Suitability Analysis of Solid Waste Disposal Site using GIS Techniques for Sululta Town: Oromia Special Zone Surrounding Finfinne, Oromia, Ethiopia

BY

LAMESSA KENATE

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This is to certify that the project prepared by Lamessa Kenate, entitled: *Suitability Analysis of Solid Waste Disposal Site Using GIS Techniques for Sululta Town: Oromia Special Zone Surrounding Finfinne, Ethiopia* and submitted in partial fulfillment for the Degree of Master of Arts in Geography and Environmental Studies (Specialization in GIS, RS and Digital Cartography) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

External Examiner Ermias Teferi (PhD) Signature________________Date_______________

Internal Examiner Assefa Abegaz (PhD) Signature_______________Date_______________

Advisor Fekadu Gurmessa (PhD) Signature ______________Date________________

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Chair of Department or Graduate Program Coordinator

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Abbreviations

AHP	Analytical Hierarchy Process
DEM	Digital Elevation Model
EMUDC	Ethiopian Ministry of Urban Development and Construction
GIS	Geographic Information System
MCDA	Multi Criterion Decision Analysis
MCDM	Multi Criterion Decision Making
MCE	Multi Criteria Evaluation
MET	Ministry for the Environment and Territory
OUPI	Oromia Urban Planning Institute
RS	Remote Sensing
SP	Structure Plan
UTM	Universal Transverse Mercator
WGS	World Geodetic System

Abstract

Generation of solid waste is immensely increasing as the rate of population influx into urban area is increasing. This condition demands scientific approach of solid waste disposal site selection for proper urban solid waste management. Therefore, the aim of this study was to identify suitable solid waste disposal site that consider environmental friendly, economically cost effective and socially acceptable in Sululta Town, Oromia Special Zone Surrounding Finfinne, by using the geographical information system and the analytic hierarchy process. The criteria for site selection used are slope, surface material, geological feature, hydro geological feature, distance from the water body, prevailing wind direction, distance from built-up areas, and distance from the main roads. Multi-criteria evaluation methods are used for solid waste disposal site selection. The final weighted model was grouped as unsuitable, least suitable, moderately suitable, and suitable site. The results of the analysis show that 7% of the study area was suitable for solid waste disposal, 10% moderately suitable, 21% least suitable and 62% of the total area is unsuitable. Evaluating those potential suitable solid waste disposal sites was made through determinant criteria such as distance from river, size of the site, wind direction, distance from built up area and distance from main roads so as to choose the best suitable site. However, evaluation of candidate sites in relation to their size shows that all suitable solid waste disposal site 1(24 ha), 2(30 ha), 3(69 ha) and 4(300 ha) with area coverage of more than 24 ha, are equally suitable sites as it could serve for longer years. But, from the wind direction perspective, the dominant wind blows from southern direction followed by south eastern which posed further pollution to the down central town residents if the site determined along the area. Hence, suitable solid waste disposal site 1 was more preferable site than other sites in terms of many set criteria and proposed best suitable site for solid waste disposal in the town.

Key words: Suitability, Solid waste disposal site, Analytical Hierarchical Process

CHAPTER ONE

INTRODUCTION

1.1Back ground of the study

Solid waste disposal site is important because of the essential nature of solid waste disposals due to the expanding population and the corresponding volume of garbage (Al-Hanbali et al., 2011). Source reduction, recycling and waste transformation are methods widely used to manage solid waste. However, in all these methods there is always a residual matter to be disposed of even after the recovery process. The technique of getting rid of these wastes in an economic and environmentally friendly approach is called Solid waste disposal. Hence waste disposing is an important part of waste management system, which requires much attention to avoid environmental pollution (Karthihea and Yeshodha, 2016).Ethiopia is facing rapid urbanization leading to overcrowding and the development of slums and informal settlements with poor waste management practices. Urban dwellers generally consume more resources than rural dwellers, and so generate huge quantities of solid wastes (Tewodros, 2011).

Solid waste management and selecting its suitable disposal site has been a big challenge to both the developed and developing countries all over the world. Site selection of new solid waste disposals for municipal solid waste disposal is a great concern for the urban government as old solid waste disposal sites are being filled-up and demand for new sites is increasing. This demonstrates the necessity of developing integrated, computerized systems for obtaining more generalized and optimal solutions for the management of urban solid waste (Karthihea and Yeshodha, 2016).Several studies have been conducted on different levels of town to find the optimum locations for solid waste disposal sites in different countries or its parts. The selection of their ultimate site is complex. It must combine social, environmental, ecological, technical and economical parameters. Also, the location must comply with the requirements of the governmental regulations in order to be acceptable (Al-Hanbali et al., 2011).

In Ethiopia, like other developing countries, proper solid waste management is one of the problems that are confronting various municipal authorities as it has posed threats to lives and the environment. Indiscriminate disposal of effluent and toxic waste have endangered healthy living. Diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses are some of the problems associated with improper management of solid waste (Shyllon andOlusina,2014).

Sululta town is characterized by rapid population growth caused by natural increase and migration from rural and other urban areas. Such rapid increase in population together with rapid development of the town has produced increasing volumes of solid waste and in turn it induced greater infrastructural demand, institutional setup and community participation for its management.

1.2. Statement of the Problem

Solid waste disposal site is an environmentally acceptable method of waste disposing on the ground. Many developing countries do not have criteria for solid waste disposal site selections and some have regulations of developed countries without modifying to their local conditions .But taking regulations of developed countries without considering local conditions is a problem because the development of engineered solid waste disposals involves complex engineering design and construction techniques. These sophisticated engineered solid waste disposals can occur where the local economycan afford thehigh level of expenditurerequired for constructionand operation of the solid waste disposal and where the technical resources to achieve high standards of construction and operation are made available. Therefore, in developing sitting criteria for new solid waste disposals sit it is important to ensure that the constructional and operational capabilities of the local communities. Additionally, available financial and human resources, the composition of the waste and the climate of the area should be considered (Kumel, 2014).

The natural anaerobic decomposition of the waste in some solid waste disposals used to recover energy and produces solid waste disposal gases which include carbon dioxide, methane and traces of other gases. Methane can be used as an energy source to produce heat or electricity. These solid waste disposals present the least environmental and health risk and the records kept can be a good source of information for future use in waste management, however, the cost of establishing these sanitary solid waste disposals are high when compared to the other land disposal methods (Minalu, 2016).

Sululta town is one of the fastest growing towns in Oromia in terms of population.This population influx mainly resulted from dynamics of change such as natural increase (birth and death) and migration (rural to the town, small urban areas to the town, large urban areas like Addis Ababa to the town)which increases the population growth of the town (OUPI, 2016). The growth of high population and expansion of the town towards neighborhood rural areas resulted the town to re-structure its urban plan and area as stated from the Town Municipality (2016).

Such rapid increase in population together with rapid development of the town has produced increasing volumes of solid waste and in turn it induced greater infrastructural demand, institutional setup and community participation for its management.In Sululta town currently wastes are generated from residential, commercial, industrial and institutional areas in huge amount. Recently the number of industries and commercial centers in the town are increasing, and these are the major sources of solid waste in addition to hotels and house-holds in the town. Most of solid wastes that are generated in the town remain uncollected and simply dumped in open areas, road sides, river courses, gullies. The accumulation of waste on incorrect dumping site creates opportunity to access for germ carriers like fly, rodents and other animals that contaminate the town.The environmental and sanitary conditions of the town have become more and more serious over time, and people are suffering from living in such conditions of bad odor resulted in health problem.

There is also a need from the municipality of the town to ensure effective and efficient disposal of both residential and industrial solid wastes in Sululta town, Oromia Special Zone Surrounding Finfinne, Oromia, Ethiopia. To assist in achieving effective and efficient waste management, this research is aimed at the determination of solid waste disposal site using Geographic Information Systems (GIS), Remote Sensing technology and Multi-Criteria Evaluation (MCE).

GIS has been found to play a significant role in the domain of sitting of waste disposal sites. Many factors must be incorporated in to solid waste disposal sitting decisions and GIS is ideal for this kind of studies due to its ability to manage large volumes of spatial data from a variety of sources (Debishree, 2014).Geographic Information System (GIS) and Remote Sensing are such computerized systems that can be integrated to get optimal solutions for efficient and effective solid waste management planning. It is a tool that allows users to analyze spatial information, edit data, maps, and present the results of any spatial and non-spatial based analysis (Karthihea and Yeshodha, 2016).

In Ethiopia, for some towns, researchers have conducted studies on solid waste disposal site selection using GIS and remote sensing. For example, as TsegayeMekuria(2006), Tirusew Ayisheshim and Amare Sewnet (2013), Kumel Beshir (2014), Genemo Berisa and Yohanis Birhanu (2015) and Minalu Ambaneh (2016) have conducted studies on solid waste disposal sites selection using GIS and remote sensing for Addis Ababa, Bahir Dar, Wolkite, Jigjiga and Mojo respectively. In the study area, there were no studies conducted about how municipal wastes are managed and solid waste disposal site is selected by using GIS based study.

1.3. Objectives of the Study

1.3.1 General objective

The overall objective of this study is to identifysuitable solid waste disposal site that consider environmental friendly, economically cost effective and socially acceptable in Sululta town.

1.3.2. Specific objectives

The specific objectives of the study are:

- to assess the current situation of solid waste disposal in the town;
- to identify candidate solid waste disposal sites that meets the criterions; and
- to identify the most suitable solid waste disposal site in the town.

1.4. Research Questions

- What are the practices and techniques used to manage solid wastes inthetown?
- What are the optimum sites that meet solid waste disposal siteselection criteria?
- Whereisthe best suitable site for solid waste disposal in the town?

1.5. Delimitation of the study

The study is conducted in Sululta Town, Oromia Special Zone Surrounding Finfinne, Oromia Regional State, Ethiopia. The main objective of the study was determining suitable solid waste disposal site by using GIS technique for the town. In order to identify suitable solid waste disposal site the criteria considered were distance of solid waste disposal site from the built up areas, rivers and roads in addition to the slope, slope surface material, geology, hydrogeology, wind direction and size of the site in the study area.

1.6. Significance of the study

- The findings of the study will serve as a working document for Sululta Town management officials in the identification and selection of suitable solid waste disposal site for the town.
- If the proposed site is used as solid waste disposal location with proper management the town will be clean and neat.
- The techniques and procedures used in this study may be used as a reference material for any concerned body or individual for further study to conduct in other places.

1.7. Limitations of the study

- The depth of groundwater table was not considered as a parameter in the solid waste disposal siteselection in this study. Thus, the overall suitability analysis result obtained after weighted overlay of criteria could be influenced by the exclusion of the groundwater table level and other parameters.
- Since the involvement of the town management and the community in the decision making, acceptability of the selected site may be challenged.

1.8. Organization of the paper

This paper has been organized in to five chapters. The first chapter states about back ground of the study, statement of the problem, objectives,research questions, significance of the study, scope of the study and limitation of the research. The second chapter highlights a review of literature that consists of both conceptual review literature and research related review literature.The third chapter dealsabout background of study area and methodology of the research. The fourth chapter talks about data analysis and interpretation. The fifth chapter stated aboutconclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1General Concepts

Solid wasterefers to the range of garbage arising from animal and human activities that are discarded as unwanted and useless. Solid waste is generated from industrial, residential and commercial activities in a given area. As such, solid waste disposals are typically classified as sanitary, municipal, construction and demolition or industrial waste sites.

Table 2.1: Sources and types of wastes(Hoornweget al., 1999).

Source	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes.).
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
Institutional	Schools, hospitals, prisons, government centers.	Same as commercial.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Process (manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off-specification products, slay, tailings.
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

In Sululta town currently wastes are mainly generated from residential, commercial and industrial areas in huge amount without segregation dumped in open site. The accumulation of waste on incorrect dumping site creates opportunity to access for germ carriers like flies, rodents and other animals that contaminate the town.

Solid Wastes Generation

Municipal solid waste is defined as waste arising from human activities in household, commercial and institutional areas that are useless or unwanted. The knowledge of the sources and types of solid wastes, along with data on composition and rates of generation, is basic to the design and operation of the functional elements associated with the management of solid wastes. Sources of solid wastes in a community are, in general, related to the land use and zoning (Tchobanoglous, 1993).

The amount of solid wastes generated is usually directly related with the wealth of a society. The more affluent the country or community is, the greater will be the rate at which it generates wastes. Country wide average rates of waste generation in most industrialized countries lie between 0.8 and 1.4 kg per capita per day. In developing countries the average generation rate is within the range of 0.3 to 0.5 kg per capita per day (EMUDC, 2012).For Arada Sub-city of Addis Ababa, estimated yearly waste was 17,885 tons per year (Yitayal, 2005), 12, 856.8 tons per year for Adama town (Lemma, 2007),for Jimma 9125 tons per year (Melaku, 2008)and 4729.56 tons per year in Hosaina (Abiot et al, 2012).

The density of wastes varies considerably, depending on the relative affluence of the community and the way in which waste is handled and stored. Industrialized country refuse contains a considerable quantity of packing materials which occupy large volumes but are light in weight. Consequently, refuses in industrialized countries are characteristically low in density, typically ranging between 100 and 150 kg per cu m. Similarly, wastes of developing countries have a density value ranging 250-500 kg/m3 (Cointreau, 1982).

Higher solid waste generation rates along these cities are attributed to high population. The waste in developing countries is naturally dense, typically ranging between 300 and 550 kg per cu m. Where waste densities are low, as in the case with industrialized country refuse, in order that vehicle productivity can be maximized through the transporting of maximum payloads, it is necessary to compact the refuse in order to increase its density. Compaction trucks are typically designed to compact light refuse (e.g., 100 kg/cu m density to about 400 kg/cu m), but the naturally occurring density of developing country refuse is usually around 400 kg/cu m (EMUDC, 2012).

Solid Waste Management

Solid Waste Management is defined as the discipline associated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and other environmental considerations. Therefore, the type of solid management systemfocused here was in identifying suitable solid waste disposal site by using GIS techniques in this study.

Solid waste disposal site

A solid waste disposal site is also known as a tip, dump, rubbish dump, garbage dump or dumping ground and is a site for the disposal of waste materials by burial. It is a carefully designed structure built into or on top of the ground, in which trash is separated from the area around it (Tchobanoglous, 1993). Although there is a public opposition to solid waste disposals, it is necessary and there is no combination of waste management technique that does not require solid waste disposal site. Solid waste disposal site includes monitoring of the incoming waste stream, placement and the compaction of waste and installation of solid waste disposal environmental monitoring and control facilities (Sener,2004).

Solid waste disposal site is a common solution for the final disposal of wastes in low-income countries and a large majority of community's practice subsistence solid waste disposal siting or open dumping as their main method of waste disposal. Recently, due to the growing urgency of urban environmental problems, solid waste management in low income countries has attracted much attention and there is now a movement toward solid waste disposal design to increase environmental protection (Tsegaye, 2006).

Solid waste disposal has been recognized as the cheapest form for the final disposal of municipal solid waste and it has been the most used method in the world. However, sitting solid waste disposal is an extremely complex task mainly due to the fact that the identification and selection process involves many factors and strict regulations. For proper identification and selection of appropriate sites for solid waste disposals careful and systematic procedures need to be adopted and followed. Wrong sitting of solid waste disposal many result in environmental degradation and public opposition. The sitting of solid waste solid waste disposal must also involve processing of a significant amount of spatial data, regulations and acceptance criteria, as well as an efficient correlation between them (Sumathi,2007).

Disposal of waste in a solid waste disposal involves burying the waste, and this remains common practice in most countries. Solid waste disposals areoften established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed solid waste disposal can be a hygienic and relatively inexpensive method of disposing of waste materials. A solid waste disposal site is also known as a tip dump, rubbish dump, garbage dump or dumping ground. Historically, solid waste disposals have been the most common method of organized waste disposal method and remains in many places around the world (Minalu, 2016).

2.2 Typesof solid waste disposal

There are common types used for solid waste disposal site to manage municipal solid wastes.These are: excavated cell/trench, area, and canyon.

Excavatedcell/ trench

The excavated cell/trenchmethodof solid waste disposal site is suitable for areas where an adequate depth of cover material is available at the side and where the water table is not near the surface. Typically, solid wastes are placed in cells or trenches excavated in the soil. The excavated soil from the site is used for daily and final cover. The excavated cells or trenches are usually lined with synthetic membrane liners or low permeability clay or a combination of the two to limit the movement both solid waste disposal gases and leachate (Sener, 2004). Though the water table in the study area was not investigated, this type of solid waste disposing is not recommended in the area. But it can be used after undertaking further investigation and identification of the site in the study area so as to keep the leachates in the solid wastes not contaminate the underground water.

Open land/area

The area method is used when the terrain is unsuitable for the excavation of cells or trenches. High groundwater conditions necessitate the use of the area type solid waste disposals. Site preparation includes the installation of a liner and leachate control system. Cover materials must be carried by truck or earthmoving equipment from adjacent land or from borrow-pit areas. In locations with limited availability of material compost produced from waste can be used as cover. Other techniques include the use of movable temporary cover materials such as soil and geo-membranes. Temporarily placed soil and geo-membranes over a completed cell, can be removed before the next lift is begun (Sener, 2004). Using this type of solid waste disposal system depends on the economic and technical capacity of the town to install a liner and leachate control system in addition to carrying cover materials by earth moving equipment from other areas or adjacent. Therefore, in the study area, this may be a challenging type of solid waste disposing since it incurs high cost.

Canyon/Depression

In this method, canyons ,dry borrow pits, and quarries are used for solid waste disposals. The techniques to place and compact solid wastes in canyon/depression solid waste disposal vary with the geometry of the site, the characteristics of the available cover material, the hydrology and geology of the site, the type of the leachate and gas control facilities to be used, and the access to the site. The availability of adequate material to cover the individual lifts and to provide a final cover over the entire solid waste disposal site is very important .Cover material is excavated from the canyon walls or floor before the liner system is installed. Borrow pits and abandoned quarries may not contain sufficient soil for intermediate cover, so that it may have to be important (BasakS., 2004). In this study area, this type of solid waste disposal system could be used since thetechniques toplaceandcompactsolidwastesincanyon/depressionsolid waste disposalvaried with geometry of the site, available cover material, leachate controlling system access to the site, hydrology and hydrogeology of the site.

2.3Solid Waste Disposal Site Selection

A waste disposal area is a matter of public health concern. Considering the high rate of urbanization, one should take the long-term land use planning of bounds into consideration to locate the disposal area. Moreover, the present and future of garbage trucks traffic should be taken into account. There are many factors which should be considered in locating a waste disposal area. These factors mainly consist of: topography of the area, hydrology, geology, proximity to the residential and industrial areas and the future land use of the area (Chang etal.,2007).

Final selection of a disposal site usually is based on the results of detailed site survey, engineering design and cost studies, and an environmental impact assessment (Mohammad et al., 2009). Solid waste disposal sitting is difficult task to accomplish because of its selection process depends on different factors, regulations and data from diverse social and environmental fields such as water supply sources, land use, sensitive sites and road network. These data often involve processing of a significant amount of spatial information which can be used by GIS as an important tool for land use suitability analysis (Seiied,2015)

Solid waste disposal sitting is become increasingly difficult due to growing environmental awareness, decreased amount of governmental and municipal funding with extreme political and social opposition. The increasing of population, public health concerns and less land available for solid waste disposal construction added more difficulties to the problem to overcome. Therefore, the environmental factors must be considered in solid waste disposal sitting, unless it might affect the biophysical environment and the ecology of the surrounding areas, several techniques can be found for site selection of solid waste disposal. Such sitting techniques combine multiple criteria decision analysis (MCDA) and GIS. The result of these techniques is the evaluation of the suitability for the entire study area based on suitability index, which is useful in order to make an initial ranking of the most suitable area (Mohammed et al, 2014)

Sitting a sanitary solid waste disposal requires an extensive evaluation process in order to identify the optimum available disposal location. Therefore, the sitting of a solid waste disposal must also involve processing of a significant amount of spatial data, regulations and acceptance criteria, as well as an efficient correlation between them. GIS has been found to play a significant role in the domain of sitting of solid waste disposal sites. Many factors must be incorporated in to solid waste disposal sitting decisions and GIS is ideal for this kind of preliminary studies due to its ability y to manage large volumes of spatial data from a variety of sources. The integration of GIS and Analytical Hierarchy Process (AHP) is a powerful tool to solve the solid waste disposal site selection problem, because GIS provides efficient manipulation and presentation of the data and AHP supplies consistent ranking of the potential solid waste disposal areas based on variety of criteria (Debishere et al, 2014),

Solid waste disposal site selection in an urban area is a critical issue because of its enormous impact on the economy and the environmental health of the region and many sitting factors and criteria should be carefully organized and analyzed. One of the complicated steps is locating of waste solid waste disposal sites have precise steps including site selecting and preparation of waste solid waste disposal site. If these solid waste disposal sites are near the individual's work place or living area, it is considered as a negative outcome and it may cause irreparable consequences to human life (Seiied, 2015).

2.3.1Global Practices for Solid Waste Disposal Site Selection Criteria

International practices always account for environmental, economic, social, and technical factors in the construction of solid waste disposals. Solid waste disposal designers are primarily concerned with the viability of a site. To be commercially and environmentally viable, a solid waste disposal must be constructed in accordance with specific rules, regulations, factors and constraints which vary from place to place or from country to country. These specific rules, regulations, factors, and constraints must cover: geomorphology, land value, slope and proximity to recreational areas (Erkut and Moran, 1991).

Deliberate disposal of waste at point sources such as solid waste disposals, septic tanks, injection wells and storm drain wells can have an impact on the quality of ground water in an aquifer. Thus, refuse certainly should not be deposited below the level of the water table, as in standing water, surface runoff should not be allowed to enter or to leave the site and buried refuse should still be above the highest seasonal level of the water table after final covering of the site. That solid waste can be disposed at almost any site without creating an undue groundwater pollution hazard, provided the site is properly designed and operated(Schneider, 1985).

Slope is a topographical factor in determining the suitability of solid waste disposal sites.It is an important factor in suitability site selection process because it determines the amount of surface runoff produced the precipitation rate and displacement of water to the potential site in addition to the construction cost.Different research shows that areas with depressions associated with unstable area should be avoided because they may cause to contamination of groundwater sources of drinking water. Other topographical depressions resulting from human activities, such as stone quarries, depths, and narrow piece cannot be suitable for solid waste disposals. It means that when the slope is gentle it decrease the construction cost as compared to the sharp slope area (Tsegaye, 2006). Flat and gently rolling hills that are not subjected to flooding are the best sites for solid waste disposal. However, this type of topography is also suitable for other land uses like agriculture, residential or commercial development that lead to higher land prices (Basak, 2004).This study considered the modest slope is more suitable than the land with more flat and higher slope class in the study area.

The type of pollution that may arise is directly related to the type of refuse and the manner of disposal. Leachates from open dumps and sanitary solid waste disposal usually contain both biological and chemical constituents. Organic matter, decomposing under aerobic conditions, produces carbon dioxide which combines with the leaching water to form carbonic acid. This, in turn, acts upon metals in the refuse and upon calcareous materials in the soil and rocks, resulting in increasing hardness of the water(Schneider, 1985).

Generations of toxic fumes are not expected nature of waste to be off; handling of waste in the disposal facility may create air pollution in the form of dust formation. Prominent wind direction may affect the population on the downstream side of the facility. So, any village within a distance of one kilometer downstream of the sites can be vulnerable to any air pollution due to the operation of solid waste disposal (Schneider, 1985).

Table.2.2 Criteria for specifying the best site for solid waste disposal (Chang et al. 2007)

No	Proposed criteria	Distance(km)
1	Distance from historical sites, ancient areas and international museums	>1
2	Distance from well water or water supply	>1
3	Distance from roads	>0.75
4	Distance from rivers	>1
5	Distance from urban residential areas	0.15-5
6	Selected area should not be often flood	

In this study, criteria found on number 3, 4, 5 used by those researchers were considered to determine suitable solid waste disposal site selection in the study area.

2.3.2 Ethiopian Practices for Solid waste disposal Site Selection Criteria

Different researchers used different criteria's to set suitable solid waste disposal sites as of their existing interest of study, condition, available data and some other factors. Besides, there are also most common criteria that have been used by scholars and institutions. Therefore, consideration needs to be given to the comparison of site characteristics with alternative locations; potential for engineered systems to overcome site deficiencies; methods of operation proposed for the site; and socio-cultural issues associated with the site. In order to minimize future risk to the environment from solid waste disposal activities, primary consideration should be given to key issues and potential critical flaw with respect to geology, hydrogeology, surface hydrology and site stability (DPIWE 2004 as cited in Genemo and Yohannis, 2015). The major important factors considered to locate the best suitable location for solid waste disposal site according to the towns existing situation identified were distance from protected areas, slope, settlement, land use/land cover, river and lake, distance from main roads to solid waste dumping site (Tirusew, 2013).

Solid waste disposal is a technique for the final disposal of solid waste in the ground that causes no nuisance or danger to public health or safety; neither does it harm the environment during its operations or after its closure. This technique uses engineering principles to confine the waste to as small areas as possible, covering it daily with layers of earth and compacted to reduce its volume. The preliminary identification of available sites for sanitary landfills should be carried out as follows:- preliminary calculation of the total area needed for the sanitary landfill; perimeter delimitation of rural and industrial zones and conservation areas existing in the municipality; survey of theavailable sites within the delimited perimeters, where there are no zoning or land use restrictions and sites have dimensions compatible with the preliminary calculation, giving priority to land owned by the municipality; determination of ownership of surveyedsites and review of documents relating to the sites(MET et al,2008).

Table 2.3 Factors that should be considered for selection of sanitary landfills (MET et al, 2008)

No.	Criteria	Distance/time span
1	Distance from protected forests, gas lines, sewerage lines and water lines	>0.5km
2	Distance from Airports	>3km
3	Distance from memorial sites, churches and schools	>1km
4	Distance from water bodies	>0.3km
5	Distance from residential areas	>0.3km
6	Distance from main roads	1km-10km
7	Land area and volume	10yrs
8	Flood plain subjected to flood	10yrs

In this study, criteria found on number 3, 4, 5, 6, and 7 used by those researchers were considered to determine suitable solid waste disposal site selection in the study area.

In Sululta Town, currently wastes are generated from residential, commercial, industrial and institutional areas in huge amount. Recently the number of industries and commercial centers in the town are increasing, and these are the major sources of solid waste in addition to hotels and house-holds in the town. Most of solid wastes that are generated in the town remain uncollected and simply dumped in open areas, road sides, river courses, gullies. Solid wastes are rarely dumped in the existing site even after collected from sources. The residents nearer to the existing open dump site are suffering from odourpollution and pollution of the river around and downstream for they cannot use it for home consumption and irrigation. Solid waste that disposed in the open field close to the river contaminates the river highly because of runoff and wind since the slope towards the river is steep. As a result, surface water pollution is the main problem. However, the negative impacts from solid waste disposal can be minimized through selecting an appropriate site which minimizespotential environmental impact by applying GIS and RS techniques.

Solid waste disposal site Capacity

A waste disposal area is a matter of public health concern. Considering the high rate of urbanization, one should take the long term land use planning of suburbs into consideration to locate the disposal area. Moreover, the present and future of garbage trucks traffic should be taken into account.The life of the solid waste disposal and the demand for future solid waste disposal space should be considered during the site selection process. Proponents should consider the type and quantities of waste generated within the area being serviced by the solid waste disposal, the current disposal pathways for these wastes, projected quantities and types of waste requiring disposal and the remaining solid waste disposalcapatown at existing solid waste disposals sites which service the area. Solid waste disposals should be designed to ensure that sufficient capatown exists for the current and future waste management needs of the community into the foreseeable future (Genemo and Yohannis, 2015).

Size of solid waste disposal is one of the determinant criteria for sustainable solid waste management as size of land selected for solid waste disposal determines the number of years for which the solid waste disposal will be used as waste disposal site. From sustainability and economical point of views, larger size of land that will serve for at least ten years are more preferable than small size.The site selected as thebest solid waste disposal is expected to serve the purpose for longer than 10 years in order to reduce the cost of solid waste disposal sites election and construction of another site over and again(Genemo and Yohannis, 2015).

As a result, the rates and volumes of solid waste generated from the municipality should carefully be determined to further decide the dimension of the solid waste disposal site during construction. This is because selecting large sized solid waste disposal site can minimize the cost of site selection, design and closure that will be performed at the end of its lifespan (Schneider, 1985). Adequate land area and volume to provide sanitary solid waste disposal capacity of the town to meet projected needs for at least 10 years, so that costly investments in access roads, drainage, fencing, and weighing stations are justifiable(EMUDC,2012).

2.3.3 GIS and Remote Sensing Applicationfor Solid waste Disposal Site Selection

2.3.3.1 The Role of GIS for Solid waste Disposal Site Selection

GIS is a tool that not only reduces time and cost of the site selection but also provides digital data bank for future monitoring program of the site. GIS application can help in determining the solid waste disposal location in accordance with the technical requirements, with overlay the thematic map to get an appropriate solid waste disposal (Akbari et al., 2008). Therefore, the GIS offers the spatial analytical capabilities to quickly eliminate parcel of land unsuitable for solid waste disposalsite after constraining the application to the selected attributes and hence reduce cost and time of sitting processes (Chang et al., 2007).

One of the benefits of GIS is its capability for solid waste disposal site selection. Solid waste disposal sitting is complex, tedious and costly as it requires multiple criterions from environment, social and economic point of view. Moreover, solid waste disposal sitting is a complicated process requiring a detailed assessment over a vast area to identify suitable location for constructing a solid waste disposal subject to many different criteria (Chang et al., 2007).

2.3.3.2Application of Remote Sensing for Solid waste disposal Site Selection

Remote sensing is defined as the science or art of obtaining information about an object, area or phenomenon through the analysis of the data acquired by a device that is not in contact with theobject, area or phenomenon under investigation (Lillesand et al., 2004 as cited in Kumel, 2014). With the availability of remotely sensed data from different sensors of various platforms with a wide range of spatio-temporal, radiometric and spectral resolutions has made remote sensing as one of the best source of data for large scale applications and study (Assefa et al., 2007).

In the recent years, most environmental related researches have been performed with advanced image processing and analysis. One of the most important applications of remote sensing can be found in the case of solid waste disposal site selection where remote sensing data (satellite images) are used for extracting solid waste disposal site selection criteria example, mapping land use/land cover, geology, surface water and etc. (Oštir et al.,2003).

2.4 Empirical Research

In Ethiopia, for some towns, researchers have conducted studies on solid waste disposal site selection using GIS and remote sensing. For example, as Tsegaye Mekuria (2006), Tirusew Ayisheshim and Amare Sewnet (2013), Kumel Beshir (2014),Genemo Berisa and Yohanis Birhanu (2015) and Minalu Ambaneh (2016) have conducted studies on solid waste disposal sites selection using GIS and remote sensing for Addis Ababa, Bahir Dar, Wolkite, Jigjiga and Mojo respectively.

In the study area, there were no studies conducted about how municipal wastes are managed and solid waste disposal site is selected by using GIS based study. All researchers in their study focused on suitable solid waste disposal site should consider environmental, physical and socio-economic safety criteria. Furthermore, some of the studies used nearly the same criteria and approach. There were also others that focused in adding values to what others did. Hence, in this study there were criteria used by the aforementioned researchers. The criteria that this study differed from other studies were considering wind direction and size of a site as a factor that determine to select solid waste disposal site.

CHAPTER THREE

METHODOLOGY

3.1Study Area

Sululta Town is one of the urban centers of Oromia Special Zone Surrounding Finfinne, Oromia National Regional State, Ethiopia. The town is situated at 25km to the north of Addis Ababa along Fiche road segmenton 10,214ha area. The astronomical location of Sululta Town is $9^{0}5'$ - $9^{0}12'30''$ N Latitude and $38^{0}43'$ -$38^{0}50'30''$ ELongitude.Relatively, Sululta Town is found to the north of Addis Ababa, to the south of Chancho Town, to the southwest and to the South East of Sululta District, to the East of Walmara District. The location map of the study area is given in Figure 3.1.

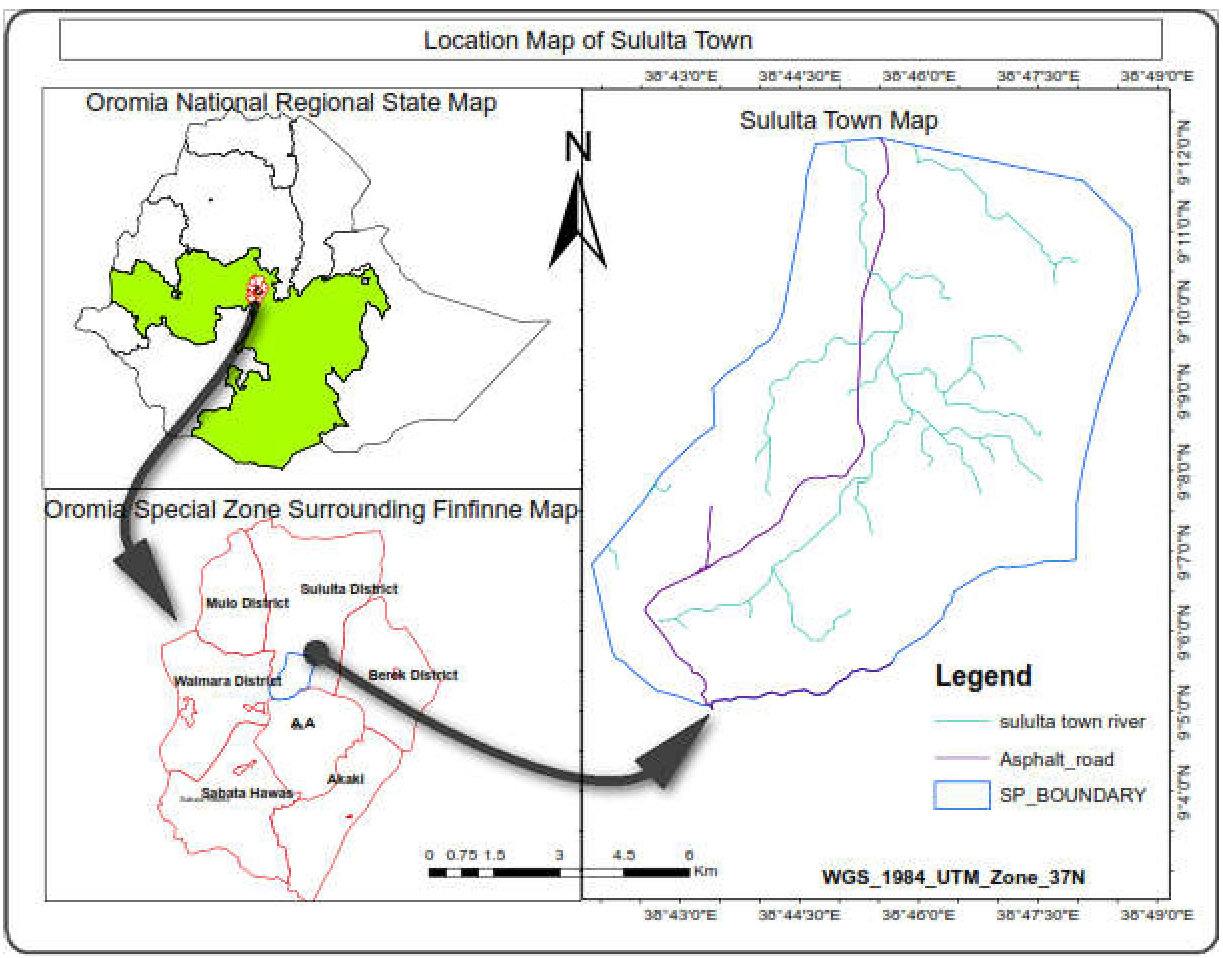

Figure 3.4Location map of Sululta Town

3.1.1. Topography

Altitude of Sululta Town varies from2528m in the northwest and 3081m a.s.l. in the south east of Sululta. As the town is found very close to the foot of Entoto Mountain chain (Fig. 3.2), it falls under highland or temperate agro-climatic zone.

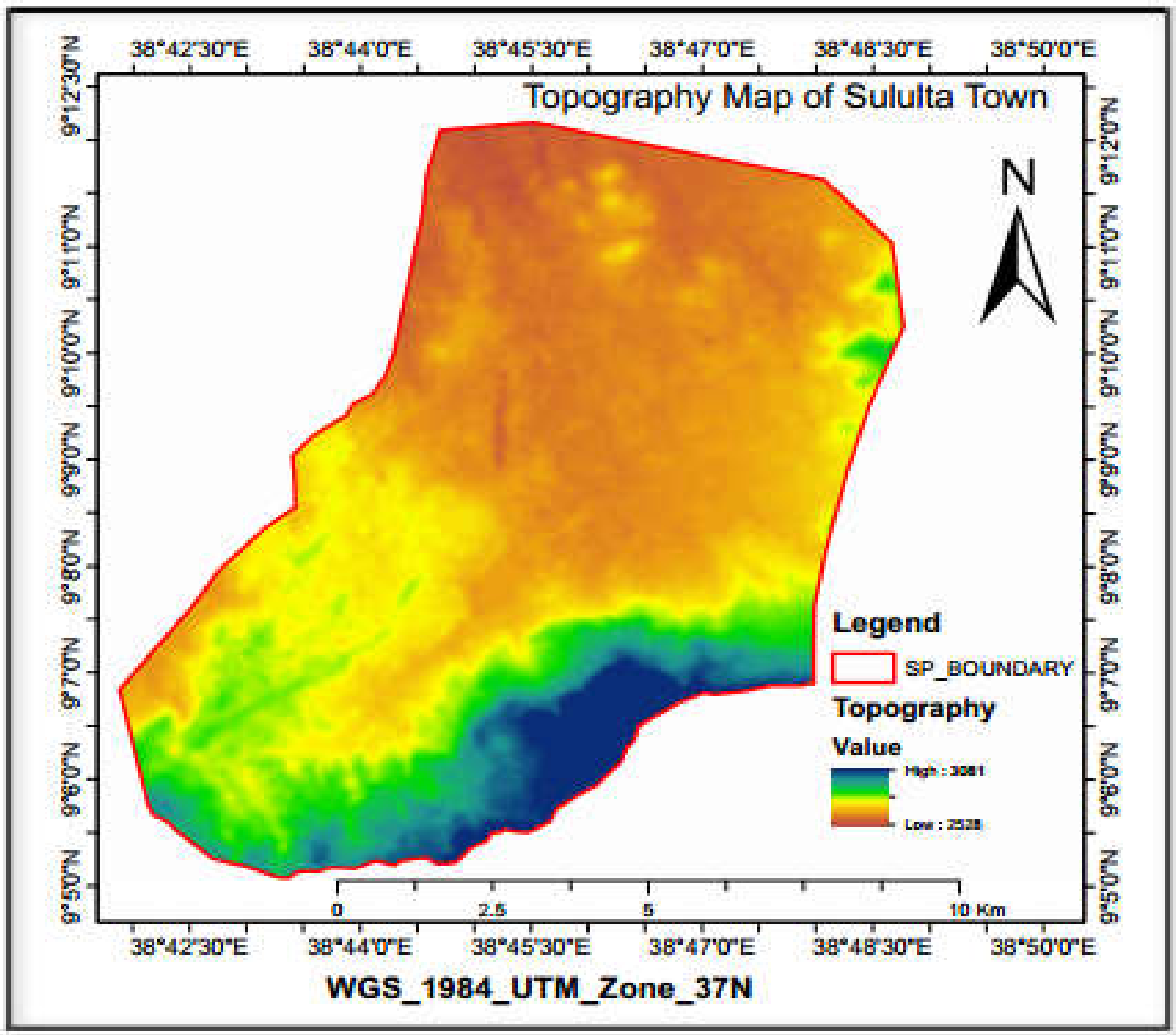

Figure 3.5Topographic map of Sululta Town

3.1.2. Drainage

Sululta Town is engulfed in Abay drainage basin. Due to its location at the foot of Entoto mountain chains, the town is crossed by a number of perennial and intermittent streams that drain from south to northwest towards Abay River basin.

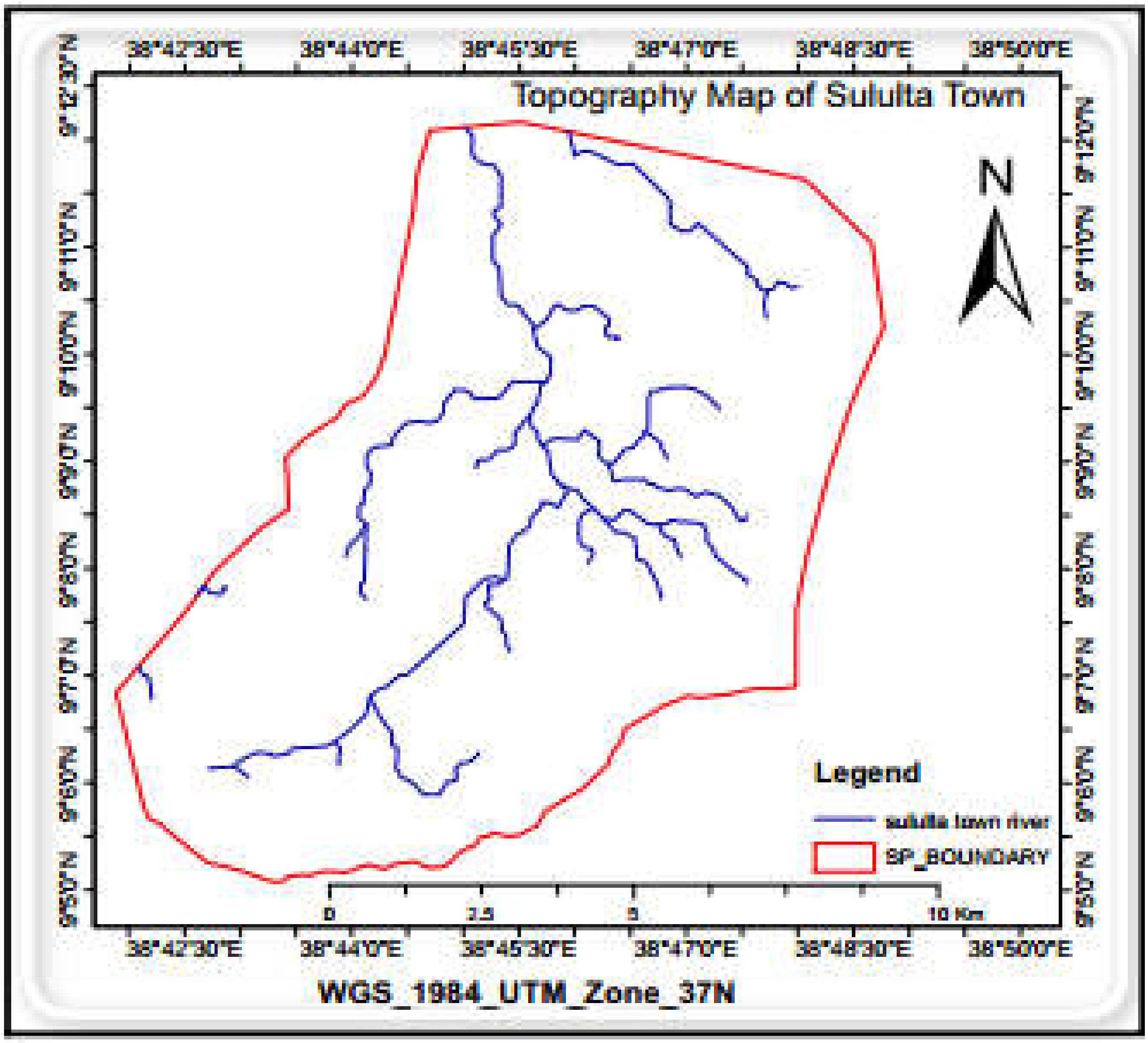

Figure3.6 Drainage map of Sululta Town

3.1.3.Climatic Conditions

The only data types obtained for the analysis of climatic condition of Sululta town is temperatureand rainfall data. The monthly and annual temperature data is found from National Meteorology Service Agencyobtained from 2004 to 2015. The analysis of mean monthly and mean average annual temperature of the town shows that the town has experienced a cold temperature that can be categorized in the temperateclimatic zone. Sululta town area is categorized under the thermal zone range of < 10-20^{0}C, which is cool temperature sensation. Thermal zones are mainly based on the relationship between altitude and temperature and hence are function of altitude. Thus, the mean average annual temperature of the town (14.3^{0}C) is closer to the cool temperature sensation category. Therefore, Sululta Town has a cool temperature that to a lesser extent needs room heating intervention whenever the temperature tends to fall below 10^{0}C.

Sululta town gets rainfall almost throughout a year. The pattern of rainfall varies on monthly basis throughout the year. that the average monthly rainfall ranges from 3.4mm in themonth of December up to 332.7mm in the month of July. From 2004 to 2015, the town has got average annual rainfall of 1232.3mm which enables the town to be categorized under big rainfall places of the country. Heavy rain is received in summer(June to August) and light rain is in spring season (December to February).

3.1.4Population

Sululta Town is one of the fastest growing towns in Oromia in terms of population. Though, obtaining demographic data in Oromia Special Zone in general and Sululta town is a problem, according to the second and third censuses carried out at national level in 1994 and 2007 the population size of Sululta town was 1,271and 6,407, respectively. These two censuses are misleading and cannot represent the present condition (only focused on Sululta as one *Ganda/kebele.* The demographic feature in towns around Finfinne has unique features unlike most urban areas in the region. The only data that incorporates all the localities that are incorporated under town administration /*Ganda/* is that of the town profile conducted in 2014(OUPI,2016).Taking into consideration this data problem, the two population censuses and town profile/survey conducted by town administration in 2014 and estimates made based on the past trends. According to the report, the urban population size of Sululta town was counted to be 37,988 in 2014. Based on this figure attempt has been made to estimate the population size of Sululta, and hence, the 2016 population size of the town was reckoned to be close to 52,126(OUPI, 2016).

3.2.Data Sources and Collection Techniques

Data from primary and secondary sources were used in this study. The primary data source was obtained throughnon-structured interview,photo cameraand field observationof the existing dump sites in Sululta Town. Secondary data, such asgeology and hydrogeology of the town were obtainedfrom Addis Ababa Water Sewerage and Sanitation Agency. On the other handSululta Town base map,DEM30mx30m resolution was obtained from Oromia Urban Planning Institute.

3.3Geographical information system

Geographic information system, GIS, has various applications in human life. One of these applications is suitability analysis for solid waste disposal sitesite selection in the solid waste management system of urban areas. The software ArcMAP is the dominant and very famous computer program which has been widely used in the land management including solid waste disposal siteing site selection and urban planning.

3.3.1 Data input and analysis

For the suitability analysis of the land in Sululta Town for the purpose of solid waste solid waste disposal siteing different data were employed as input data for ArcMAP. DEM was used to generate slope, drainage using the computer program ArcMAP 10.3.1(ESRI). The procedures applied to generate slope, slope surface material, elevation and drainage given,to extract main road and built up areas from topographic base map of the town;and hydro geological and geological map were given in Figure 3.4.

3.3.1.1Data analysis and presentation

There are different types of GIS spatial operation tools that would be used to achieve the objectives of this study. The methods used haveincluded buffering, overlay, spatial analysis, 3D analysis and other extensions.

Buffering

Buffering is a spatial analysis also called proximity analysis. It is used to generate areas of a given distance around the specified criteria has been used for waste disposal site selection. Such as polygons around roads and line or polygon around streams based on the specified distance to each criterion. The features that buffered include: roads, surface waters, and built upareas with different values. In GIS buffering, multiple ring buffer toolhas been used to screen out unsuitable areas based on the defined criteria. All the sitting of waste disposal requires a substantial evaluation process in order to identify the best available disposal location, that is, a location which meets the requirements of government regulations and minimizes economic, environmental, health, and social cost (Siddiqui et al., 1996).

Overlay

An overlay operation will be performed to identify areas that fulfill all the site selection criteria and to show areas that do not meet these criteria. GIS can overlay different types of information that helps to understand the association between network analysis and specific geographic features (Tsegaye, 2006). In this study, the overlays can use different input features to the base map (structural plan of the study area), such as DEM, geology and hydrogeology data from different sources. The final map was intersected by using overlay operation.

Spatial Analysis

Solid waste disposal site selection is the complex, tedious and costly process that needs to consider many conflicting criteria. To make analysis, ArcGIS Spatial Analysis is a powerful tool used to generateslope, hydrology, contourand conversion from their sources.

3.3.1.2Multi-criteria Decision-making

Multi-criteria evaluation (MCE) technique is used to deal with the difficulties that decision makers encounter in handling large amounts of complex information. The principle of the method is to divide the decision problems into more smaller understandable parts, analyze each part separately, and then integrate the parts in a logical manner (Malczewski, 1997). Multi-criteria analysis is a set of mathematical tools and methods allowing the comparison of different alternatives according to many criteria, often conflicting, to guide the decision maker towards a judicious choice (Chakhar and Mousseau, 2008).

MCDA consists of a series of techniques such as weighted summation or concordance analysis that permit a range of criteria relating to a particular issue to be scored, weighted and then ranked by, for example, experts, interest groups and/or stakeholders according to their degree of suitability or importance for locating/sitting a particular facility/service (Malczewski, 2004) like solid waste disposals. Analytic Hierarchy Process (AHP) in which Pair wise comparisons will also be used to determine the relative importance of each alternative in terms of each criterion is one of the most commonly used MCDM tools. A measure of how far a matrix is from consistency is determined by computing the Consistency Ratio (C.R.). This is obtained by calculating the matrix product of the pair-wise comparison matrix and the weight vectors, and then adding all elements of the resulting vector. After that, a Consistency Index (C.I.) is computed using the following formula:

$$CI = \frac{\lambda\text{max} \quad \text{n}}{n \quad 1}$$

Where *n* is the number of criteria and *λ*max is the biggest eigenvalue (Malczewski, 1999). To determine if the comparisons are consistent or not, the Consistency Ratio (*C.R.*) is calculated using the formula:

$$CR = \frac{CI}{RI}$$

Where *R.I.* is the Random Inconsistency index that is dependent on the sample size (Table 3.1). A reasonablelevel of consistency in the pair-wise comparisons is assumed if *C.R.* < 0.10, while *C.R.* ≥ 0.10 indicates inconsistentjudgments.

Table 3.1: Random Consistency Index (R.I.) for *N*=1, 2 … 8 (Adapted from Saaty,2008).

N	1	2	3	4	5	6	7	8
R.I	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41

3.3.1.3Solid waste disposalsite selection criteria

Numerous studies conducted in different parts of our globe employed a set of criteria for solid waste disposal site selection. Accordingly in this study a set of parameters for solid waste disposal site selection for Sululta Town were considered and given in Table 3.1. Different researchers recommend different distance for solid waste disposal site from the built up area. As EMET et al (2008) claimed that disposal site should be 300m away from the residential areas. However, in this study the distances of the solid waste disposal site from built up is set to be 1000m, which is the average of the distances recommended by EMUDC(2012), and Chang et al., (2007).

The waste disposal areas should not be in the vicinity of rivers, lakes, or swamps where the underground water level is high. Since major rivers have a higher discharge and greater downstream influence, no solid waste disposal should be sited within the floodplains of major rivers (Seiied,2015). In this study, the streams/rivers were generated from DEM of the Sululta Town, using spatial analyst tool of hydrology extension. As Chang et al. (2007) states, the distance away from rivers of not less than 1 kmwhereas, MET et al (2008) stated distance from the river as to be 300m away, and the standards of EMUDC(2012)claims that to maintain the environmental health of water sources sites for solid waste disposals should be located at least 500 m away from water sources.

Road is one of the criteria that should be considered in selecting suitability site for solid waste disposal. Accordingly, the solid waste disposal sites should not be very close to roads to eliminate the public health problem. In addition, the solid waste disposal site should be placed not much far from existing roads for saving road development, transportation and collection costs. In general, the solid waste disposals shall not be located within 1000 mof any major highways, town streets or other transportation routes. Solid waste dumping site should be located at a suitable distance from roads network in order to facilitate transportation. Thus, it is preferred to locate solid waste disposals 1000 m away from roads (EMUDC, 2012).According to Chang et al. (2007), the distance of a given solid waste disposal site from the road shouldnot be less than 750 m away. However, the maximum distance of locating solid waste disposal site from main road in this study is the 900 – 1200 m, which is the average of the distances set by different researchers (EMUDC, 2012; Chang et al., 2007)

Slope is a topographical factor determining the suitability a land for solid waste disposal.It is an important factor insolid waste disposal suitability site selection process because it determines the amount of surface runoff. It also dictates the displacement velocity of water to the potential site. Besides, as the steep of the land increases, the cost of construction for a solid waste disposal also increases (Tsegaye, 2006). On the other hand, flat and gently rolling hills that are not subjected to flooding are the best sites for solid waste disposal (Basak, 2004).Moreover, Ersoy and Bulut (2009) state that areas with slope <20% is optimally suitable site for solid waste disposals. Similarly, the land with a slope < 10% is highly suitable for solid waste dumping (EMUDC, 2012).

In this study, by considering bench mark stated by various researchers (Tsegaye, 2006; Ersoy and Bulut, 2009; EMUDC, 2012), areas with slope category >20% was ranked as it is least suitable for solid waste disposal. Land with 3-15% slope was ranked in suitable for solid waste disposal, because of its optimum suitability for easy control of runoff and operation. Areas with 15-20% slope were considered as moderately suitable for solid waste disposal. Lastly, 0-3% slope class was ranked as unsuitable for solid waste disposal site due to water logging problem, downstream surface and ground water pollution (Centre for Advanced Engineering, 2000). The slope of Sululta Townwas extracted from DEM 30m x 30m resolution using ArcGIS software spatial analyst extension of surface tool.

Majority of the study area is covered by the alluvium soil deposit followed by the colluvium soil type. The residual soil material is mainly red clay and has granitic and organic origin which is moderately suitable for solid waste dumping site. From field observation, the sticky clayey nature of the soil has been observed while it is moist. Moreover, the good permeability natures of the soil allow infiltration of water which saturates the slope material (Gemechis, 2015).It is recommendable that the soil of the selected site has tohave good natural impermeability in order to reduce the possibility of aquifer contamination (EMUDC, 2012).

The Tarmaber Basalt which is the dominant unit covered in the central plateau parts in the study area. This type of geological feature is highly weathered, fractured and pinkish to grayish in color (Andualem, 2008). Because of its nature and susceptibility to weathering and fracturing, this type of geological feature is not suitable for solid waste disposal site. It is grayish pink and reddish brown to yellowish grey color when weathered (Reys, 2016).

Wind direction is an important planning input to propose land uses that have pollution impact on the nearby land uses. In the study area, the dominant wind prevailing around is the wind that comes from south direction followed by south east parts of the town. The blowing wind could take with itself toxic fumes and partculate materials from waste disposal sites hence affecting human health(OUPI, 2016). Therefore, considering wind direction for appropriate solid waste disposal selection is one of the crucial parameters.The sites have to take due account to the impact on the downstream.

Size of solid waste disposal is one of the determinant criteria for sustainable solid waste management as size of land selected for solid waste disposal determines the number of years for which the solid waste disposal will be used as waste disposal site. From sustainability and economical point of views, larger size of land that will serve for at least ten years are more preferable than small size. This is because selecting large sized solid waste disposal site can minimize the cost of site selection, design and closure that will be performed at the end of itslifespan (Schneider, 1985).The location of the facility should be selected in such manner that there is no or minimum effect at the downstream habitation.

Currently in Sululta town, solid waste generation is calculated on the base of Ethiopia's average per capita solid waste generation rate, which is in between0.3-0.5kg/day (EMUDC, 2012). The amount of solid waste generated to the existing population which is estimated to be 52,126of the town is about 15,637 kg/day to its minimum rate. Table 3.2 shows the amount and projected solid waste generated per capita in 0.3kg/day rate to the population of Sululta town. The total household solid waste generation rate in the town by weight and volume was estimated by using the average per capita waste generation rates of the country. Hence the estimated daily and yearly solid waste generated was 15,637kg and 5,707,505 kg or 5,707.5 ton respectively.

The waste in developing countries is naturally dense, typically ranging between 300 and 550 kg per cu m. Where waste densities are low, as in the case with industrialized country refuse, in order that vehicle productivity can be maximized through the transporting of maximum payloads, it is necessary to compact the refuse in order to increase its density. Compaction trucks are typically designed to compact light refuse (e.g., 100 kg/cu m density to about 400 kg/cu m), but the naturally occurring density of developing country refuse is usually around 400 kg/cu m (EMUDC, 2012). In terms of volume the estimateddaily and yearly waste generation rates were 30m^3 and14,268.76 m^3 respectively in the study area.

Table 3.2 Projected per capita solid waste generation with population(OUPI,2016)

Year	***Population***	***Weight***			***Volume***	
		Kg)/ Day	***Kg/year***	***Ton/year***	***M^3 /day***	***M^3 /year***
2016	52,126	15,637	5,707,505	5,707.5	30	14,268.76
2026	260,776	78,233	28,555,045	28,555.05	195.58	71,387.6125

The projected population data was obtained from OUPI (2016) which helped the researcher as a spring board to project the amount of solid waste generated.

Table 3.3Solid waste disposal site selection criteria, level of suitability, classes andrating scales

No.	Selected criteria	Level of suitability, classes and values of rating				Influence in %
		Unsuitable (1)	Less suitable (2)	Moderately suitable (3)	Suitable(4)	
1	Distance from built up area(m)	0-300	300-600	600-900	900-1200	40
2	Distance from rivers (m)	0-300	300-600	600-1000	>1000	20
3	Distance from the Main road(m)	0-1000	1000-1500	2000-2500	1500-2000	10
4	Slope (%)	0-3	>20	15-20	3-15	10
5	Surface material (%)	Alluvium	Colluvium	Residual	Rock	6
6	Geological feature (ha)	Basalt	-	-	Rhyolite	7
7	Hydro geological feature(ha)	Basalt aquifer	-	-	Conglomerate aquifer	7
					Total	100%
8	Wind direction	Used to make decision when evaluating the potential solid waste disposal sites				
9	Size of the site					

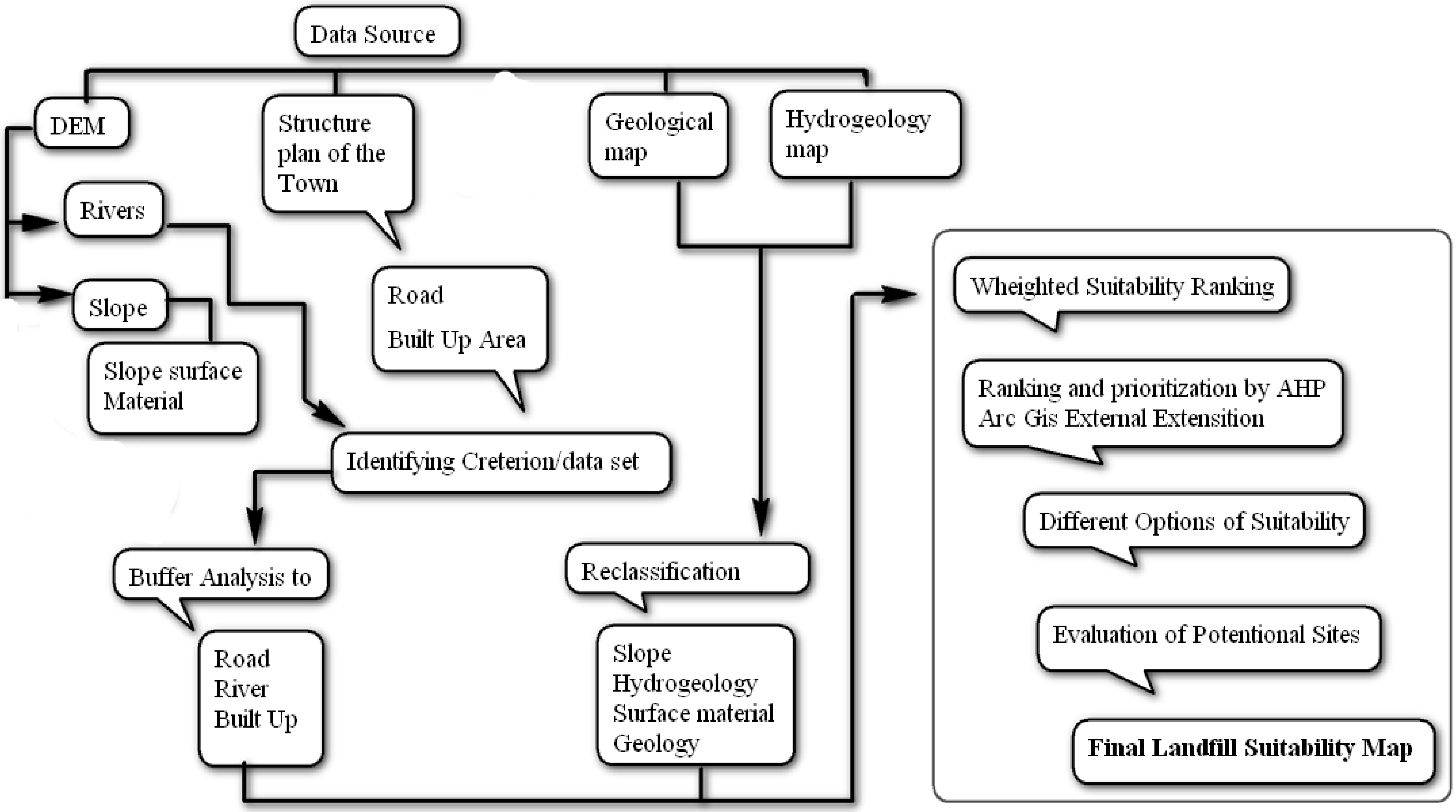

Fig. 3.4 Methodological Flowchart

CHAPTER FOUR

4. Results and Discussions

This chapter discusses different data sets that were used to determine suitable solid waste disposal site. In this study, suitable site of solid waste was determined for Sululta town by using the GIS environment and weighting product of AHP method. For this study ninesuitability criteria (distance from built up area, main road, surface water, geology, hydrogeology, slope, surface material, size of the site and wind direction) were used based on the relevant literatures, standards of Ethiopian Ministry of Urban Development and Construction, in addition to international practices. Maps were created for each suitability criterion and the final composite map was finally produced by simple overlaying of the individual maps. The layers, buffer zones used, rankings and layer's weights were summarized using tables.

4.1 The current condition of solid waste management system in Sululta Town

In Sululta town currently wastes are generated from residential, commercial and institutional areas in huge amount and without segregation dumped in open solid waste disposal site. Although there are containers for solid wastes placed at inappropriate place and not evacuated properly. The accumulation of waste on unsuitable dumping site creates opportunity to access for germ carriers like fly and other animals that contaminate the town.

In the study area, there wereindividuals organized to collect solid wastes from door to door by donkey drawn carts, transported and stored it in containers that are situated at the back of existing abattoir and wait for several time without evacuation . The following photos show containers location and storage sites.

Figure4.1 a) open dump along steeply abattoir place and b) open dump in the interior town on the Laga Billawa river bank c) Solid waste containers placed near existing abattoir.

Source: Photo taken on December10, 2016

The firstobjective of the research was to assess the present waste disposal site and their strategies in Sululta town. This obje ctive was achieved through field observation and interview with experts of Municipal Beautification and sanitation department of Sululta town. The result showed that the municipal of the town together with the land administration office selected and prepared the existing open dumping site based on the criteria only distance from center of the town. According to the observation and interview, the existing solid waste disposal site is not suitable, because the existing site does not consider major environmental and health factors, like distance from water bodies, topography and settlement.

In the study area, solid wastes are rarely dumped in the existing site even after collected from sources. Most of the solid wastes generated from different sources were dumped elsewhere in the town. The residents nearer to the existing open dump site are suffering from odour pollution and pollution of the river around and downstream for they cannot use it for home consumption and irrigation. Solid waste that disposed in the open field close to the river contaminates the river highly because of runoff and wind since the slope towards the river is steep. As a result, surface water pollution is the main problem. However, the negative impacts from solid waste disposalcan be minimized through selecting an appropriate site, which minimize potential environmental impact, GIS and RS techniques are effective for the purpose.

4.2Solid waste disposal site selection criteria

Table 4.1 Area in ha and % under each suitability class of each criterion

No.	Criteria	Area	Unsuitable (1)	Less suitable(2)	Moderately suitable(3)	Suitable(4)	Total	Map
1	Distance from built up area (m)	ha	4357	1790	1186	818	8151	Suitability from built up area
		%	53.45	21.96	14.55	10.04	100	
2	Distance from rivers (m)	ha	4348	1797	3013	189	9347	Suitability from rivers
		%	46.9	19.23	32.23	2.02	100	
3	Distance from the Main road (m)	ha	3876	1609	1153	724	7362	Suitability from main roads
		%	52.65	21.86	15.66	9.83	100	
4	Slope (%))	ha	4869	537	1572	3235	10213	Suitability slope
		%	47.67	5.26	15.39	31.68	100	
5	Surface material (%)	ha	4869	3235	1572	537	10213	Suitability of surface material
		%	47.67	31.68	15.39	5.26	100	
6	Geological (ha)	ha	5151	-	-	5063	10214	Suitability of geology
		%	50.43	-	-	49.57	100	
7	Hydro geological (ha)	ha	5151	-	-	5063	10214	Suitability of hydrogeology
		%	50.43	-	-	49.57	100	

4.2.1 Distance of a Solid waste disposal to a Built-Up area

The suitability level when considering distance from the builtup area is given in Table 4.1. The results show that out of the total area, 4357 ha was unsuitable for solid waste disposal site. The least suitable level shared 1790 ha. The moderately suitable land based on the distance from the built up area accounted for 1186 ha. The rest area which is 818 ha was evaluated as suitable for solid waste disposal site. It can be concluded that the area that was categorized as suitable for solid waste disposal site was sufficient to dispose the waste generated by the residences of the town.

Proximity of a solid waste disposal to a built-up is an important environmental criterion in the solid waste disposal site selection. Built-up area includes settlements, commercial areas, governmental and private institutions, schools, health centers, religious institutions, educational institutions and other social service areas. Hence, solid waste disposal should be placed away from built-up areas. The existing built up area of Sululta town was obtained and Multiple Ring Buffer tools were used to prepare buffer zones around the built-up areafrom its topographic map.

As Chang, et.al, 2007;EMUDC, 2012 stated that, the solid waste disposal should not be less than 1 Km situated at a significant distance away from urban residential areas, historical sites including ancientinternational museums and other social activitiesdue to public concerns, such as aesthetics, odor, noise, and decrease in property value.As MET et al. (2008) claimed that disposal site should be 300m away from the residential areas. Different researchers set different built-up criteria for solid waste disposal site selection. In this project, built-up suitability used 900-1200m distance from built-up area. However, built-up suitability distance <300m considered as unsuitable for solid waste disposal site.Built-up buffer suitability map of the study area is shown as:

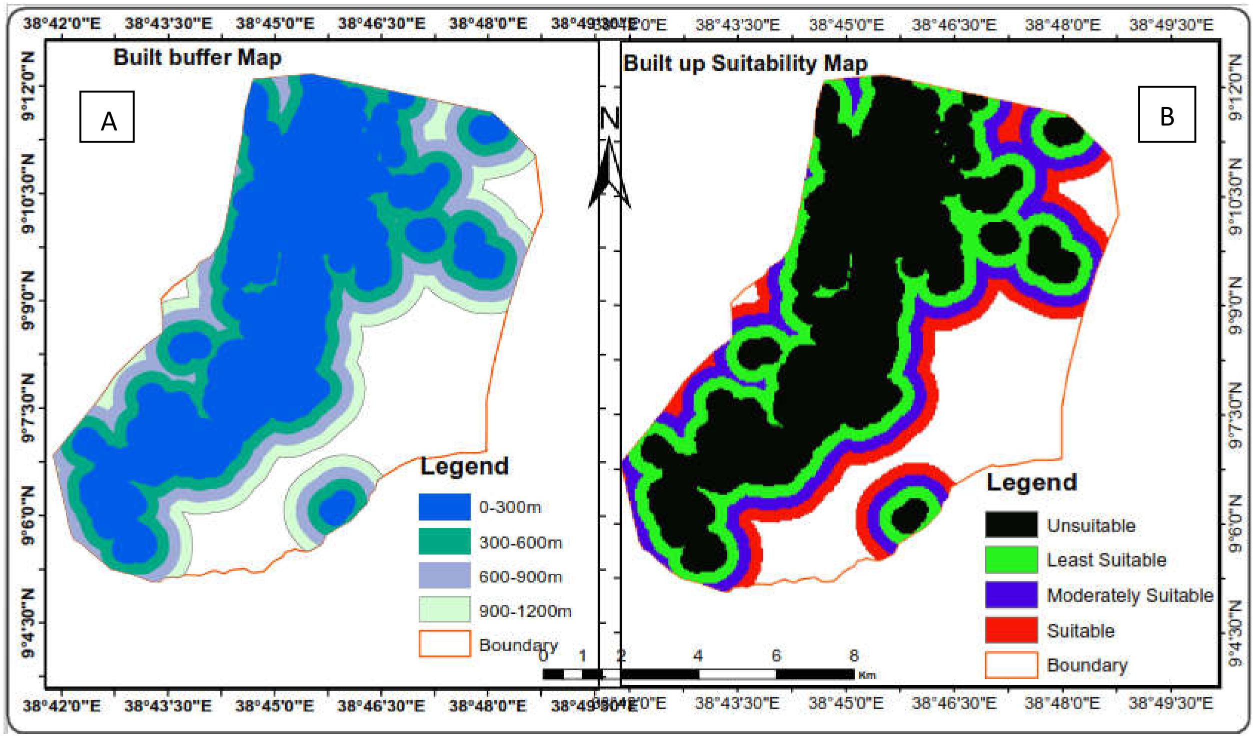

Fig.4.2A: Built Up Area Buffer MapB) Built up area suitability map

4.2.2 Surface Water

The hydrology class and suitability level is given in Table 3.3 and 4.1 respectively. The analysis results show that 4348 ha was found unsuitable for solid waste disposal site. The area that was least suitable for solid waste disposal site shared 1797 ha. The part of the land that was moderately suitable for solid waste disposal site covered 3013 ha. The rest area which is 189 ha was observed as suitable area for solid waste disposal site. Therefore, as the distance between the solid waste disposaland water bodies decreases, the probability of polluting the water becomes high.

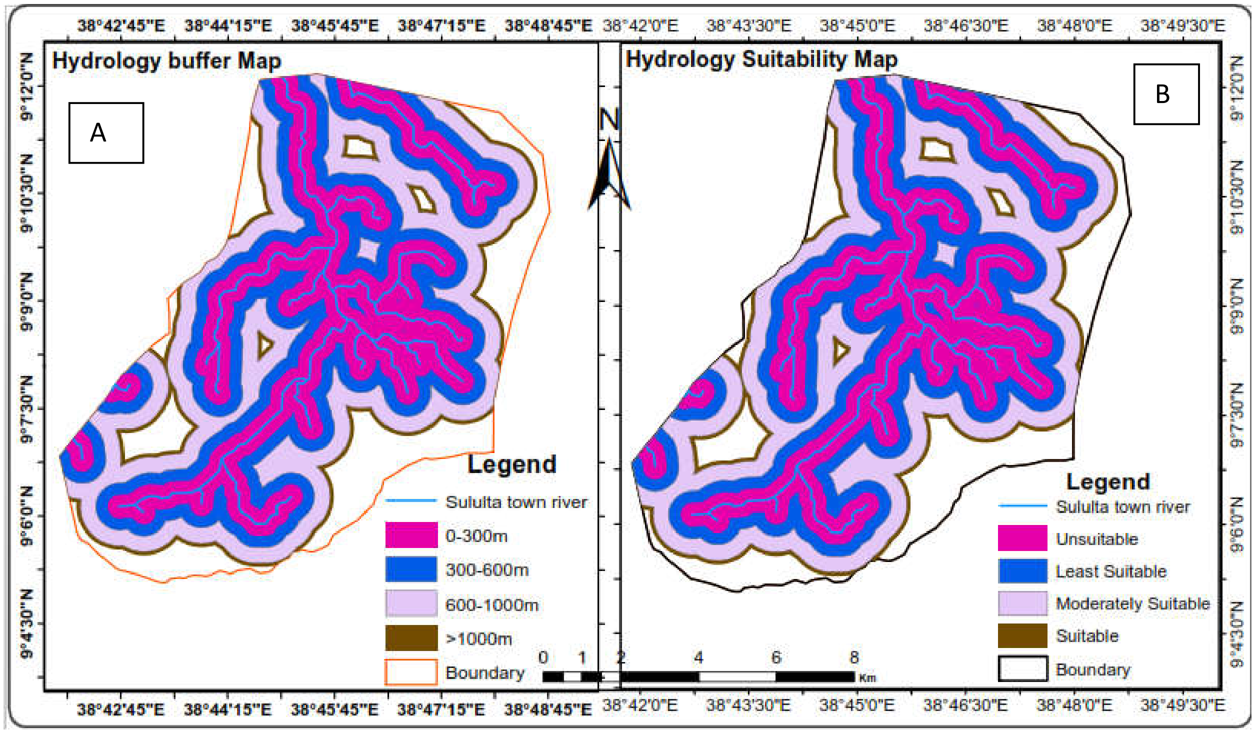

Fig.4.3A) Surface water buffer map B) Surface water suitability map

Most of the surface water in the study area is streams. The waste disposal areas should not be in the vicinity of rivers, lakes, or swamps where the underground water level is high. Since major rivers have a higher discharge and greater downstream influence, no solid waste disposal should be sited within the floodplains of major rivers (Bagchi, 1994). In this study, the streams/rivers were generated from DEM of the Sululta town, using spatial analyst tool of hydrology extension. As Chang et al. (2007) stated, the distance away from rivers of not less than 1 kmwhereas, the standards of EMUDC, 2012claimed to maintain the environmental health of water sources at least 500 m buffered distance should to locate suitable sites for solid waste disposals. Accordingly, four different zones were specified: in which far buffers from streams are more suitable while buffers near to streams are unsuitable for solid waste disposal sitting.

4.2.3 Distance from the main road

The suitability level when considering distance from the main road is given in Table 3.3 and 4.1. The results show that out of the total area, 3876 ha was unsuitable for solid waste disposal site. The least suitable level shared 1609 ha. The moderately suitable land based on the distance from the built up area accounted for 1153 ha. The rest area which is 724 ha was evaluated as suitable for solid waste disposal site. It can be concluded that the area that was categorized as suitable for solid waste disposal site was sufficient to dispose the waste generated by the residences of the town.

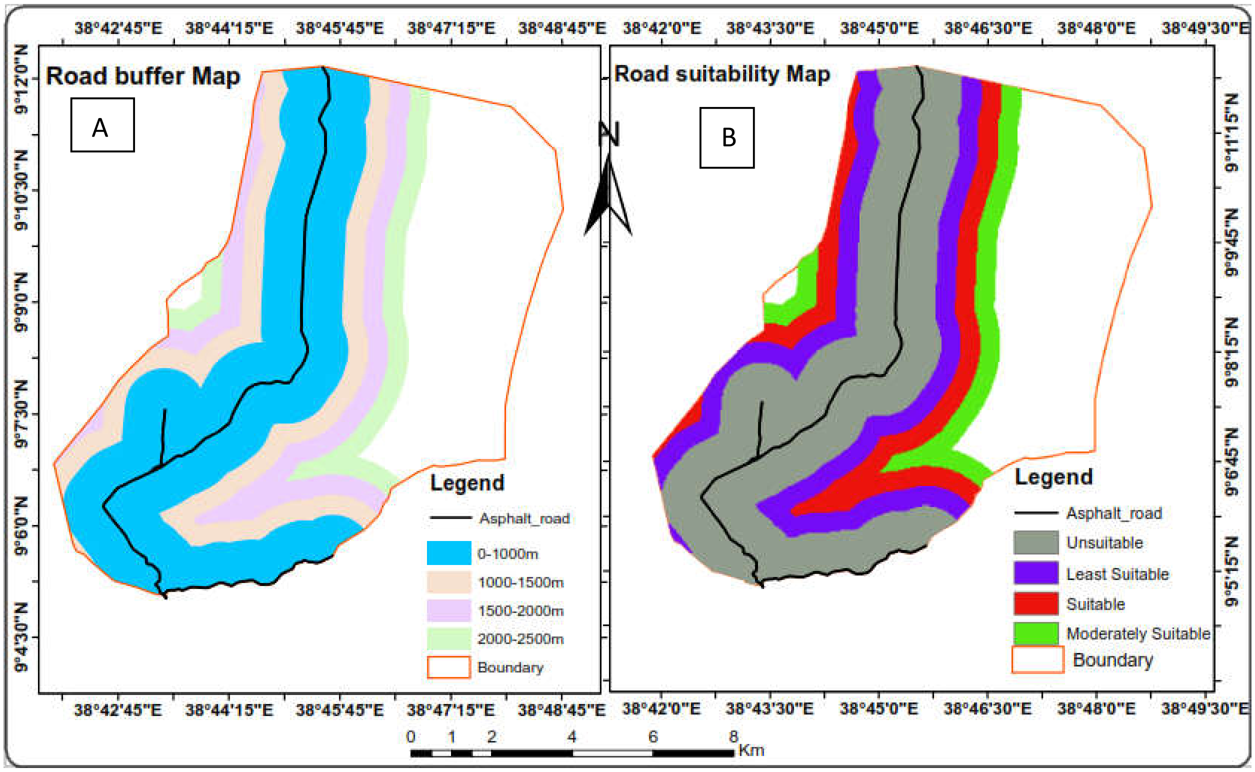

Fig.4.4A) Road buffer map B) Road suitability map

Road is one of the criteria that should be considered in suitability analysis. Solid waste disposal sites should not be very close to roads, this is because as solid waste disposals close to roads may result public health problem. In addition, the solid waste disposal site should be placed not much far from existing roads for saving road development, transportation and collection costs. As the general concept, the solid waste disposals shall not be located within 1000 meterof any major highways, town streets or other transportation routes. Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and it is preferred to locate solid waste disposals away 1000meterdistance from roads (EMUDC, 2012).According to Chang et al (2007), the distance of a given solid waste disposal site from the road has not less than 750 m away.

4.2.4 Slope

The suitability level when considering slope is given in Table 3.3 and 4.1.Majority of the study area falls under the slope class of 0-3% covered48.2% of the total study area wasunsuitable for solid waste dumping. Whereas, about 5.3% less suitable, 15.5% moderately suitable and 31.7% was suitablein which each area was covered by slope classes >20%, 15-20% and 3-15% respectively.It is concluded that, the best slope for solid waste disposal should be suitable slopes, between 3-15% is found to be an appropriate slope class for solid waste dumping site selection in Sululta town.

Slope is a topographical factor in determining the suitability of solid waste disposal sites.It is an important factor in suitability site selection process because it determines the amount of surface runoff produced the precipitation rate and displacement velocity of water to the potential site in addition to the construction cost. It means that when the slope is gentle it decreases the construction cost as compared to the sharp slope area (Tsegaye, 2006). Flat and gently rolling hills that are not subjected to flooding are the best sites for solid waste disposal. However, this type of topography is also suitable for other land uses like agriculture, residential or commercial development that lead to higher land prices (Basak, 2004).

This study considered the modest slope is more suitable than the land with more flat and higher slope class in the study area. Different research shows that areas with depressions associated with unstable area should be avoided because they may cause to contamination of groundwater sources of drinking water. Other topographical depressions resulting from human activities, such as stone quarries, depths, and narrow piece cannot be suitable for solid waste disposals. Hence, slope of the study area was extracted from Digital Elevation Model (DEM) of 30m x 30m resolution by using ArcGIS software spatial analyst extension of surface tool. Then the slope raster was reclassified into four classes of slope percent. The reclassified slope was ranked from 1 to 4, as 4 are suitable and 1 is for the unsuitable site selection.

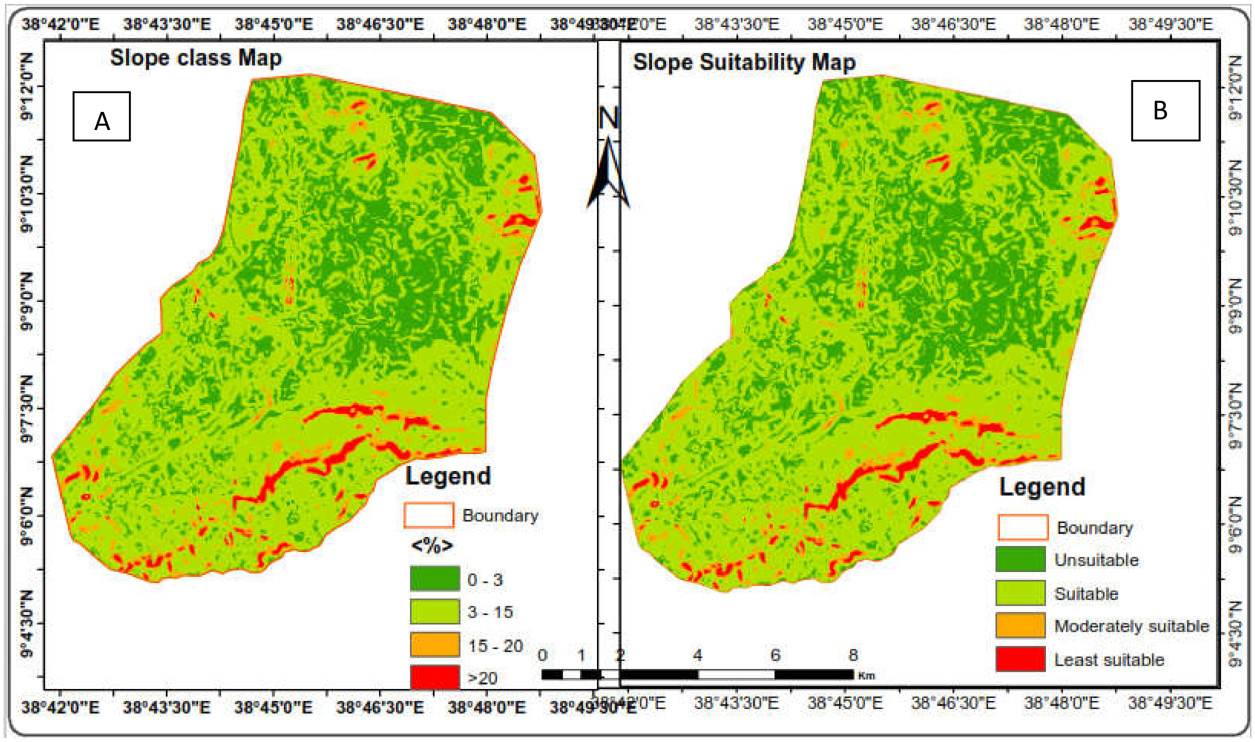

Fig.4.5A) Slope class map B) Slope Suitability Map

Moreover, as Ersoy and Bulul (2009) stated that areas with slope <20% is optimum site for solid waste disposals. The land with a slope less than 10% is highly suitable for solid waste dumping (EMUDC, 2012).In this study by considering the stated bench mark,areas with slope category >20% wasranked as it is least suitable for solid waste disposal becausehigh topography areas reduce the stability of the side slopes (increased risk of landslides), difficulty posed in construction or leveling which incur additional cost and increase leachate movement and 3-15% slope was ranked in the first place and suitable, because of its optimum suitability for easy control of runoff and operation. Areas with 15-20% slope were the second option for solid waste disposal, this is because as steepness increases, operation will be difficult and construction cost will increase and vice versa, and 0-3% slope class was ranked as unsuitable for solid waste disposal site due to water logging problem, downstream surface and ground water pollution (Centre for Advanced Engineering, 2000).

4.2.5 Surface Material suitability

The suitability level when considering slope material typeis given in Table 3.3 and 4.1. The result showed that, out of total area 47.7% of the slope surface material is unsuitable for solid waste disposal sitting. Whereas, 31.7% shared least suitable, 15.3% analyzed as moderately suitable and 5.3% of the area it encompasses were covered suitable for solid waste solid waste disposal site selection.

As observed in the field three different types of soils were classified on the basis of mode of slope, transportation and color, are broadly classified into: residual, alluvial and colluvial soils together with land covered by rock (Fig.4.6).

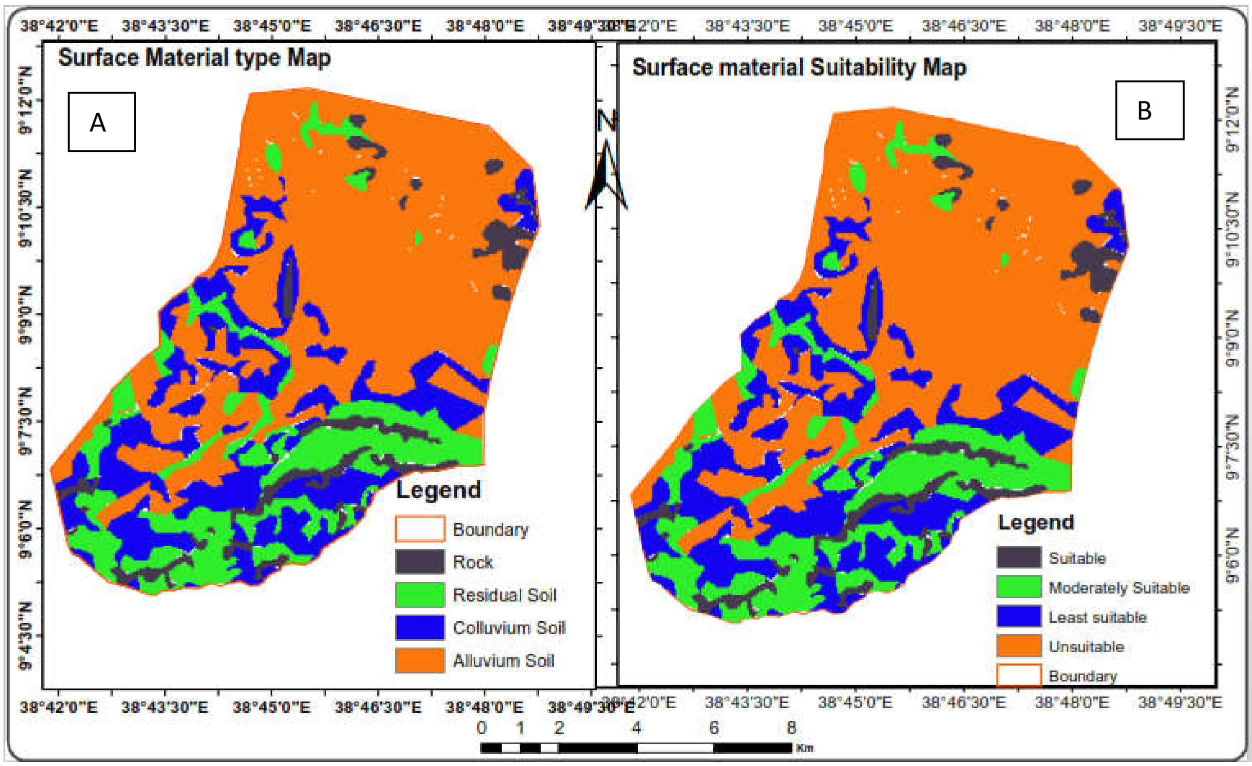

Fig.4.6 A) Slope Material mapB) Slope Material suitability map

Majority of the study area is covered by the alluvium soil deposit followed by the colluvium soil type. The residual soil material is mainly red clay and has granitic and organic origin which is moderately suitable for solid waste dumping site. From field observation in the spring and from the interview of the community, the sticky clayey nature of the soil has been observed while it is moist. Moreover, the good permeability natures of the soil allow infiltration of water which saturates the slope material (Gemechis Chimdi, 2015).

Further, the colluvial soil material in the study area consists of coarse and stony debris detached from blocky soils and carried down the slope by gravity. It is loose and unconsolidated material that has been deposited at the base of the slopes by variable processes (e.g. rain-wash) which may create less suitability for sitting it for solid waste disposal.In general, it is common to observe different kinds of instability in the colluvial soil. Colluvial material may get disintegratedand can facilitate the percolation of rain water during the rainy season.Alluvium soil is a fine-grained fertile soil deposited by water flowing over flood plains or in river beds. If the water velocity decreases, finer particles (sand and silt) are deposited, while fine silt and clay particles are deposited by slow-moving water that found associated with deltas in lower slope areas where highest water stagnation occurred and in turn not suitable for solid waste disposal sitting.

4.2.6 Geology

The suitability level when considering geological type is given in Table 3.3 and 4.1. The result showed that out of the total area,the Tarma ber basalt type of geological feature covers 5151ha. While,5063 ha out of the area was covered by Entoto-becho rhyolitetype of geological feature. It is concluded that, the Tarma ber basalt type was unsuitable geological feature for solid waste disposal sitting because of its fault lineshigh aquifer component it produces. Entoto becho ryolite geological feature has massive structure beneath which may hinders percolation of wastes to the interior part to contaminate groundwater.

Major Geological features observed in Sululta Town were Entoto-becho rhyolite: obisidian rich rhyolite and Tarmaber basalt: Leaticular basalt with a large amount of lava flows are found toward a watershed divide of Abay River basins in the study area. The Entoto ridge forms steep slope towards the Abay basin steep to gentle slope towards north in the study area and is rich in obsidian at the picks of the cones in which this study lied. The Entoto_becho rhyolite covers north and south parts of the study area and relatively suitable than that of its characteristics for solid waste disposal site.

The geology of an area will directly control the soil types created from the parent material, loading bearing capacity of the solid waste disposal's foundation soil, and the migration of leachate. Rock and its structure type will determine the nature of soils and the permeability of the bedrock. Geologic structure will influence the movement of leachate and potential rock-slope failure along joints and tilted bedding planes.

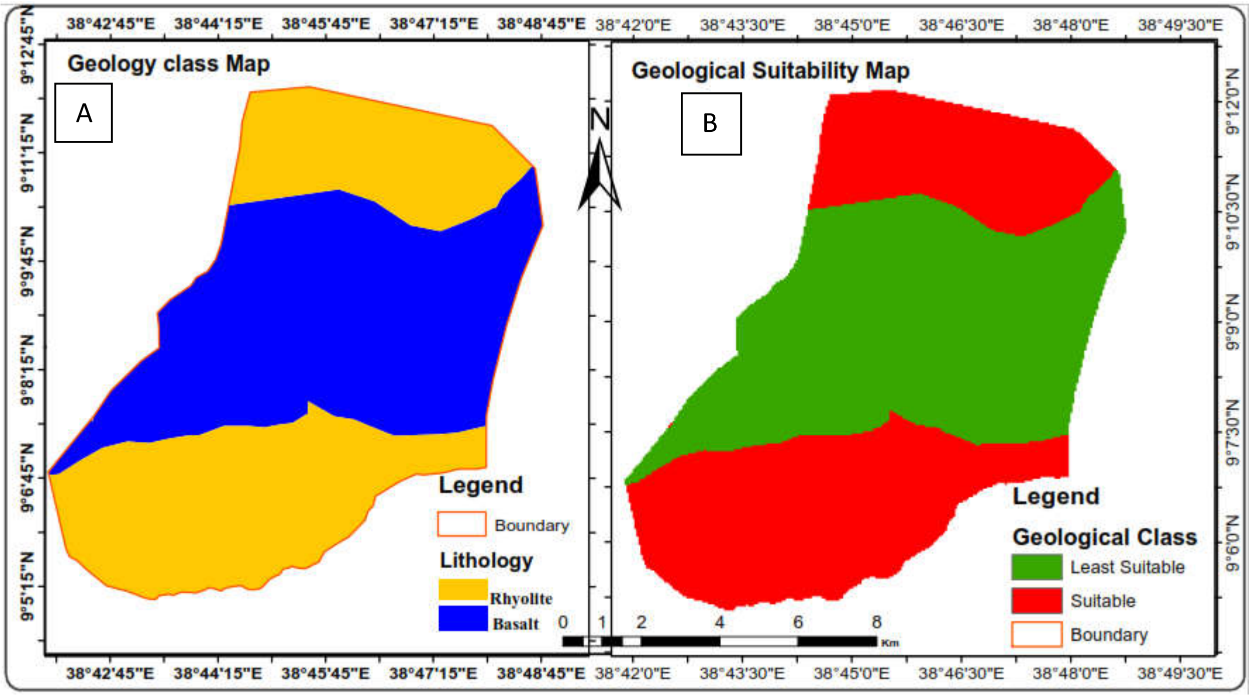

Fig 4.7A) Geological class MapB) Geological Suitability Map

The Tarmaber Basalt which is the dominant unit covered in the central plateau parts in the study area. This type of geological feature is highly weathered, fractured and pinkish to grayish in color according toAndualem(2008). Because of its nature and susceptibility to weathering and fracturing, this type of geological feature is not suitable for solid waste disposal site. It is grayish pink and reddish brown to yellowish grey color when weathered (Reys, 2016).

4.2.7 Hydrogeology

The suitability level considering hydro geological feature is depicted on Table3.3 and4.1. The result showed that out of the total area,the B2-basaltic lava flow aquifer type of hydrogeological feature covers 5151ha. While, 5063 ha out of the area was covered by C3-conglomerate aquifertype of hydrogeological feature. It is concluded that,B2-basaltic lava flow aquifer is porous and permeable which make excellent aquifers lebeled by green color was found to be least suitable for solid waste disposal site selection. While the other part of the area lebeled as C3-conglomerate aquifertype of clastic sedimentary stone composed of large, well rounded grainswould be alternative site for solid waste disposal system since it has massive structure beneath.It is recommendable that the soil of the selected site has good natural impermeability in order to reduce the possibility of aquifer contamination (EMUDC, 2012).

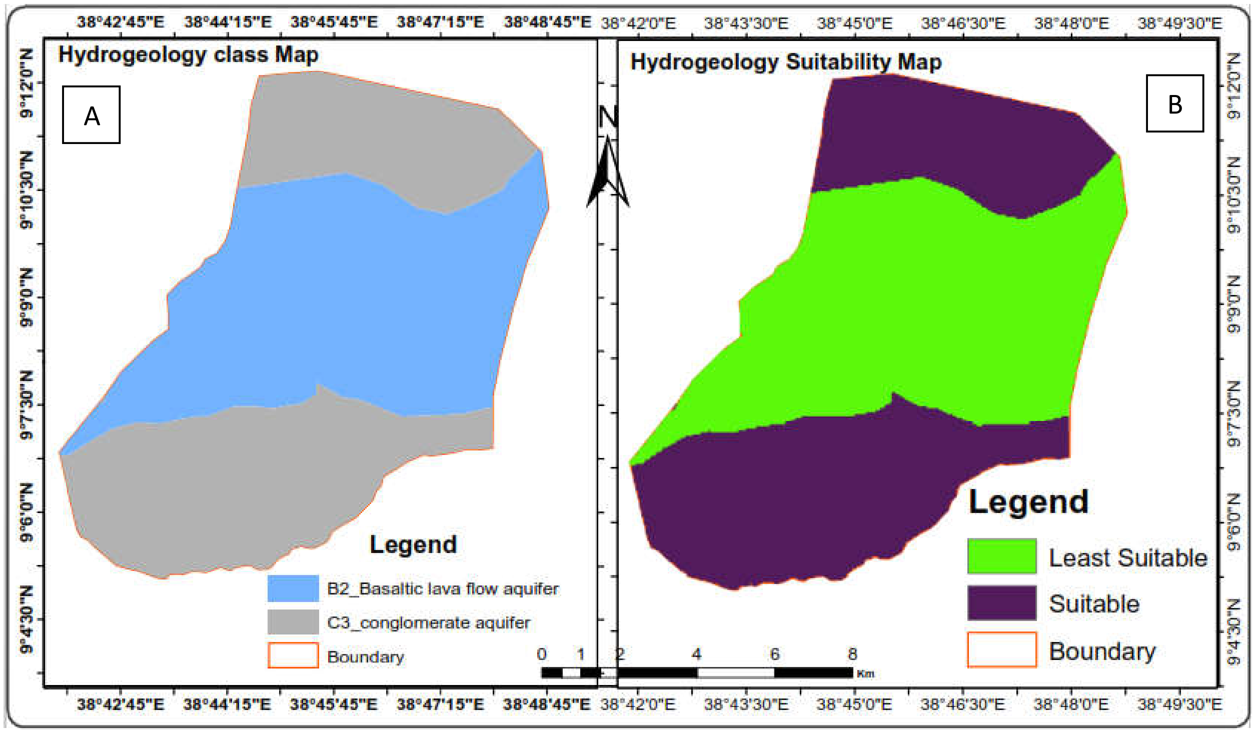

Fig.4.8 A) Hydrogeology Class Map B) Hydrogeology Suitability Map

Deliberate disposal of waste at point sources such as solid waste disposals, septic tanks, injection wells and storm drain wells can have an impact on the quality of ground water in an aquifer.Leachates from opendumps and sanitary solid waste disposal usuallycontain both biological and chemical constituents. Organic matter, decomposing under aerobicconditions, producescarbon dioxide which combineswith the leaching water to form carbonic acid. This,inturn, acts upon metals in the refuse and uponcalcareous materials in the soil and rocks, resulting in increasing hardness of the water(Schneider, 1985).

4.2.8 Wind direction

Wind is the horizontal movement of air which is characterized by its direction and speed. Wind direction is the direction from where wind is blowing at a certain speed in a given time. .In the study area, the dominant wind prevailing around is the wind direction comes from South direction followed by South East parts of the town. Therefore, wind direction is an important planning input to propose land uses that have pollution impact on the nearby land uses. This includes abattoir, waste disposal, orientation of runways, and industrial zone(OUPI, 2016).

Though, generations of toxic fumes are not expected nature of waste to be off, handling of waste in the disposal facility may create air pollution in the form of dust formation. Prominent wind direction may affect the population on the downstream side of the facility. So, any village within a distance of one kilometer downstream of the sites can be vulnerable to any air pollution due to the operation of solid waste disposal(Schneider, 1985). The sites have to take due account to the impact on the downstream. The location of the facility should be selected in such manner that there is no or minimum effect at the downstream habitation.

4.3. Potential Solid waste disposal Sites Thematic Map

4.3.1 Assigning Criteria Weights

One of the components of GIS-Based Multi Criteria Evaluation (MCE) methodology is assigning criteria weights for each factor maps. The purpose of weighting in solid waste disposal site selection process is to express the importance or preference of each factor relative to other factor effect on solid waste disposal sitting.A number of criterion-weighting procedures based on the judgments of decision makers have been proposed in the multi-criteria decision literature. Accordingly, one of the most promising is pair-wise comparison developed in context of a decision making process is known as the Analytical Hierarchical Process (AHP).

AHP is a decision-making technique utilized for solving complex problems, with many parameters of interrelated objectives or concerned criteria. The level of each parameter is not equal; some parameters are dominant over others. Different weights can generate the difference in the level of suitability (Abdi et al, 2017).The ranking is related to their relative importance as listed in Table 4.2. The relative importancehas a range from 1 to 9; 1 means an equal contribution of the pairwise parameter and 9 means a very important parameter (Saaty, 2008)

Table 4.2: Saaty’s(2008)Relative wheight Parameters and their explanation

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one parameter overanother
5	Strong importance	Experience and judgment strongl favor one parameter over another
7	Very strong importance	One parameter is favored very strongly and is considered superior to another its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one parameter as superior to another is of the highest possible order of affirmation
2,4,6, 8	Intermediate values	Compromising criteria is needed

4.3.2 Ranking Method

In Ranking Method, every criterion under consideration is ranked as per decision maker’s preference. To generate criterion values for each evaluation unit, each factor was weighted according to the estimated significance for determining solid waste disposal site .In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 (value 1 = unsuitable, value 2 = less suitable, value 3 = moderately suitable, value 4 = suitable) was performed.

To calculate the weight and ranking in each factor, the pairwise comparison matrix and factor map are employed. The weight value provided the prioritize factor expressed as a percentage value between 0 and 100%. The ranking of each reclassified factor is based on the literature reviewed and personsal judgment. The range of ranking was 1 to 4; the highest influence factor ranked4 and the lowest influence factor was 1.

4.3.3. Ranking Variables Criteria by AHP

The main use of AHP is the ranking and prioritization of multi-criteria parameter. Priorityframework quality affects the effectiveness of available sources which are the essential judgment from the decision maker (Andi et al, 2017). Furthermore, the experts usually use their experiential judgment when making the decision. Each of the expert participants determined the weight to the design factors and gave the wheights depend on the Table 4.2parameters of the factors. The responses of the experts were computed in Table4.3 below:

Table 4.3: A Matrix of Pair-Wise Comparisons of Seven Criteria for the AHP Process.

	BU	RIV	S	MAT	RD	GEO	HG
BU	1	3	5	7	3	6	6
RIV	0.333	1	3	3	4	2	2
S	0.2	0.333	1	1	3	1	1
MAT	0.143	0.333	1	1	0.5	3	1
RD	0.333	0.25	0.333	2	1	1	2
GEO	0.167	0.5	1	1	0.333	1	1
HG	0.167	0.5	1	1	0.5	1	1
TOTAL	2.343	5.916	12.333	16	12.333	15	14

Where, BU = Buillt Up; RIV = River/Streams; MAT = Slope Material type; S = Slope; RD = Road; GEO= Geology; HG = Hydrogeology

Table 4.4: Determined relative criterion weights

	BU	RIV	S	MAT	RD	GEO	HG	EIGENVECTOR	%AGE
BU	0.43	0.5	0.4	0.44	0.21	0.4	0.44	0.4	40
RIV	0.14	0.17	0.24	0.19	0.32	0.13	0.14	0.2	20
S	0.09	0.06	0.08	0.06	0.23	0.06	0.07	0.1	10
MAT	0.06	0.06	0.08	0.06	0.04	0.23	0.07	0.06	6
RD	0.14	0.05	0.03	0.13	0.08	0.06	0.14	0.1	10
GEO	0.07	0.08	0.09	0.06	0.08	0.06	0.07	0.07	7
HG	0.07	0.08	0.08	0.06	0.04	0.06	0.07	0.07	7
TOTAL	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**100**

Consistency Ratio= 0.07

In AHP, weight can be derived by taking the principal eigenvector of a square reciprocal matrix of pair-wise comparisons between the criteria.The eigenvector is an estimate of the relative weights of the criteria been compared. Because individual judgment will never agree perfectly the degree of consistency achieved in the rating is measured by a Consistency Ratio (CR) indicating the probability that the matrix ratings were randomly generated. The rule of thumb is that a CR less than or equal to 0.1 indicates an acceptable reciprocal matrix, a ratio over 0.1 indicates that the matrix should be revised. The consistency ratio of this study indicated that 0.07 was acceptable. Revising the matrix entails, finding inconsistent judgments regarding to the importance of criteria, revising these judgments by comparing again the pairs of criteria judged inconsistently(Sani, 2008).

The comparisons concern the relative importance of the two criteria involved at a time, in for the stated objective. Accordingly, in order to determine suitability all possible combinations of two factors were compared based on expert judgment to prepare a pair-wise comparison matrix from which the module calculates a set of weights and consistency ratio. This ratio is very important as it shows any inconsistencies that may have arisen during the pair-wise comparison process shown in Table 4.4revealed the AHP weight derivation interface to derive the weights, with its consistency ratio, for solid waste solid waste disposal site selection.

4.4. Solid waste disposal suitability analysis results

Out of the total area of Suitability, 7% (437 ha) fall under Suitable area (4) for solid waste disposal site. The moderately suitable area (3) covers an area of 10% (615 ha). The area which covers 21% (1330 ha) is under least suitable class (2) and the remaining 62 %(3933 ha) is under unsuitability class (1) Table 4.5. By using the stated criteria, suggested suitable areas for solid waste dumping sites were potentialsfound on the south-western pockets and south central parts from the town (Figure 4.9). The total area of the study area in the structural plan of the town is 10,214ha. But the total area among the variables varied in the analysis resulted from the difference buffer distance and reclassification used as indicated in the Table 3.2. Therefore, the total area of the weighted overlay suitability of solid waste disposal site was analyzed as of the final suitability result obtained from all criterion used.

Table 4.5: Weighted Overlay Solid waste disposal Site Suitability Area

Suitability Level	Value	Area	
		(ha)	%
Unsuitable	1	3933	62
Least Suitable	2	1330	21
Moderately Suitable	3	615	10
Suitable	4	437	7
Total		6315	100

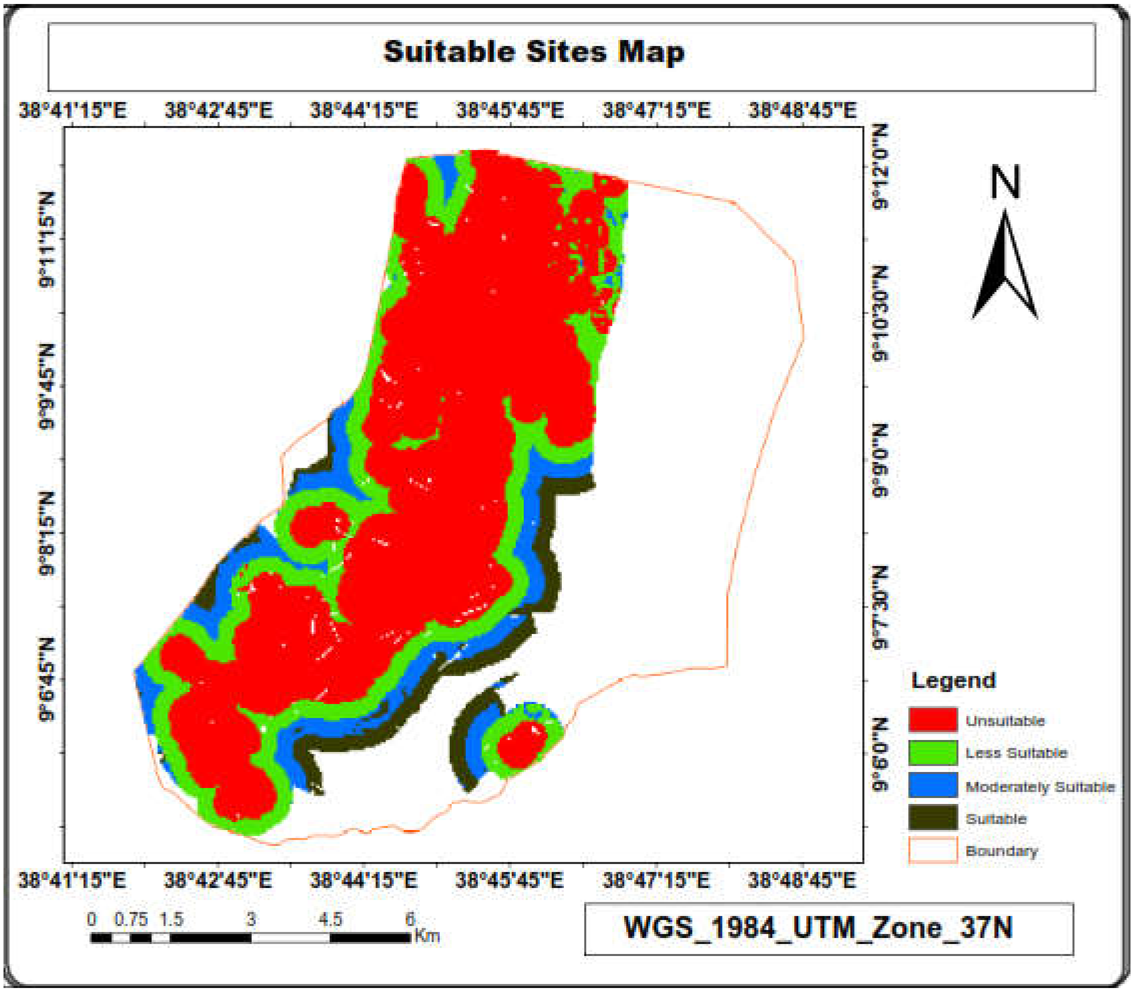

Fig.4.9: Overlay Suitability Map

4.5. Evaluating SuitableSolid waste disposal Sites

From physical criteria river, size of the siteand wind direction; and from socio-economic criteria distance from built uparea anddistance from main roadare the determinant criteria used to evaluate potential solid waste disposal site so as to choose the best suitable. Size of solid waste disposal is one of the determinant criteria for sustainable solid waste management as size of land selected for solid waste disposal determines the number of years for which the solid waste disposal will be used as waste disposal site. From sustainability and economical point of views, larger size of land that will serve for at least ten years are more preferable than small size. This is because selecting large sized solid waste disposal site can minimize the cost of site selection, design and closure that will be performed at the end of itslifespan.

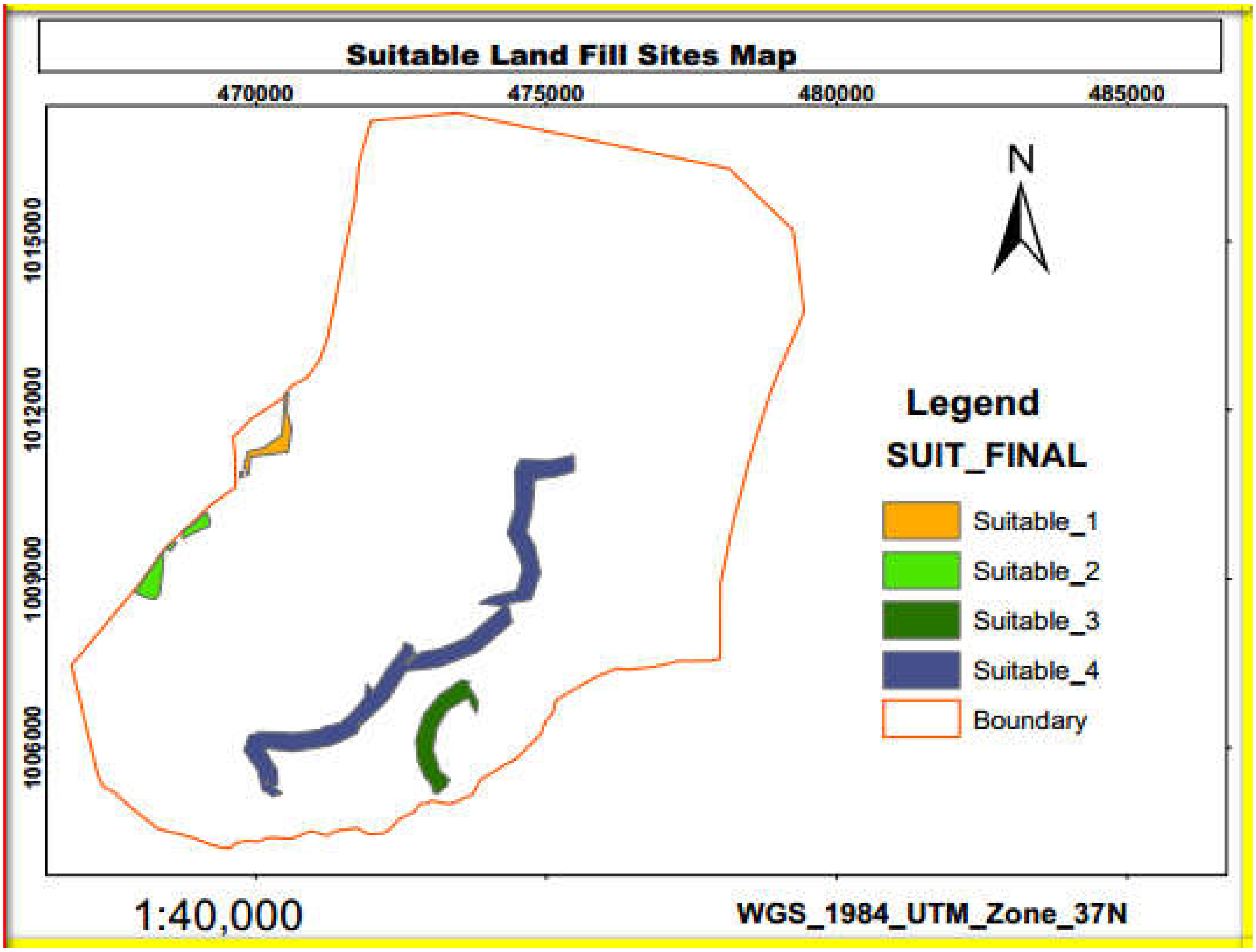

Fig.4.10: SuitableSolid waste disposal site Sites Map

Accordingly, the analysis of thepotential solid waste disposal sites in GIS environment, suitable sites with very insignificant area coverage and those sites occurred in built-up area due to high weight of other factors are economically and environmentally not feasible and hence excluded from further analysis. The rest sites with area covering greater than24ha are preferable and selected to further evaluation with criteriaset in this study. Accordingly, the result of the analysis shows four (4)solid waste disposal sites are selected for further evaluation.

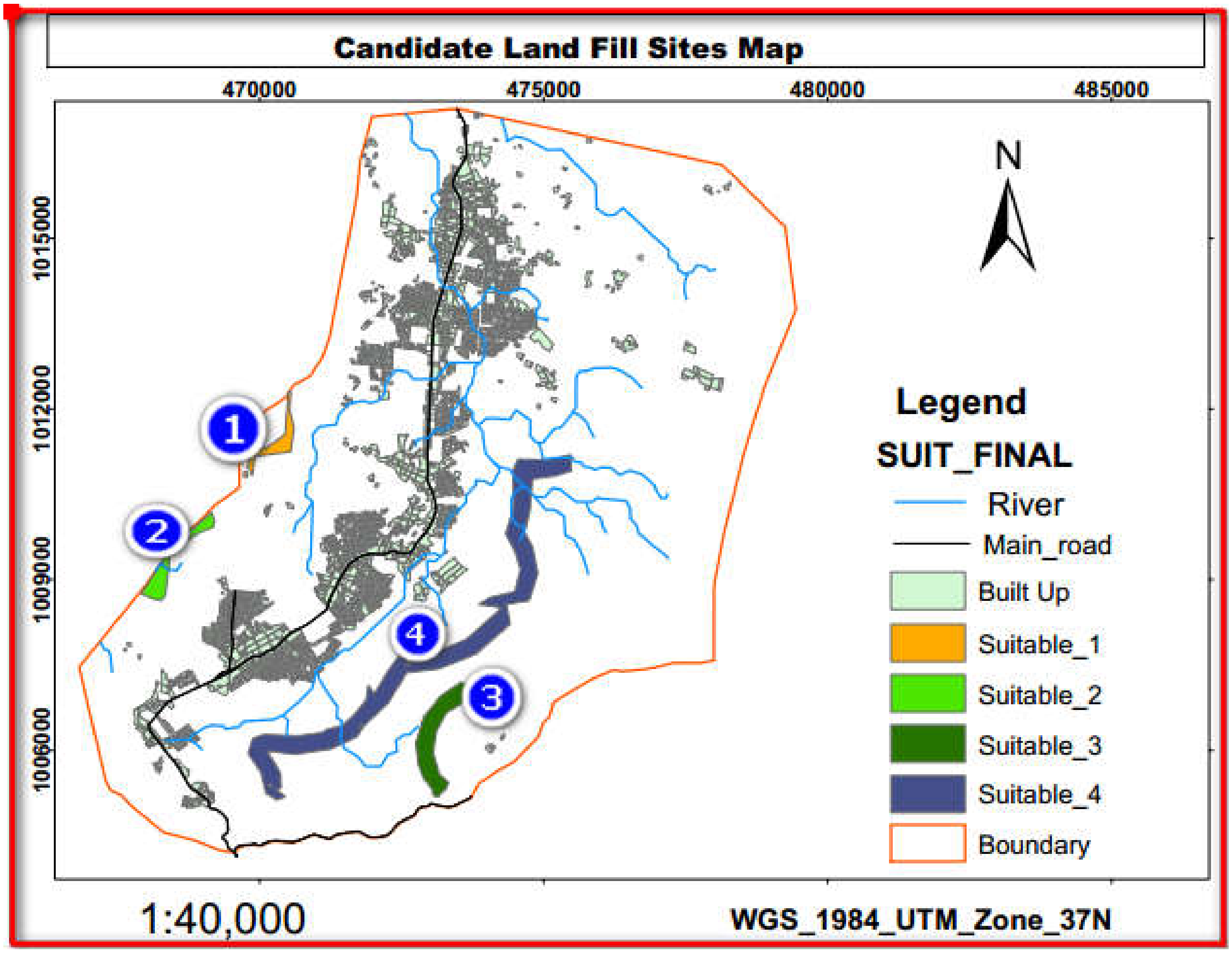

Fig.4.11: CandidateSolid waste disposal site Map

For evaluating solid waste disposal site, distance from the built up area is one of the important criterion from socio-economic point of view. Solid waste disposal far from the built up areais preferable due to low odor and health problemit poses to the settlements and other users social services. In line to this, suitable solid waste disposal site 1 is found to be more suitable than the rest sites. Because solid waste disposal site 1(1.2km) which is fartherthan solid waste disposal site 3(0.91km), 4(0.92km) and 2(1.07km) from the built up area respectively.

Distance of solid waste disposal site from river is also another factor that determines suitable solid waste disposal site. As already set criteria, the more the solid waste disposal site sites are far from the water bodies the more suitable the site is. As a result, solid waste disposal site 1(1.15km) is found in a suitable distance from water bodies than solid waste disposal sites 3(0.11), 2(0.25km), and 4(0.85km) respectively.In addition, distance of a suitable solid waste disposal site from the main road has to be in an optimal and accessible distance so that reasonable transportation cost that will be incurred during its life time. Therefore, site close to the main road creates high traffic congestion and disturbs residents by posing pollution in very nearby areas roadside than areas found in a modest distance from the main road along with considering transportation cost and residents actually live around is more preferable. The analysis of the entire candidate solid waste disposal sites with distance from the roads showed that, suitable solid waste disposal site 4 is 1.61km optimally preferable compared to other solid waste disposalsites 1(2.38km), 3(0.32km) and 2(1.27km). From the wind direction perspective,the dominant wind blows in southern followed by south eastern direction which further poses pollution to the down central town residents.

Solid waste disposal should not be located near settlement area as it poses negative impact on human health.Hence,solid waste disposal site 1 is the most suitable solid waste disposal of all candidate sites. However,evaluation of candidate sites in relation to their size shows that all suitable solid waste disposal site 1(24ha),2 (30ha),3(69ha) and 4(300ha) with area coverage of more than 24 ha, are equally the most suitable sites as it will serve for longer years.

Finally, a site with 24ha area which carries about135,763,200kg of solid waste generated within 339,408 $m^3$is selected. The site is about 1.2km away from residences, 1.15km away from rivers, 2.38km close to the major roads and found in the western direction of the study area andproposed as the most suitable site for the municipal solid waste disposal. Hence, suitable solid waste disposal site 1 is the most suitablefor municipal solid waste disposingsystem.

Therefore, the following map tried to verify the best suitable solid waste disposal site determined. The map was indicating the location of the best suitable solid waste disposal site helped by overlayed boundary on the Google earth image 2016.

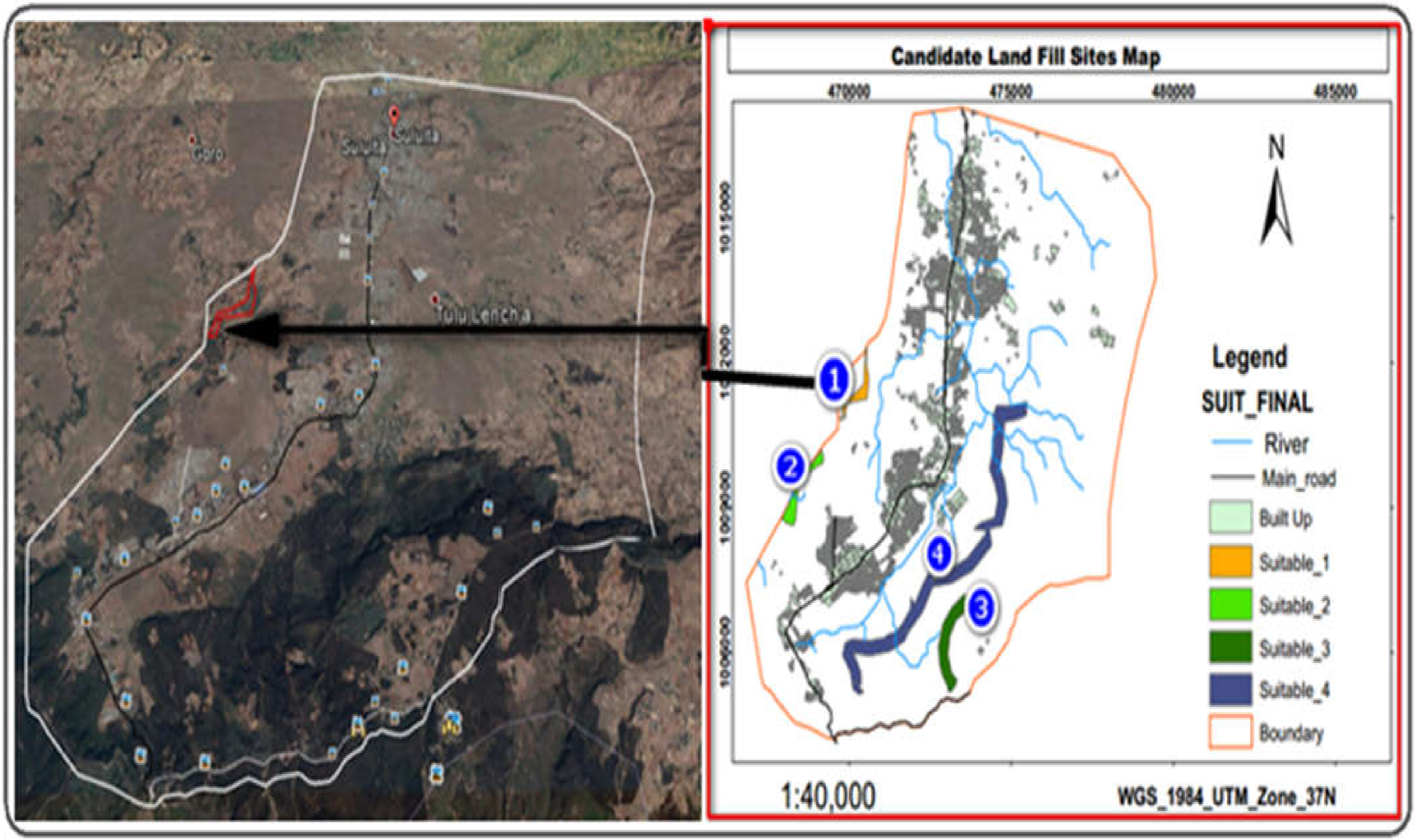

Fig.12: Verification map of the selected suitable solid waste disposal site in the town.

CHAPTER FIVE

5. Conclusion and Recommendations

5.1 Conclusions

Based on the findings of the study the following conclusions are drawn.

- Application of GIS techniques in the analysis of proposed solid waste disposal sitewould generate valuable information from images such as DEM.
- Integrating AHP with GIS for spatial decision-making process is a worthwhile technique to handle large and conflicting criteria in solid waste disposal site selection processes.
- The generated information about the suitability analysis of the site is very important for decision making before designing the solid waste disposal structure. This could eliminate unnecessary cost.
- The results of the evaluation of the positional suitable site for solid waste disposal in Sululta Town indicates that about 24 ha is suitable area for solid waste disposal could be sufficient for presently generated solid waste from the residential of the town.
- In case the generation of solid waste from the residents of the town greatly increases that the expected one, it would be possible to use the moderately suitable areas of the land evaluated for solid waste disposal site. But it may require some further investigation.
- As the highly increasing of population and expansion of urban areas for the future another method of solid waste management approach would be used like incineration.

5.2 Recommendations

- Suitable solid waste disposal site must follow safety criteriathat will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment.
- The municipal need to dispose its solid wastes properly at the site this research has indicated for optimum solid waste management and a healthier environment rather than the existing practice of dumping it here and there in the town.
- Ground water table depth and community preferences were not incorporated as evaluation criteria, partly because of expensiveness of remotely sensed data. Hence, further study should fill this research gap by including these layers as evaluating criteria.
- The rates and volumes of solid waste produced from the town should be segregated at its source and known in order to determine the dimension of the solid waste disposal site.
- The selected solid waste disposal site should serve at least for 10-15 years to reduce the cost of solid waste disposal site selection by considering the amount of solid wastes generated per individual.
- Further studies are necessary about the design and costs of construction of the potential solid waste disposals.

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