2020

Suitable site selection for solid waste disposal by using geographic information system and remote sensing in Assosa Town, Benishangul-Gumuz National Regional State, Ethiopia

Kebede, Morka

BAHIR DAR UNIVERSITY

BAHIR DAR INSTITUTE OF TECHNOLOGY

SCHOOL OF RESEARCH AND POSTGRADUATE STUDIES

CHEMICAL AND FOOD ENGINEERING

Suitable site selection for solid waste disposal by using geographic information system and remote sensing in Assosa Town, Benishangul-Gumuz National Regional State, Ethiopia

By

Morka Kebede

Bahir Dar, Ethiopia

September 8, 2020

BAHIR DAR UNIVERSITY

BAHIR DAR INSTITUTE OF TECHNOLOGY

SCHOOL OF RESEARCH AND POSTGRADUATE STUDIES

CHEMICAL AND FOOD ENGINEERING

Suitable site selection for solid waste disposal by using geographic information system and remote sensing in Assosa Town, Benishangul-Gumuz National Regional State, Ethiopia

By

Morka Kebede

A thesis submitted to the school of Research and Graduate Studies of Bahir Dar Institute of Technology, Bahir Dar University in partial fulfillment of the requirements for the degree of Master of science in Environmental Engineering in the Faculty of Chemical and Food Engineering.

September 8, 2020

Bahir Dar, Ethiopia

DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

Name of the student Morka Kebede Signature_____________Date of submission: ……… E.C

Bahir Dar University

Bahir Dar Institute of Technology-

School of Research and Graduate Studies

Chemical and Food Engineering

Thesis Approval Sheet

Student: Name Merka kebede Signature .... Date ...03/13/12........

The following graduate faculty members certify that this student has successfully presented the necessary written final thesis and oral presentation for partial fulfillment of the thesis requirements for the Degree of Master of Science in Environmental Engineering.

Board of Examiners

Advisor: Belay Tefera Signature .... Date 03/13/2012

Name of External examiner:

Abraham Mebrat (PhD) Signature .... Date........................

Name of Internal Examiner:

Alemayehu Kiflu (PhD) Signature .... Date 03/13/12

Name of Chairperson

Elias Wagari (PhD) Signature .... Date 03/13/2012

Name of Chair Holder:

Elias Wagari (PhD) Signature .... Date 03/13/2012

Faculty Dean:

Ali Seid Signature .... Date 09/09/2020

ACKNOWLEDGMENTS

First and for most I would like to thank God for being with me throughout my hardship times during this thesis work. I would also like to express my appreciations to my adviser Belay Tefera(Phd candidate) for his constructive advices, comments, criticisms and judgments during my thesis work. My warm acknowledgement is also goes to the staff members of Assosa town Sanitation,Beautification,Environmental protection, Forestry and Greenery Process Department. I am also equally grateful to forward my special appreciation to my friends and all whom I did not mention them here for the positive recommendations and suggestions during my stay here at Bahir Dar University Institution of Technology Faculty of Chemical and Food Engineering.

ABSTRACT

The problem of environmental pollution and health hazards due to inappropriate solid waste disposal is critical in developing countries like Ethiopia, Assosa town is one of the town in Ethiopia facing from environmental pollution due to lack of appropriate dumping site which leads pollution of surface and ground water and environment in and around dumping area. Therefore, the main objective of this study is selection of suitable site for disposal of solid waste using Geographic Information System (GIS) tools. The data used for this study were ground point survey (GPS) to collect ground control points, a spatial resolution of (DEM 30m*3om), satellite map (landsat 8) to generate current LULC of the town, geological and soil map of the study area and structural map of the study area which was collected from different institutions and governmental organization. Selection of the most suitable landfill site was determined through the integration of geographic information system (GIS) tools, multi criteria decision analysis (MCDA) and remote sensing techniques. To select suitable landfill site several parameters were considered such as slope, built up area, , road, surface water, land use/land cover, geology, ground water well and soil. After analysis of suitability of solid waste disposal site using GIS tools and weighted analysis methods. Suitability map was prepared by overlay analyses on GIS based Weighted Linear Combination (WLC) analysis to select the suitable solid waste disposal sites and assigned as the value given 1; unsuitable, 2; low suitable 3; moderately suitable and 4; highly suitable were determined.

Waste management system should be improved to protect sensitive environmental components and to improve life of the community. The collection, storage, transportation and disposal of solid wastes System in Assosa town are inappropriate and unrecognized, and accumulated on open lands and drainage ditches are the main practices and thus providing breeding grounds for disease vectors and create a nuisance and unaesthetic view to the Assosa town.

Key words: GIS, Landfill, Parameter, Solid waste, Suitability

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION AND ACRONYMS

AHP	Analytic Hierarchy process
CSA	Central Statistics Agency
CBO’s	Community Based Organizations
DEM	Digital Elevation Model
EPA	Environmental Protection Authority
GIS	Geographic information system
GPS	Global Positioning System
GSE	Geological Survey of Ethiopia
ISWM	Integrate Solid Waste Management
IWM	Integrated Waste Management
MSW	Municipality Solid Waste
MCDM	Multi-Criteria Decision Making
UNEP	United Nation Environment Program.
SW	Solid Waste
SWM	Solid Waste Management
WLC	Weighted Linear Combination

CHAPTER ONE

INTRODUCTION

1.1 Background

Solid waste was the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Aibor M. S. and Olorunda, 2006). It was one of the global environmental problems in the world in both developing and developed countries. Population growth, rapid urbanization, booming economy and the increase standard of living in a community enhance solid waste generation in the world (Tirusew Aysheshim. and Amare Sewnet, 2013). Now days there were an increasing quantity and complexity of solid waste production in world mainly due to growing economic development, urbanization and improving living standards in cities which intern was at the expense of the environmental cost (Smit *et al.* 1996).

Selecting and managing appropriate solid waste disposal site was also a big challenge in developing country. Most developing countries do not have any organized means of controlling solid waste. The lack of status and poor salary associated with the profession discourage qualified employees and they have also lack of human resource that have enough experience to handle solid waste efficiently. On the top of that there are limited opportunities to learn about solid waste in education and on job training program. In low income country over 90% of wastes is often disposed in unregulated dumps and openly burned (World Bank, 2018). This practice leads serious health, safety and environmental consequence. Globally, urbanization and rapid population growth can lead to an enormous increase of solid waste generation per unit area (Peter, 2015). Therefore population growth rate increase in urban area and increase in per capita income has a negative effect on environmental quality and human health (Javaheri, 2006). In Africa most developing countries have no effective solid waste management system because of lack of good governance, public commitment, planning and technology.

Several studies show that in developing countries much of municipal solid waste was generated in from household (55% - 80%), market area (10% - 30%) and the other from institutions (Nabegu, 2010) and (Nagabooshnam, 2011). Assosa town was faced under such problems for a long period of time due to lack of Suitable site selection for solid waste disposal and proper management. The appropriate site for these solid wastes was not selected due to this reasons the community of the town was dumping their waste around their homes and near to the street (unsuitable area). The Solid waste disposal site suitability analysis using Geographic information system (GIS) tools was very important to solve that all problems discussed above and in complex decision making processes involving multi thematic layers and their pair wise comparison, Analytic Hierarchy process (AHP) has proved to be a very useful decision making tool. Most of the studies on the selection of suitable sites, therefore, are based on GIS and AHP (Akbari, *et al*., 2008).Though the problem is increasing time to time there was no any research done on this area. So this study will fill gap to develop socio economic wellbeing of the community of the town

1.2 Statement of the Problem

Solid waste management has been a big challenge in all over the world. The amount of volume of solid waste generation is increased cause of rapid population and development activities. Due to improper management and disposal of solid waste urban cities facing various problems like diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic loses (Jayprakash, *et al*., 2015).

Assosa was one of the highly expanding and rapidly growing towns in Ethiopia. Due to this the dispersal and accumulation of illegally discarded solid wastes all over the town especially road sides, riversides, open areas (especially bridges) around the households residence and working areas was the common and clearly visible problems.

The peoples who live in Assosa have limited awareness about the household solid waste disposal and its negative impacts on human health and environment. Even if the concerning body's particularly the government does not pay attention to reduce the negative impacts of solid waste disposal practices in the area of study.

Thus, unsafe solid waste disposal practices in the town leads to a very serious problem up on the health of the residents in the town and the environment. These uncontrolled disposing of solid waste in open areas, roadsides, streams etc deteriorate the socio-economic life of the society. In addition, it also decreases the aesthetic value of the town. Therefore, the solid waste generation and disposal site of Assosa town needs detail investigation and evaluation.

Collection, storage, transportation and disposal of solid wastes are inappropriate and unrecognized, but accumulated on open lands and drainage ditches thus providing breeding grounds for disease vectors and create a nuisance and unaesthetic view to the Assosa town.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this thesis was to select suitable site for solid waste disposal by using Geographic Information System and remote sensing in Assosa Town, Benishangul-Gumuz National Regional State, Ethiopia

1.3.2 Specific Objectives

- ✓ To evaluate the existing solid waste disposal site of the Town;
- ✓ To identify important parameters for suitability analysis of solid waste disposal site
- ✓ To identify appropriate solid waste disposal site of the Town

1.4 Research Questions

- ❖ What are the conditions of existing solid waste disposal site of the town?
- ❖ What are the main parameters used to suitability analysis to allocate suitable solid waste disposal site?
- ❖ How Geospatial technologies can be applicable for allocate appropriate solid waste disposal site?

1.5 Scope of the Study

It will have great importance if the research topic could have focused both on solid as well as the liquid waste problems and management in the study area. However, due to broadness of the topic and time limitation, the study is limited to solid hazardous waste problems and management in Assosa town. And mainly focused on identifying suitable site for solid waste disposal by using GIS and AHP method in Assosa town by considering environmental, social and economic factors

1.6 Significance of the study

This study is very important to protect environmental safety of Asossa town by selecting suitable site for waste disposal using different parameters. This study will reduce surface and ground water, air, and soil pollution due to solid waste management system in the town. It will help community of the town to solve problem face with landfill suitability. And also it helps to improve the existing solid waste management system of the town by selecting suitable site for solid waste disposal using Geographic information system.

1.7 Limitation of the Study

Offices were busy for meeting as there has been a security problem. Due to popular protests and hard security situation in my region and surrounding, in general in my study area in particular specially collecting GPS readings of sample site with sanitary problems was difficult.

Data collection with GPS Receiver was almost hard during my fieldwork period for security reasons. It was no allowed to have the instrument let alone collecting sensitive positional data. This problem has been settled through permission to collect GPS point data along with personal field observation. The solutions have been considered as ethical and appropriate to accomplish during the fieldwork. Finally, the summer field work data collection was almost feasible economically and successful with lots of ups and downs within the specified period of time.

1.8 Organization of the thesis

This research has four chapters. Chapter one is an introduction part which consists of the introduction, statement of the problem, the objectives, research equations, significance, scope of the study, Limitation of the Study and the organization of the study. The second chapter deals with review of related literature obtained from various published and unpublished reference materials.

CHAPTER TWO

LITERATURE REVIEW

2.1. General

Solid wastes was all those wastes that was useless, unwanted and cast off materials arising from production and consumption or from human and animal activities (Arifur and Tanisa, 2013). According to (Sasikumar and Krishna, 2009), solid waste is non-liquid materials from domestic, trade, commercial, agricultural and industrial activities, and from public services.

The term solid waste describes all materials that are normally solid, and which are discarded as useless or unwanted. These materials normally arise from human life activities. Thus, it refers to heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of industrial, agricultural and mineral wastes. It also includes waste particulate that are temporarily suspended in air (Jaramillo, 2003).

2.2. Solid Waste Disposal

The Basel convention of 1989 has been taken as a good example in enforcing international environmental laws that ban the improper of disposal of pollutant and wastes. Many developing countries especially Africa countries located along coasts are highly vulnerable to accept uncontrolled wastes for dumping in their territory by the developed countries in return for money. This has resulted in number of environmental and health problems among the local people. Thus, the Convention is designed specifically to prevent the uncontrolled transport and dumping of hazardous wastes, including incidents of illegal dumping in developing nations by companies from developed countries (Moen 2008).

Similarly, Nnorom&Osibanjo (2008), in arguing for the enforcement of the international environmental laws and legislations, has discussed on how much the developing countries are suffering in management and utilization of wastes from electric and electronic equipment produced locally and illegally imported from the developed countries. The equipment and machines imported from developing countries in the name of filling the so called ‘‘ Digital Divide’’, a means to fill the technology gap are of less standard and are much outdated and resulting in sever environmental and health problems in developing countries.

McDougall et al. (2008) forwarded reasons like losing its natural state and its mixture composition with others materials as the main reasons for the lack of object.

They have concluded that there is inverse relationship between degree of mixing and value of the waste product. Therefore, separation of wasted based on their composition will generally increase their value. There are other definitions of wastes based on their type and sources. The following are some of the definitions given by authors. ‘‘Any garbage, refuse, sludge from a waste treatment plan, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industries, commercial mining, and agricultural activities, and from Community activities’’(Chandler et al.1997:15). Others still differentiate wastes based on their sources and scope of responsibility, there are generally two types of wastes the Municipal and Non-Municipal wastes. Since definition of waste is general that includes liquid waste and other wastes, for this thesis however due to the broadness of the term and type of waste, the focus is given to Solid waste and defined as follows. ‘‘Solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper , appliances, paint cans, batteries, etc., produced in a society , which do not generally carry any value to the first user (s). Solid wastes, thus, encompass both a heterogeneous mass wastes from the urban community as well as a more homogeneous accumulation of agricultural, industrial and mineral wastes ’’ (Ramachandra 2006:2). Even though, there has not been standard definition given for Municipal Solid waste, this definition is accepted by many authors in the area. McDougall et al.(2008) had added similar to the definition give above where, they clearly identified Household and commercial waste together considered as Municipal Solid Waste (MSW) as they are lighter and relatively smaller in scope to be covered by the municipality.

2.3. Municipal solid waste

The disposal of domestic, commercial and industrial garbage in the world is a problem that continues to grow with human civilization (Abduls Salam, 2009). Solid municipal wastes, due to insufficient collection and improper disposal, is a major concern for many rapidly growing cities in developing countries (Adamo et al., 2009). Lack of appropriate planning, resource constraint and ineffective management of domestic and industrial solid wastes are also among the factors aggravating the problems associated with municipal solid wastes. So far, there is no method of municipal wastes disposal that is completely safe (Abduls Salam, 2011).

Amongst all the classes, solid municipal waste pose the greatest threat to life since it has the potential of polluting the terrestrial, aquatic and aerial environment. Solid municipal wastes are sources of environmental pollution through introduction of chemical substances above the threshold limit of the environment (Obasi et al., 2012). Land pollution by component of refuse such as heavy metals has been of great concern in the last decades because of their health hazards to man and other organisms when accumulated within a biological system (Adekunle et al., 2003).

Open dumping sites of solid wastes are very common in developing countries (SWMM, 2012). Most of Ethiopian cities currently depend on open dumping sites for SW disposal. In open dumping sites, solid wastes are generally spread over large areas which are sources of food and harborage for rats, flies and vermin, and also be a source of bad odor and smoke nuisance, a fire hazard, and a cause of water pollution (SWMM, 2012).

2.4. Solid waste management

Waste management was monitoring, collection, transportation, processing or disposal of waste. As urbanization increase, solid waste management (SWM) becomes a major public health and environmental threat in urban areas (Mohammad, et al., 2016). In most developing countries in the world use inappropriate handling and disposal of municipal solid waste was the most visible cause of environmental degradation, i.e., air pollution, soil contamination, surface and ground water pollution, etc., resulted from inappropriate disposal of municipal solid wastes (WHO, 1996). To control the generation, storage, collection, transfer and transport, processing and recovery, and final disposal of solid wastes in a manner that the term usually relates to materials produced by human activity and to reduce its effect on health, the environment or aesthetics SWM is needed (Jaya, 2004).

2.4.1. Solid waste management in world wide

In worldwide an estimated 11.2 billion tonnes of solid waste was collected in and decay of organic proportion of solid waste was contributing about 5% of global greenhouse gas emission (UNEP, 2005). These wastes are from electrical and electronic equipment which having a new and hazardous substance presents a fastest growing challenge in both developing and developed country. Around the world waste generation rates are increasing. In 2016 the worlds' cities generated 2.01 billion tonnes of solid waste and it is 0.74 kilogram per person per day. With increase Population growth and urbanization annual waste generation is expected3.4 billion tonnes in 2050 (World Bank, 2018).

According to (Rathore, et al., 2016), because of the degree of rapid urbanization and increasing number of population growth, solid waste management was a big challenge for the cities administrations in many developing countries. The amount of solid waste generation increased cause of this population growth. In most of developing countries, municipal solid waste management (MSWM) is inadequate and beyond the capabilities of their economic setup for handling and disposal (World Bank, 1999).

2.4.2. Solid waste management in Ethiopia

Solid waste management (SWM) in Ethiopia was a sector requiring significant attention. The rapid rate of urbanization is resulting in major challenges for main Ethiopian cities in providing their increasing populations with adequate and sustainable waste disposal service. According to UN estimates, Ethiopia’s urban population will triple between 2010 and 2040. As a result, the demand for waste disposal service for industrial, commercial and domestic units continues to rise while the financial and technical capacities of most cities is limited, resulting in increased competition for this limited resources. Solid waste disposal facilities are among municipal urban-infrastructures that were used to safely dispose of solid waste generated by day-to-day activities of city residents. In most of the city’s solid waste management is very poor and very much below the standards as compared to other countries.

This problem is likely to become greater in the future as towns grow in size and become more densely populated. The Federal Democratic Republic of Ethiopia has ratified several international conventions that have meaningful implication to solid waste management in the country (Solomon Cheru, 2010). The solid waste management proclamation (Solid waste management proclamation, 2007) gives emphasis of its essential in community participation in order to prevent the adverse effects and to enhance the benefits resulting from solid wastes. Like the other cities of developing countries, due to the lack of waste management information and implementation of the proclamation most of the towns of Ethiopia are suffering from the adverse effects of the plastic materials (ZebenayKassa, 2010)). Although, Ethiopia ratifies solid waste management on plastic bags, the proclamation doesn’t clearly indicate the adverse effects of plastic water bottles after their use.

Solid waste generation in Ethiopia has negative effects on environment and public health. Rapid expansion of urbanization, industrial activities, and agriculture and population growth produced large amount of solid waste that pollute environment and has an effect on public health problem. The disposal of MSW in developing countries has a challenge due to changing economic trends and rapid urbanization (Peter, 2015). On the top of that for municipalities and urban governments in the developing countries, urban waste management has been a challenge, due to poor infrastructure, bureaucratic competence and limited institutional capacity of the municipalities (Birhanu and Berisa, 2015).

In Ethiopia, rapid urbanization with increased urban population in the last decade has an effect on increasing solid waste amount that brought enormous pressure on municipal services, mainly in the management of solid waste (Hailemariam and Ajeme, 2014). According to (Sasikumar and Krishna, 2009), almost half of the total generated waste remains uncollected in developing world. (Degenet,2008), state that, like in many other developing countries, the majority of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, such as open dumping, burning and burying.

In Ethiopia most of the solid wastes are dumped in drainage lines, open space, near to the street and informally burned. Open dumps pollute surface and ground water, soil and the natural environment as a whole. Generally according to (Birhanu and Berisa, 2015), 43% of wastes are collected in country are properly collected and dumped in open landfill. (World bank, 2004), stated that study conducted in per capita amount of waste generated in Ethiopia range from 0.17 to 0.48 kg/person/day for urban area to about 0.11 to 0.35 kg/capita/day for rural area. Generally, in Ethiopia solid waste generated in most of cities are not correctly managed.

2.4.3. Current Status of Solid Waste Disposal in Assosa

The current solid waste disposal status in Assosa town was open area dumping at different locations. One dumping site was found in the road to awera Godana which was bounded by residence buildings and other public facilities in quite a short distance from city center. However, the site was a depressed land bounded all around by hills. Wastes of all nature are indiscriminately disposed with no further treatment. Hauling of solid wastes and final dumping was not well scheduled and coordinated as refuses are observed to have been disposed of haphazardly, litters spatter everywhere before reaching the designated final dumping site and such practices was even worsening during the rainy seasons.

The other wastes were also not well collected as observed from the field observation. An open landfill was a poorly sited disposal and devoid of infrastructures. This kind of site is often without prior studies of capacity, leachate management, gas management, and fence and cell planning to estimate its lifespan. Such sites have considerable impact on humans and the environment due to high levels of environmental contamination, human health risks, ground and surface water contamination, and the overuse of the site due to its unknown capacity. Given these drawbacks, open landfills are easy to access and need minimum capital and operational costs (UNEP, 1996).

2.5. Landfill

A landfill is a licensed and officially permitted area for waste disposal (Heimlich et al 1992). It is also defined as a well-engineered site that is designed to minimize pollution and loss of amenity.

McDougall et al (2008) has also described a land filling as the simplest and in many areas the cheapest of disposal methods that is affordable for many Developed and developing countries. Thought the rise in price of a land and environmental pressures, it has been accepted as a principal component of integrated waste management system in the world. Most the most common type of landfill in the developing countries is the ‘‘The open dump approach’’ which is the traditional methods where people throw waste in open dumping sites with no further discrimination of wastes and limited control of state authorities sanitary . Sanitary landfill is however, a properly planned site that is situated at an optimum site where wastes are collected, disposed and treated systematically in a way that does not adversely affect the surrounding environment (Ghose et al. 2006). ‘‘Sitting a sanitary landfill requires a substantial evaluation process in order to identify the best available disposal location, that was, a location which meets the requirements of government regulations and best minimizes economic, environmental, health, and social costs ’’ (Siddiqui et al. 1996:515).

Similarly, Al-Shalabi (2006) argued the selection process of suitable site was rather a complex process that takes in to account the analysis of multiple factors and criteria in determining the suitability of a particular area for a defined land use.

The application of GIS models in waste management system doesn’t just limit to selection of suitable site for a landfill but also involves an assessment of optimal routing and bins (Ghose*etal*.2006).

2.6. Landfill suitability

Landfill was an engineered physical facility used for the disposal of Solid Waste and Solid Waste residuals in the surface soils of Earth. According to the United States Environmental Protection Agency (EPA, 1995), a landfill is a large area of land or an excavated site that was specifically designed and built to receive wastes. (Tchobanoglous, et al., 1977) and Frank (2002), also describe land filling as the use of physical facilities for the disposal of solid wastes in the surface soils of the earth. It was the most common type of waste disposal facilities and was an integral part of an integrated waste management system.

According to (Sener, 2004), the methodology for a landfill site selection should have the following: A systematic and impartial way of evaluation and assessment of sites that can be reasonably considered available for landfill, A mechanism for the comparison of potential sites based on their suitability and then ranking them based on suitable and unsuitable, A technique that was practicable to implement, based on commonly available data and cost effective, It should be easy to implement in a computerize system and It should be able to produce and present self-explanatory results in format that was easily understood by all stakeholders. (Hakan and Fikri, 2009), states that a GIS and AHP-based methodology that was carried out with the aim of identifying and ranking the candidate landfill sites.

According to (EPA, 1995), leachate describes any liquid percolating through the deposited wastes and emitted from or contained within a landfill. The composition and characteristics of leachate depends on factors such as: the type of the wastes deposited, rainfall and other climatic factors, the degree of surface and groundwater ingress, the age of deposited waste, degree of compaction; and cover, capping and restoration. Landfill gas was the mixture of gases; it mainly consists of methane (CH_4) and carbon dioxide (CO_2). These were the main products of the anaerobic decomposition of the biodegradable organic fraction of the municipal solid waste in the landfill. Other components of landfill gas include atmospheric nitrogen and oxygen, ammonia, and trace organic compounds (Samuthi, *et a*l., 2007)

2.7. Site selection criteria

Suitable landfill sitting requires an extensive evaluation process in order to identify the optimum available disposal location. This location must full-fill with the requirements of the existing governmental regulations and at the same time must minimize economic, environmental, health, and social costs (Siddiqui, et al., 1996). Factors that should be considered for selection of landfill disposal sites: Soils that have low permeability, No environmentally significant wetlands of important biodiversity, there should be placed away from private or public drinking, irrigation or livestock water supply wells down-gradient of the landfill boundaries to minimize the risk of contamination of ground water and leachate movement, No residential development is adjacent to the perimeter of the site boundary, No fault lines or significantly fractured geological structure that would allow unpredictable movement of gas or leachate, The site is not within 3 km of an airport and The site should not be placed within 1 km of socio politically sensitive sites (e.g., memorial sites, churches, schools) (Philip and Michael, 1999).

While assessing suitability of landfill site, landfill site criteria was key issue that needs to be considered. (DPIWE, 2004), states that 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 for the site; and Social and cultural issues associated with the site. To be commercially and environmentally acceptable, a landfill must be constructed in accordance with specific rules, regulations, factors and constraints which vary from place to place or from country to country (Olusina and Shyllon, 2014). The specific rules, regulations, factors, and constraints must cover: geomorphology, land value, slope and proximity t o recreational areas (Kao and Lin, 1996). Generally, (Kontos, et al., 2005), gave the following criteria's for specifying the best Site for landfill these are water sources, surface water, sensitive ecosystem, urban centre, slope, cultural area, road and land use land cover. On the other hand, landfill site was a complex process that needs consideration of many criteria which was environmental, social and economic criteria to select the best site (Kabite, et al., 2012). (Kabite, et al., 2012), gave the following criteria for select the best site for landfill these are river/ stream, geology, slope, airport, fault, road, bore hole, land use/ land cover, soil, ground water depth.

In order to minimize future risk to the environment from landfill activities, Environmental, technical, economic and social factors influence the suitability of a site, and so achieving a balance among all these factors is very important (EPA, 2002). Baban and Flannagan (1998), states that there are a number of criteria for landfill site selection these are environmental, political, financial and economic, hydrologic and hydro-geologic, topographical, geological, availability of construction materials, built up area, climatic, and difficult infrastructural provisions.

2.7.1. Geological criteria

Solid waste becomes a part of the geologic environment, however, when it was deposited in the earth materials of a sanitary landfill, and it was then subject to such normal geologic processes as weathering and movement of water through waste. As a result of these natural processes, hidden and irreversible groundwater contamination or surface water contamination may result. Low permeability of rocks such as shale, marl clay stone and schist are suitable for landfill. While rocks like limestone, sandstone, dolomite, alluvium and terraces are high permeability and has low suitable for solid waste disposal site (Kontos, et al., 2005). Generally, areas with low permeability material are preferred.

2.7.2. Soil

Soils with a high percentage of clay particles (but which are workable in wet conditions) are generally the preferred soil type, suitability for on-site disposal of leachate by surface or subsurface irrigation and the potential effects of failure of leachate containment and collection systems (land fill guideline, 2000). Impermeable strata and consolidated material are suitable for landfill site as they do not allow movement of leachate and hence minimize the risk of groundwater contamination from landfill leachate (Hakan and Fikri, 2009). According to (Sener, 2004) and (Ismail, et al., 2016), soil with high rate of permeability (Sand, Sandstones, Gravel, Limestone) are considered unsuitable for solid waste disposal/landfills while soils with medium rate of permeability (Silt, Granites, Siltstones) and low rate permeability (clay, mudstones, gneisses, pebbly clay) are considered suitable. The soil type that have less porous, less infiltration into ground like clay soil types was the most preferred for landfill site to control pollution of environment (Ismail, et al., 2016).

2.7.3. Prevailing wind directions

Wind is the main transporting agent that carries materials. Investigation of solid waste site selection is directly influenced by wind direction so that knowing the prevailing wind direction is very important in structural plan preparation of any town and city which has many advantages. The location of landfill site, industrial zones and warehouses is dependent on the wind direction of the town. It is also a reference for contractors and owners of projects in the area so that the building orientation will be appropriate. Accordingly the prevailing wind direction of the town is from Northwest to Southeast direction while the selected site is found at southwestern direction of Assosa City.

2.7.4. Hydrological criteria

There are risks of surface water pollution if landfills were sited in close proximity to water ways. When landfill sited near to waterways can be a source of water pollution by leakage of leachate and runoff. It is generally undesirable to site a landfill in the following areas: flood plains _ these are generally areas which could be affected by a major (1 in 100 year) flood event, land that was designated as a water supply catchment or reserves for public water supply, water courses and locations requiring culverts through the site and beneath the landfill and estuaries, marshes and wetlands (Kontos, et al., 2005).

Ground water contamination if once it was contaminated it was difficult to restore the original water, degrades water quality producing an objectionable taste, odor and excessive hardness so it was irreversible (Gawsia, et al., 2014) Ground water was one of the main sources of drinking water so it should be better to control ground water from any contamination. Factors affecting groundwater are nature of bedrock geology, depth from surface soil, vegetation, climatic variation, permeability of sediments, and topography, while anthropogenic are nature of human activities, urbanization, industrialization and waste management disposal, amongst others (Ifeoma, 2014). Areas near landfills have great possibility of groundwater pollution because of the potential pollution source of leachate originating from the nearby site (Afolayan, et al., 2012). Such pollution of groundwater results in a substantial risk to local groundwater resource user and to the natural environment.

2.7.5. Surface Water (Rivers, Streams)

So as to avoid pollution of surface waters such as rivers, lakes or streams, a land fill must be located at 150m minimum distance away from surface waters. All areas Marginally than 150m are not suitable and are labeled as constraints and are ignore from consideration (Valentina 2011). Berisa & Birhanu (2016) on the other hand put 200m, as a minimum distance a landfill should be located away from water bodies. In consideration of the local context, a 200m minimum distance buffer zone is used in this research project work. Those areas located within this buffer distance are unsuitable as their under underground water level is high and higher discharge and greater downstream influence The interval suitability distances are much dependent up on others factors like topography, but 200m is accepted generally as suitable for damping site as there will be Marginally exposure of water bodies for ground water contamination.

2.7.6. Distance to Well/Reservoir

Wells and reservoirs' sites are among sensitive sites that should be considered in dealing with waste disposal system.

''Proximity to wells was an important criterion to accessing the landfill site. For this reason, a 300m buffer would be placed using the function in GIS software, which will be used to generate the buffer around all wells'' (Nas et al. 2010:497).Similarly, Shamshiry et al.(2011) have recommended a minimum distance of 300m off from wells and reservoirs for locating a dumping sites .Therefore, 300m minimum distance that a landfill should be placed away from wells and reservoirs has been accepted in this thesis work. Areas located within this distance are unsuitable and areas further from 300m distance at equal interval are considered suitable. The more the long distance a land fill moves the more the suitability is due to Marginally exposure to pollution and contamination.

2.7.7. Land use /Land Cover

Land cover describes the physical state of the earth's surface and immediate subsurface in terms of the natural environment (such as vegetation, soils, and surfaces and ground water) and the man-made structures (e.g. buildings) and the term Land use itself is the human employment of a land-cover type (Malczewski, 2006). aim of site selection analysis is to identify the best site for some activity given the set of potential (feasible) sites therefore land-use suitability analysis aims are to identify the most appropriate spatial pattern for future land uses according to specified requirements, preferences, or predictors of some activity (Collins et al., 2001). To identify the best landfill disposal site according to prevent the public health and odour, disease outbreak, noise complaints, scavenging, rodents and other animals' complaints, and decreased property value landfill site should be implemented far away from built up area. And also landfill sites should not

be located too far away from road causes that will increase costs significantly and the site locating nearby the road might cause odour and environmental pollution (Goskel, et al., 2016).

Unlike others criteria, whose suitability was determined based on some commonly accepted distance to the planned landfill site, here the natural value of a land plays an important role in determining a dumping site. The lower the natural value of a given land use what so ever type of use being serving will be given more priority to be chosen as a landfill site. This criteria seems a bit subjective that the others. Valentina (2011) have summarized his argument as follows.

‘‘The criterion classifies the area in five classes: urbanized areas, agricultural areas, forests, wetlands, and hydrological network.

In consideration to study area’s land use/land cover natural values , suitable sites for landfill should be located away from settlement (built up areas), in the low-density population areas, near to agricultural, bush land /or forest land and on open areas .

2.7.8. Topographical criteria

Topographical criteria are important for landfill capacity that can reduce or increase the potential for adverse effects on the environment from odour, noise, litter, and visual effects on neighboring properties and it is used to decide the type of landfill (Subhrajyoti and Sujt, 2012). In considering potential landfill sites an assessment of the potential for existing topographical features to assist in minimizing impacts should be made. (Hasan, et al., 2009) set areas with slope <15-20% as the best site for landfill, while (Chang, et al., 2007) describe slope <12% as the best site and slope>12% unsuitable for landfill. Very steep areas considered to have a smaller value because it was feared could cause a fatal avalanche especially when there is rain or high water seepage (Akbari, et al., 2008). Modest slopes enable easier storm water control, leachate control and site stability measures, as well as facilitating the operation of the site.

2.7.9. Slope

An area whose steepness results in low average cost and easy for construction and mentainance is highly recommended for the location of waste disposal site. Approximately about 8–12 degree average steepness is acceptable for development of a landfill. This is due to the fact that too steep of a slope would make it difficult to construct and maintain and too flat of a slope would affect the runoff drainage (Nas et al. 2010). Shamshiry et al. (2011) has also recommended slope steepness with marginally than 3 degree as a highly acceptable for locating a landfill site. Most parts of Assosa town’s steepness are not greater than 4 degree. Therefore, the study area is highly suitable in this regard.

2.7.10. Distance to Social Services

In addition to the natural resources, social service sites, places where people gather and do their day to day activities are also among the sensitive sites need careful planning in waste disposal process. Some of the most common social services centers are health center and schools. Therefore a buffer distance from the social service sites should be considered in landfill planning. Due to the need to avoid possible interventions and risk against human health, a dumping area should be placed at a distance of greater than 300 m buffer built up areas in general and social services in particular (Berisa & Birhanu 2016). Therefore, 300m buffer distance from a landfill is taken as an appropriate distance to identify areas that are rejected in the analysis part of this thesis.

The whole suitability classification of the resulting suitability maps would be based on the 1993 FAO's guidelines for land-use planning. There would be four suitability classes of the resulting maps ranging from highly suitable (4), Moderately Suitable (3), Marginally Suitable (3), Unsuitable (1).

Finally, a Model for the analysis would be created in the Arc Toolbox in Arc Map that is named by Suitable Landfill Site and finally all the prepared maps are analyzed in this new model.

The measurement scale of land use map and the rest were different i.e. while the land use map has a discrete values, the rest have a continuous or floating value. Therefore, the datasets would be ready for weighted overlay analysis if they had a common measurement of scale called suitability scale.

With this, each datasets that had been floating are reclassified and discrete values have been given for each value in each map. Therefore, reclassify tool was used to reclassify the datasets based on the predefined criteria. The suitability values range from extremely high to least and not suitable areas and a summation of the values for every raster cell were calculated. The reclassification values used ranged from 1 to 4, with 4 being the most suitable for sites for landfill development, 3 and 2 were listed as least and 1 not suitable for locating a landfill site respectively. The higher class value, the higher the suitability for choosing a given land for a dumping site. The area that did not fall within 1- 4 reclassified groups were reclassified as No Data.

2.7.11. Road Network

Road network and accessibility is one of the important parameters given due consideration in locating suitable site for a landfill. Road network provides linkage between the settlements, factories and industrial areas, which are all source for waste production to the remotely located waste disposal sites. Cost of transport, efficiency and effectiveness of waste management system can significantly influenced by the roads networks. Valentina (2011) stated suitable landfill should be situated on the minimum distance to the main roads at about 60 m buffer zone, where those areas located within a buffer distance of 60m are considered as no suitable and labeled as constraint for landfill site selection. Areas above 60m are considered in general as suitable for a landfill.

On contrary, Nas et al. (2010) said a landfill located within a distance of 200m is not suitable as stated below.

‘‘Landfills shall not be located within 200 m of any major highways and town streets. On the other hand, the landfill site should not be placed too far away from existed road networks, to avoid the expensive cost of constructing connecting roads’’ (Nas et al. 2010:496)

According to Berisa & Birhanu (2016), local made research output argued that landfill sites must not be located within the distance of 100m due environmental concerns and a bad smell affecting the surrounding. This buffer distance has been accepted in this thesis work based on similar environmental and topographic similarities.

2.8. Environmentally Sensitive Areas

According to (Kontos, et al., 2005) landfills should generally be located to avoid areas where sensitive natural ecosystems would be adversely affected, such as: significant wetlands, inter-tidal areas, significant areas of native bush including the Forest, recognized wildlife habitats, national/regional and local parks and reserve lands (for example, cemeteries); and any areas where release of contaminants from the site could severely affect fish/wildlife/aquatic resources and sites of historical or cultural significance.

2.9. Application of GIS and remote sensing

According to (Whitach, 1977), Remote Sensing includes all methods of obtaining pictures or other forms of electromagnetic records of Earth's surface from a distance, and the treatment and Processing of the picture data, Remote Sensing then in the widest sense is concerned with detecting and recording electromagnetic radiation from the target areas in the field of view of the sensor instrument. And its multispectral capability provides appropriate contrast between various natural features where as its repetitive coverage provides information on the dynamic changes taking place over the earth surface and the natural environment (Adeofun, et al., 2011)

GIS is a powerful tool that can integrate driven types of spatial data and perform a variety of spatial analysis. This evolution had been driven by significant advances in computer technology and the availability and quantity of data (Amuda, et al., 2014). On the other hands GIS was used as a tool to find solid waste and land fill sites, which are environmentally safe and acceptable to people. Particularly GIS is used to view, understand, question, interpret and visualize huge amount of spatial and non-spatial data in many ways that reveals relationships, patterns and trends in the form of maps, reports and charts, which will be important for critical decision making GIS plays a considerable role in the selection of landfill sites. The application of GIS in the selection of a potential landfill site reduce time and enhance accuracy, it easily helps to capture, store, and manage spatially referenced data, it helps to perform analysis of spatially referenced input data, it helps to extract or classify spatial features while searching suitable sites, it helps to communicate model results and used in selection of solid waste site (Jayprakash, et al., 2015). In GIS-based land-use suitability analysis, it is always assumed that the study area is partitioned into sets of polygons or raster data sets which are the basic units of observations (Malczewski, 2006). Satellite remote sensing data and Geographical Information system (GIS), is an intelligent system providing more realistic analysis and models based on different Criteria to convert spatial and non-spatial data into useful information which helps the decision maker to make critical decisions for landfill site selection (Rathore, et al.,2016).

2.10. Multi criteria decision making analysis

MCDA is a process that transforms and integrates spatial data and the decision maker's preferences to obtain information for decision making (Malczewski, 2006). GIS-based MCDA can be thought of as a process that combines and transforms spatial and non-spatial data (input) into a resultant decision (output) (Malczewski, 2006). The main objective of MCDA is the design of mathematical tools to support the subjective evaluation of a finite number of decision alternatives under a finite number of criteria in order to find the best choice (Pournamdarian, 2010).

According to (Malczewski, 2006) and (Sener, 2004), Steps in solving problems with MCDA: A specific or a set of goals that the decision maker wants to achieve, The decision maker or a group of decision makers involved in the decision making, process with their preferences on the evaluation criteria, a set of evaluation criteria, a set of decision alternatives, a set of uncontrollable (independent) variables or states of nature and a set of results corresponding to each alternative.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the Study area

3.1.1. Location

Assosa town is the capital town of Benishangul Gumuz Regional State, which is one of the nine regional states comprising federal structure Ethiopia. According to information obtained from the municipality of the town, Assosa is a town located in a western extreme part of Ethiopia about 687km from Addis Ababa in Benishangul Gumuz Regional State. Therefore, the town is one of the border towns in the country and located 90 km away from the Ethio-Sudanese border. It situated on a flat plane at an average altitude of 1,550m.a.s. (MWR, 2001).

The town is geographically located between 10˚00' and 10°03' north and between 34°35' to 34°39' east and lies on an area of about 2006 ha. It is surrounded by resettlement villages: in the North by Amba 8, in the South by Amba 38 and Amba 3, in the East by Amba 4 and in the West Komosha town (National Urban Planning Institute, 1995). The area accessed through ground and air transportation. The ground access is via Ambo- Nekemte-Gimbi-Nejo-Mendi-Bambasi and then to the Assosa town. The remaining access to the area is possible by vehicles on a dry weather road.

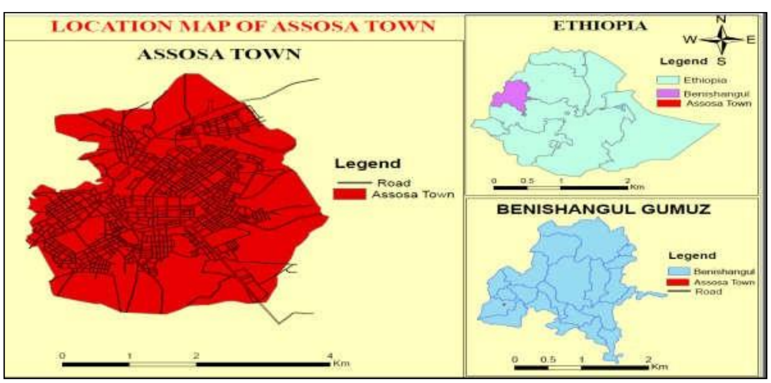

Figure 3-1: location map of Assosa town (Ethio GIS 2017)

3.1.2. Climate

Generally, the climate pattern of Ethiopia is determined by the alternations of the intertropical convergence zone and the influence of the Indian Monsoon throughout the year (Moron et al, 1998). In order to assess the climate condition of the study area, rainfall and temperature data recorded at Assosa metrological station was obtained from Ethiopian national meteorological agency.

3.1.3. Rainfall

Based on recorded rainfall data the climate of the area can be categorized into two broad seasons: the dry season (winter) which covers the period from October to May and the wet season extend from June to September, with slight rainfall during autumn and spring. The monthly fluctuation of rainfall data in the study area is presented in Table 3 The mean annual rainfall is about 105.5mm. The rainy season extends from April to October, but the maximum rainfall occurs in the summer season.

Table 0-1: Monthly Average Rain Fall (2013-17)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av-RF	0	0.36	24.28	26.62	167	175.78	209.18	256.46	220.24	170.44	16.42	4.22

Source National Meteorological Agency

3.1.4. Temperature

Assosa town is located in the Kola climatic zone. It has to mean maximum and minimum temperatures of 32°c and 13°c respectively. Average maximum temperature is recorded from December to April while the temperature is relatively decreased in summer season.

Table 0-2: Temperature of Assosa Town

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av min	30.6	32	32.7	31	27	28	23.5	24	25.1	26.7	27.3	29.1

Av max	13	13.2	15.5	16.1	17	16.4	15.7	17.2	15.9	15.1	13	13.8

Source: National Meteorological Agency

The characteristic of the vegetation is the reflection of climate. Thus, the vegetation of the town and its surroundings mainly consists of woodland and savanna grass. They are mixed deciduous woodlands and savanna with various types of acacia. Most of the trees are deciduous that shed their leaves during the dry season. Although there are different types of trees in the town; the dominant species is the Mango tree. The other types of trees growing in the town include eucalyptus, and Papaya etc.

3.1.5. Prevailing wind directions

Wind is the main transporting agent that carries materials. Investigation of solid waste site selection is directly influenced by wind direction so that knowing the prevailing wind direction is very important in structural plan preparation of any town and city which has many advantages. The location of landfill site, industrial zones and warehouses is dependent on the wind direction of the town. It is also a reference for contractors and owners of projects in the area so that the building orientation will be appropriate. Accordingly the prevailing wind direction of the town is from Northwest to Southeast direction while the selected site is found at southwestern direction of Assosa City.

3.1.6. Geology and Soil

Geological and hydro geological conditions are the most important parameters that primarily influence the suitability of waste disposal site thus, importance of both bedrock and drift geology to protect of groundwater contamination is very important. A systematic geological and hydro geological survey is important to ensure suitability of selected site for solid waste disposal in order to produce a directory of such sites for future planning with supplementary input by professional is advocated. However, the capacity to undertake such surveys is severely limited by the absence of a nationwide coverage in basic geological and hydro geological maps, a deficiency that seems unlikely to be rectified in the short term.

3.1.7. Hydrogeology

Understanding nature of groundwater in the project site is very important to identify the suitability of the selected site for solid waste disposal. The hydro geological nature of the project site is controlled by three important geological patterns that control the nature and distribution of hydro geological units in the geologic system. These are lithology, stratigraphy, and geological structures. Lithology is the physical characteristics of rock. Stratigraphy describes the geometrical and age relationships between various formations in the geologic system. Structural features, such as fractures and faults are the geometrical properties of the geologic system produced by tectonics or during crystallization.

In the various formations the variation in groundwater storage, transmission and yield are the basis for the classification of aquifers. Lithology, topography, area coverage, fracture, weathering etc. are considered for the qualitative classification of the aquifers. The occurrence of groundwater depends not only on the nature of the rock but also in their geologic history.

3.2. Data Study design and period

The study was done by applied study design. This study was analyzed using GIS based MCDA to select suitable solid waste disposal site in the study area. Different data that are used for this study were collected from different organization and satellite image. Different criteria were applied for selecting appropriate solid waste disposal site, in this study slope, geology, soil, LULC of the town and distance to ground water well, surface water, road, airport, and fault and built up area. For each parameter buffer zone has been done and then lists of weight for each criteria and weighted linear combination has been done for locating suitable site for solid waste disposal in Assosa town.

3.3. Data Sources and types

For this study both primary data and secondary data source were used and all the necessary data were collected and analyzed accordingly

3.3.1. Primary data source:

To conduct the study primary data collection processes were conducted by both observation and field survey. The Primary data source were obtained from field observation and field work by using (GPS data Collection), non- structured interviews, photo camera of the current dumping site mainly which found in the road to awera Godana and bounded by residence buildings and other public facilities in quite a short distance from city center and some other illegal dumping site . Data from field survey such as Universal Transverse Mercator (UTM) locations of current dumping site, other illegal temporally dumping site/practices, and sensitive areas have been collected by using Geographical Positioning System (GPS Garmin 72) and DEM with special resolution of (30m*3om) that were extracted within the study area boundary using special analysis tools and it used to generate slope and drainage within the arc map environment.

3.3.2. Secondary data

This have been collected from the responsible organization like Administrations Sanitation, Beautification, Environmental protection, Forestry and Greenery Process Department and Assosa town municipality. The town master plan was taken from town municipality and geological map of the study area was obtained from geological survey shape file of Ethiopia (GSE). Road network and social services of the area from the city master plan. Additional the data sources especially for literatures are secondary data sources such as Books, Articles, and Journals, satellite images, scanned and hardcopy maps and other published and unpublished documents.

3.4. Materials and Tools used

Tools/software's used for this study are ArcGIS 10.3 used for digitizing, buffering, reclassifying, overlaying and identifying suitable disposal site, GPS GERMI used for acquire coordinates for LULC and for current landfill site,

3.5. Data analysis and presentation

In this study, an integration of GIS and MCDM method was used to identify appropriate solid waste disposal site areas at Assosa town. GIS and MCDM methods are recommended for sitting landfills because they are powerful and integrated tools that are able to solve the problems that arise in landfill site selection (Chabuk et al., 2017).

3.5.1. Criteria for selecting potential landfill site

Sitting landfill 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).

Literatures directly related the study along with local regulation for selecting the criteria namely; Surface water, Slope, Geology, built up area, roads, ground water wells, soil, faults, land use land cover and airport to determine the appropriate location of solid waste landfill site. The above mentioned criteria were classified into two which are environmental criteria (surface water, ground water wells, soil and geology) and socio economic criteria (slope, road, land use, built-up area, and airport). Classifications were carried out on various layers with the assigned value ranging from most suitable to unsuitable and the reclassification were signed 1's, 2's, 3's and 4's ranking system, where 1 refers to unsuitable, 2 low suitable, 3 moderate suitable and 4 highly suitable. These criteria were selected by referring different sources from the literature as indicated above.

3.5.2. Buffering

A buffer is useful for proximity analysis. Buffer is a zone that is drowns around any point, line or polygon that encompasses all of the area within the specified distance of the feature. In landfill site selection it was carried out for generating areas in a given distance around the specified criteria. By referring different researcher, the buffering analysis was carried out for faults, surface water, and road, airport, built up area, and ground water well.

Table 3-3: Buffering distance for different parameter from different sources

Parameter	Proximity to standard	Sources
Soil type	Clay textured soil (low	Senser (2004) and Ismail *et*
Geology	Impermeable strata and	Erosy and bulut (2009)
Ground water well	300 – 1000 m 400m	Allen *et al.,* (2003) Akbari *et al.,*(2008)
Road	300 m Within 60m	Akbari *et al.*, (2008) Valentina (2011)
Airport	3000 m	Kontos *et al*., (2005), World bank
Slope	> 20 % not suitable 8–12 degree suitable	Akbari *et al.*, (2008) (Nas et al. 2010). Shamshiry et al. (2011) has

3.5.3. Assigning weight to evaluation criteria

A weight can be defined as a value assigned to an evaluation criterion indicative of its importance relative to other criteria under consideration (Samo Drobne and Anka, 2009). AHP is one of the types of MCDM process which was developed by Thomas Saaty in 1980 to standardize the multi-criteria decision-making process. AHP is a multi-objective, multi criteria decision-making technique which was used to assigning weights to all the factors (Olusina and Shyllon, 2014). And it is widely accepted decision making method to assign weights of the selected criteria, which is one of the problems faced during multi-criteria decision analysis because it was a powerful MCDM tool to assign weights and rank the selected sites for selecting the best site among the competent. Pair wise comparison method is one of the most essential methods in AHP which was proposed by (Saaty, 1980) and many researchers is interested to use pair wise comparison method which is used to determine the relative importance of each alternative in terms of each criterion.

The whole suitability classification of the resulting suitability analysis would be based on the 1993 FAO's guidelines for land-use planning. There would be four suitability classes of the resulting analysis ranging from highly suitable (4), Moderately Suitable (3), Marginally Suitable (2), Unsuitable (1).

The suitability values range from extremely high to least and not suitable areas and a summation of the values for every raster cell were calculated. The reclassification values used ranged from 1 to 4, with 4 being the most suitable for sites for landfill development, 3 and 2 were listed as least and 1 not suitable for locating a landfill site respectively. The higher class value, the higher the suitability for choosing a given land for a dumping site. The area that did not fall within 1- 4 reclassified groups were reclassified as No Data

3.5.4. Weighted linear combination

Weighted Linear Combination is a type of Multi Criteria Evaluation Method in GIS environment used to evaluate the suitability of a site for landfill. It is an analytical technique, which is used when there are more than one criteria to be considered based on the content of weighting average (Habiba et al., 2018). On the top of that WLC also known as Simple Additive Weighting, which combines maps by applying a standardized score to each class of a certain parameter and a factor weight to the parameters themselves (Samo and Anka, 2009). Simple additive weighting is defined by the following equation for calculation of final grading values in multi-criteria problems (Saaty, 1980). It multiplies each standardized factor map by its factor weight then sums the results. Based on, this it provides better site selection because of its flexibility in selecting the solid waste disposal sites. The WLC analysis was determined using the following equation.

$V(y) = \sum wiyi$ …
(3.3)

Where V(y) is suitability index for the area, w is the weight or the importance factor of a criterion, y is the grade or the compliance level of a criterion and i is the criterion number. In this study, GIS based Multi Criteria Evaluation Analysis was employed. This methodology is best suited for sitting suitable landfills accurately in time and cost effective manner and hence it is used by many researchers. Because the technique effective to select suitable disposal site. Appropriate solid waste disposal site selection methodology was carried out through two ways of weighting process. In the first step, each layer was internally weighted based on the minimum and maximum distances and environmental evaluation, excluding unsuitable (restricted) area based on standards and criteria set by national and international environmental acts and rules was identify potential landfill sites and the remaining areas were classified into classes of high and low priority for being used as waste disposal areas. Finally, the layers were standardized and thematic map of each criterion/layer was produced. In the second way each layer was externally weighted based on the fact that how critical and important the data layer is to the waste disposal problem.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Current Status of Solid Waste Disposal in Assosa

The current solid waste disposal practice in Assosa town was open dumping type at different locations. The main dumping site is found in the road to local named awera Godana which is bounded by residence buildings and other public facilities in quite a short distance from city center. However, the site is a depressed land bounded all around by hills. Wastes of all nature are indiscriminately disposed with no further treatment. Hauling of solid wastes and final dumping is not well scheduled and coordinated as refuses are observed to have been disposed of haphazardly, litters spatter everywhere before reaching the designated final dumping site and such practices are even worsening during the rainy seasons.

The other wastes are also not well collected as observed from the field observation. An open landfill is a poorly sited disposal and devoid of infrastructures. This kind of site is often without prior studies of capacity, leachate management, gas management, and fence and cell planning to estimate its lifespan. Such sites have considerable impact on humans and the environment due to high levels of environmental contamination, human health risks, ground and surface water contamination, and the overuse of the site due to its unknown capacity. Given these drawbacks, open landfills are easy to access and need minimum capital and operational costs (UNEP, 1996).

The existing dumping site located surrounding in residential areas which has an impact on environments, public health and aesthetics. The X and Y coordinates of existing landfill site were collected through filed survey method that was used GPS to acquire coordinates. These are

Table 4-1: X and Y coordinate of existing landfill site

X (m)	Y (m)	Z (m)
669279	1115045	1548
669146	1114926	1543

The collected coordinates of existing landfill site were entered into GIS 10.30 as a text file and then converted into shape file to demonstrate solid waste dumping site.

4.2. Determinants of suitable solid waste disposal site selection

4.2.1. Soil suitability

Soil is one of the criteria to select landfill site. Landfill site should not be sited in the area with high permeability soil to minimize the risk of leachate movement.

Almost all soil in Assosa towns and surrounding are similar in type and engineering properties. The similarity of this soil is related with their genetic. In fact, the soil is the end product of weathering. The site is dominantly constituted by residual soils comprising: Silt clay soil, highly rounded gravel to boulder size materials, highly fractured volcanic (basalt rock the first aquifer), slightly massive basalt, massive basalt, slightly massive basement rock and highly massive granite.

Figure 4-1 Soil suitability map

4.2.2. Distance from Road Network

Road network and accessibility is one of the important parameters given due consideration in locating suitable site for a landfill. Road network provides linkage between the settlements, factories and industrial areas, which are all source for waste production to the remotely located waste disposal sites. Cost of transport, efficiency and effectiveness of waste management system can significantly influenced by the roads networks. Valentina (2011) stated suitable landfill should be situated on the minimum distance to the main roads at about 60 m buffer zone, where those areas located within a buffer distance of 60m are considered as no suitable and labeled as constraint for landfill site selection. Areas above 60m are considered in general as suitable for a landfill. On contrary, Nas et al. (2010) said a landfill located within a distance of 200m is not suitable as stated below. ‘‘Landfills shall not be located within 200 m of any major highways and town streets. On the other hand, the landfill site should not be placed too far away from existed road networks, to avoid the expensive cost of constructing connecting roads’’ (Nas et al. 2010:496)

According to Berisa & Birhanu (2016), local made research output argued that landfill sites must not be located within the distance of 100m due environmental concerns and a bad smell affecting the surrounding. This buffer distance has been accepted in this thesis work based on similar environmental and topographic similarities.

An interval of 500m from the buffer zone is chosen as most suitable for disposal site in the town of Assosa.

Landfill sites should not be located too far away from road causes that will increase costs significantly and also should not be near to the road that might cause odour and environmental pollution. To prevent the public health and minimize the cost of transportation, according to (EPA, 2007) used 500 m and (Allen, *et al*., 2003) used 60–600m. Therefore, according to (Allen, *et al*., 2003) and (EPA, 2007), 500m buffer distance considered for this study as restricted distance. However, based on the effect of waste transportation and public health; the area was classified into four buffer zones classes: 0 – 500m, 500 – 1000m, 1000 – 1500m and >1500m.Road and the area within 500m considered as unsuitable (restricted) and the remained area classified according to their suitability. Distance classification of road is illustrated in Table 4-2 and Figure 4-2.2.

Table 2: Distance to road, and its suitability for the study area

Distance (m)	Suitability	Rank	Area(km^2)	Area (%)
0-300	Unsuitability	1	8.74	44.93

300-500	Marginally suitability	3	3.06	15.71
500-700	Moderately suitability	4	2.53	13.02
>700	highly Suitability	2	5.13	26.35

Source attribute table of Arc map

Table 2 shows that unsuitable area covered 44.93% of the study area and given value 1 and the second ranked marginally suitable area covering the 15.71% of the study area and the remaining areas are moderately and highly suitable areas covering 13.02% and 26.35% respectively. The ranked and suitability map of road was illustrated in Figure 4-2.2

Figure 4-2 road suitability map

4.2.3. Surface Water (Rivers, Streams)

So as to avoid pollution of surface waters such as rivers, lakes or streams, a land fill must be located at 150m minimum distance away from surface waters. All areas Marginally than 150m are not suitable and are labeled as constraints and are ignore from consideration (Valentina 2011). Berisa & Birhanu (2016) on the other hand put 200m, as a minimum distance a landfill should be located away from water bodies. In consideration of the local context, a 200m minimum distance buffer zone is used in this research project work. Those areas located within this buffer distance are unsuitable as their under underground water level is high and higher discharge and greater downstream influence The interval suitability distances are much dependent up on others factors like topography, but 200m is accepted generally as suitable for damping site as there will be Marginally exposure of water bodies for ground water contamination.

Table 3: Criteria for Surface Water (Rivers, Streams)

Factor	Critical class	Suitability type	Rank	Area(km^2)	Area (%)
Surface Water (Rivers, Streams)	0-200m	Unsuitability	1	6.72	34.52
	200-250m	Marginally suitability	2	1.73	8.87
	250-300	Moderately suitability	3	1.69	8.67
	>300	highly Suitability	4	9.33	47.94

Table 4-3 shows that unsuitable area covered 34.52% of the study area and given value 1 and the second ranked marginally suitable area covering the 8.87% of the study area and the remaining areas are moderately and highly suitable areas covering 8.67% and 47.94% respectively. The ranked and suitability map of Surface Water (Rivers, Streams) was illustrated in Figure 4-2.3

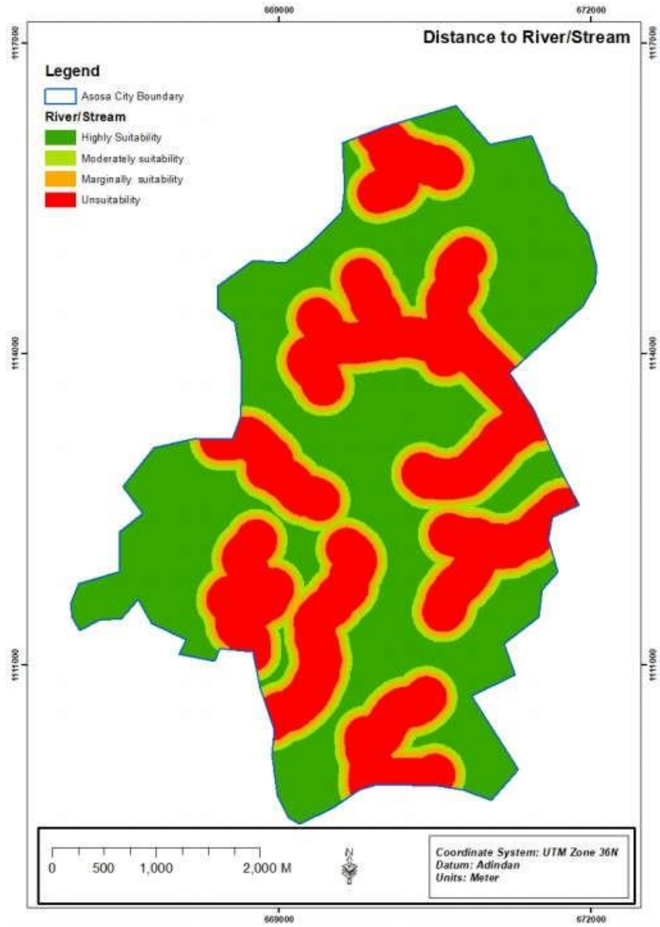

Figure 4-3 Rivers, Streams suitability map

4.2.4. Distance to Well/Reservoir.

Wells and reservoirs' sites are among sensitive sites that should be considered in dealing with waste disposal system.

''Proximity to wells was an important criterion to accessing the landfill site. For this reason, a 300m buffer would be placed using the function in GIS software, which will be used to generate the buffer around all wells'' (Nas et al. 2010:497).Similarly, Shamshiry et al.(2011) have recommended a minimum distance of 300m off from wells and reservoirs for locating a dumping sites .Therefore, 300m minimum distance that a landfill should be placed away from wells and reservoirs has been accepted in this thesis work. Areas located within this distance are unsuitable and areas further from 300m distance at equal interval are considered suitable. The more the long distance a land fill moves the more the suitability is due to Marginally exposure to pollution and contamination.

Table 4: Criteria for Distance to Well/Reservoir

Factor	Critical class	Suitability type	Rank	Area(km^2)	Area (%)
Distance to Well/Reservoir	0 -300m	Unsuitability	1	0.92	4.75
	300m-350m	Marginally suitability	2	0.27	1.39
	350m-400m	Moderately suitability	3	0.30	1.55
	>400m	highly Suitability	4	17.96	92.31

Table 4-4 shows that unsuitable area covered 4.75% of the study area and given value 1 and the second ranked marginally suitable area covering the 1.39% of the study area and the remaining areas are moderately and highly suitable areas covering 1.55% and 92.31% respectively. The ranked and suitability map of *Well/Reservoir* was illustrated in Figure 4-2.4

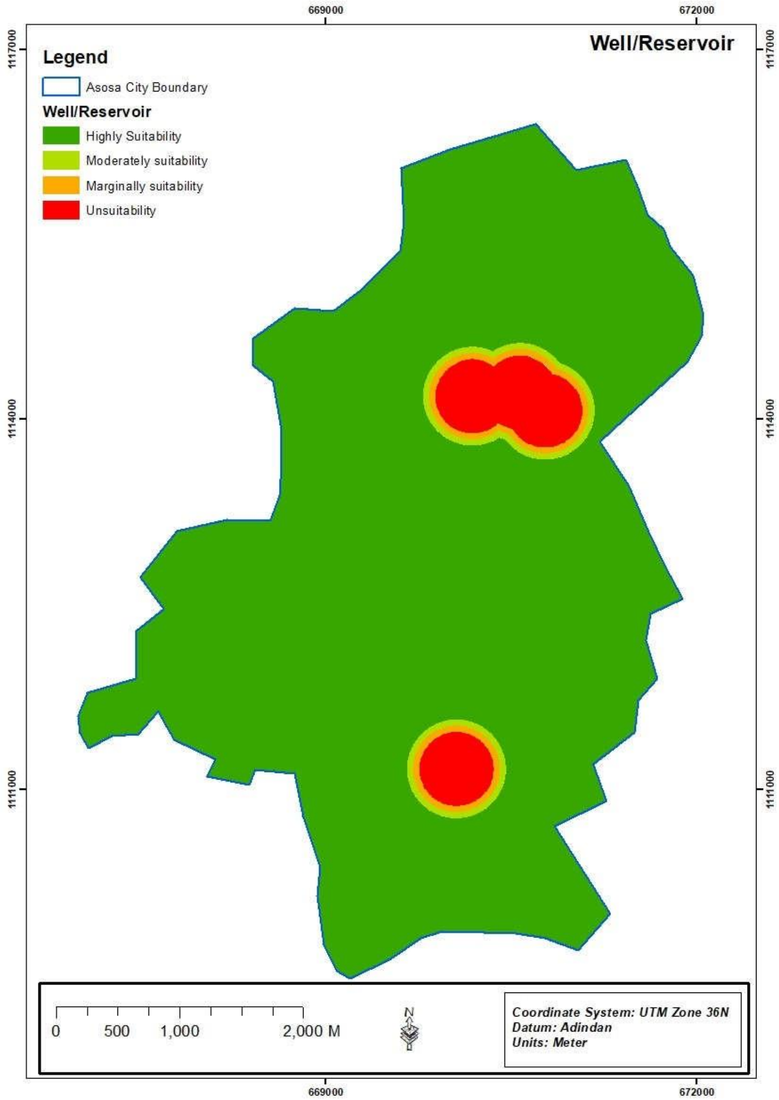

Figure 4-4 Well/Reservoir suitability map

4.2.5. Land use /Land Cover

Unlike others criteria, whose suitability is determined based on some commonly accepted distance to the planned landfill site, here the natural value of a land plays an important role in determining a dumping site. The lower the natural value of a given land use what so ever type of use being serving will be given more priority to be chosen as a landfill site. This criteria seems a bit subjective that the others. Valentina (2011) have summarized his argument as follows.

‘‘The criterion classifies the area in five classes: urbanized areas, agricultural areas, forests, wetlands, and hydrological network.

In consideration to study area’s land use/land cover natural values , suitable sites for landfill should be located away from settlement (built up areas), in the low-density population areas, near to agricultural, bush land /or forest land and on open areas .

Table 5: Ccriteria for land use/land cover type classification

Factor	land use type	Suitability type	Rank	Area(km^2)	Area (%)
land use/land cover	Wetland	unsuitability	1	0.32	1.64
	Urbanization	unsuitability	1	13.11	67.38
	Agricultural	Marginally suitability	2	1.33	6.82
	Forest	Moderately suitability	3	2.64	13.56
	Open area	highly Suitability	4	2.06	10.60

Source attribute table of Arc map

Table 5 shows that unsuitable area covered 69.02% of the study area and given value 1 and the second ranked marginally suitable area covering the 6.82% of the study area and the remaining areas are moderately and highly suitable areas covering 13.56% and 10.60% respectively. The ranked and suitability map of land use/land cover was illustrated in Figure 4-2.5

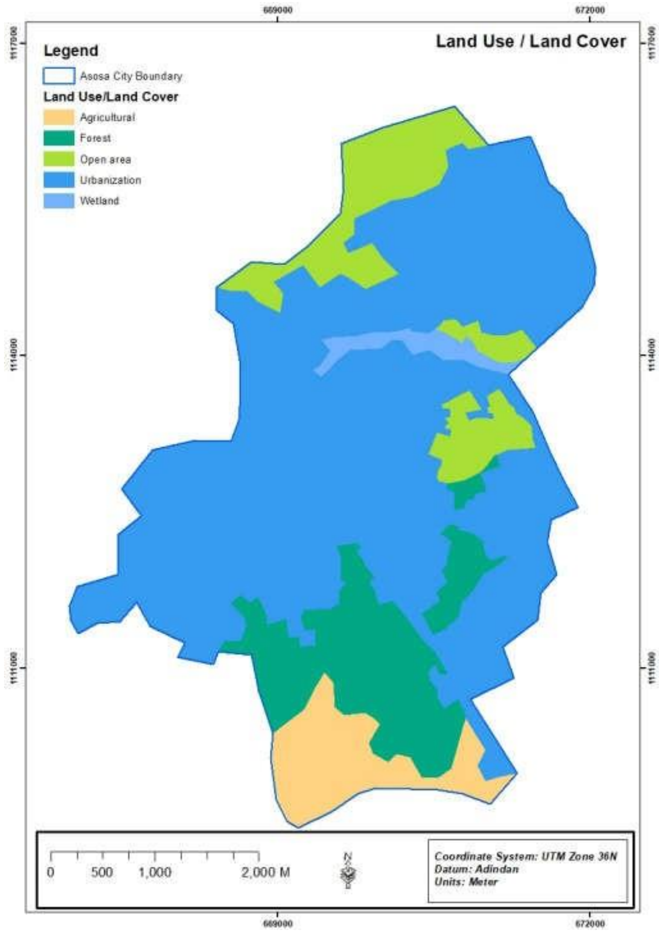

Figure 4-5 land use/land cover suitability map

4.2.6. Slope

An area whose steepness results in low average cost and easy for construction and mentainance is highly recommended for the location of waste disposal site. Approximately about 8–12 degree average steepness is acceptable for development of a landfill. This is due to the fact that too steep of a slope would make it difficult to construct and maintain and too flat of a slope would affect the runoff drainage (Nas et al. 2010). Shamshiry et al. (2011) has also recommended slope steepness with marginally than 3 degree as a highly acceptable for locating a landfill site. Most parts of Assosa town’s steepness are not greater than 4 degree. Therefore, the study area is highly suitable in this regard.

Table 6: Criteria for Slope

Factor	Critical class″	Suitability type	Rank	Area(km^2)	Area (%)
Slope	0-1	Unsuitability	1	0.00	0.00
	1-2	Marginally suitability	2	0.03	0.14
	2-3	Moderately suitability	3	0.00	0.00
	3-12	highly Suitability	4	19.43	99.86

Table 4-6 shows that unsuitable area covered 0.00% of the study area and given value 1 and the second ranked marginally suitable area covering the 0.14% of the study area and the remaining areas are moderately and highly suitable areas covering 0.00% and 99.86% respectively. The ranked and suitability map of *Slope* was illustrated in Figure 4-2.6

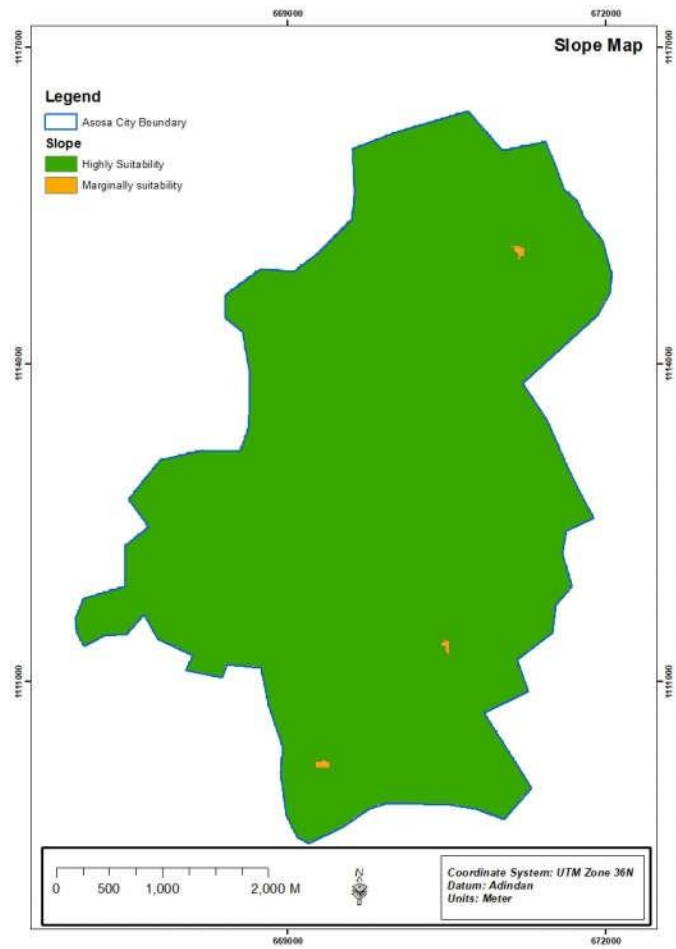

Figure 4-6 Slope suitability map

4.2.7. Distance to Social Services

In addition to the natural resources, social service sites, places where people gather and do their day to day activities are also among the sensitive sites need careful planning in waste disposal process. Some of the most common social services centers are health center and schools. Therefore a buffer distance from the social service sites should be considered in landfill planning. Due to the need to avoid possible interventions and risk against human health, a dumping area should be placed at a distance of greater than 300 m buffer built up areas in general and social services in particular (Berisa & Birhanu 2016). Therefore, 300m buffer distance from a landfill is taken as an appropriate distance to identify areas that are rejected in the analysis part of this thesis.

The whole suitability classification of the resulting suitability maps would be based on the 1993 FAO's guidelines for land-use planning. There would be five suitability classes of the resulting maps ranging from highly suitable (4), Moderately Suitable (3), Marginally Suitable (3), Unsuitable (1).

Table 7: Criteria for Distance to Social Services

Factor	Critical class	Suitability type	Rank	Area(km^2)	Area (%)
Distance to Social Services	0-250m	Unsuitability	1	1.69	8.67
	250-300m	Marginally suitability	2	0.63	3.26
	300-350m	Moderately suitability	3	0.69	3.53
	>350m	highly Suitability	4	16.45	84.54

Table 7 shows that unsuitable area covered 8.67% of the study area and given value 1 and the second ranked marginally suitable area covering the 3.26% of the study area and the remaining areas are moderately and highly suitable areas covering 3.53% and 84.54% respectively. The ranked and suitability map of Social Services was illustrated in Figure 4-2.7

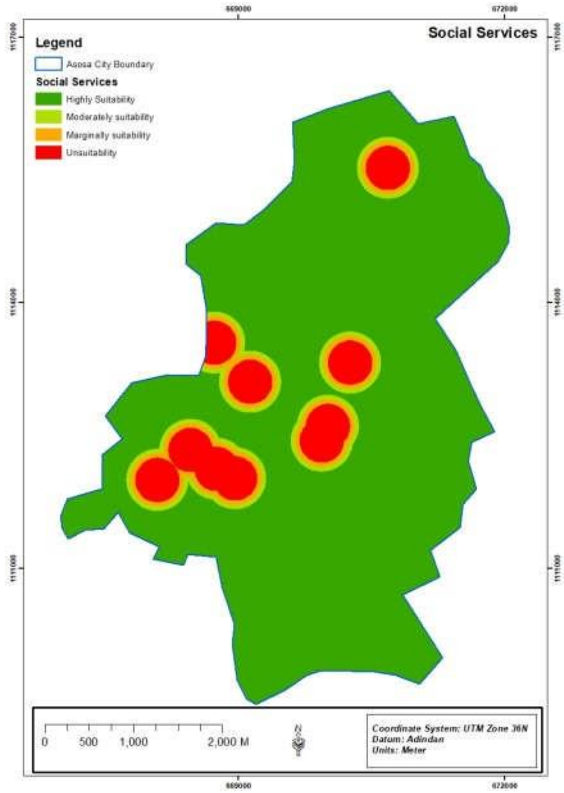

Figure 4-7 Social Services suitability map

4.2.8. Distance to built-up area

Solid waste disposal sites should not be located near to the people, since they might cause different types of pollution. Built up area includes commercial areas, governmental and private institutions, schools, health-centres, religious institutions, educational institutions, residential area and other social services area. The greater the distance from residential areas the more suitable for landfill site selection, according to (EPA, 2007) set a built up distance 500 m as a minimum buffer distance and (Hasan, *et al*., 2009) set 500 – 2000m. To control the effects of public health and aesthetic value of the land the area was classified into four buffer zones: 0-500m, 500- 800m, 800-1000m and >1000m. The built up area within 500m considered as unsuitable (restricted) and the remained area classified and ranked according to their suitability with the help of literature review. The distance classification of built up area is shown in Table 4-8.

Table 4-8: Distance to built-up area, area coverage and its suitability for disposal site

Distance (m)	Suitability	Rank	Area(km^2)	Area (%)
0-500	Unsuitable	1	17.91	92.02
500-800	Low suitable	2	0.76	3.89
800-1000	Moderately suitable	3	0.29	1.47
>1000	Highly suitable	4	0.51	2.62

Source attribute table of Arc map

Table 4-8 shows that unsuitable area covered 92.02% of the study area and given value 1 and the second ranked marginally suitable area covering the 3.89% of the study area and the remaining areas are moderately and highly suitable areas covering 1.47% and 2.62% respectively. The ranked and suitability map of built-up area was illustrated in Figure 4-2.8

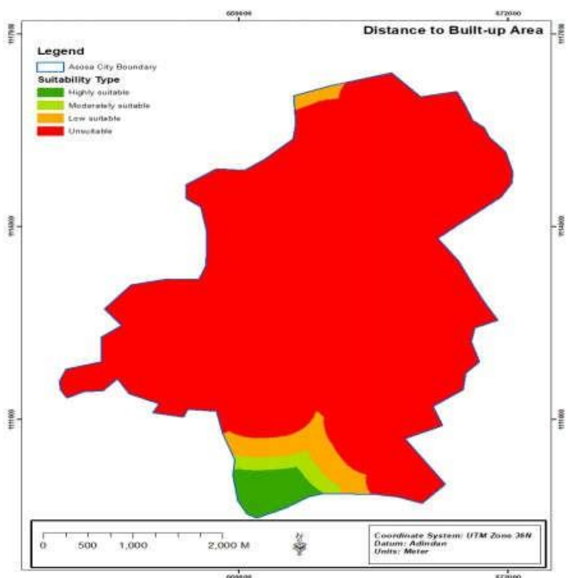

Figure 4-8 built-up area suitability map

4.2.9. Distance to Airport

Landfill sites attract variety of birds to be accumulated around which may interfere with the operation of airplanes. To control the interfere with airplane operation, according to (Kontos, *et al.*, 2005), (Worldbank, 2004) and (UNEP, 2005) 3000m used as safe distance for landfill site selection. For this study the area was classified into four buffer zones: - 0 - 1000 m, 1000 – 1500 m, 1500 – 3000 m and > 3000m. The airport area within 3000m considered as unsuitable (restricted) and the remained area classified and ranked according to their suitability with the help of literature review. And the distance classification is illustrated in the Table 4-9

Table 4-9: Distance to airport and its suitability for disposal site

		Rank	Area(km^2)	Area
< 1000	Unsuitable	1	0	0
1000 - 1500	Low suitable	2	0	0
1500 - 3000	Moderately suitable	3	1.13	5.78
> 3000	Highly suitable	4	18.33	94.22

Source attribute table of Arc map

Table 4-9 shows that unsuitable area covered 0.0 % of the study area and given value 1 and the second ranked marginally suitable area covering the 0.0 %of the study area and the remaining areas are moderately and highly suitable areas covering 5.78% and 94.22% respectively. The ranked and suitability map of *airport* was illustrated in Figure 4-2.9

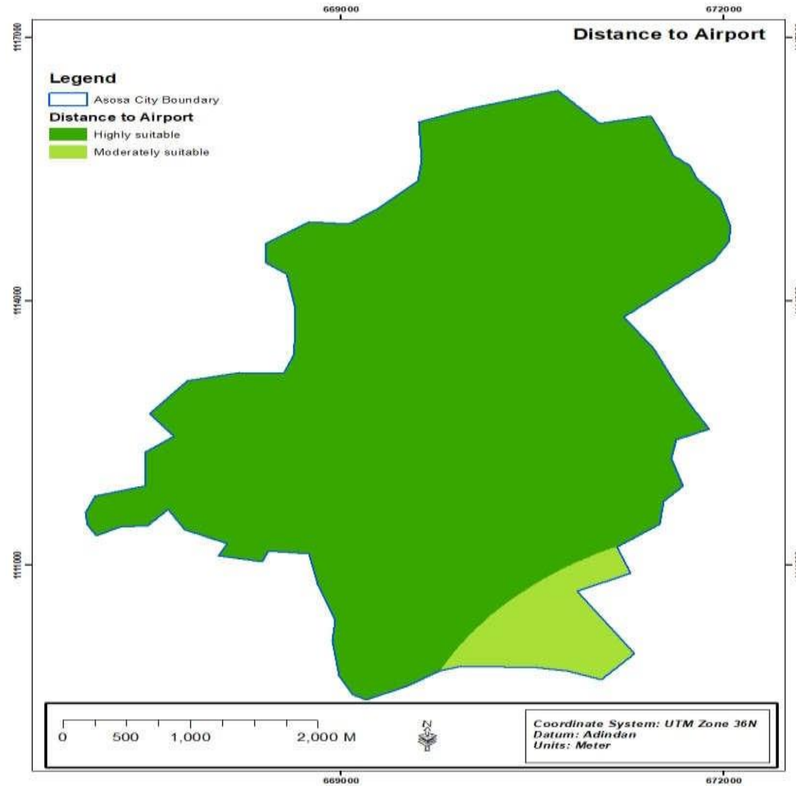

Figure 4-9Airport suitability map

Table 4-10: suitability for disposal Appropriate solid waste disposal site of the Town

Landfill suitability	Rank	Area (km^2)	Area (%)
Unsuitable	1	17.57	90.30
Marginally suitable	2	1.38	7.08
Moderately suitable	3	0	0
Highly suitable	4	0.51	2.62

Table 4-10 shows that unsuitable area covered 90.30% of the study area and given value 1 and the second ranked marginally suitable area covering the 7.08% of the study area and the remaining areas are moderately and highly suitable areas covering 0% and 2.62% respectively. The ranked and suitability map of road was illustrated in Figure 4- 2.10

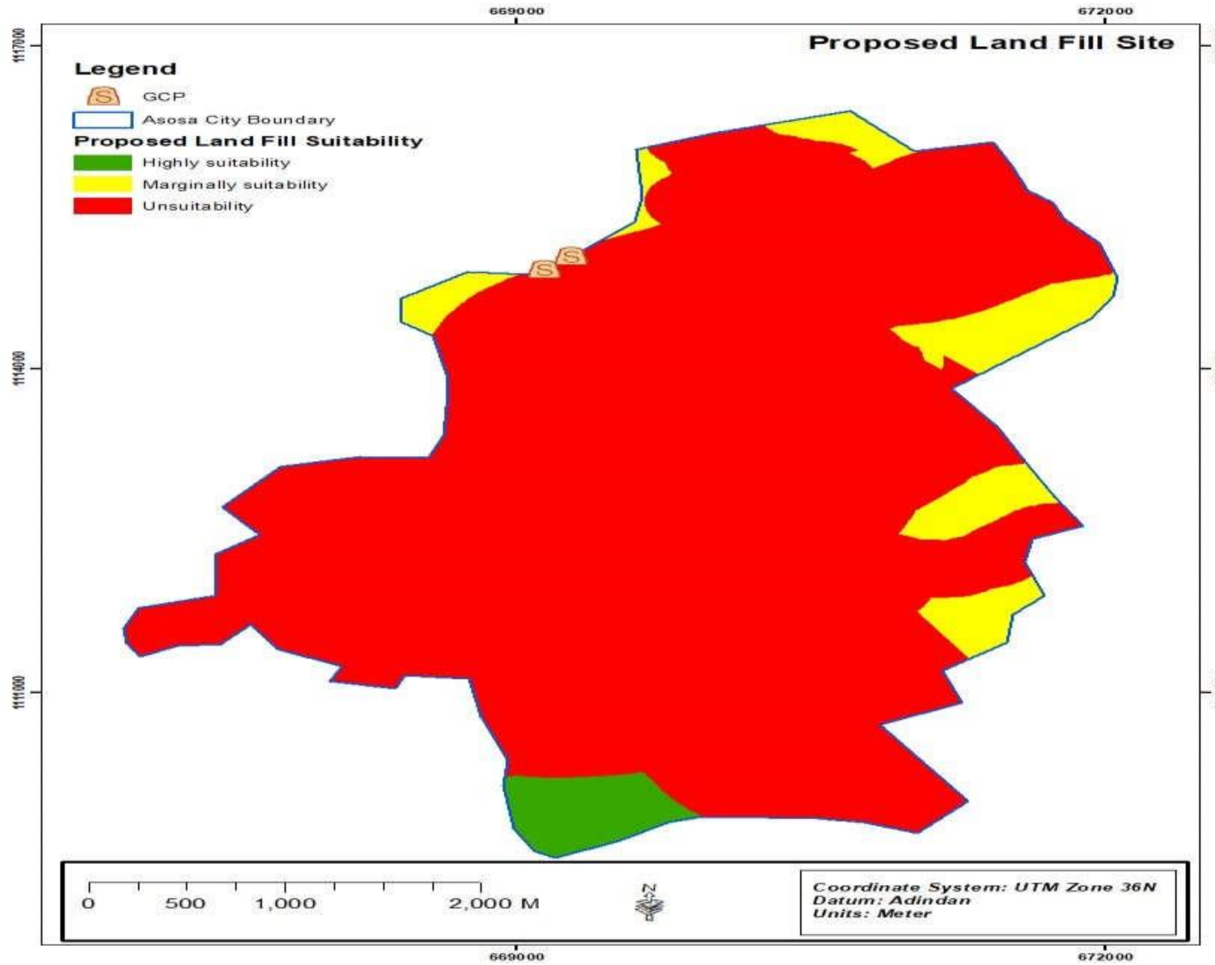

Figure 4-10 appropriate solid waste disposal site suitability map
Source attribute table of Arc map

4.3. Identify appropriate solid waste disposal site of the Town;

4.3.1. Analysis of allocated solid waste disposal site

Based on identified parameters analysis, the allocated area is an ideal site for the sanitary landfill. Because the site is not belong to private farmers of the area, it is flat which makes excavation easy, little vegetation coverage, no nearby surface water, good access road and the distance from the town is also comparable.

As described on figure 4-2.10 and based on suitability land fill disposal site selection criteria GIS analysis (soil texture, river/stream buffer zone, road buffer, social service buffer, air port buffer, well/reservoir buffer, slope analysis, land use /land cover and built up area buffer) 2.62 % of the study area was suitable. This suitable land fill disposal site was located in direction of Abrammo. As this study described, instead of using the current existing solid waste disposal site, it is better to use this suitable allocated results land fill disposal site for Assosa town municipality.

Figure 4-2.10 shows that;-

The red color is the current landfill site which is found in unsuitable area because it is located near to the road and built up area.

The yellow color indicates that the marginally suitable area that is found far away from residential area, free from environmental and public health risks; and

The green color indicates that a highly suitable in almost all parameters analysis result currently and also it may facilitate transportation and reduce the cost of transportation.

4.3.2. Analysis of to be suggested solid waste disposal site

The above selected solid waste disposal site can safely serves the town for an estimated (15) fifteen years of design period.

Even though, Assosa the capital city B/G/R/S is one of the Ethiopian towns that is with rapid urbanization, due to the absence of future plan data to create shape file of the selected parameters, it is difficult to forecast whether the current selected land fill site will serves sustainably or a now site has to be selected after 15 years.

CHAPTER FIVE

Conclusions and Recommendations

5.1. Conclusions

The solid waste management of Assosa town is poor. Solid waste disposal at open fields and at river shores have caused environmental pollution, public health problems and aesthetic impacts in the town. Hence, the construction of Assosa sanitary landfill construction alleviates the management problems of solid waste management if properly implemented and monitored by the regulatory bodies.

The waste management hierarchy would be better if it follows the principles of sustainable development that encourages using scarce natural resources more efficiently, and avoiding the environmental impacts of waste disposal. That is: Avoiding waste, Re- using materials, recycling and reprocessing materials, and Waste disposal (if the first three are not possible).

To select suitable site for Assosa town nine criteria were considered, namely geology, , distance to surface water, ground water well, , soil texture, land use/land cover, slope, distance to road, distance to built- up area and distance to airport for appropriate landfill site selection in Assosa town. A map was created for each suitability criteria using GIS technique.

The overlay analysis of all factors using GIS based AHP analysis produced suitable dumping site of the town shown in Figure 4-2.11. The final solid waste disposal site suitability map was divided into four categories: unsuitable, Marginally suitable, moderate suitable and Highly suitable and ranked as value 1, 2, 3 and 4. The suitability classes showed that that 2.62% (0.51 km^2) highly suitable. 0% (0 km^2) of the area falls under moderately suitable area, 7.08% (1.38 km^2) of the study area are low suitable and the remaining 90.30% (17.57 km^2) falls under unsuitable (restricted) for landfill.

The most suitable disposal sites were located in direction of Abrammo/ south direction that have no negative effect on environment and public health because it is located far away from built up area, water sources and 3-12 degree of slope. And it is easy for access of transportation. The total area of the highly suitable site is 0.51 km^2.

5.2. Recommendations

The following recommendations are given based on the finding of the study.

- ❖ The current dumping site around awera Godana Amba 8 settlers was located in unsuitable area that near to community settlement and close to the main road.
- ❖ Therefore, the concerned body should solve this problem by stop disposing of the solid waste at this site.
- ❖ The selected solid waste disposal site expected to 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.
- ❖ The selected solid waste disposal site used for only for non-hazardous waste.
- ❖ If these can be achieved, the researcher is confident to say it will create a favorable social, economic and environmental situation for the residents of the town of Assosa.

References

1. Akbari, V., Rajabi, M., Chavoshi, S. & Shams, R., 2008. Landfill site selection by combining GIS and fuzzy multi criteria decision analysis, Case study: Bandar Abbas, Iran. *World Applied Sciences Journal,.,* 3(Department of Surveying and Geomatics Engineering, College of Engineering, University of Tehran, Iran), pp. 39-47.
2. Allen, G. et al., 2003. Lands fill site selection process incorporating GIS modeling.
3. Amuda, O.S., Adebisi, S.,Jimoda, L.,Alade, A, 2014. Challenges and Possible Panacea to the Municipal Solid Waste Manegementin Nigeria. *J. Sust. Dev. Studies,*6(1), pp. 64-70.
4. Arifur, R ad Tanisa, T, 2013. Solid Waste Management Strategy & Improvement of Existing Scenario Based on Market Waste. *Global Journal of Researches in Engineering Civil and Structural Engineering,* p. 13(1).
5. Birhanu Y and Berisa, G., 2015. Assesment of Solid Waste Management Practices and The Role of Public Participation in Jigjia Town.. *International Journal Of Environmental Protection and Policy,,* 3(5), pp. 153-16.
6. Degenet, A., 2008. Determinants of solid waste disposal practices in urban areas of Ethiopia: a household-level analysis.. *East Africa Social Science Research.,*
7. DPIWE, 2004. *Landfill Sustainability Guide, Department of Primary Industries, Water and Environment,* Tasmania: s.n.
8. EPA, 2007. *Environmental management of landfill facilities,* s.l.: s.n.
9. Gawsia J, Harendra K. ad Sharma, M, 2014. Impact of municipal solid waste dump on ground water quality at Danda Lokhand landfill site in Dehradun city, India. *International journal of environmental sciences,* Volume 5, p. 3.
10. Goskel, D. et al., 2016. Selection alternative land fills location by using a geographical information system European side of Istanbul. *Journal of Environmental protection Engineering,* Volume 42, pp. 60-110.
11. Hailemariam M and Ajeme, A., 2014. Solid Waste Management in Adama, Ethiopia: Aspects and Challenges. *International Journal of Environmental and Ecological Engineering,* 8(9), pp. 670 - 676.
12. Hakan, E. and Fikri, B., 2009. Spatial and Multi-criteria Decision Analysis-based

Methodology for Landfill Site Selection in Growing Urban Regions. *Journal of Waste Management & Research*, pp. 27, p. 489–500.

13. Hasan, R.M., Tetsuo, K.and Islam, A.S.,, 2009. Landfill demand and allocation for municipal solid waste disposal in Dhaka city-an assessment in a GIS environment. *Journal of Civil Engineering Dhaka University.*

14. Ifeoma, J., 2014. *Effects of landfill sites on groundwater quality in igando, alimosho localgovernment area, lagos state,* s.l.: s.n.

15. Ismail, U., Ibrahim, M. & Ibrahim, I., 2016. Site sutability analysis for municipal solid waste disposal in birnin kebbi, Nigeria. *Journal of humanity and social science,*21(7),

16. Jaya, D., 2004. *). Developing a Framework of Best Practices for Sustainable Solid waste management in small Tourist Islands,* University of Cincinnati, USA, s.n.

17. Kabite, G., Suryabhagavan, K. V. and Sulaiman, H., 2012. GIS-Based Solid Waste Landfill Site Selection in Addis Ababa, Ethiopia. *International Journal of Ecology and Environmental Sciences,* Volume 38, pp. 59-72.

18. Kontos, T.D., koilis, D.P and Halvadakis, C.P., 2005. 2005. Siting MSW landfills with a spatial multiple criteria analysis methodology. *Journal ofwaste management,* Volume 25, pp. 818-832.

19. Malczewski, 1999. *GIS and Multicriteria Decision Analysis. John Wiley and Sons,* New York,USA: s.n.

20. Malczewski, J., 2004. GIS-based land-use suitability analysis: A Critical Overview. Progress in Planning. Volume 62, pp. 3-65.

21. Malczewski, J., 2006. GIS-based multicriteria decision analysis: A survey of the literature.. *International Journal of Geographical Information Science,* pp. 20:7, p.703– 726.

22. Nagabooshnam, J., 2011. *Solid Waste Generation and Composition in Gaborone, Botswana,* Botswana: Department of Management Engineering.

23. Olusina, J.O. and Shyllon, D.O., 2014. Suitability Analysis in Determining Optimal Landfill Location Using Multi-Criteria Evaluation (MCE), GIS & Remote Sensing.. *International Journal of Computational Engineering Research,* pp. 04(6): 7-20.

24. Peter, J., 2015. Patterns and correlates of solid waste disposal practices in Dares Salaam

city, Tanzania. *African Journal of Environmental Science and Technology,*9(6),

25. Pournamdarian, A., 2010. *Mul ti-criteria Decision Making by usi ng Inner Product of Vectors.* s.l.: s.n.
26. PPCB, 2007. *Status Report on waste in punjab,,* Patiala, Punjab: Punjab Pollution Control.
27. Rathore.S, Ahmad. S.R. and Shirazie. S.R, 2016. Use of the Suitability Model to Identify Landfill Sites in LahorePakistan. *Journal of Basic & Applied Sciences,* Volume 12, pp. 103
28. Saaty, T., 1980. *The analytical hierarchy process,* s.l.: Mc Graw-Hill, New York. P.978..
29. Samo Drobne and Anka, L., 2009. Multi attribute decision analysis in GIS. *Journal of Informatica,* Volume 33, pp. 409-474.
30. Samuthi, V., Usha, N. & Chinmoy, S., 2007. GIS-based approach for optimized siting of municipal solid waste landfill.. *Journal of Solid Waste Management,* Volume 28,
31. Satty, 1998. *Tge analytical herarchy process,* New york: MC Graw-Hill.
32. Sener, B., 2004. *Landfill Site Selection by Using Geographic Information Systems: A Thesis Submitted to the Graduate School of Natural and Applied Sciences of Middle East Technical University,* s.l.: s.n.
33. Senser, S., Senser, E. & Nas, B., 2011. Selection of land fill site using GIS and multi criteria decision analysis for Beyeshi lake catchment area Konya, Turkey. *Journal of Engineering science Des,* 1(3), pp. 134-144.
34. Siddiqui, M.Z., Everett, J.W., Vieux, B.E, 1996. Landfill siting using geographic information systems: a demonstration.. *Journal of Environmental Engineering,* Volume 122, p. 515–523..
35. Tchobanoglous, G., Theisen, H. and Eliassen, A, 1977. *Solid waste: engineering principles and management issues.* Tokyo. Japan: McGraw-Hill. Kogakusha, ltd.
36. Tirusew Aysheshim. and Amare Sewnet, m., 2013. Solid waste dumping site suitability analysis using geographic information system & remote sensing for Bahirdar Town. *African journal of environmental science and technology,* 7(11),
37. UNEP, 2005. *State of World Population 2007: Unleashing the Potential of Urban Growth.,* New York, USA. s.n.

38. Whitach, E., 1977. Systematic approaches to environmental impact assessment: an evaluation.. *Water Resources Bulletin*, pp. 12, 123–137.
39. WHO, 1996. *Guides for Municipal Solid Waste Management's in pacific countries, Health Cites, Health Islands Document Series No.6*, Western pacific region: World Health organization.
40. World Bank, 1999. *Technical Guidance Report on Municipal Solid Waste Incineration*, s.l.: s.n.
41. World Bank, 2004. *Sanitary landfill design and sitting criteria*, s.l.: s.n.
42. Heimlich, J. E., Hughes, K. L., & Christy, A. D. (1992). Integrated solid waste management. Publication-Louisiana Cooperative Extension Service.
43. McDougall, F. R., White, P. R., Franke, M., & Hindle, P. (2008). Integrated solid waste management: a life cycle inventory. John Wiley & Sons .
44. Siddiqui, M. Z., Everett, J. W., & Vieux, B. E. (1996). Landfill sitting using geographic information systems: a demonstration. Journal of environmental engineering, 122(6), 515-523.
45. Smit, J., Nasr, J., & Ratta, A. (1996). Urban agriculture: food, jobs and sustainable cities. New York, USA, 2, 35-37.

APPENDICES

Appendix 1: municipal solid waste disposal practice in Asaosa town

Figure11 Open area disposal practice

Figure 12: Road side disposal type

Figure1 3: Current Solid waste disposal site in Assosa Town