buffer zone around the river were created as unsuitable, low suitable moderately suitable and highly suitable class and reclassified drainage map (Fig 3.8)

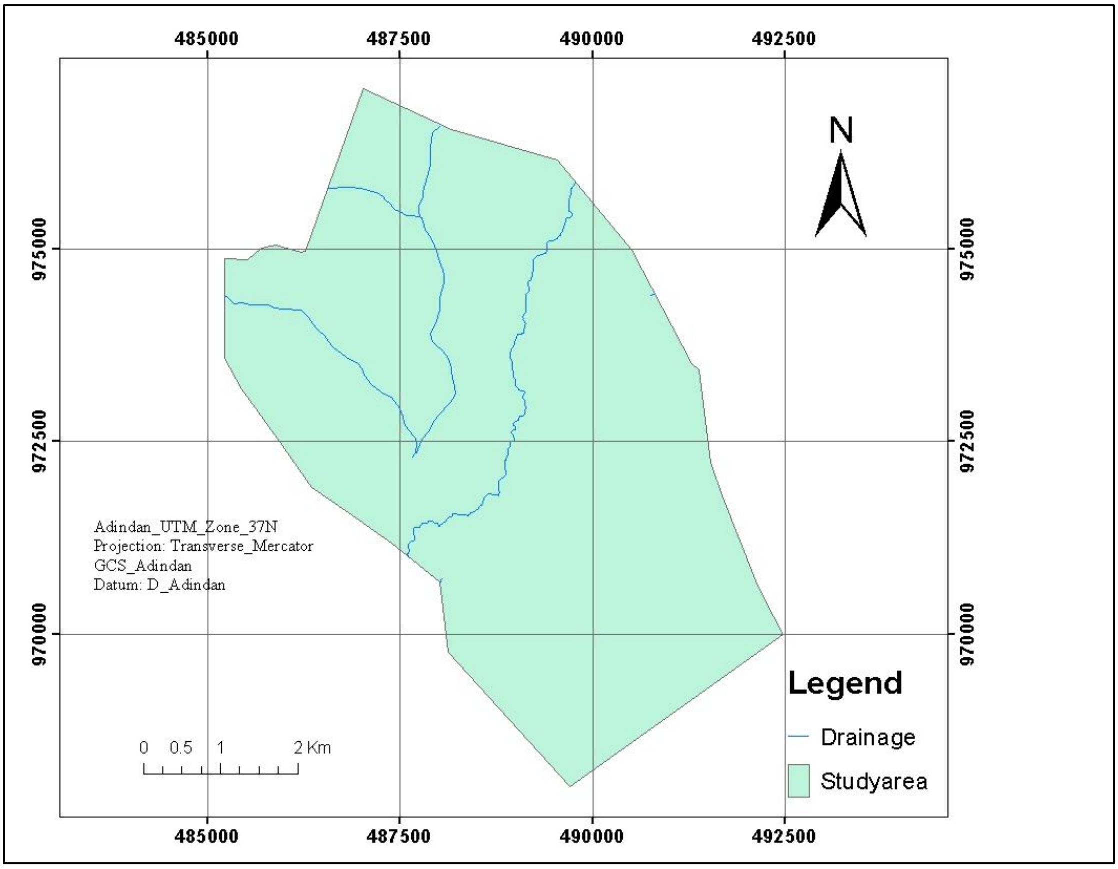

Figure 3.7 Drainage map

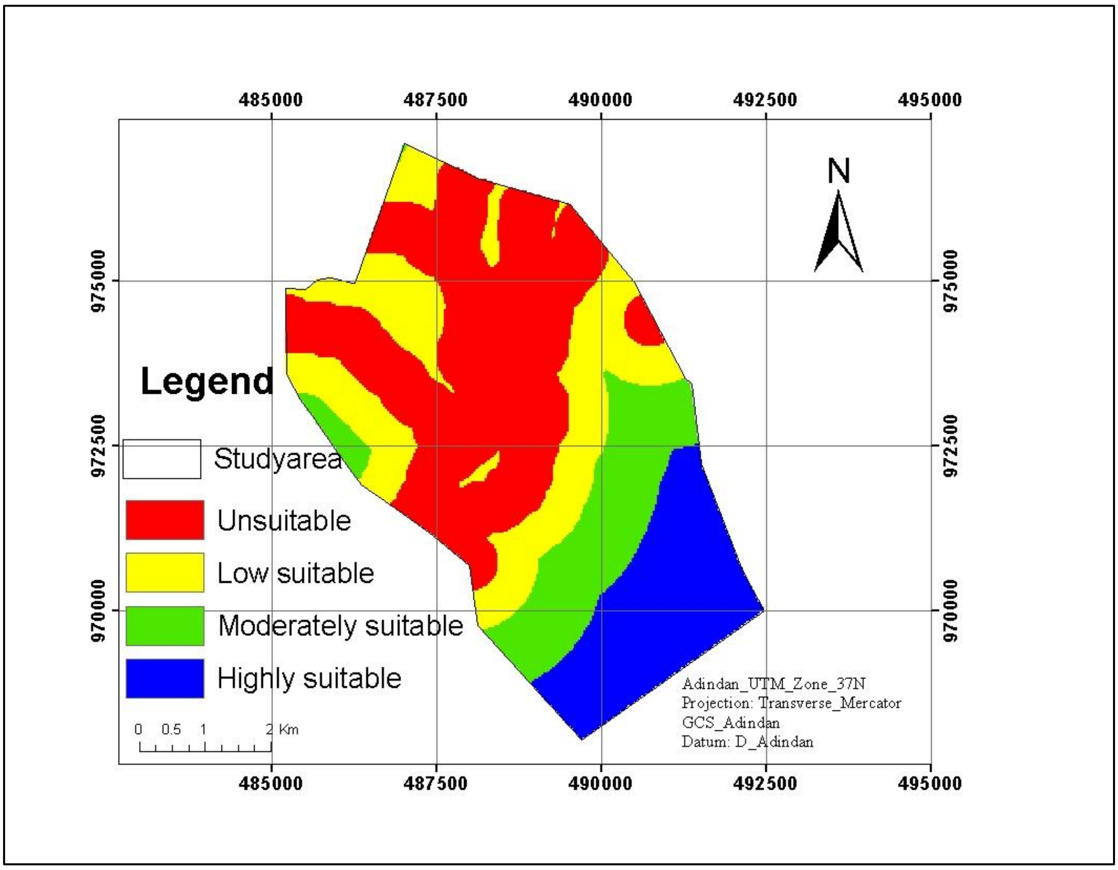

Figure 3.8 Reclassified drainage map

Suitability of land use/land cover

The land use map (Fig 3.9) displays the land utilized by the human and the natural cover in the Dukem town. It is the basic map of the study and helps in generating many thematic maps required for overlay analysis. The land use map indicates the areas of settlements, bush shrub land, cultivated land, open grass land, and bare land the majority of the town occupied by cultivated land. The majority of the settlement areas occur at the center of the study area. By reviewing different literature, it was advisable to select land, which was occupied by bare land, bush shrub land, open grass lands for solid waste disposal Sener et al. (2011).

Hence, the highest value is given for suitable land class types to solid waste disposal site selection. The land which is covered by bare land, bush shrub land and grass lands. For the purpose of this study, land use/land cover of the area was analyzed from landfill siting point of views. Accordingly, landfill should not be sited in settlement areas as they are high value lands and thus excluded from siting processes. Bare land and bush shrubs lands in the study area were identified as best option for solid waste landfill site. The rest of the lands like open grass land and cultivated land areas were used as last option for landfill site. Therefore, land-use/land-cover of the study area was reclassified in to three classes of unsuitable, moderate suitable and highly suitable (Fig 3.10 and Table 3.2)

Table 3. 3 Land use land covers class with respective suitability levels

Land use/ land cover	Level of suitability	Area in (km^2)
Bare land	Highly suitable	2.63
Bush shrub land	Highly suitable	0.96
Open grass land	Moderately suitable	0.38
Cultivated land	Moderately suitable	22.66
Settlements	Unsuitable	9.21

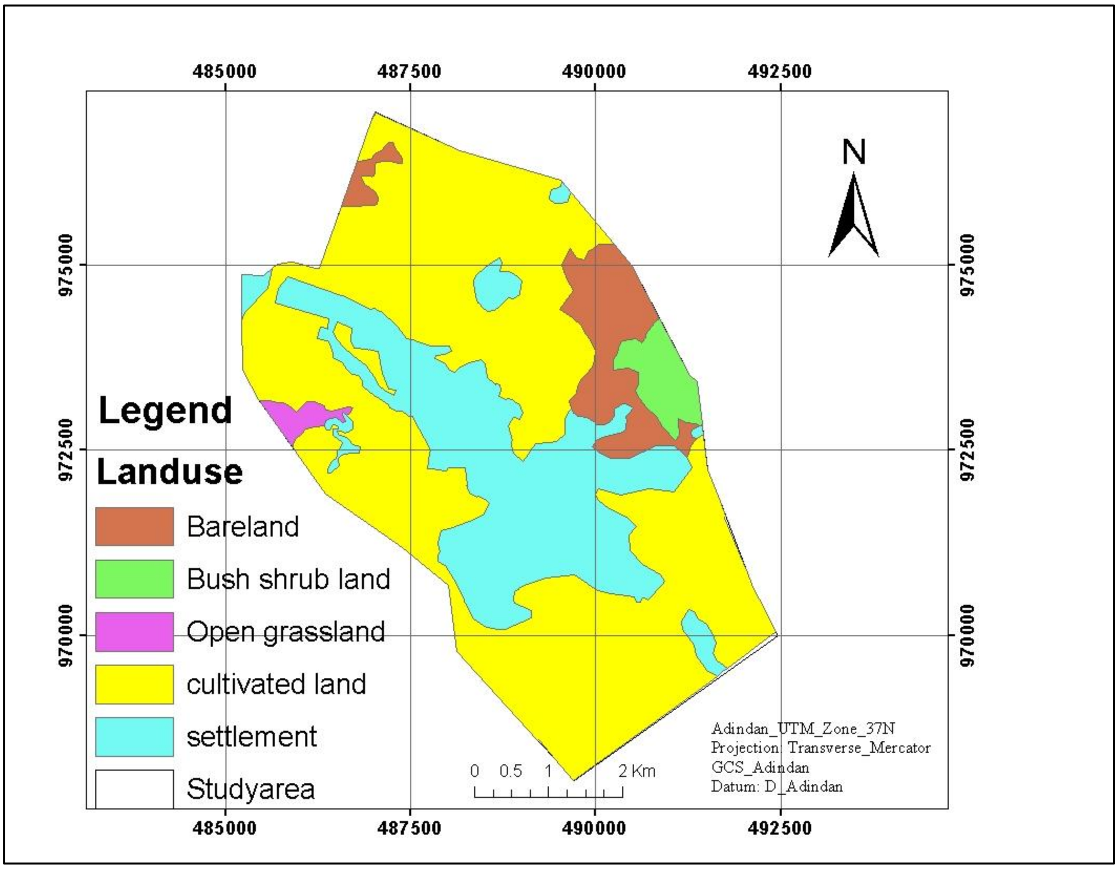

Figure 3.9 Land use/ land cover map

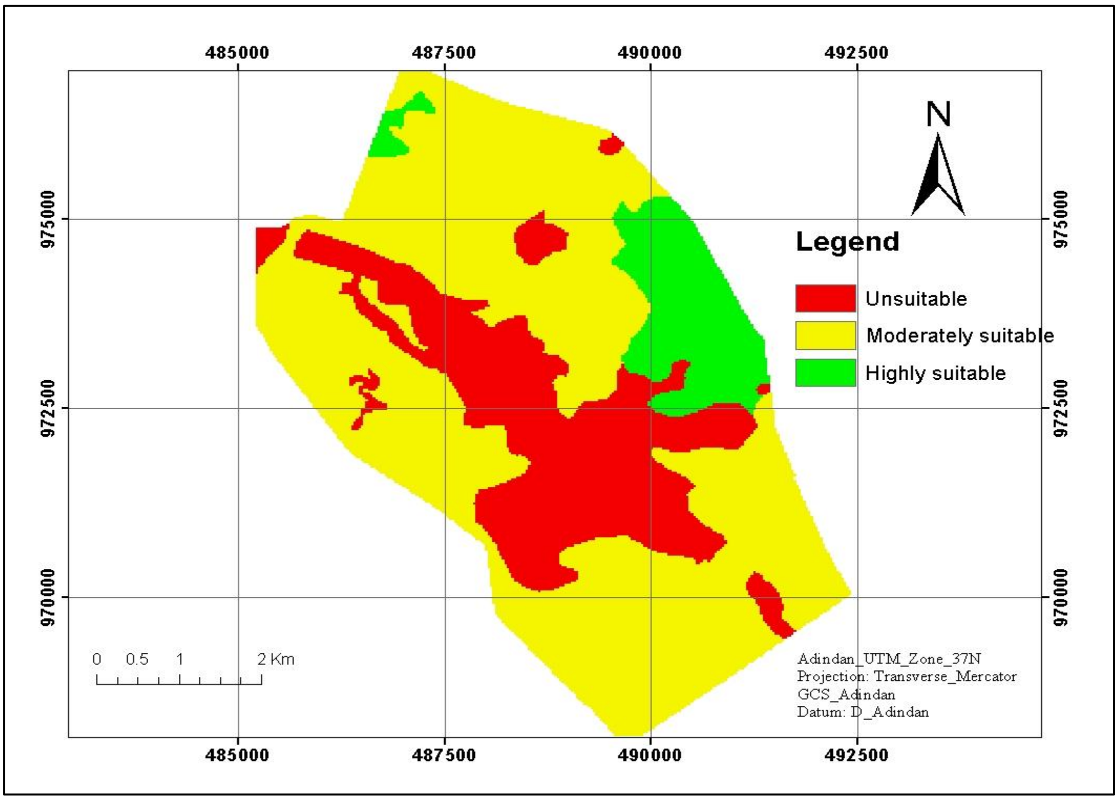

Figure 3.10 Reclassified land use /land cover map

Digital Elevation Model (DEM)

Digital Elevation Model (DEM) with 30 m spatial resolution also referred as the Digital Terrain Analysis is a digital representation of earth's topography in a continuous way. Digital Elevation Model (DEM), also referred to as the Digital Terrain Analysis, is a digital representation of earth's topography in a continuous way (Fig 3.13). A slope map was generated from DEM. The potential for slope failure was related to the degree or grade of the topography. Slope failure underneath or adjacent to landfills, will result in waste containment failure and release of debris into the surrounding area. Land with slopes greater than 15% should be considered less suitable for waste disposal sites because it facilitate flowing of contaminants to the stream Al-Hanbali et al. (2011).

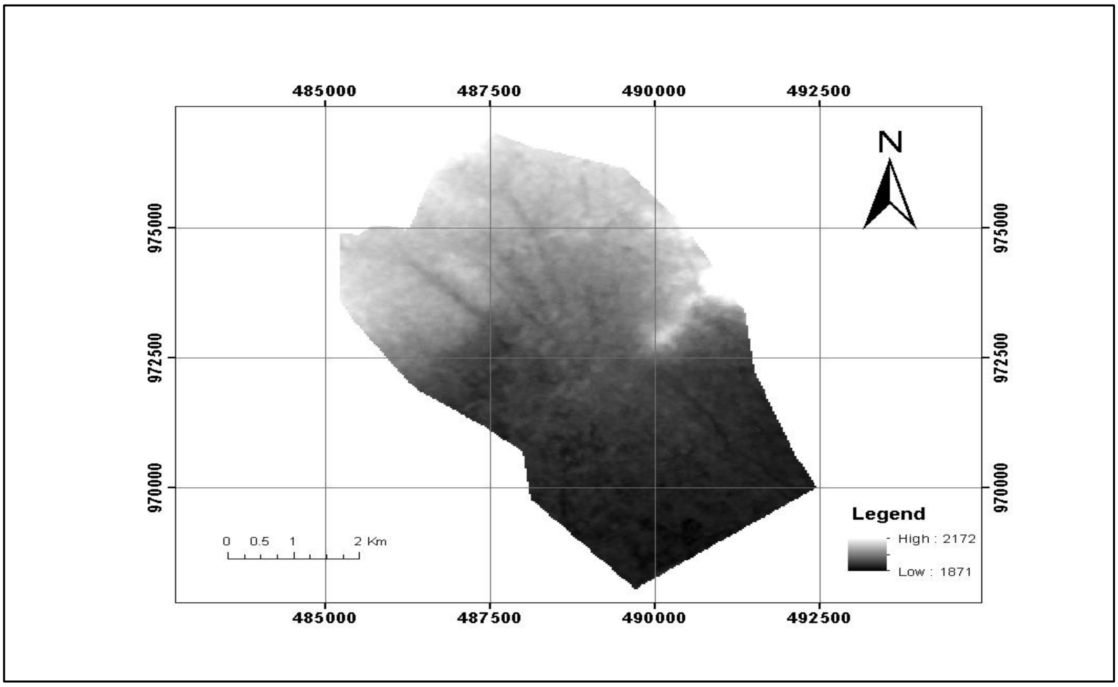

Figure 3.13 Elevation map

Slope layer

This study considered the lower slope more highly suitable than the land with higher slope. Different research shows that areas with high slopes will have high risk of pollution and potentially not a good site for dumping. The slope map is prepared in percent using the DEM of 30 m spatial resolution. This study considered the lower slope more highly suitable than the land with higher slope. The slope values are subdivided into four main classes. These classes are: Slopes between 0-5 percent, 5 - 15%, 15-25% and 25-75% will be in the most favorable class Al-Hanbali et al. (2011) (Fig 3.14)

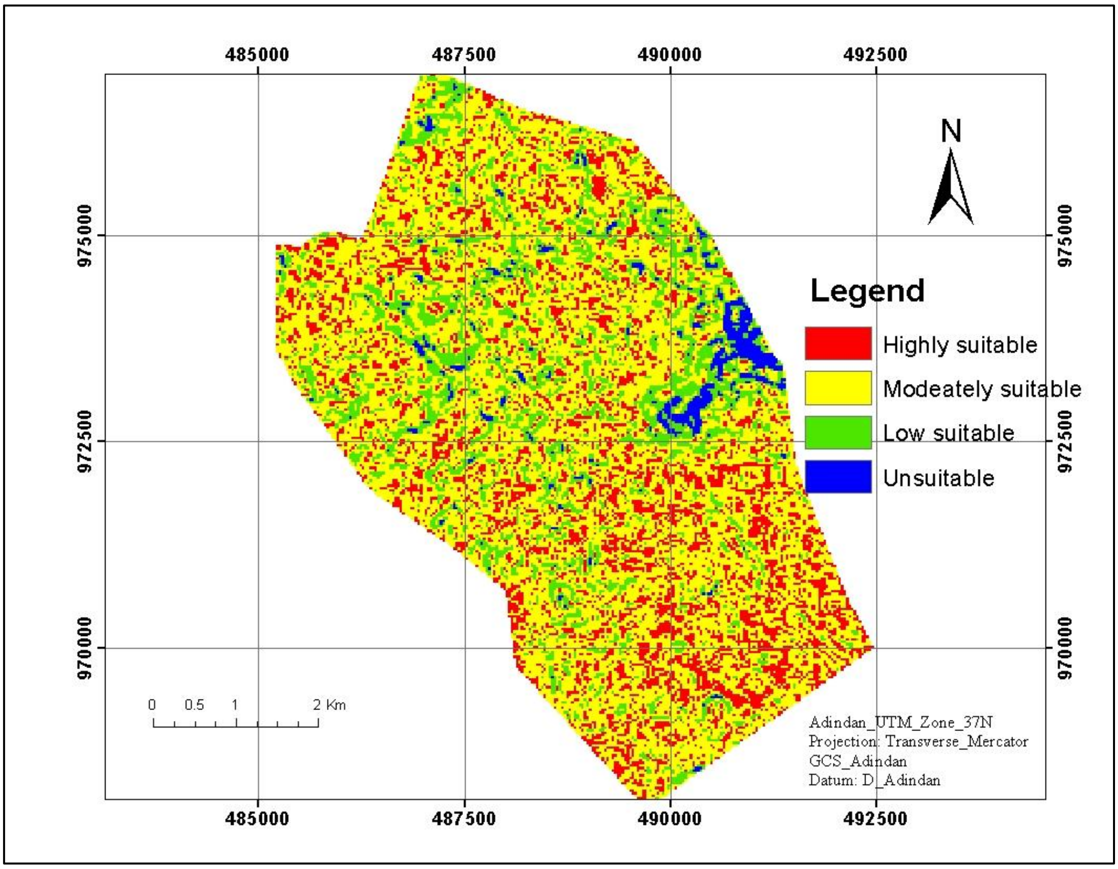

Figure 3.14 Reclassified Slope map

Depth to Groundwater Table Layer

Groundwater is a major source of water supply for the town which is reflected by regular extraction of groundwater through ever increasing number of municipal, industrial and private bore wells. Monitoring groundwater levels and quality is useful to understand impact of uncontrolled drilling of bore wells, point and non point sources of pollutants. Such studies provide early indicators of changes in groundwater resource and help to understand how to protect it. A total of 6 bore wells are found in the study area. The Spatial coordinates were registered on site for each bore well with a GPS instrument and water depth below the ground level is measured during well preparation.

GIS map showing groundwater depth is developed. These maps are very useful for urban planning and sustainable groundwater usage. Depth to groundwater table layer is prepared due to its significance on the performance of the foundation stability and excavation works. Six of the boreholes are located inside the study area. The locations of these boreholes are given in (Fig 3.16). Depth to groundwater table values is calculated by subtracting the groundwater table elevations from the topographical elevations that are obtained from the GPS data. After preparing the depth to groundwater table map using GIS software by interpolation method, the map is edited, evaluated and to protect flowing of contaminants into ground water and divided into three classes. Depth range of 0 – 28 m is classified as unsuitable favorable class, 29 – 31 m less suitable, and 31-33, 33-4210 m as moderate and highly suitable in respectively. The depth to groundwater table layer of the study area is given (Fig 3.15).

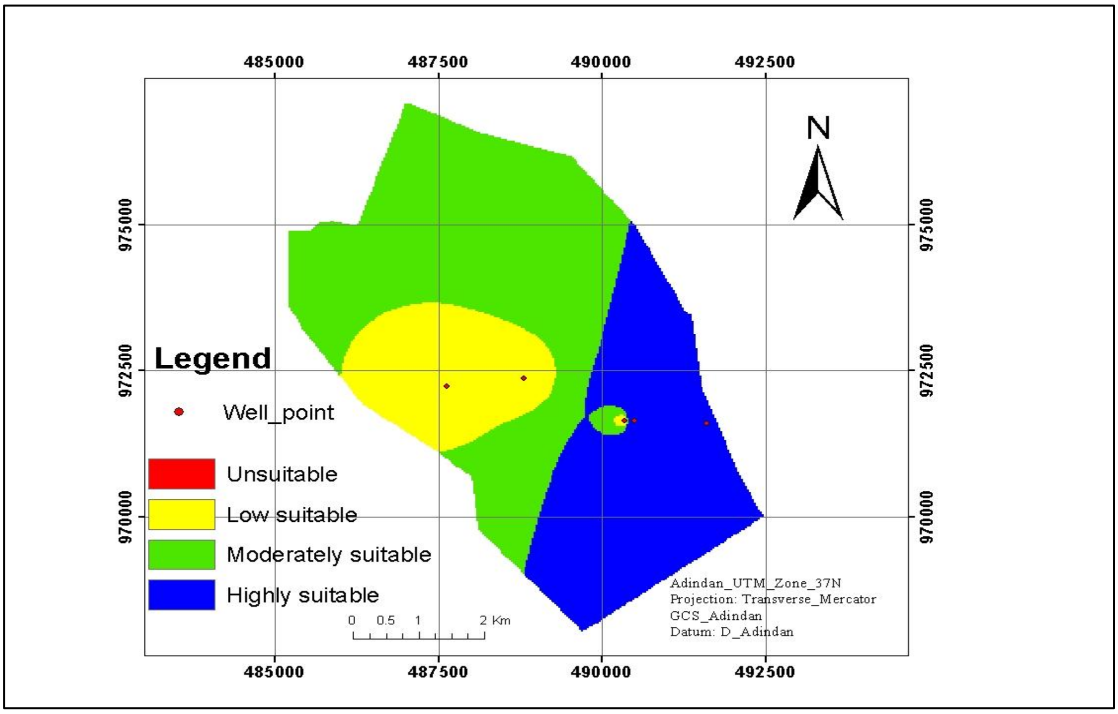

Figure 3.15 Depths to ground water table map

Well data

The well layer is constructed in order to generate a buffer zone around because it is unsuitable to place close to a landfill. This is due to the possibility of contaminants flowing into wells. This is also primarily due to environmental concerns, where a location further away from a well source would be preferred. The landfill site is prevented to be located within 500 m from the wells; a 500 m buffer around wells was created by using Euclidean distance method to protect well flowing contaminants into it. So the available area excluded buffer zone around wells areas (Fig 3.17).

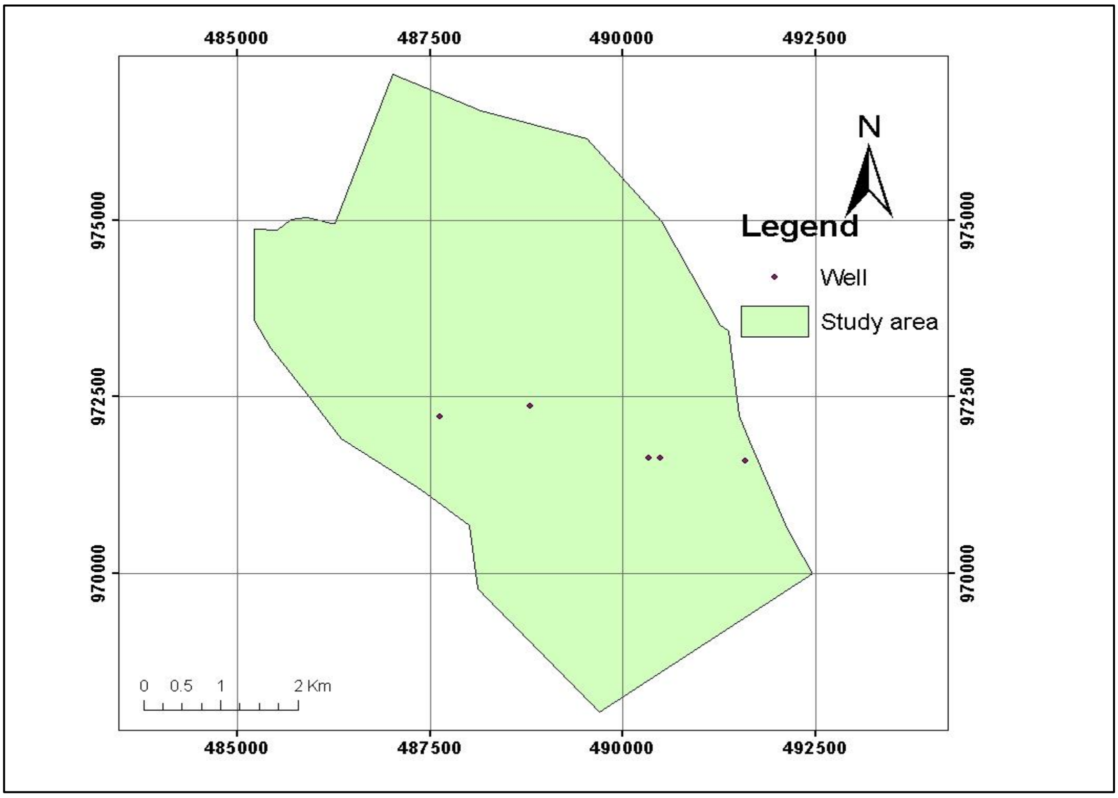

Figure 3.16 Well map

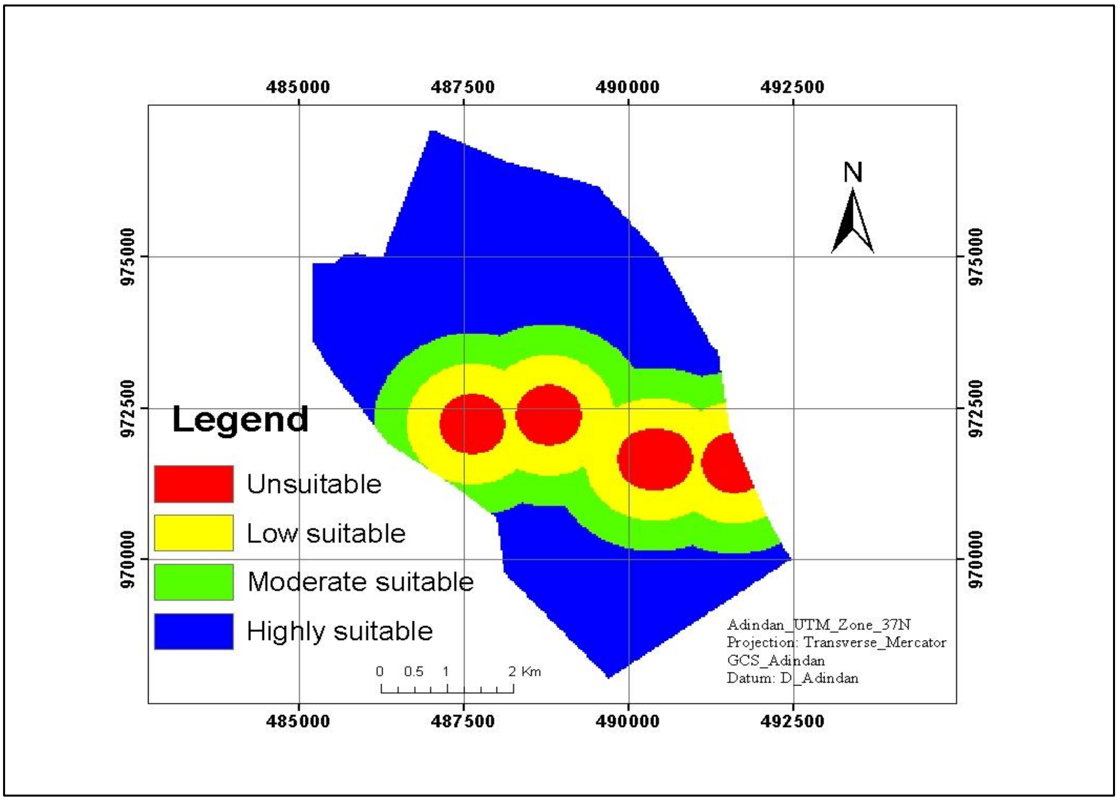

Figure 3.17 Reclassified well map

3.5.3 Weighted Overlay analysis

Weighted Overlay is one of the Overlay Analysis tools included in the Spatial Analyst extension. The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multicriteria problems such as site selection and suitability models. Commonly is used to solve multi criteria problems such as optimal site selection or suitability modeling .It is a technique for applying a common scale of values to diverse and dissimilar inputs to create an integrated analysis. Used to identify the best or most preferred locations for a specific phenomenon. To combine the layers in an analysis: each cell for each criteria must be reclassified into a common preference scale Example: 1 to 4, with 4 the most favorable and 1 least favorable (Malczewski, 1999).

3.5.4 Set scale values

The cell values for each input raster in the analysis are assigned values from the evaluation scale. This makes it possible to perform arithmetic operations on rasters that originally held dissimilar types of values. To find suitable locations on which to dump, you would assign scale values depending on which land-use types are more suitable. For example, with an evaluation scale set at 1 to 9 by 1, you might assign the following scale values: cultivated land and open grass land= 7, settlement = Restricted, Barren land = 9, bush shrubs land = 9 because to minimize cost for land value if the landfill proposed in settlement and cultivated land the is fee for land to protect this barren land and bush shrubs land is good.

3.5.5 Identify weights for input layers

The site selection for solid waste disposal dumping site involves comparison of different options based on environmental, social and economical impact. Hence, based on experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility. Various factors in the model may have different importance: slope and ground water table may be more important than land use and which could be more important than the other parameters. Before the factors are combined the factors can be weighted, or assigned a percentage of influence, based on their importance. The total influence for all rasters must equal to 100 percent.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Results

This paper examines an approach for identifying the optimum site for the construction of a landfill site in a Dukem. A multi-criteria approach was employed in conjunction with GIS-based overlay analysis to identify the most suitable site for landfill development in the town. The study was based upon a set of key criteria, which were selected based upon the already available knowledge from research literature as well as the pre-existing local level factors (Twumasi *et al.,* 2006, Gizachew Kabite *et al.,* 2011).

In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 5, 7, 8 (value 1 = unsuitable (restricted), value 5 = low suitable, value 7 = moderately suitable, value 8 = highly suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map and reclassified/rank in to four classes like unsuitable, low suitable, moderately and highly suitable. The factors, their values and weights are summarized in (Table 4.1). According to the degree of importance, they have the role of selecting suitable solid waste dumping site. After the overlay analysis of the given factors the suitable solid waste dumping site map was produced. The areas were most suitable for solid waste dumping site are selected identified.

Table 4.1 Derived factor maps, ranking and weight for Solid waste dumping site selection

Factors	Class	Rank	Level of suitability	Scale values	Influence /weight
Land use	Settlement	1	Unsuitable/restricted	Restricted	20
	Open grass/Cultivated land	2	Moderately suitable	7	
	Bare land/Bush shrubs land	3	Highly suitable	9	
Slope (%)	25−75	4	Unsuitable	9	15
	15−25	3	Low suitable	5	
	5−15	2	Moderately suitable	7	
	0−5	1	Highly suitable	9	
Distance from Drainage	0−400	1	Unsuitable	1	10
	400−1000	2	Low suitable	5	
	1000−2000	3	Moderately suitable	7	
	2000−4200	4	Highly suitable	9	
Distance from road	0−300	1	Unsuitable	1	10
	300−600	2	Low suitable	5	
	600−1000	3	Moderately suitable	7	
	1000−2000	4	Highly suitable	9	
Distance from wells	0−500	1	Unsuitable	1	10
	500−100	2	Low suitable	5	
	1000−1500	3	Moderately suitable	7	
	1500−5000	4	Highly suitable	9	
Depth to ground water	0−28	1	Unsuitable	1	15
	29−31	2	Low suitable	5	
	31−33	3	Moderately suitable	7	
	33−42	4	Highly suitable	9	
Soil	Leptosol	1	Unsuitable	1	20
	Fluvisol/Cambisol	2	Low suitable	5	
	Luvisol	3	Moderately suitable	7	
	Vertisol	4	Highly suitable	9	

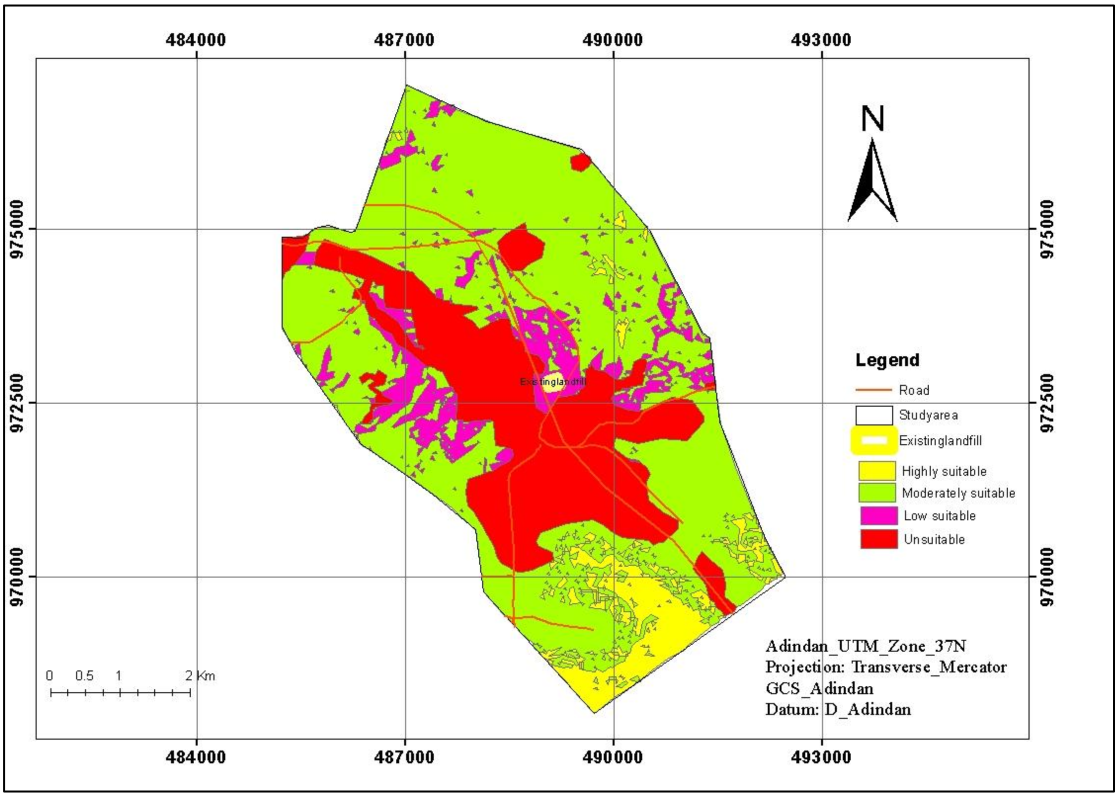

Figure 4.1 Landfill site suitability map of Dukem town.

4.1.1 Landfill Suitability Analysis Results

The importance of environmental factors like land use, permeability, ground water table depth, and socio-economic factors such as slope, proximity from groundwater well, road and Streams/rivers, for determining landfill sites are not the same. Weighted overlay Combination result showed four classes of suitability levels. These are unsuitable (restricted), low suitable, moderately suitable and highly suitable (Fig.4.1). The area coverage of each suitability class was calculated in GIS environment after converting raster map to vector. The result showed 9.2 km^2 of the study area is unsuitable (restricted) as the areas are environmentally unfriendly, socially unacceptable and/or economically unfeasible for landfill and Settlement, steep slope, areas close to hospital, road, and ground water well, ground water depth, rivers/streams and school also not suitable.

The main purpose is to protect human health and environment from potential effects of landfill and as well to minimize the cost of construction and waste transportation. However, 3 km^2 of the region satisfies the environmental, social and economical criteria set as identified as highly suitable. These areas are more preferable land for landfill because of their minimum effect on environment and public health and cost effective than other parts of the area. And also low suitable and moderate suitable area covered 3 and 21 km^2 respectively (Table 4.2). Most of the highly suitable landfill sites were identified in the southern and northern part of the study area.

Table 4.2 Suitability classes for landfill site with their respective area

Suitability class	Area in (km^2)
Unsuitable/restricted area	8.8
Less suitable	3
Moderately suitable	21
Highly suitable	3

4.1.2 Evaluating selected Landfill Sites

Socio-economic criteria like size of the site, distance from nearby settlements and distance from the center of the city are the determinant criteria used to evaluate potential landfill site so as to choose the best suitable. Size of landfill is one of the determinant criteria for sustainable solid waste management as size of land selected for landfill determines the number of years for which the landfill will be used as waste disposal site. The selected site areas are significantly at the optimum distance from settlement, drainage, school, and from well. The land use and slope are cultivated land and less than 15% respectively. The soil types where vertisols which means low permeability and most of study area covered by vertisols which means suitable for solid waste dumping site.

Several researchers suggested that (Bagchi, 1994; Lin and Kao, 1999; Gaim, 2004; Twumasi et al., 2006; Despotakis and Economopoulos, 2007; Chang et al., 2008).

1. Site should be capable of providing at least 10 years of use in order to; minimize costs for site establishment and closure, smooth running of operations, and provision of adequate time for acquiring the next site.
2. Location of a landfill facility should not endanger any environmentally sensitive areas or have a negative impact on existing or future land uses.
3. The landfill should be situated at a significant distance away from urban residential areas due to public concerns, such as aesthetics, odor

4. Recommends that areas with a population density less than 200 were regarded as suitable for landfills based on this just I select the appropriate area for potential landfill.

The sites with small areas are economically not feasible and hence excluded from further analysis. As indicated on (Fig.4.2) suitable sites were evaluated against other criteria mainly distance from nearby settlements, river size of site and distance from the center of the town were determined for each candidate site. Finally, three sites A and B and C (Fig 4.2.) are indentified as the best suitable dumping sites for the town. Similarly to the above suggestions, Babalola and Busu (2010) and Al-Hanbali et al. (2011) suggested that selecting the optimum site for solid waste dumping may facilitate transportation and reduce the cost of transport. Moreover, suitability, for slope analyses had shown that slope 15% and less than are more suitable in order to minimize environmental impacts. Similar to findings of Sener et al. (2011), the suitable area was far away from settlement and urban center. Due to this reason we can categories the highly selected areas and the all landfill site map shown in (Fig 4.2).

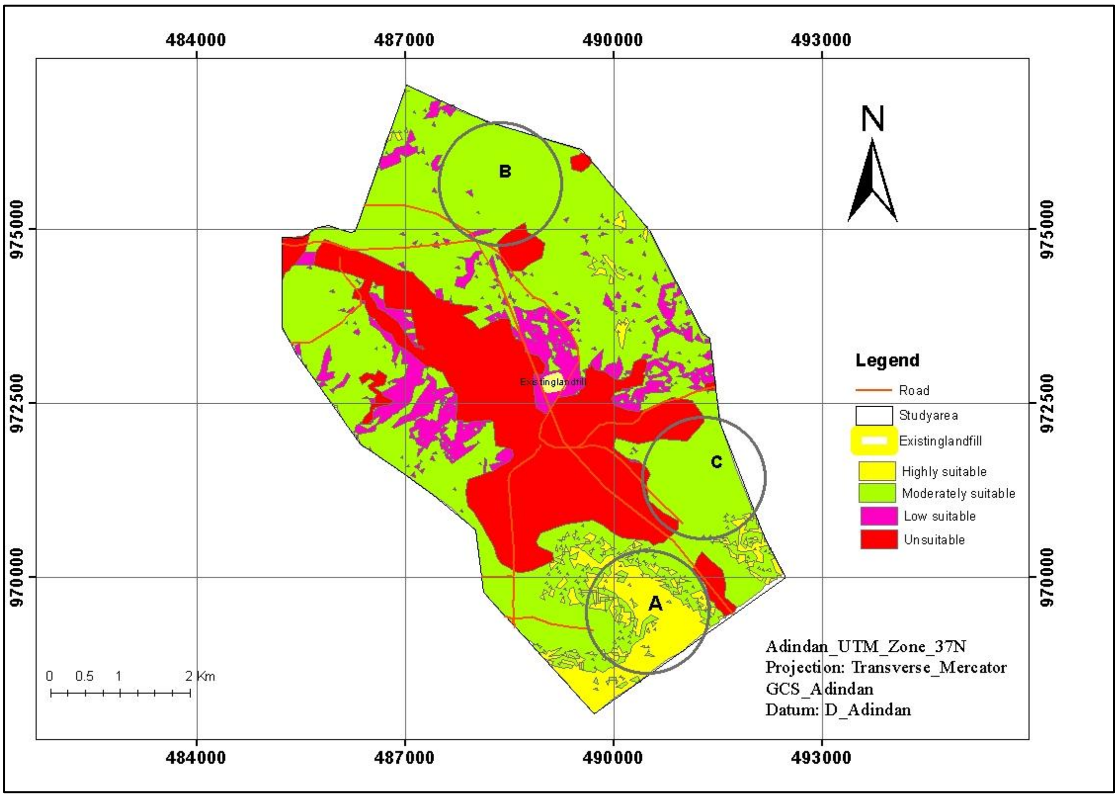

Figure 4.2 Candidate landfill site map

4.2 Discussion

The first objective of the research was to propose new landfill in Dukem town. The municipal of the town together with the land administration office selected and prepared the existing dumping site by traditionally approach by simple randomly taking area far away from settlement for dumping site in 2009. At that time the area far away from settlement but now by urban growing close to each other and currently it is not recommended to dispose waste at that site. In the town solid waste is collected from residences, institutions and asphalt roads, transported to one dumping site (Gizachew Kabite *et al.,* 2011).

To do this the office gave contract to small macro enterprise for collecting the solid wastes from the town. The collectors gather the waste from houses two per week and from others (institutions) two per weeks and transport it to dumping site using horse carts (Fig 1.1). As the town is becoming an industrial zone the municipality gives great concern to beatification and solid waste disposal and management. This basic service is currently receiving wide attention in many towns of Ethiopia. This is mainly because solid wastes that are generated in most towns of Ethiopia are not appropriately handled and managed. If the site is not suitably sited and managed, it can lead to serious contamination to the environment and risk for health. In Dukem, solid waste is mainly disposed of on open dumps, and near river canal. There has not been any systematic solid waste disposal strategy to this area (Fig 1.1). Provision of enabling a waste management system for successful implementation of a waste program is very important for the protection of the environment (Gizachew Kabite *et al.,* 2011).

There are several aspects of solid waste management: technical, financial, institutional and social. Each of these aspects has certain issues, which need to be deliberated upon to achieve sustainable and effective waste management. There is indicators produce poor solid waste management

- ✓ Inadequate technical expertise and planning capability in most of the urban local bodies
- ✓ Low priority for research and development in solid waste management sector

- ✓ unable to generate adequate funds from their own sources, such as municipal taxes
- ✓ Coordination of solid waste management projects and activities by dedicated department
- ✓ Inadequate coordination between the relevant agencies
- ✓ Lack of public awareness and school education program
- ✓ Low paid employment for waste workers. Those are mainly problem encountered in the town.

Site selection should be performed for every municipality in Ethiopia, but it is very cumbersome, time consuming and expensive. Therefore, the use of GIS as a support decision tool can effectively be employed in preliminary studies due to the ability of GIS to manage spatial and non spatial attributes from a variety of sources. This allows decision makers to combine environmental criteria with other constraints based on established guidelines for selecting suitable sites.

In the present study, a methodology for finding potential suitable sites for municipal solid waste landfill was developed using GIS. Based on this, suitable potential sites that require for landfill were determined .For this aim, there were several aspects of constraints taken into consideration using standard established criteria. The first was to analyze the datasets in the area. The selection concern was to find the environmental constraints of the location (Table 4.1). This was done by defining proximity distance from natural features, infrastructure provision and close proximity to sensitive land uses. The land uses were aggregated to contain; bush shrub land, cultivated land, open grass land, and bare land and so on. Also, the soil layer was extracted and a map produced .GIS was used to perform analysis such as buffer, clip operation, extraction by selection, spatial join and overlay analysis with other functions (Fig 4.2). At the end of the analysis, potential sites were determined for the municipality. The main environmental issue which should be considered in disposal of the solid waste is the location of its land filling. The proposed method may be used for site selection processes in other conditions and locations where the intensity of introduced parameters shows discrepancies.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

GIS as a decision support tool for landfill siting has been proven to be useful in finding suitable sites for landfill siting purposes. In this study, GIS software was used to locate landfill sites by creating maps according to the set criteria. A landfill siting process requires evaluating many criteria and processing much spatial information. Using GIS for locating landfill sites is an economical and practical way for the evaluation of and production of maps in a short time when there is a need for fast valuation.

Secondly, the result of the application of GIS-based models was based on environmental factors, potential sites were found based on these criteria. The proximity of the potential sites is not within the zone of environmental interest or natural features, and was located distances away from settlement, which minimizes social conflict, health hazards and environmental impacts. At the end of the analysis, appropriate most Solid waste landfill sites are identified. These sites generally satisfy the minimum requirements of the landfill sites given before.

The study demonstrated the capacity to use GIS, GPS and remote sensing technology for the effective assessment of solid waste management system will minimize the environmental risk and human health problems. The present study considered nine factors namely: slope, soil types, ground water table depth, land use/land cover, and proximity from roads, ground water well, school, drainage/rivers and health center for proper landfill site selection.

5.2 Recommendation

- ✓ Coming researchers should focus on finding solutions for these problems in advance.
- ✓ The Dukem municipality should integrate the efforts toward an integrated solid waste management taking into consideration the results obtained in this study.

- ✓ An urgent need of dust bin in the town to minimize illegal waste disposes.
- ✓ To use the selected site for many years and use of land appropriately it must use recycle of waste.
- ✓ There should be public awareness and participation in waste management system in the town.

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