Master Thesis on

GIS and Remote Sensing application in Solid Waste Management and optimal Site suitability assessment for landfill
The case of Shashemene City, Ethiopia

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Abstract

Now a day, many cities and towns are growing rapidly in Ethiopia. Among the fast growing towns and cities, Shashemene is probably the prominent one. This is due to its strategic position located along the ancient long distance trade routes. The city is expanding rapidly with increasing number of industries and service sectors such as hotels, restaurants, small and micro enterprises. As town grows, so does the amount of waste production specially the solid hazard waste. It is inevitable that waste production and management problems increases with rapid urban growth resulting in pressure on sanitary related problems in the city. Because of Improper waste management practices and limited public and community trucks and containers, people are being forced to dispose their wastes in any open fields. Poor sanitary situation has become a common characteristics of many villages in the city. This necessitates the applications of Geo-information systems on landfill site suitability assessment as a solution to address the problem and effectively manage the wastes in the city. Although the city has already one solid waste disposal site located in South Western part of the city, it not been scientifically chosen and no technological applications have been made in selection of the disposal site.

Factor maps such as Land use, slope, road map, social service maps, water well and stream data have been used on this thesis. Once all necessary arrangements are made, Geodatabase have been created to hold all feature classes and raster data during the analysis process. Different Geoprocessing tools and spatial analysis operation were carried out in a model builder created for this particular thesis. All factor maps having constraint are made restricted and the rest are given a suitability scale from the highest four to the lowest one suitability scale. The weights, which have been applied against each factor maps, were based on reviewing literatures, personal experiences and judgement and consultation of experts in the area. Finally, a weighted overlay tool from spatial analysis tools have been used and factor maps are inserted in accordance of their weighing. As a result, highly suitable areas for a landfill development cover very small area in southeastern, northeastern and southwestern borders of the city, constituting approximately 1.1% of the total area of the city while unsuitable areas cover the central and wider area of the city of Shashemene, constituting approximately half of the city's areal coverage. Most parts of South central and northern parts of the city where there exist built up and services facilities are shown as unsuitable for a landfill site development.

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Abbreviations

CBO   Community Based Organization
CSA   Central Statistics Authority
DEM   Digital Elevation Model
FAO   Food and Agricultural Organization
GIS   Geographical Information system
GPS   Global Positioning System
ISWM Integrate Solid Waste Management
IWM   Integrated Waste Management
MCDM Multi Criteria Decision Making
SDGs   Sustainable Development Goals
UN   United Nations
UNDP United Nations Development Program
UNEP United Nations Environmental Programme
USGS   United States Geological Survey
UTM   Universal Transverse Mercator
WGS   World Geodetic System

Chapter One

1. Introduction

Now a days there is an increasing quantity and complexity of waste solid waste production in world mainly because of growing economic development, urbanization and improving living standards in cities which intern is at the expense of the environmental cost (Smit et al. 1996). Uncontrolled population growth together with booming economy and rapid rate of urbanization have greatly accelerated the municipal waste generation rate in developing countries (Minghua et al. 2009). Currently municipalities have become unable to overcome the problems of solid waste and its management due to financial difficulties and lack of organization. This have resulted in serious dissatisfaction among to the inhabitants (Sujauddin et al.2008). Similarly, Burnley (2007) have discussed mainly, financial resources, complexity and system multi dimensionality as the main causes for in efficient and ineffective waste management system in different municipalities in developing countries. This necessitates the effective management and planning of optimum dumping site. Having a properly planned Waste disposal site is one of the most important management activities, which need to be carefully planned (Regassa et al. 2011). The study area is not exception from these problems like many towns and cities in Ethiopia. So as to solve these problems, the application of Geo-information systems have been taken to play a vital role in addressing the problem and effective management system.

2. Problem Statement

Shashemene is among the fast growing towns in Ethiopia. It is expanding rapidly with increasing number of industries and service sectors such as hotels, restaurants, small and micro enterprises. Thus as town grows, so does the amount of waste production specially the solid hazard waste. It is inevitable that waste production increases with rapid urban growth, which in turn results in pressure on sanitary related problems in the town.

"In Shashemene City, most waste generated and disposed in the waste disposal site are organic wastes and this shows that wastes are not considered as resources in the city. Open air burning of wastes, inland fills, and incineration plants that lack effective treatment for gas emission can cause air pollution. Improper waste management practice and limited public and community toilets, etc forced the people to dispose their wastes in any open fields " (Shashemene City Administration Finance and Economic Development Office Environmental Report 2016:36).

These days due to inefficient and in adequate collection and disposal of house hold wastes, local governments, city administration and municipalities are facing a persistence waste management problems (Shashemene City Administration Finance and Economic Development Office Environmental Report 2016).

According to Al-Hanibali et al. (2011) because of urbanization process, a need always rise to consider monitoring the direction of urban expansion in order to avoid a conflicting interest of different land use planning. Therefore, in order to have effective planning, there is a need to carryout Site suitability analysis for hazard waste disposal and management of sanitary problems in the study area. This does not mean that all wastes are useful. It does not mean also that all wastes are useless. This thesis work has been based on integrated waste management framework; where there exist different stages of solid waste management processes including recycling and disposing of wastes. It also gives emphasis on multidimensional methods, where different areas interest is given much focus namely socio-economic and environmental sustainability. Therefore, the primary focus of this research is how solid hazardous wastes are effectively managed in Shashemene.

"The selection of ultimate site is so complex that it taken in to account the social, environmental, technical and economic parameters. This is done just for identifying and avoiding the socio-economic, environmental effects of the solid waste disposal sites" (Al-Hanibali et al. 2011:267)

Site suitability assessment for optimal waste disposal sites is a combination of Geospatial data (maps, aerial photographs and satellite images) with the quantitative, qualitative and descriptive information in databases (Al-Hanibali et al. 2011).

According to Al-Hanbali et al. (2011), identifying optimal Solid waste disposal site is the final stage in solid waste management and decision-making process.

Although the city has already one solid waste disposal site located in South Western part of the city , in Bulchana Sub city , it not been scientifically chosen and no technological applications have been made in selection of the disposal site. The

exact location of the existing solid waste disposal site is indicated in small red circle symbol on final suitability map on the last page of this thesis.

Therefore, for this thesis different criterion maps and socio-economic data was collected for the assessment of solid waste problems and optimal site selection process.

3. Objectives of the Study

Any research is carried out for the attainment of certain intended objectives. Likewise, this master thesis has a general and well as specific objectives to be achieved at the end of the work. Therefore, the general objective of this thesis is to assess the solid waste problems and find software solution for optimal site selection for disposal in the study area.

3.1 Specific Objectives

- ✓ Identify the economic values of solid waste in the town
- ✓ pointing out the main contributing factors affecting the solid Waste Management process in the town
- ✓ Identifying conflicting interests among actors in collection, processing and disposal of solid waste products
- ✓ Mapping out the main sources of solid hazard waste in shashemene town and Apply Geospatial technologies for optimal site selection for hazardous solid waste disposal

4. Research Questions

- ✓ What are the possible sources of economic values can be achieved from solid waste?
- ✓ What challenges are currently contributing to the poor solid waste management system in the area under investigation?
- ✓ What are the rationalities behind conflicting interest of actors in the solid waste management process?
- ✓ Which sites are highly exposed for hazardous waste in the town?
- ✓ How Geospatial technologies can be applicable for optimal site selection for waste disposal

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 Shashemene town. Shashemene town is a town located in southwestern part of Ethiopia. Economically, the town serves as a center for people in southern Ethiopia as well as a connection for the surrounding area regions. It is located about 250 km south of the capital Addis Ababa. As a result, the town is hosting much number of people with different level of economy. This has led to the expansion of industries, hotels, restaurants and other

sources of waste producing organization.

6. Limitation of the Study

There were interruptions during the summer fieldwork periods. Offices were busy for meeting as the month was a budget closing for the academic year and there has been a security problem. Due to popular protests and hard security situation in my region, 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 have 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 with in the specified period of time.

Data that had been planned to be downloaded (different articles, Books, Journal and Magazine) was not done due to internet network for security reasons. These have been compensated after coming back to Norway.

7. Methodology of the Study

Throughout the master thesis, different methods of data collection were applied for both collecting socio-economic as well geospatial data. The method will also integrate socio-economic and the technical aspects (Softwares based) analysis of field data.

7.1 Sampling Methods

Purposive sampling method was employed for selecting the target respondents where respondents were purposefully identified based on their direct and indirect connection with the topic solid waste problem, management and disposal.

The target sample respondents were of three groups namely, the households in the selected poor sanitary area, the municipality staffs and Community Based Organizations (CBO's) members. All the respondents are adults aged between 18-40 years and all households were economically poor settled with in the town and its vicinity. With exception of CBO's , municipality staffs and few households , the rest household's source of income is informal source where daily labor based and are not earn consistently each day. In short, their sources of income are fluctuating from day to day.

7.2 Methods of Data Collection

Since the data sources for this particular thesis work are data from fieldwork, different instruments for data collection are applied during the field data collection period. Some of these methods are interviews, survey questionnaires, geospatial data collection with the use of Global Positioning Systems (GPS Receivers) as well as field observation.

7.3 Data Sources

Throughout the master thesis two kinds of data were used i.e. the socio-economic and geospatial data. The primary data for this master thesis are data obtained from field observation and field work (GPS data Collection) for mapping highly exposed areas for sanitary problems and data collected with the survey questionnaires and GPS data are used to create accessibility maps such as access to social services (to health centers, schools, roads, etc.).GPS reading was also take from field to map where exactly sanitary exposed areas exist so that I would later help in decision of suitable site location. These data are mainly point and line features. However, much of the data sources especially for literatures are secondary data sources such as Books, Articles, Journals, satellite images, scanned and hardcopy maps and other published and unpublished documents.

7.4 Tools, Software and Instruments

7.4.1 Hand Held GPS Receiver for Collection GPS Points and Readings

7.4.2 ArcGIS Software

ArcGIS software 10.2 Version for Analysis, weighted overlay for optimal site selection. Much of the analysis part of the thesis was carried out using ArcGIS software specially model building, suitability map creation and weighed overlay analysis.

7.4.3 Edrisi

Edrisis was used for rating and weighting the criteria maps. In addition, other software components of a personal computer like Microsoft Office were among the application software used during the thesis work process.

7.5 Methods of Data Analysis

The data collected from field survey and fieldwork though the methods mentioned above will be analyzed using different statistical and as well as technical methods such as descriptive analysis in tables, percentages and maps.

Chapter Two

2. Review of Related Literature

2.1 Concepts of Waste

What is a waste?

Different scholars have forwarded different definitions for a waste. Among different definitions, a definition by McDoughall et al. (2008) and Chandler et al. (1997) have been preferred as an appropriate to forward a general and detailed explanation for the term waste for this thesis. McDougall et al. (2008) defined a waste as an object that lacks use or value, or 'useless remains'. It also refers to a remnant or a by-product of human activity. It can be any physical object, similar with materials as are found in useful products; but differs from these products as it lacks values.

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.

2.2 Concerns of Waste

Now days the issue of waste is getting much broader focus than getting safer and healthy environment. People in different parts of the world are worrying of its sustainability. Different actors of waste management process including the sources institutions and households are raising the questions of its sustainability. Waste management needs to be long lasting and sustainable. Different authors had their say on what a waste management process should be. McDougall et al. (2008) argue that goals of waste management need to go beyond current concern of human health and environmental safety to how waste management should be long lasting and sustainable than seasonal and temporary. They raised the term ''Sustainability '' in relation to the managements of waste.

Sustainable Development is developments that enable people to meet their current needs and wants without harming or compromising the ability future generation to meet their needs and wants. It also stands for a kind of development that prioritize the wise use and conservation of natural as well as man-made resources, proper management of pollutants and wastes (Kates et al.2005). Accordingly, McDougall et al. (2008) has to put the diagram showing how current days' waste management looks like. In order to say certain waste management activity sustainable, one can see the achievement of three most pillars questions. There are shown below in question form

1. Are the waste management activities economically affordable?

2. Are the actions taken to manage wastes are socially acceptable? and

3. Are the actions taken to manage a waste are environmentally effective?

Sustainable waste management should achieve the above-mentioned question in order to achieve its intended objectives. In other words, while managing wastes in proper way waste management workers should be aware of its economic cost (cost effectiveness), create social awareness and avoid damaging impact on the environment.

Figure 2.1 Three pillars of Sustainable Management
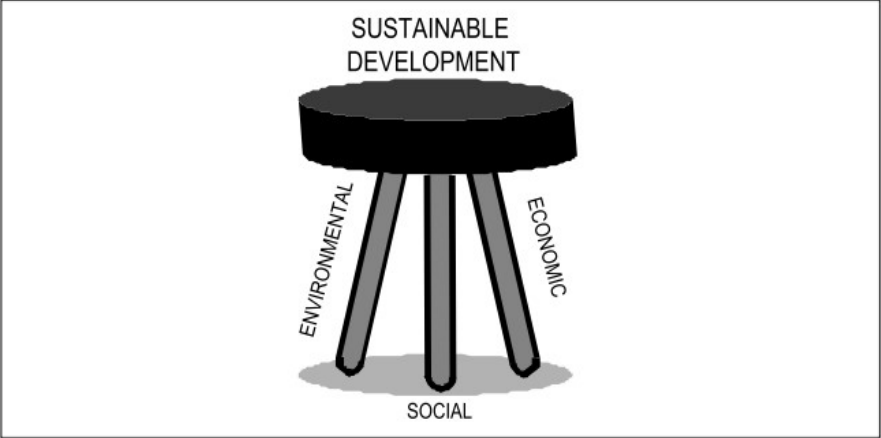
McDougall et al. (2008:3)

Even though the production waste has long history in human existence, it is only recent time since human being started to give high concern for management of waste. During the early life of human being as hunter and gatherer and agrarian, the issue of waste management was not a real cause of concern, as there was a small population in very vast area and plenty of open spaces to discard and throw food and related wastes (Chandler et al. 1997).

As it is discussed below, the concept of sustainable management of waste has got dynamic change in the few decades. What should be focused in the suitable waste management have been a big agenda among scholars in times. In relation to the effects of waste on the environment, the issue of sustainability had two concerns over past decades.

2.2.1 Old Concern of Waste on Environment

Due to less technological advancement and few visible impacts of waste, earlier goals of sustainable waste management were limited to consumption and conservation resource. There was much consumption of resources specially the non-renewable resources. The rate of regeneration row materials was far less than its rate of consumption, which results in much loss of raw materials and much production of waste (Meadows et al. 1992) .As a result, the concern was much on conservation and eco-efficiency use of resource.

2.2.2 New Concerns Waste on Environment

UNDP (1998) reported that these days the earth where life depends for existence is suffering from two other crises than resource consumption that are resulting in deterioration of earth's carrying capacity. These are ever-increasing release of pollution and wastes that exerts pressure on the living environment. Resulting in global climate change catastrophes such as flooding, occurrence of storms and droughts and others. The report concludes that much focus should be given to these issues in order to achieve sustainable management of wastes.

Concerning the old and new concerns of the impact of waste production on environment, McDougall et al. (2008) has put the following diagram to show the comparison of old and the new sustainable waste management activities.

Figure 2.2 Old and New Concern over waste
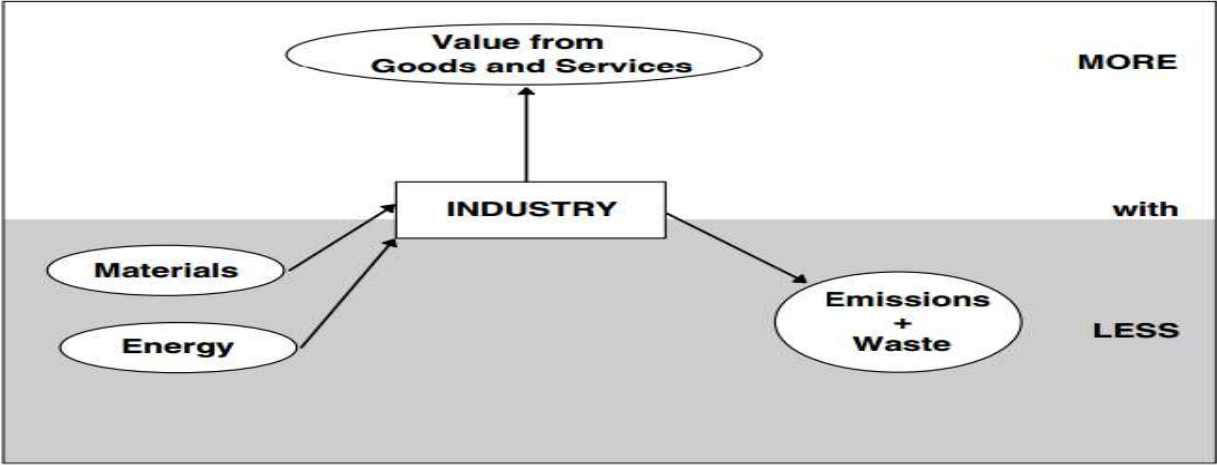
McDougall et al. (2008:5)

As it shown on the above diagram , waste sources such as Industries should be efficient enough to produce more values (as indicated on the top) from resources with less comsumption of materials and energy , there by emit less waste as by product.

''Solid waste management systems need to ensure human health and safety. They must be
safe for workers and safeguard public health by preventing the spread of disease. In addition
to these prerequisites, a sustainable system for solid waste management must be environmentally effective, economically
affordable and socially acceptable'' **(**McDougall et al.2008:18).

 McDougall et al. (2008), has also explained details of each of the pillar issues to be considered. Waste management system should reduce environmental impacts of waste management like emission of toxic and pollutant particles to land, air and water. The management of waste also must be economically affordable to all stakeholders (local communities, government office, Community Based Organizations, private firms and others) involved in the process. It should at the same time be done in democratic ways, where many public hearing works shops arranged and get approval of majority of the people.

''A Sustainable Waste Management system is likely to be integrated, market oriented, flexible and socially acceptable. The execution of these principles will vary on a regional basis. A key requirement, is the 'customer–supplier relationship''
(McDougall et al. 2008:18)

2.3 Waste Management and Sustainable Development Goals

The issue of waste and sanitary management had been central agenda of different institutions at all levels such as international, regional and local levels. The highest governing body at international level, the United Nationations Organization has been giving much priority for environmental protection and sustainable development. For the success of

its objectives, it has been developing goals at different time. One of the goals of the United Nations Organization that give much focus for environmental safety is the millenium development goals which were effective between September 2000 to September 2015.

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 .

According to Ezeah (2010), the current state of solid waste management particularly in cities and towns in developing countries is at alarming rate, putting pressure on social and environmental safety. The worse waste management problem combined with multiple environmental challenges such as poverty, rapid population growth, urbanization aggravated the concern of environmental issues at different scales of the world. This had led the issues of waste and sanitary concern to the higher-level attention at the United Nations Organization level, where three of eight Millennium Development goals were concerning waste management, sanitary and wise use of resources.

Among the Millennium Development goals declared by the United Nations Organization in 2000, the 7th goal was directly related to the achievement of Environmental Sustainability, where it was expected by the member states to ensure safe environment, make access to clean and safe water and sanitation, and pollution free environment and wise utilization of environmental resources others (Poverty 2015) and (Waage et al. 2010).

Similarly, another UN meeting on June 2016 has given due focus on the possible impacts of unmanaged solid waste on environment in general on human life in particular. Here below was a speech by UN general secretary solid waste management.

''...Likewise, managing solid waste is often problematic in densely populated areas. In fact, in many developing regions, less than half of solid waste is safely disposed of. As per capita waste generation continues to rise, the collection and safe disposal of solid waste will continue to require serious attention.'' (UN Secretary-General Report 2016:11).

2.3.1 Sustainable Development Goals

As it is shown below , there are about 17 Sustainable Development goals have been adopted and declared by heads of states , Governments and high representatives of the United Nations Organization at the Head quarter of UN general Assembly in New York between September 25-27. This was one of the UN's general assembly, where lots of duties and responsibilities have been loaded by every member states to achieve by the end of 2030. The set Sustainable Development Goals have are a continuation of the Already expired Millennium Development goas where more related concepts are adopted from it in addition of some new elements (UN Secretary-General Report 2016).

Figure 2.3 Sustainable Development Goals

Unlike the older Millennium Development goals, it is in this Sustainable Development (SDGs) plan of action that the people of the world have given due attention to the issue of Environmental problems such as pollution, waste and resource degradation. It was also during the conference on Sustainable Development Goals that much of goals and targets related to environmental problems have been included at the global level. About three to four goals and approximately 7 targets of the Global Sustainable Goals are related to Waste management issues to be solve by 2030. (UN Secretary-General Report 2016).

Accordingly, Sustainable Development Goal 6 target 3 deals with the commitment by member state and all concerned bodies to have improved their water quality service by employing the preventive methods such as reducing the pollution, avoiding dumping and minimizing of the release of materials that are threat to the environment, proper use of wastewater and encouraging recycling and reuse of materials (UN Secretary-General Report 2016).

2.4 Theoretical Frame Work of the Research

The theoretical framework of this thesis is based on Integrated Solid Waste Management System model. The main rationale behind the choice of this theoretical framework for this thesis is because it is based on the principle that there is no single solution in waste management system, dealing with the reuse and recycling of waste products than just disposing in to the ground. It is also inclusive of all necessary procedures and phases in waste management system than focusing merely on disposal phase, where an integrated waste management system considers different phases of a modern waste management system including resource reuse and recycling before final disposal. Unlike others solid waste management models, which gives emphasis on either of the specific stages such as recycling or disposal, integrated solid waste management considers all are necessary part of the waste management processes (Heimlich et al. 1992).

''Integrated Waste Management (IWM) systems combine waste streams, waste collection, treatment and disposal methods, with the objective of achieving environmental benefits, economic optimization and societal acceptability. This will lead to a practical waste management system for any specific region'' (McDougall et al. 2008:15)

An integrated system as the name indicates is a waste management system that considers multiple steps and activities, which are equally importance and mutually interdependent alternatives in waste management system. These include minimization of wastes production, efficient collection and sorting, reusing, recycling, treatment and proper disposal system (McDougall et al. 2008).

Figure 2.4 Hierarchy of Integrated Waste Management System
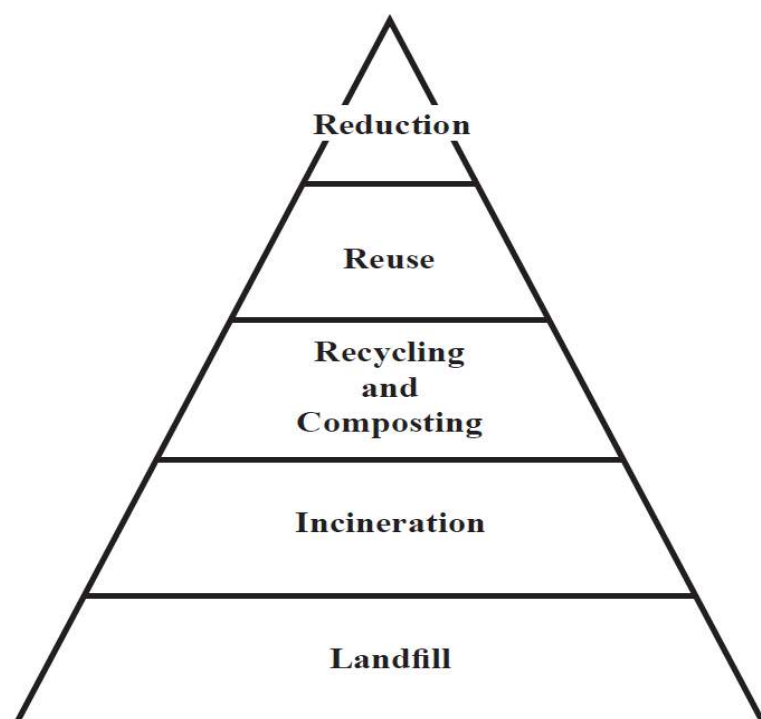
Heimlich et al (1992:2)

Integrate Solid Waste Management (ISWM) is a model that looks in to complex and multidimensional aspects of solid waste management in integrated way where different interested stakeholders' from different sectors are involved in analyzing, developing or changing a waste management system. The system acknowledges the importance of stakeholders' involvement and all kind of enabling sectors in waste collection, transfer and transport, generation and separation, treatment, recycling and final disposal. The system is based multi-dimensional processes where it principle considers all wastes are not wastes and all wastes are not useful in socio/economic and environmental agenda (Guerrero et al 2013. This shows that all stages are necessary part of solid Waste management. Similarly, Heimlich et al. (1992), further argues this idea with the following quotation.

''No single solution completely answers the question of what to do with our waste''
(Heimlich et al.1992:1).

A 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 that is designed to minimize pollution and loss of amenity.

McDougall et al (2008) has also described a landfilling 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).

''Siting a sanitary 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 best minimizes economic, environmental, health, and social costs '' (Siddiqui et al. 1996:515).

Similarly, Al-Shalabi (2006) argued the selection process of suitable site is 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 limited to selection of suitable site for a landfill but also involves an assessment of optimal routing and bins (Ghose et al. 2006).

Figure 2.5   Integrated Sustainable Waste Management Model
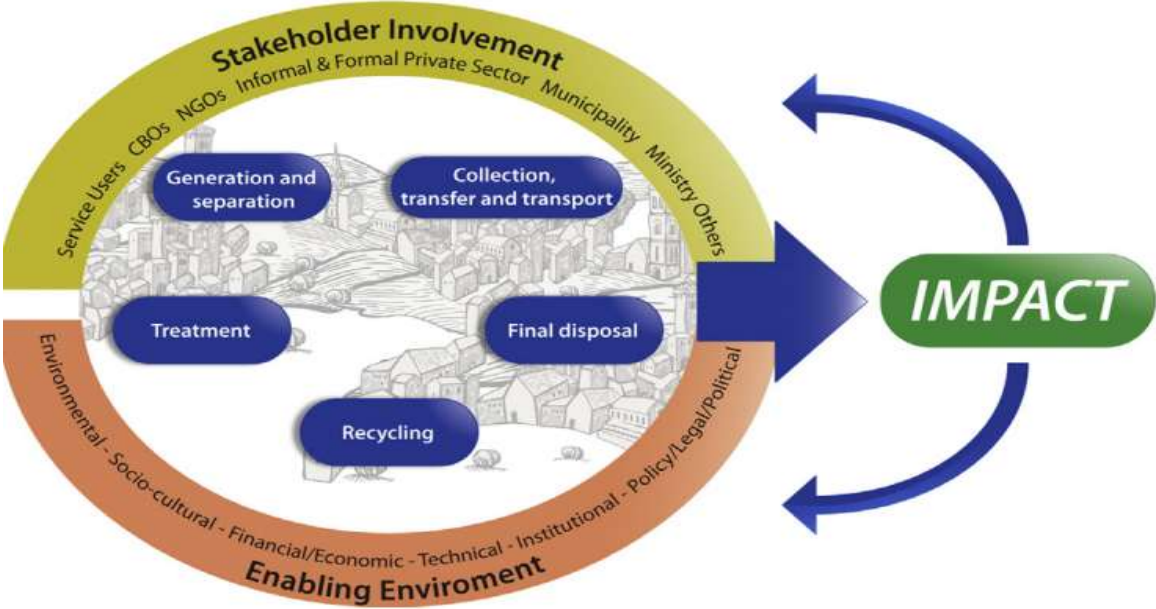
Guerrero et al. (2013:221)

As the figure above shows, the whole system is broadly grouped in to two and each group are all importance in the stages and processes mentioned above. Accordingly, Stakeholders involvement consists of   Services Users, Community based

Organizations (CBO's), NGO's, Formal and informal sectors, Municipality, Ministries and others. Enabling Environment such as Environmental, Socio-economic, Financial/Economic, Technical-Institutional and Political sectors.

But why Integrated Waste Management?

''The operations within any waste management system are clearly interconnected. The collection and sorting method employed, for example, will affect the ability to recover materials or produce marketable compost. Similarly, recovery of materials from the waste stream may affect the viability of energy recovery schemes. It is necessary, therefore, to consider the entire waste management system in a holistic way. What is required is an overall system that is both economically and environmentally sustainable'' (McDougall et al. 2008:22).

2.5 Development of the Integrated Waste Management Concept

Looking at the diversity   and complexity of problems related to waste management W.R. Lynn in 1962, had proposed the idea of system and integrated approach in management of waste problem, where he raised importance of interconnectedness of different components and functions in waste management process. Since then many concepts related to mathematical modelling and system analysis to optimize the waste management activities started to pave the way to the concept of Integrate Waste Management. Decade later, the idea was further developed in 1975 when these concepts are given attention in development of comprehensive implementation plan called ''Solid Waste Authority of Palm Beach County in Florida. Some of the concepts such transportation, processing, recycling, resource recovery and disposal have been included in the solid waste management processes (McDougall et al. 2008).

Even though Municipal Solid Waste management is so crucial in keeping clean sanitation and environment, it has been considered as neglected aspect of environmental management in most low and middle-income countries. Though the solid waste management sector is being given a lion shore of the operational budget in municipalities often between 10 and 50% of operational expenditures, it remains poor in its achieving its target in the towns and cities of lowest and middle-income countries (McDougall et al.2008).

The beginning of the practical applications of waste management practices particularly, the solid waste management practices in developing countries are attributes to the uncontrolled and rapid growth of population in the region. Because of population boom in the region, the issue of sanitary and solid waste management has been given due consideration in the planning process of urban land use. Unprecedented amount of money have been included in the budget of municipalities in for solid waste management activities (Ghose et al .2006).

''The final and most significant definition of IWM took place in 1991, when a task force from the Economic Commission for Europe published a Draft Regional Strategy for Integrated Waste Management that defined IWM as a 'process of change in which the concept of waste Management is gradually broadened to eventually include the necessary control of gaseous,

liquid and solid material flows in the human environment.' This brought all waste arising under the umbrella of IWM'' (*McDougall* et al. 2008:21).

Gradually, different local and international institutions started to recognize the importance of integrated waste management system. The United Nations Environmental Programme (UNEP) on its report in 1996 have discussed on the importance designing and implementing of the elements of integrated waste management system as a sound waste management practice (McDougall et al. 2008).

2.6 Factors Hindering Efficient Solid Waste Management and Disposal System

The inefficient nature of waste management system, especially the solid waste management of the developing country cities like, Abuja Nigeria is attributed to four main categories barriers namely, main: institutional/regulatory barriers, natural/physical barriers, operational barriers and socioeconomic barriers (Ezeah & Roberts. 2012). According to Ezeah & Roberts (2012) research output, low level of public awareness, poor payment of waste workers and unsuitable and obsolete equipment are some of the most important social-operational factors hindering Sustainable Solid Waste management system in Abuja, Nigeria. Physical factors such as density and moisture content of waste are listed among the least natural/ physical barrier for solid waste management and disposal system in the town Johannessen & Boyer (1999) argue that due to a number of generic issues shared in common among developing countries, the above listed barrier factors works well for cities and town in Africa. More specifically Tadesse et al. (2008) have identified waste facilities such as access to and distant from communal containers, finance and presence absence of suitable disposal site are the key factors that determine household's improper disposal of wastes. In connection with access to container or recycle bins, González-Torre & Adenso-Díaz (2005), described distance to recycle bins can greatly affect people choice and culture of proper waste disposal. He concluded that as the distance to travel to recycling bins decreases, very small number of people keeps waste at home. This can be an indication of how the access to recycle bins affects people's decision where to depose.

Similarly, some other scholars have also pointed out the most influential factors affecting the waste management and disposal systems. According to Sujauddin et al. (2008) family size in a household, their awareness and their income level all have an impact of the production and disposal of waste materials and Scheinberg (2011) added payment (fee) for collection service as a determining factor in waste management and disposal of waste . So as to get their public health and environment safe, all beneficiaries from local population to industries and government offices should discharge their obligation of payment for the integrated waste management services.

''All beneficiaries of the Integrated Waste Management system, the public, the recycling industry and local authority, should pay for waste management services. An Integrated Waste Management system minimises risks to public health and results in a clean, healthy environment for all citizens.'' (McDougall et al.2008:24).

Moghadam et al.(2009) and Henry et al. (2006) focused much on infrastructure such as weak road networks, absence of efficient machineries and vehicle as the reasons for poor waste management and disposal system.

2.7 Geospatial Technology and Land Suitability Assessment

2.7.1 The role of GIS and Remote Sensing in Waste Management and Planning

In the majority of nations of the world, especially in developing countries, the application of GIS and Remote Sensing techniques on land suitability assessment is very recent. GIS has been applicable on land use planning and assessment since the 1980's .This has been facilitated by the beginning of GIS and Remote Sensing applications (Mu 2006). This means in other words that prior to the beginning of GIS and Remote Sensing applications, decisions related to the suitability assessment in urban areas were dominated by the traditional methods. Today, however, it is unthinkable to assess a suitability of a given land without the aid of GIS and Remote Sensing system.

Geographical Information system is a digital database management system designed to manage and store large volume of data from variety of sources. Due to its efficiency in storing, management, analysis, retrieves and display geographical information according to the user-defined specifications, it has become very useful in site selection studies and project works (Siddiqui et al. 1996)

Land use can be defined as the human manipulation and alteration of land for specific purpose. It includes commercial, residential, pastoral, range land, recreational, and so forth (Mu 2006).

Landuse suitability assessment is a typical analysis approach for land evaluation. It is the process of determining the fitness of a given tact of land for a defined use (Steiner 1991). It is indispensable part of land evaluation in the process of landuse decision making.

Now adays in many developing countries, the value and demand for land becomes more pressing every year due to factors such as population growth, technical change and economic development (Mu 2006). This has resulted in the need of wise use of the limited land resource to avoid possible land use conflicts. Therefore, land use planning and assessment have become more important to make better use of limited land resources. Within land use planning and assessment, there a term called 'Land Suitability'. It refers to the analysis of how well a land unit matches the requirement of the land utilization type and it is seen as an appropriate way to quantify land development constrains and opportunities and help planners to cope up with the land use plan design (McDonald and Brown 1984).

''Suitability analysis is performed to identify sites (usually grid cells or pixels) suitable for a specific purpose so that management decisions can be made in a site-specific manner'' (Basnet& Apan 2007:74).

Suitability analysis is a step-by-step assessment of different parameters of a given land for specific usage. This step-by-step process of determining the fitness of a given land for a defined use is termed as a Land use suitability assessment (Steiner 1991). Its objective is to help decision makers in finding the most appropriate site or patterns of a locationsfor fulfilling the goals of the involved stakeholders .Land suitability analysis needs the combination and integration of several data sets to model landuse requirements and characteristics of a land for alternatives. In this respect, geo_information provides a tool in integration and analysis resources to determine suitability for a landuse or several landuses (Jankowski and Rechards1994). Geographical Information Systems are commonly described as computerized information systems for the acquisition, storage, manipulation, analysis, and display of geographically referenced data according to user-defined specifications (Laurini & Thompson 1992). GIS provides a common framework for integrating and analysing multiple datasets based on geographic location.

The main goal of of GIS is to take raw data and transform it, via overlay and other analytical operations, into new information, that can support decision-making processes (Mu 2006).

In the majority of nations of the world, especially in developing countries, the application of GIS and Remote Sensing techniques on land suitability assessment is very recent. GIS has been applicable on land use planning and assessment since the 1980's (Mu 2006).

Since the variables in this research are spatial in nature, the appropriate method of data analysis chosen was the Spatial Multi Criteria Decision Making.

''Spatial multi criteria decision-making method typically involves a set of geographically defined alternatives (events) from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria '' (Al-Shalabi et al.2006:4). Using Multi Criteria Decision Making (MCDM) the suitability of a given land is determined by a number of steps. These includes ranking,weighting,scoring,ratioing and defining the rate of influence for each criteria inputs

There are many ranking method are on practice today. One of these is the Straight Rank Sum (SRS) method . In straight Rank Sum , criterion are ordered from the most to the least relative importance factor in accordance to the stakeholders' point of view. After ranks are established relative weights are assigned to the factors,using the Straight Rank Sum method (Carver 1991). This equation is shown below.

$$w_j = (n - r_j + 1) / \text{summation of } (n - r_j + 1)$$

Where w_j is the normalized weight for the Jth factor

n is the number of factors under consideration and

j is the rank position of the factor.

Weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Geographic problems often require the analysis of many different factors using GIS. For

instance, finding optimal site for irrigation requires weighting of factors such as land cover, slope, soil and distance from water supply (Giap et al.2003).

Weighting in suitability analysis refers to assigning a numeric value to each factor in order to recognize its relative importance, and usually expresses in percent format. A set of weights are usually used to represent the relative importance of parameters and normalized to a constant as: Determining the weights is, however, quite controversial and is basically accomplished by decision-makers through reviewing the criterion and their relative importance concerning the objective to which they contribute (Siddiqui et al.1996)

Chapter Three

3. Description of the Study Area

3.1. Physical Features

3.1.1 Location

Shashemene city was established in 1911. It the capital city of West Arsi Zone is located at 7^0 North and $38^0 - 37^0$ East Longitude in the middle of the great Ethiopian Rift Valley Region with a distance of about 250 kilometers to South of the capital city of Ethiopia Finfinnee (Addis Ababa). Currently the city is inhabited by a total population of 246,774, about 123,057 male and 123, 717 women excluding the recently added kebeles from rural areas. Having located on the total area of 759.53, it has approximately 759.53 population density in square kilometer, making the city to the top populous in the zone (Shashemene City Administration 2016).

Figure 3.1   Location of the Study Area

The town was established in 1890's as a small village at the area originally known as ''Harufa'' later named by an elderly lady called "Shashe'' who was engaged in selling local "tobacco, Boka"in Afan Oromo from which name "Shashemene"emerged (Shashemene City Administration, 2016).

3.1.1.2 Topography

Topographically, Shashemene can be taken as flat with slope rarely exceeding 3% particularly along river courses. The slope generally decreases from southeast towards the northwest. This is due to the presence of hill and uplands in the southeastern border of the town .The average elevation of the town is about 1940. Larger areal coverage of the town has flat topography with a slope less than 5% except areas along Essa and Gogeti streams. The area along Essa and Gogeti streams has an average slope of 12% and 9% respectively. The town has an ample of land for future urban development activities (Shashemene City Administration, 2016).

3.1.1.3 Climate

The climate condition of the city administration which stretches over 1,858 hectare of land falls in to three climatic zones namely the highland (Dega), temperate (woinadega) and the lowland (Kolla) climate condition. It has an altitude ranges from 1672 to 2722 meters above the sea level experiencing a temperature value between 12 to 28 ^{0}C. The town's mean annual rainfall for years is 1735.8 mm (Shashemene City Administration, 2016).

3.1.2 Socio-Economic Characteristics

3.1.2.1 Population

The population of the town is increasing rapidly from time to time with annual growth rate of 5.4 %. The city is inhabited by a total population of 246,774, which made the city to be the most populous center in the zone (county) with a population density of 759.53 square kilometer (Shashemene City Administration 2016).It is probably the most ethnically mixed town in the region as it composes more than 14 ethnic groups. Unpublished survey conducted in 1991 indicated that, in Shashemene, mixed ethnic groups are founded who are using different languages. In addition to this, about 2500 Rastafarian community/Jamaican are living in Shashemene participating on different investment activities. The population of the town is growing at alarming speed since the 1998's E.C. This is due to high population immigration from neighboring peasant associations (CSA 2015).

This population size distributed in seven Gandas, the lowest concentration of population was observed in Ganda Awaashoo held about 11.4% of the total population, and the highest concentration observed In Ganda Burqaa Guddinaa contained

about 14.4% of the total population. The following table presents the detail distribution of population of 2015 and the projected population of 2017. It should be noticed that Kuyyaraa had its autonomous administration during the census period and later it incorporated to Shashemene because of its proximity to the town (CSA 2015).

Table 1. Actual and Projected Population Distribution of Shashemene city by Subcities
Source (Population and Housing Census of Ethiopia, 2015 documented from Shashemene Town Business and Economy development office 2016)

No	Town Administrative Division (Ganda)	Number of Population, 2015					Number of Population, 2017				
		No of HH	Total	Male	Fem.	%	No of HH	Total	Male	Fem.	%
1	Awaashoo	2582	12,907	6,557	6,350	11.4	3002	15012	7626	7386	12.0
2	Abboostoo	3016	15,079	7,619	7,460	13.4	3180	15900	8029	7871	12.7
3	Diida Boqqee	2738	13,691	6,932	6,759	12.2	3148	15740	7964	7776	12.6
4	Bulchaanaa	3079	15,396	7,557	7,839	13.7	3479	17396	8541	8855	13.9
5	Burqaa Guddina	3235	16,177	8,194	7,983	14.4	3610	18050	9151	8899	14.5
6	Araadaa	2732	13,661	6,921	6,740	12.1	2831	14153	7176	6977	11.3
7	Aleeluu	3030	15,151	7,697	7,454	13.4	3476	17379	8829	8550	13.9
8	Kuyyaraa	2118	10,586	5,414	5,172	9.4	2249	11247	5747	5500	9.1
	Total	22530	112,648	56,891	55,757	100	24975	124877	63063	61814	100

3.1.2.2 Economy (Livelihood)

Shashemene town hinterlands economy characterized by agriculture and non-agriculture economic activities. The economy of the town is dependent on trade and agriculture. Trade, which had been a source of economy for years, is still contributing a lot for the economy of the town. Starting from the ancient period, the town is known for its main route to long distance trade, which passes through the center of the town. The city's strategic location making it an international highway route connecting Ethiopia with neighboring Kenya. Agriculture is still considered as a major source of economy for the majority of the town's residence. Cereal crops constitute much of the agricultural production in and around the town. Though low

contribution to the town's economy, service and transport sectors are also among the contributors of the town's economy (Shashemene City Administration, 2016)

3.1.2.3 Sanitation and Solid Waste Management

As a result of rapid population growth and city's expansion, there are multiple issues of sanitary situation and waste management systems. Even though there have been newly constructed vacuum tankers, wells and garbage containers in the city, still there exist critical sanitary and waste management problems. Liquid and solid wastes are being disposed in open space and no treatment involved (Shashemene City Administration, 2016).

Chapter Four

4. Data Preparation and Organization

The data that have been obtained from field surveying and measurements, digital and hard copy maps, book, articles to be used for this thesis work are prepared and organized in this chapter. Although the title deals with preparation and pre-processing of the fieldwork data, much of the topics related to analysis, interpretation of the resulting maps and discussions are presented in more details in the next chapters. Under Data preparation part of this chapter, the raw data from the field are corrected and passed through different pre-processing stages before actual processing in ArcGIS environment in next coming chapters. Therefore, these initial stages of data preparation activities are followed by results and discussion of the outputs in chapters presented on the end five of the thesis.

4.1. Preprocessing and Data Preparation

Table 2. Data Sources and Description

Input Data	Entity	Attribute	Source
Master plan (2016)	Vector	Autocadfile	Office of land Development Agency, Shashemene city and Shashemene city Finance and Economy Development Office
City'sProfile Data	Vector	Landuse classes	Office of land Development Agency, Shashemene city
Slope map	Raster	Elevation	USGS, 2017
Sub-city map (2016)	Vector(s hapfiles)	Sub-cities	Office of land Development Agency, Shashemene city
GPS Readings	Point Data	ID,Name,shape,	Field Surveying
Boundary map	polygon	ID,Name,shape, Area	Office of land Development Agency

Source (field Data 2016/17)

Under preprocessing part, hard copy maps are scanned and added to the GIS environment thereby corrected geometrically (Georeferencing) and some adjustment related to projection and Transformation have been made. The choice of appropriate working directory and folders and setting environments, conversion of the structural map (Masterplan) of the town from AutoCAD format to a shape file and then projecting to a commonly used coordinate system are some of the most important preprocessing stages applied on this research work.

4.1.1. Geo-referencing

The base map for the other maps used in this thesis is the sub city map of the Shashsmene obtained in hardcopy file. With the help of ground control points located on the map, four sharp point from four corner of the city are used as a sample ground controlling points to georeferenced the base map. These reference points are presented below. These coordinate points are carefully read from the scanned map, registered and used as a control points to georeferenced it on ArcGIS.

This was done by adding these data in to Arc Map and checking the georefencing tool from the Arc Tool box then magnifying and adding the ground controlling points of the four corners of the map's layout in to georeferencing table. After the points were carefully inserted, it was necessary to rectify or apply these few points to the whole areas on a map. Therefore, rectify option have been chosen from the georeferencing tool and saved in the database.

These coordinate points listed above are shown on a base map shown below; where the first ground control point is situated on top left corner of the map while others control points are taken from each corners in a clockwise direction.

Figure 4.1 Shashemene Town Sub-city Boundary Map
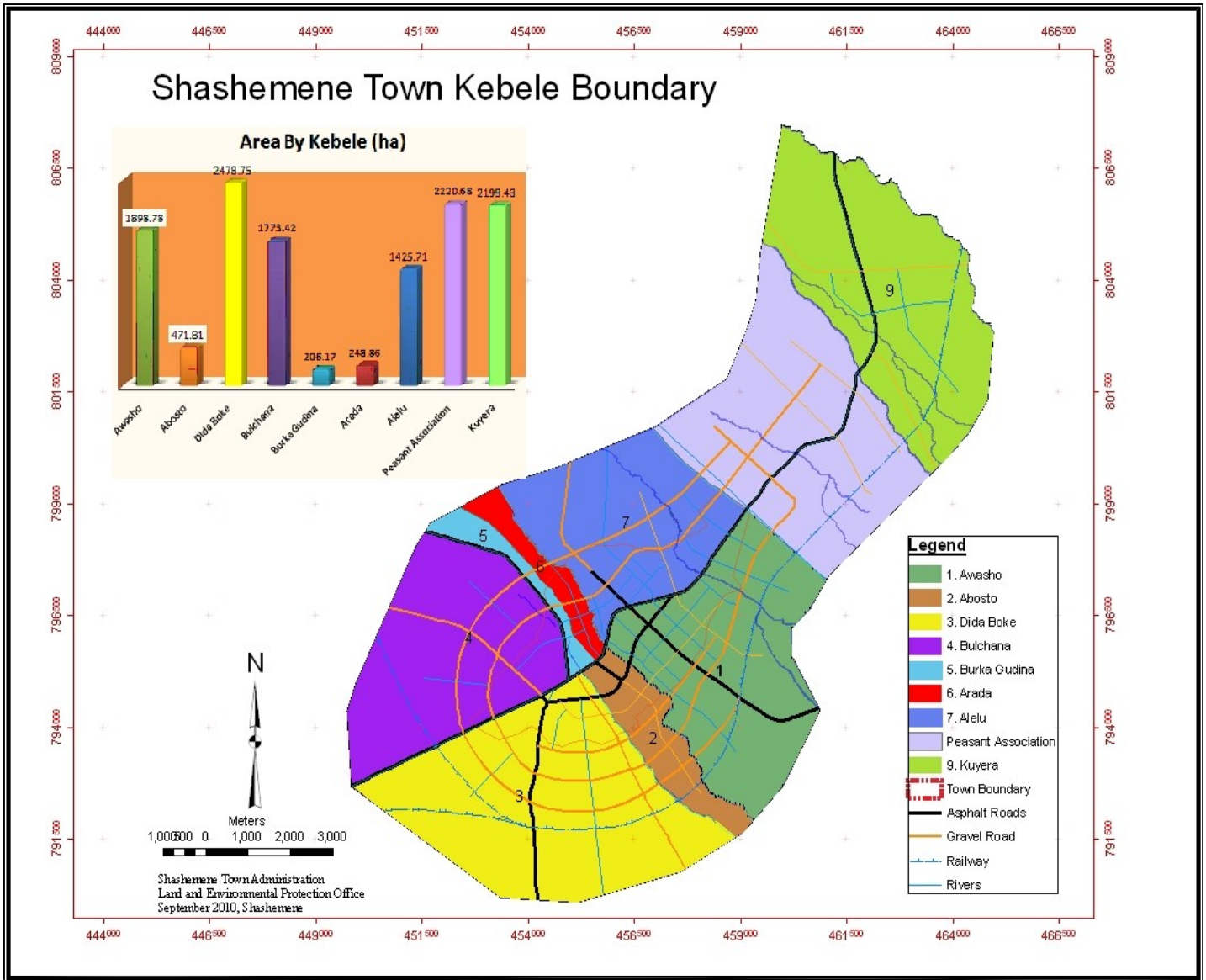
Source: Land Development Agency Shashemene City (2016/17)

4.1.2 Projection and Transformation

Some data such as Global Positioning System readings taken from highly sensitive sanitary areas on the field were in a projected coordinate system i.e in UTM WGS_1984 ZONE 37 N. The city's masterplan (structure plan) was in AutoCAD file. All the data are converted in to shape files and are projected to the coordinate system similar to the spatial reference system of base map shown above, which is Projected Coordinate System: Adindan_UTM_Zone_37N Projection: Transverse Mercator. Therefore , the data (master plan in AutoCAD file) and the Global Positioning systems data taken with GPS receiver from the field , which was in projected coordinate system UTM WGS_1984 ZONE 37 is projected and transformed in to a Projected Coordinate System: Adindan_UTM_Zone_37N Projection: Transverse Mercator. Finally, all the derived maps have automatically received Adindan_UTM_Zone_37N Projection coordinate system as a spatial reference.

4.1.3 Digitization

4.1.1.3.1 Road Map

Road map of Shashemene city is obtained through on screen digitization of the latest kebele map of the city. As the marginal information indicated on the base map, the boundary of each kebele is represented by a polygon and road features are represented by lines. The line feature shaded with blue color is an asphalt road where as the line indicating the brown color is gravel road. For this thesis work however both road types are taken as main road. Before actual digitization, main roads have been observed and detail information has been collected in terms of their type, category, length and location. With this, shape file named ''Main Roads'' is created in Arc Catalog and editor tool is checked in Arc Map and finally each road is digitized based on the collected information. Having finished the digitizing task, fields are added in to attribute table of the shape file and then all necessary attributes codes, names, shape, length and other parameter are filled. Finally, the length of each road type is calculated using the field calculator option in the attribute table of the shape file. See the following map for details.

Figure 4.2. Main Roads and Social Service distributions in Shashemene City

Main Roads Shashemene City

Legend

- Hospitals /Healthcenters
- Existing Solidwaste Disposal
- Water Well /Reserviour
- Existing Schools
- Roads
- Rivers
- Shashemene Boundary

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan

Prepared by
Zenebe Hailu , Marrch , 2018
Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

4.1.1.3.2 Boundar Map

Having a specified extent for analysis of raster files in spatial analysis is one requirement in setting the environment in model builder.   As a result, the boundary map of the city, which is obtained from scanned sub cities map is taken as a boundary or analysis extent for all resulting maps on the model builder. Therefore, the boundary map is obtained by digitizing the boundary of the town from the master plan

4.1.4 Data Conversion

The first step in the spatial analysis is the creation of raster data. All layers had to be converted from vector to raster before the Spatial Analyst could be used to perform any type of analyses. The conversion AutoCAD file to shapefile and vector data to raster layers were completed using the Spatial Analyst conversion tool. The created raster layers were in floating format, which represented continuous data that possessed no attribute tables.

4.1.5 Consideration and Specifications of Criteria Maps

Suitability of a given area varies depending on set criteria and purpose of analysis. A give land can be suitable for different purpose such as residence, commerce, military, agricultural or waste disposal (landfill) dumping ground or others. Even suitability of a land for single purpose may vary between researchers. Availability of resource, diverse physical environment and natural events play great role in choosing constrains and factors affecting the suitability of a landfill. For this thesis work however articles written by Shamshiry et al.(2011) , Berisa & Birhanu (2016), Valentina (2011) and Nas et al. (2010) have been used as a reference for setting defined evaluation criteria for constraint and factors maps for a dumping ground.

Even though Valentina (2011) argued the need to include a comprehensive set of evaluation criteria and factors that greatly affect the location of a Municipal Solid Waste landfill, due to time and resource shortage and the existence of varied natural events in shashemene city, there are omissions and additions of some criteria maps.

The following factor and criteria maps have been chosen based on consideration of the exiting resource and the natural factors. These are Distance to Main roads, Slope, Distance to Surface waters, landuse/ landcover and its distance to Social Services.

a. 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 labelled 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 city 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 city of shahsemene. The long distance the dumping trucks travel, the lesser the suitability of a land for dumping site.

b. 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 under 150m are not suitable and are labelled 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 less exposure of water bodies for ground water contamination.

c. 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 300-m 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 less exposure to pollution and contamination.

d. 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... Linear standardization (the higher the natural value of the area, the lower the score'' (Valentina 2011:243).

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, bushland /or forest land and on open areas .

e. 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 less than 3 degree as a highly acceptable for locating a landfill site. Most parts Shashemene city's steepness is not greater than greater than 4 degree. Therefore, the study area is highly suitable in this regard.

f. 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 the 1993 FAO's guidelines for land-use planning. There would be five suitability classes of the resulting maps ranging from highly suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), currently not Suitable (N1) and Permanently Not Suitable (N2).

Table 4.2 FAO's Land Use Suitability Classification

Land Suitability Orders	Land Suitability Classes
Suitable	Highly Suitable (S1)
	Moderately Suitable (S2)
	Marginally Suitable (S3)
Not Suitable	Currently Not Suitable (N1)
	Permanently Not Suitable (N2)

Source (FAO 1993)

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 model created for this research project is presented on next chapter under results and Discussion.

Chapter Five

5. Data Analysis, Results and Discussion

5.1 Geodatabase and Model Creation

The key element in GIS work is the design of the database. Among the databases used in Esri's ArcGIS program, Personal Geodatabase have been chosen as an appropriate geodatabase for this particular research work. Geodatabase is a container, similar to folder, which is used to input, store, manage feature datasets, and feature classes. The database is designed to consist of detailed information includes data related to road network, GPS readings of sample sites, accessibility maps (school network and health centers data), stream data, wells and reservoirs data, boundary map, map of sub cities, land use map as well as data in raster formats such as Digital Elevation Model (DEM) Slope data used during the analysis process DEM. Maps in vector and raster formats are used for the analysis. When landfill site suitability is assessed in a raster GIS environment, each land unit in the database is valued according to its priority in landfill site selection and each thematic layer represents its unique in the evaluation process. Following the personal Geodatabase creation, feature dataset is also created to hold the feature classes like land use map, road map, slope map and others with the same steps followed in feature dataset creation. Having finished feature class creation, domain and topology are adjusted by clicking the right mouse on feature classes and pointing to topology and domain respectively.

5.1.1 Model Creation

Model in GIS is a space where various types of data are inserted and different GIS operations are executed with the tools found on the top of the model wizard page. In other words, the term model stands for meaning a simplified representation of the whole process of a given project such as input, tasks and operations and the output. Likewise, a model named by ''landfill'' is created in the toolset called ''Suitable Dumping Site'' on Desktop/field work and Research/zenebe folder. Tools such as clip, buffer (single ring buffering) from Geoprocessing wizard, Euclidean distance (multiple ring buffering from spatial analysis tools), Reclassify (from surface analysis), add fields, Slope, feature to raster , weighted overlay and conditional tools are among the most important operational tools used in model builder wizard to carry out a landfill site suitability for the research work. Finally, all the prepared maps are analyzed in the model created for this particular purpose.

5.2. Specifying a Working Directory and the Environment

Once the criteria maps are readily available and the toolset and model is created, the next step was specifying the working directory, where all the resulting maps are stored. As a result, the resulting maps and outputs are stored in a folder. Having finished specifying a working directory, setting the environment is done. The boundary maps of the city is used as a processing extent while Slope map have been preferred as Raster analysis mask and snap raster and the cell size option have been set to default i.e. maximum of the input.

5.3 Clipping

Once the map has passed through the above discussed steps, it was necessary to clip (cut) parameters like slope, DEM, stream map, roads map, land use map and service areas based on the boundary of the study area. Therefore, the boundary map, which is obtained through onscreen digitizing from the master plan of the city, is converted to raster format. Conversion tool from Arc Tool box and then to raster option is chosen sequentially for all data to complete the conversion of features to raster format. Finally, the data in vector and raster format are clipped based on the extent of the boundary of the city.

5.4 Buffering

A buffering operation is another geoprocessing tool used in this early stage of data preparation and analysis in this thesis work. Buffering in ArcMap is an ArcMap geoprocessing operation that is used to create specific boundary or demarcate a feature databased on the specified distance provided. Criteria maps such as road network, stream map, social service areas are buffered with both manually inserted and automated distances. Two types of buffer operations have been used namely single ring and the multiple ring buffering.

5.4.1 Single Ring Buffering

For constraint map since it was needed identifying just areas that are not suitable due reasons like environmental and related issues a single ring buffer from geoprocessing wizard in ArcGIS menu bar was used. Moreover, as a constraint map just aimed at showing two options, considered and rejected areas, a single ring buffer with a manually inserted buffer distance is applied in this specific operation. Rejected areas as it is discussed later under constraint maps, are permanently unsuitable areas that are excluded areas from further analysis for having barriers or constraints in development of a landfill site. Considered areas are areas that are generally accepted for further analysis. See constraint maps below for details.

5.4.2 Multiple Ring Buffering

Unlike single ring buffering , where only a single buffer zone is created to identify just two option namely suitable and unsuitable classes, multiple ring buffering is used to identify suitability classes with multiple buffer zones of a given suitability map in the study area. It can be either three or five suitability classes. The suitability classes used in this thesis as it is mentioned on the end of the previous chapter are five, ranging from extremely higher to extremely lower suitability.

5.5 Constraint and Factor Maps

5.5.1 Constraint Maps

''Constraints, which are non-compensatory criteria that determine which areas should be excluded from or included in the suitability analysis. The excluded areas will get a nil (0) performance value in the composite index map, whereas the remaining areas will obtain a value between 0 and 1. Constraints are thus expressed in the form of a Boolean (logical) map'' (Valentina 2011:239)

Accordingly, constraint maps, as it is explained above, are areas that have some kind of constraint and are unsuitable due to environmental concerns and/or public health. Therefore, these maps are identified as constraint maps based on accepted and defined criteria. In this thesis : road networks, Slope, stream maps , accessibility maps (social services) all have certain buffer distances set to identify areas that have certain constraint. Similarly, land use has its own constraint for landfill site selection and analysis. As show in figure 5.1–5.6 below, constraint maps created based on accepted distance to a proposed landfill site in the city of shashemene. The buffer distances for each criteria maps is made based on reviewing different local and international research project works and consultation of experts in the municipality of shashemene city.

5.5.1.1 Road Constraint Map for Landfill

Road accessibility to a proposed landfill site is among the major factor affecting the choice of suitable site for a landfill. A road constraint map has been created in consistent with the local consideration**.** According to Berisa & Birhanu (2016), a research made in one of Ethiopia's city, Jigjiga, areas located within a buffer distance 100m from roads are considered to be unsuitable due to noise and possible bad smell to the road side community and environment pollution. Therefore, as road network has not been a serious barrier due to the existence of alternatives roads, an area with in a buffer distance of 200m has been considered as constraint for locating a landfill site.

Figure 5.1 Road Constraint Map for Landfill

Road Constraint Map for Landfill Suitability Analysis in Shashemene City
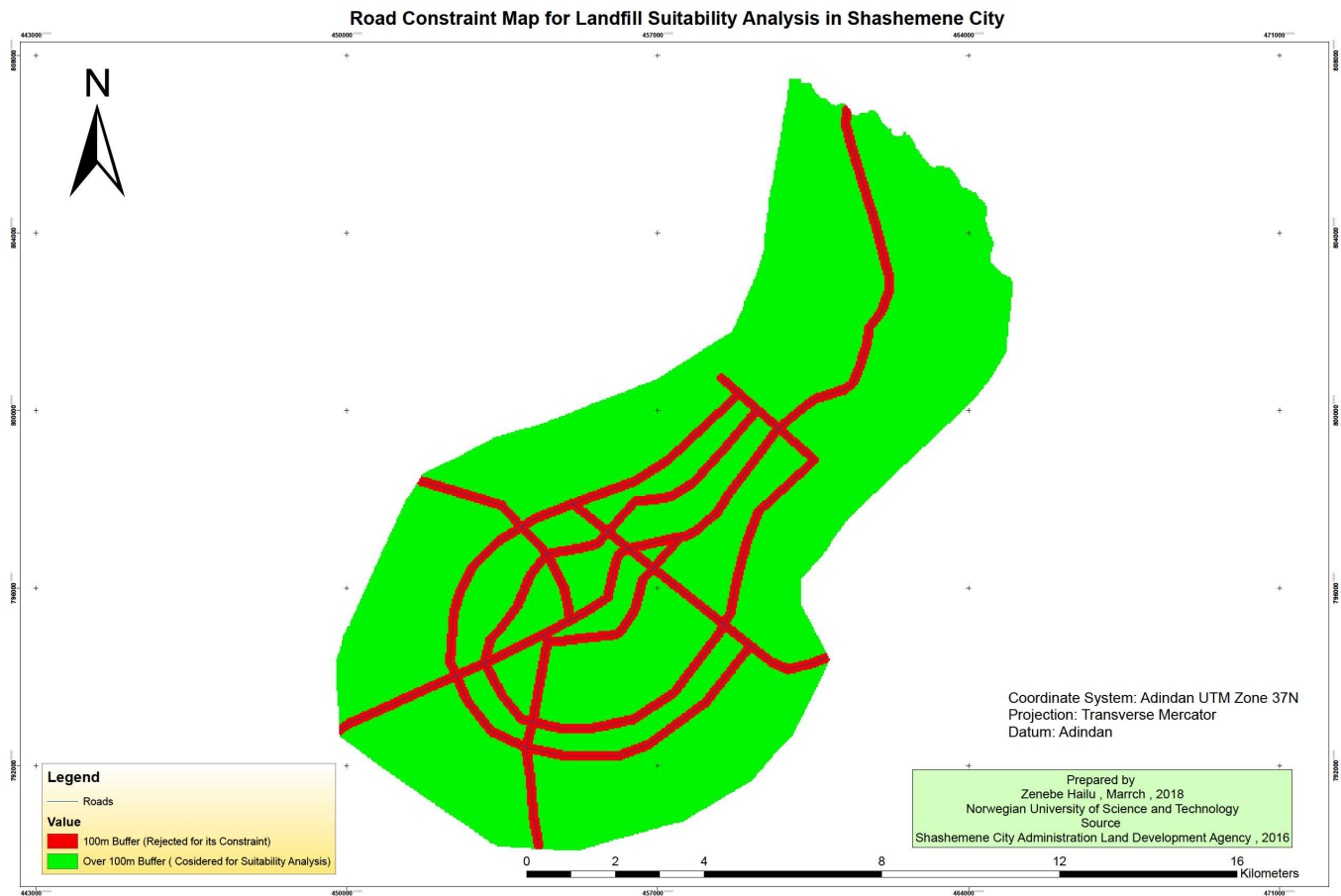
Figure 5.1 above shows roads network distribution in the city of Shashemene. The main roads with blue color are buffered in two distances i.e areas located within 200m from the main roads and areas covering greater than 200m from the main road to any parts of the city's boundary. The buffer distance applied here is based on consideration of the topography and infrastructural development status. Therefore, the more the nearness to and away from the main road, is the lesser the suitable for locating of a landfill site in the town. As a result, areas with in the first 200m buffer distance are rejected from consideration due to the possibility of health related effect on the people living along the roadside while the rest areas are considered for the analysis process.

5.5.1.2 Slope Constraint Map for Landfill

Topography plays a vital role in determining the choice of site for dumping. As it is lying on relatively flat areas, with a mean and standard deviation values are 5, 43 and 3, 19 respectively. Much of the city's topography lies on a slope steepness not greater than four degree. Though this has been seen as a minor constraint, still slope has been well considered as a constraint in locating a suitable landfill site. Slope map of the city is obtained from a Digital Elevation Model downloaded from USGS for this particular research. The following slope constraint map have been obtained based on a define

steepness level. Slope steepness with less than three degree is acceptable for locating a landfill (Shamshiry et al. 2011).

Figure 5.2 Slope Constraint Map for Landfill

Slope Constraint Map for Landfill Suitability Analysis in Shashemene City

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan

Prepared by
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Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

Legend

Value

Slope Steepness Greater than 12 Degree
Slope Steepness less than 12 Degree

The resulting slope constraint map above indicates that the areas with steep slope are shaded with dark red color while relatively gentle slope areas are shaded with light green color. The Maximum steepness for landfill site suitability analysis on this thesis is preferred 12 degree and areas with performance value of greater than 12 degree are rejected and considered as costly for construction, development and management of a landfill while those lying on steepness less than 12 degree are preferred for consideration.

5.5.1.3 Well/Reservoir Constraint Map for a Landfill

It is also recommended that a landfill and wells water reservoirs should be located apart. Sites that are found between 300m distance from a landfill and water wells are accepted as unsuitable in suitability assessment for a landfill due to pollution related problems. Shamshiry et al. (2011) has recommended a landfill should situated with a minimum distance 300m off from wells and reservoirs. Therefore, 300m buffer distance off from wells and reservoirs is made for generating a constraint map for this thesis.

Figure 5.3 Well/Reservoir Constraint Map

Water Well Constraint Map for Landfill Suitability Analysis in Shashemene City

Legend

300m Buffer from Well/Reserviour

Distance from Water Well/Reservious

Value

High : 13668

Low : 0

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan

Prepared by
Zenebe Hailu , Marrch , 2018
Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

As it is shown on figure 5.3 above, the water reservoir point data and a 300m buffer distance are overlapped on a stretched Euclidean distance raster data as a background. An area shaded with dark red color is a buffer distance of 300m from a water reservoir and is rejected from analysis due to problems related to water contamination and potential health related problems to the population of the city. Therefore, the more the location of a landfill away from the specified buffer distance from water reservoir, the better the preference for locating a landfill.

5.5.1.4 Land use Constraint Map for a Landfill

Unlike others criteria, whose suitability is determined based on some commonly accepted distance to the potential 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 , would be given more priority to be chosen as a landfill site. This criteria seems a bit subjective than the others.

Figure 5.4 Land use Constraint Map for Landfill Suitability Analysis in Shashemene City

Land use Constraint Map for Landfill Suitability Analysis in Shashemene City

Legend
Land use Constraint Map
Existing Residential mixed use/Commercial area (Rejected for some constraint)
Predominantly Forest area , open area agricultural green Area (Considered for analysis)

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan

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Source
Shashemene City Administration Land Development Agency , 2016

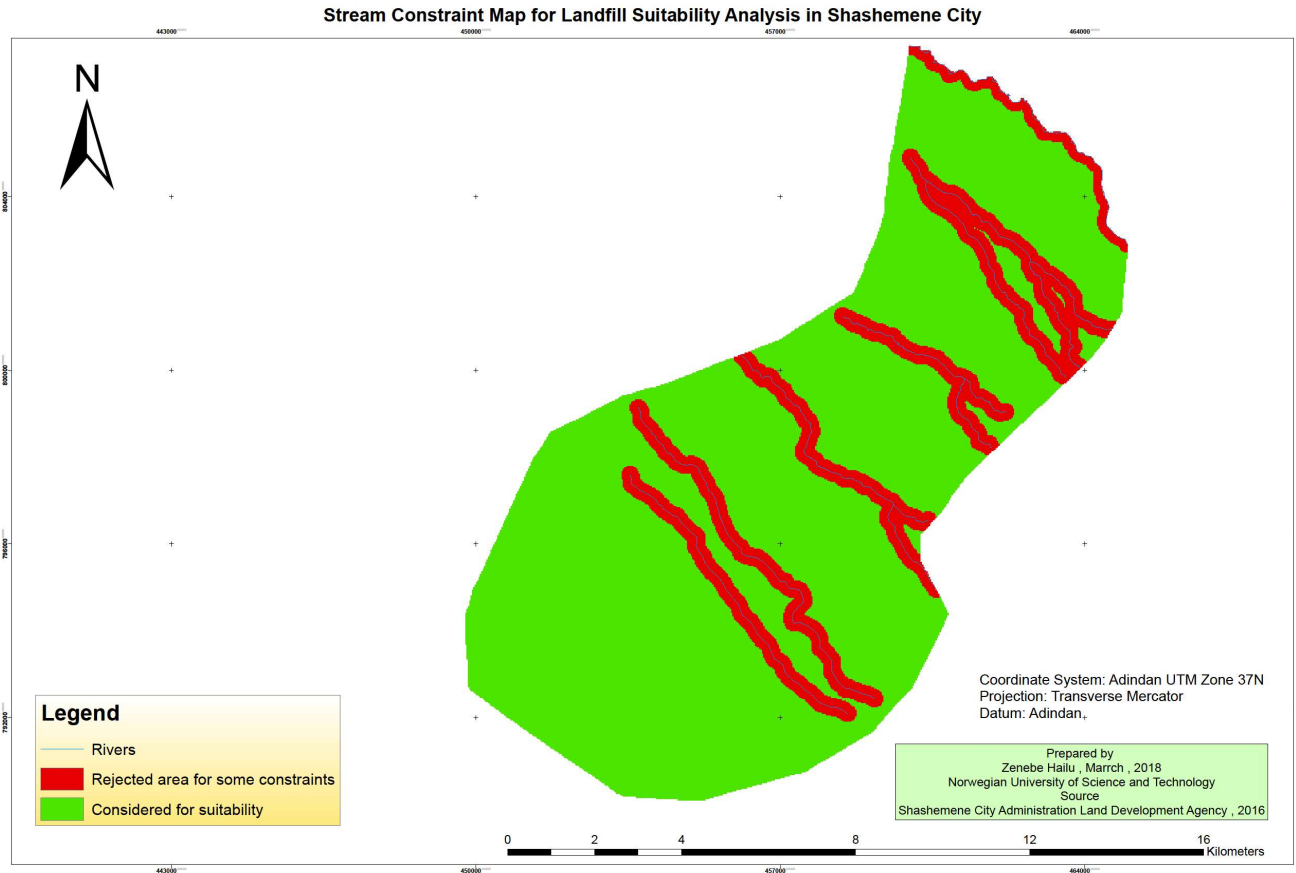In generating a constraint map shown above, issues related to environment, population, sanitary and cost of construction and management are some of the priority criteria to classify a given land use type as a constraint. As a result, suitability of sites for a landfill in the city have been considered and rejected based on issues mentioned above as criteria. Therefore suitable land use should be located away from settlement (built up areas), in the low-density population areas, near agricultural, bushland /or forestland and on open areas. A land use type shaded with dark red color on a Land use map shown above consists of commercial areas, built up areas and existing residence and are rejected from analysis while open spaces, forest and agricultural and green areas are considered as suitable for analysis.

5.5.1.5 Stream Data Constraint Map for a Landfill

Water pollution is the major causes of public health in many developing countries. Surface water is among the most vulnerable water body affected by unplanned disposal of waste in and around the rivers, streams and lakes. Therefore, a landfill should be located at least 200m away from water bodies. Those areas located within this buffer distance are unsuitable as their under underground water level is high and higher discharge and greater downstream influence (Berisa & Birhanu 2016).

As a result, the stream constraint map for this thesis is made on the basis of this buffer distance as it complies with the local environmental situation similar with the study area.

Figure 5.5 Stream Constraint Map for Landfill Suitability Analysis in Shashemene City

Stream Constraint Map for Landfill Suitability Analysis in Shashemene City

Legend

Rivers

Rejected area for some constraints

Considered for suitability

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan,

Prepared by
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Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

There are about main rivers in the city of shashemene flowing from north western and southwestern to the eastern part of the city. A 200m buffer distance is applied to demarcate areas that are permanently unsuitable for locating a landfill. These areas are shown with a dark red color on the map. The remaining area is accepted for further analysis process.

5.5.1.6 Social Service Constraint Map for a Landfill

Social services such as health centers, churches and schools are considered to be among the most sensitive places that requires protection in planning process. Landfill sites needs to be located at a distance of greater than 300 m buffer from built up areas in general and social services in particular to keep possible intervention from people living around and avoid risk to human health (Berisa & Birhanu 2016). Therefore, 300m buffer distance from a landfill is taken as an appropriate distance to identify areas that are unsuitable for selection of a landfill site. The following constraint map shows rejected areas for a landfill in shashemene city.

Figure 5.6 Social Service Constraint Map for a Landfill

Health Centesr and Schools Constraint Map for Landfill Suitability Analysis in Shashemene City
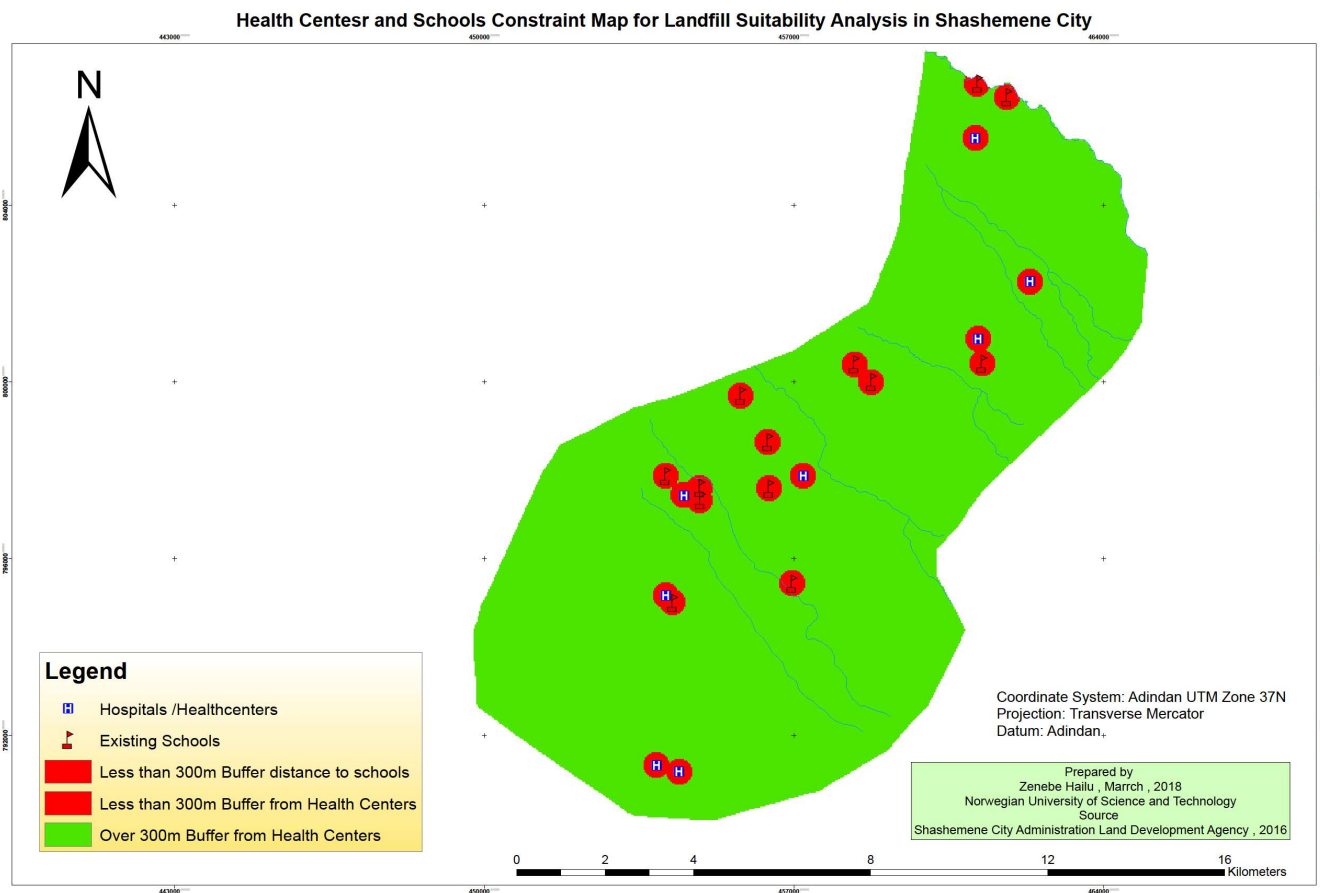
Social service areas are areas that are highly sensitive to pollution by a smell and dust from waste dumping sites. About 300m buffer zone from these sites is created and is rejected as permanently unsuitable for a landfill construction and development in the city. Both schools' and Health centers' data obtained from field are buffered with 300m to separate rejected and considered areas for further suitability analysis.

5.5.2 Suitability Maps

Suitability maps also known as factor maps are output maps showing the degree of suitability of a given factor in different suitability scales ranging from higher , medium to lower suitability of a given factor map in a given area.

''Factors, which are compensatory criteria that contribute to a certain degree to the output (suitability). There are two types of factors, (i) benefit criteria and (ii) cost criteria. A benefit criterion contributes positively to the output (the higher are the values, the better it is), whereas a cost criterion contributes negatively to the output (the lower are the values, the better it is)'' (Valentina 2011:239)
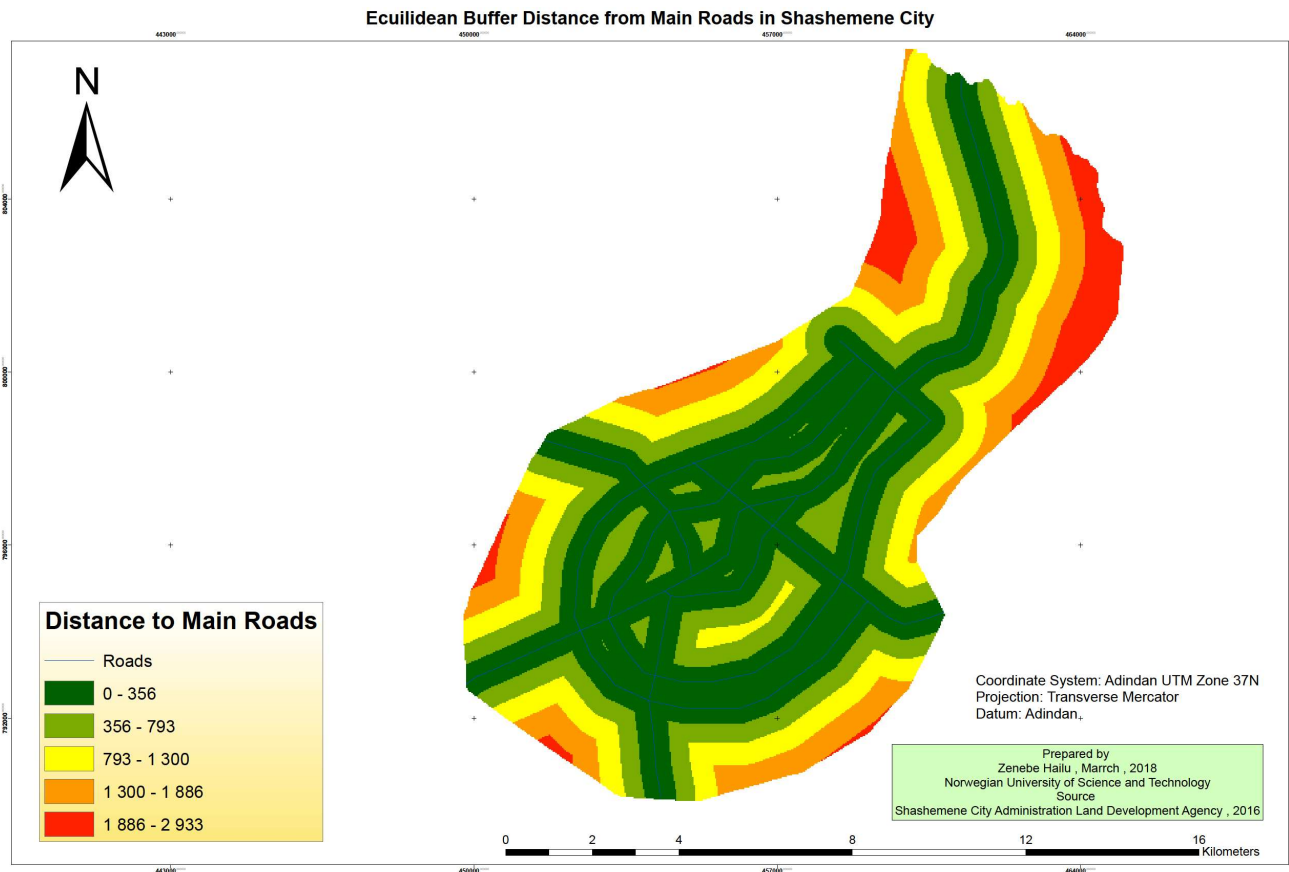
5.5.2.1 Euclidean Distance Analysis

In addition to single ring buffering, a multiple buffer operations have been used for the same criteria maps to generate more than two suitability classes. Unlike constraint maps, suitability maps here are expressed in more than two suitability classes range between extremely unsuitable, marginally unsuitable, suitable, marginally suitable and extremely suitable. Euclidean Distance Analysis is a tool used to create multiple ring buffers for some of the layers. Distance buffers were created for suitability maps showing the class range between extremely unsuitable, marginally unsuitable, suitable, marginally suitable and extremely suitable areas for waste disposal and landfill locations. The suitability of main roads, rivers, wells and reservoirs and social services are measured according to their nearness to any part of the city taking these data as a point of origin. Unlike the constraint maps, which are created with single ring buffering where two results are obtain (suitable and unsuitable) , suitability maps are created using Euclidean distance analysis to show the whole area of the city divided in to multiple classes. Therefore, multiple ring buffer i.e the Euclidean distance buffer operation have been used from ''Distance'' toolset under spatial analysis tool in arc toolbox.

5.5.2.1.1 Distance to Main Roads

A given site is said to be suitable for locating a landfill if it has an access to road transportation and is located at optimal distance from road networks. Transport network plays a vital role for communication and mobility. Because of good road network, peoples, goods and products can move from one area to the other easily. Therefore, the road network data, which is obtained from the new master plan of the town, is digitized and buffered using the Euclidean distance tool in spatial analysis tool bar. As can be seen from figure 5.7 below, areas shaded with dark red color are extremely far from and the areas shaded with dark green color are very near to the main roads. Accordingly, areas within the buffer distance of 200-500m, 500-1000m and 1000 m – 1500m are ordered as highly suitable, suitable and medium while the rest are not. Areas within 3 Consecutive buffer zone of 200 m are suitable for a landfill site selection. Final suitability map for each of the factors is shown on reclassification parts of this thesis.
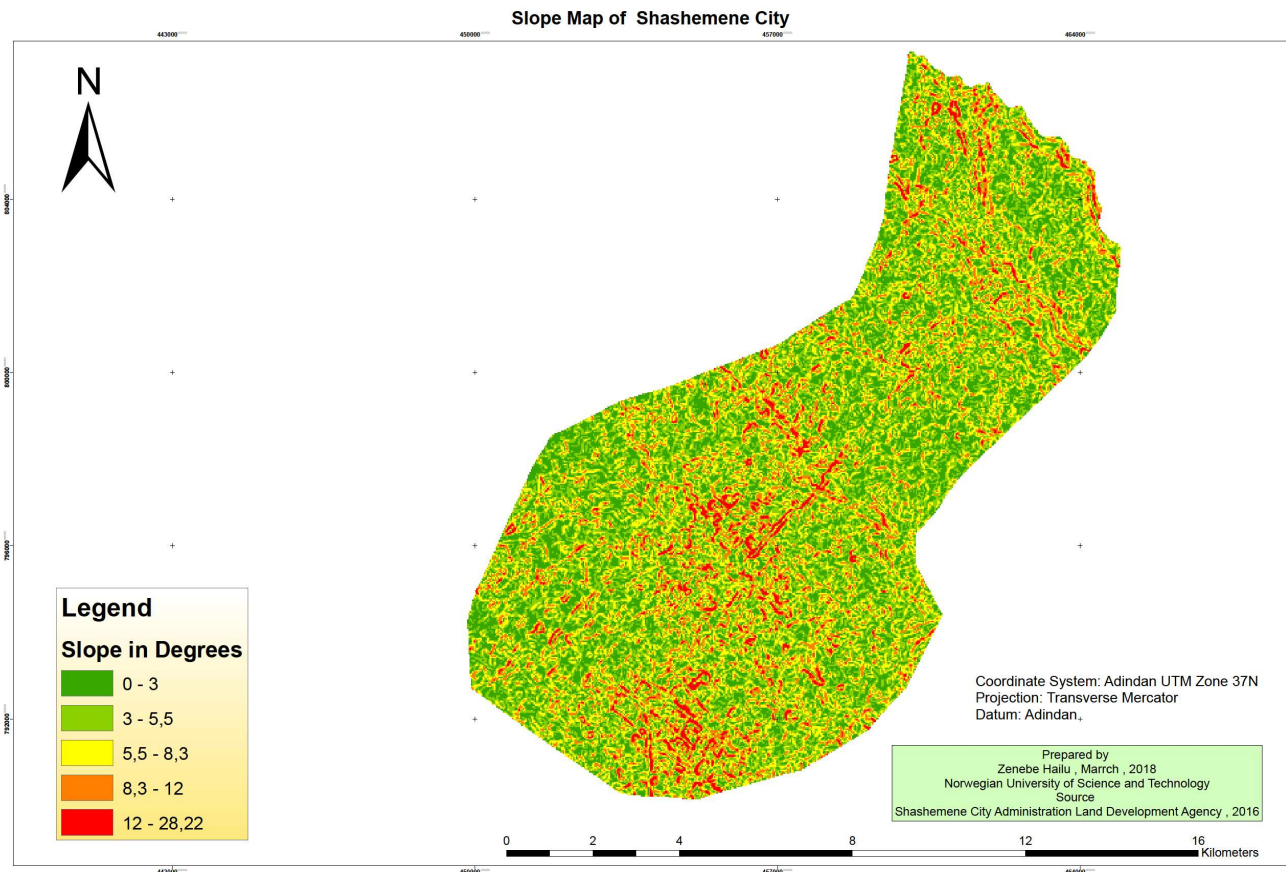
Figure 5.7 Distance from Main Roads in Meters in Shashemene

Ecuilidean Buffer Distance from Main Roads in Shashemene City

Distance to Main Roads
— Roads
0 - 356
356 - 793
793 - 1 300
1 300 - 1 886
1 886 - 2 933

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan,

Prepared by
Zenebe Hailu , Marrch , 2018
Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

0 2 4 8 12 16
Kilometers

5.5.2.1.2 Slope Suitability Analysis

The existence of terrains, ups and downs affect the preference of an area for dumping site, particularly for a landfill. Wastes products in most parts of the city of shashemene are not properly disposed even dumping grounds and waste containers are situated at inappropriate location in terms of topography, creating huge challenges on waste management system of the city. As a result, areas of flat and gentled slope are favorable for selecting a landfill site than the steeper's one. Even though there is no as such big variation in the study area, the slope map has been prepared from DEM data. As it is shown on a map under figure 5.8 below, the maximum steepness of the slope of the town is 28.3 degree. Areas exceeding 12 degree are usually not suitable for development of a landfill are rejected from further suitability analysis (see under slope constraint map above). Therefore, slope map, which is generated from DEM using slope toolset under surface tool spatial tool bar, is classified into five equal interval classes according to their steepness. The suitability of a land decreases as the steepness rises up. In general, as it is described under definition of criteria subtopic areas with slope less than 12 degree are suitable for the location of a landfill.
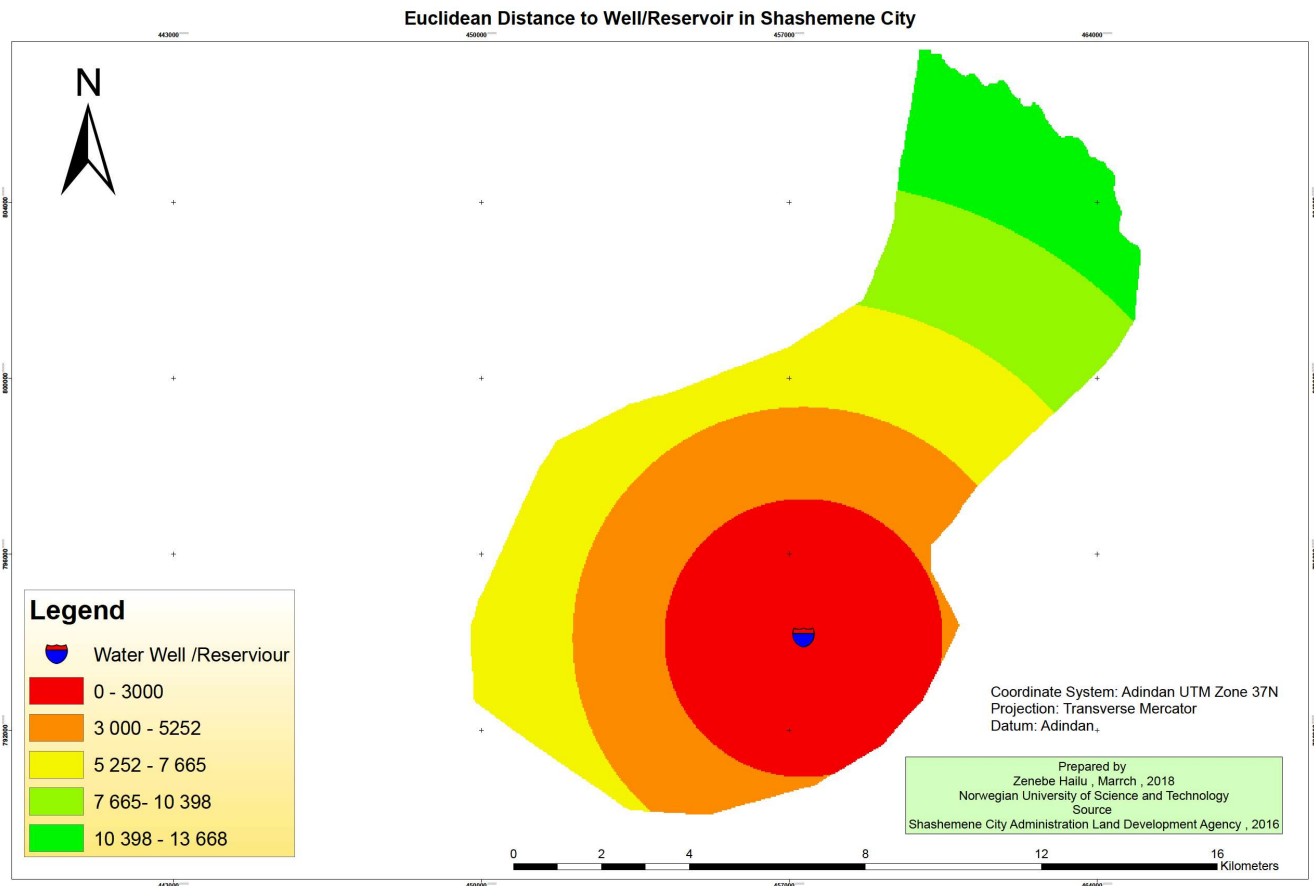
Figure 5.8. Slope Map of the Study Area in Degree

Slope Map of Shashemene City

Legend

Slope in Degrees
- 0 - 3
- 3 - 5,5
- 5,5 - 8,3
- 8,3 - 12
- 12 - 28,22

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan,

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Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

5.5.2.1.3 Euclidian Distance Analysis to Well/ Reservoir

It is clear for anyone that waste and polluted products shall be thrown away at distance far from well and reservoirs storing clean drinking water. Here distance and suitability of an area have a direct relationship , meaning the more the distant located landfill from clean water storing sites, the more the it is suitability for the selection of a dumping site. Sites that are found with in a distance of 300m distance from a landfill and water wells are accepted as unsuitable in suitability assessment for a landfill due to pollution related problems (Shamshiry etal. 2011) .Therefore as it is shown on figure 5.9 below, as one goes from dark green (suitable areas) to dark red (unsuitable areas) suitability of a land increases with distance in this particular suitability analysis.

Figure 5.9 Euclidean Distance to Well/Reservoir

Euclidean Distance to Well/Reservoir in Shashemene City

Legend

Water Well /Reserviour
0 - 3000
3 000 - 5252
5 252 - 7 665
7 665- 10 398
10 398 - 13 668

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan

Prepared by
Zenebe Hailu , Marrch , 2018
Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

5.5.2.1.4 Land Use /Cover Map

The land use /land cover map of the city is derived from the latest master plan of the town. The reason behind choosing the new data (Master plan) than the existing map is that the existing maps show only the actual development activities. Since the study focused on potential site assessment, future development activities should be considered in line with identification of new landfill sites. The row data, which was in AutoCAD data, have been converted in to feature classes and projected using conversation and project features tools respectively. Having prepared all the preconditions, object based classification and then digitizing each land use /land cover classes was carried out. Land use/land cover map is in vector data format and each boundary of polygons is sharp. It is impossible to combine this data with the other raster maps as the weighted overlay table accepts only raster data. Therefore, once land use/land cover is obtained through on screen digitization, it is converted in to raster format using feature to raster option in conversion tool of arc toolbox. The resulted map has become ready for combining and weighting with other parameters. (See figure 5.10 below).

Accordingly, about eight land use/ land cover classes are obtained through on screen digitization method namely, agricultural and green areas , commercial area, existing residential

mixed use area, forest, manufacturing and investment areas , open area, proposed mixed use residence and protected , market and reserved areas. Based on their similarities and suitability scales all these land use/land cover types would be grouped and merged together in to five suitability classes on fore coming parts of this thesis. This map (land use/ land cover) is among the major influencing factors for a landfill site analysis and selection in the city under study. Commercial sites, existing residential mixed use areas, protected, market and reserved areas are among the most important land use/ land cover types that are grouped in to least suitable site categories while the rest are given suitability scores based on some criteria.

Figure 5.10.   Land use /Land Cover Map of Shashemene City
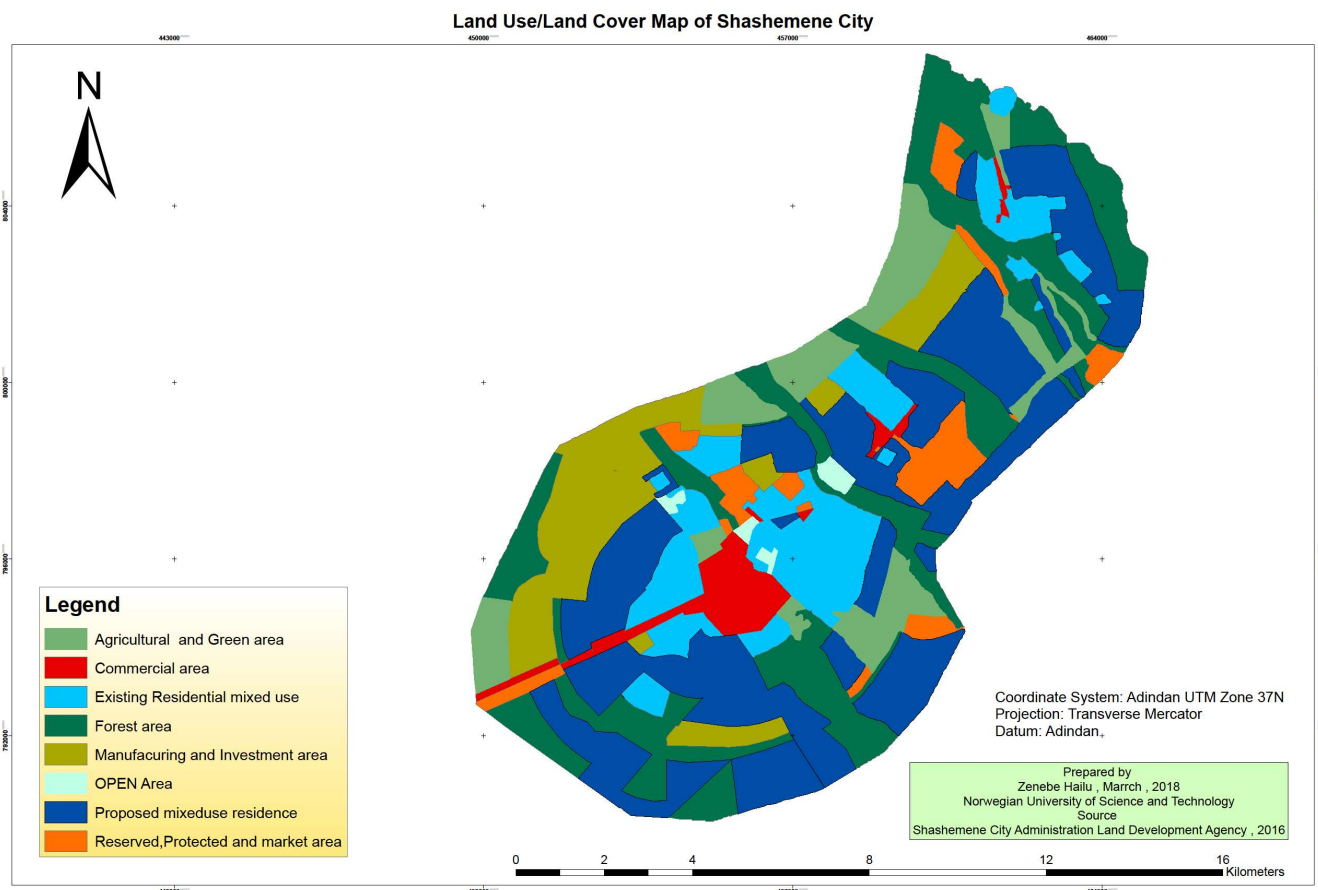
5.5.2.1.5 Stream / Rivers Buffer Analysis

Unlike well and reservoirs, where distance and suitability are directly related, here the suitability of a landfill site and its distance from rivers and streams are inversely related as rivers make up an important agents for washing and transportation of wastes from one place to the other. With exception of a buffer distance specified on constraint map part of this thesis, rivers have huge role in balancing environment, movement, transportation and disposal of wastes products. Figure 5.11 below shows Rivers in city of Shashemene are buffered and have five classes, where the more the darker shaded areas, the more their extreme suitability scales are given. While dark green areas (except for the first

200m) are highly suitable for locating a landfill site, the dark red areas are least suitable for a landfill selection.
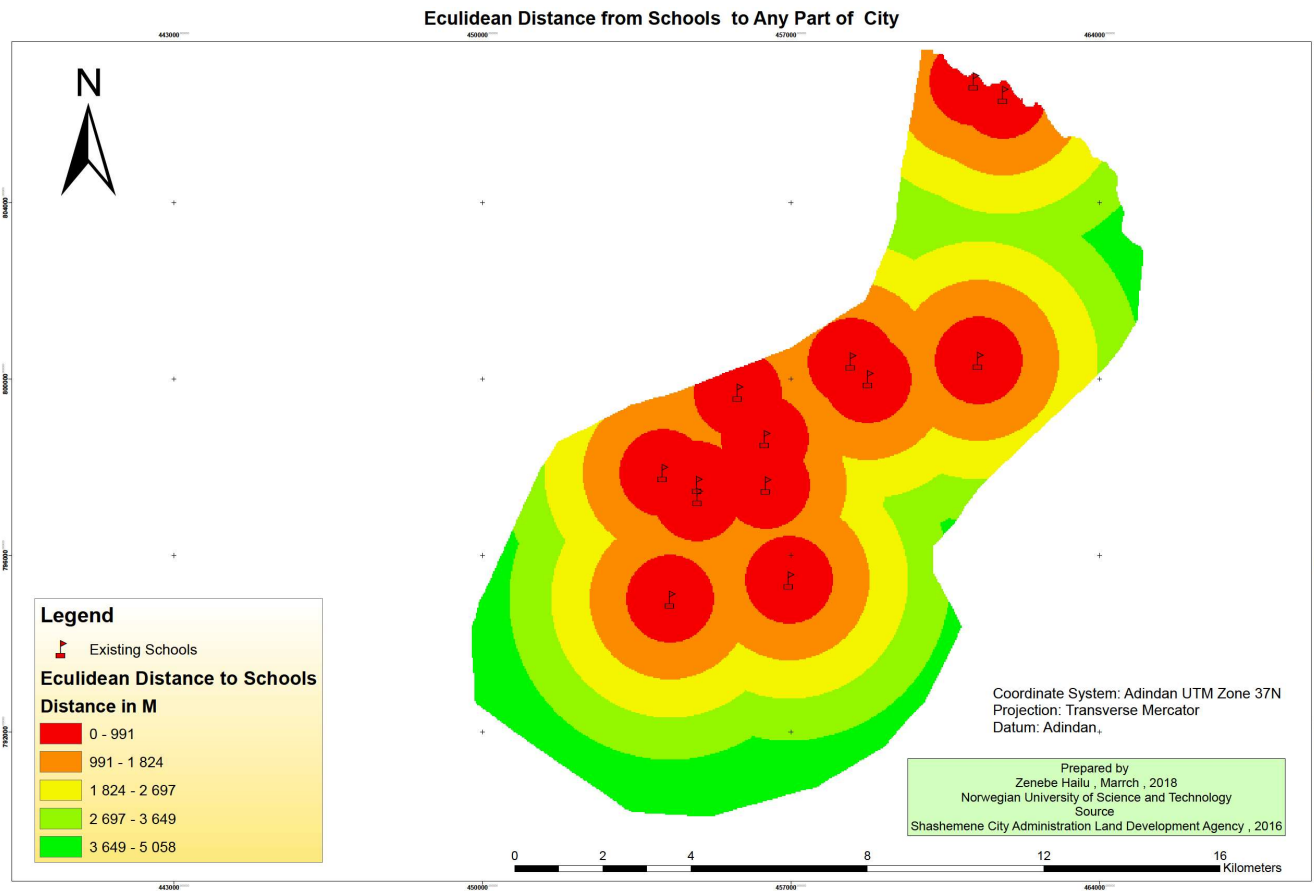
Figure 5.11 Euclidean Distance from Rivers
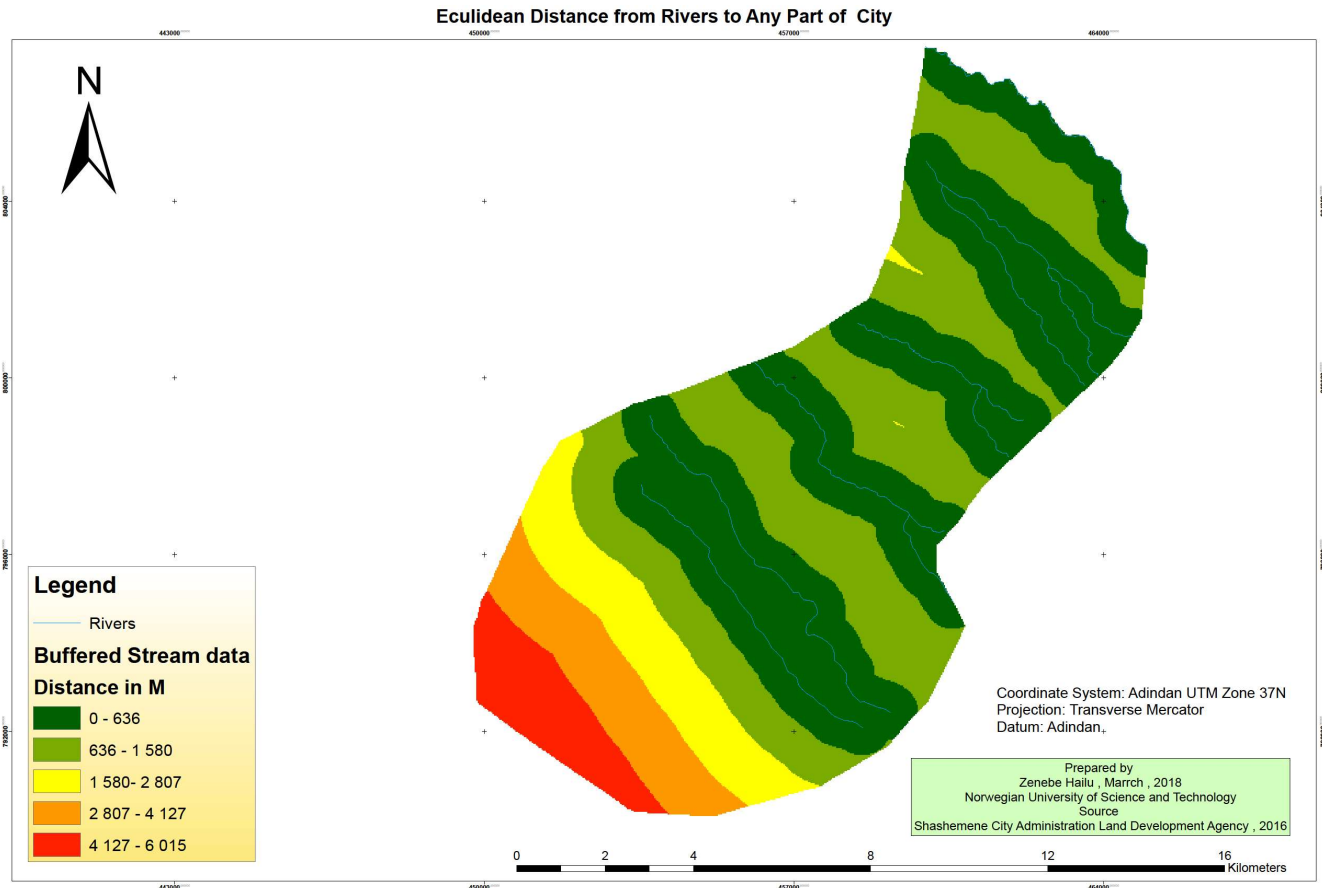
5.5.2.1.5 Euclidean Distances to School Network

Suitability of a given land for a landfill can be influenced by different factors. Its distance to and from schools is among the main factors determining the suitability of a given area for a landfill. With regard to choice of best site for a landfill and distance, optimal landfill sites and school networks have a direct relationship. The higher the distance from schools, the more the suitability value is assigned for a given area. Though there are little studies on this, due to schools are public areas and sensitive to pollutions and health problems, about a minimum distance of 300m off schools have been considered as unsuitable sites for a landfill selection keeping other things constant. Accordingly, figure 5.12 below show buffer distances from school to any part of the city have five default classes where suitability orders have been given on reclassification parts of this thesis.

Figure 5.12 Distance from School Network in Meters in Shashemene.

Eculidean Distance from Schools to Any Part of City

Legend

Existing Schools

Eculidean Distance to Schools
Distance in M

- 0 - 991
- 991 - 1 824
- 1 824 - 2 697
- 2 697 - 3 649
- 3 649 - 5 058

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan,

Prepared by
Zenebe Hailu , Marrch , 2018
Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

5.5.2.1.6 Buffer distance to Health Centers

Like schools, wells and reservoirs, due to human health related problems, health centers (hospital, health station, and clinic) should be located at a far distance from an optimal landfill sites. Health centers are among most sensitive public areas that needs to be situated far from the proposed landfill site. Optimal landfill site is an area located at a distant from public services in general and health centers in particular, where the first 300m buffer distances are ignored from consideration (Berisa & Birhanu 2016).

After locating the health centers on a map using GPS points, distance to these centers have been calculated using the same procedures applied above. This calculation was not arbitrarily made. It was on the basis of different works as well as the existing situation in the study area. These buffer distances would be reclassified in to suitability scales on the next part of the thesis. See figure 5.13 below for more.

Figure 5.13. Euclidian Distance from Health Centers in Shashemene
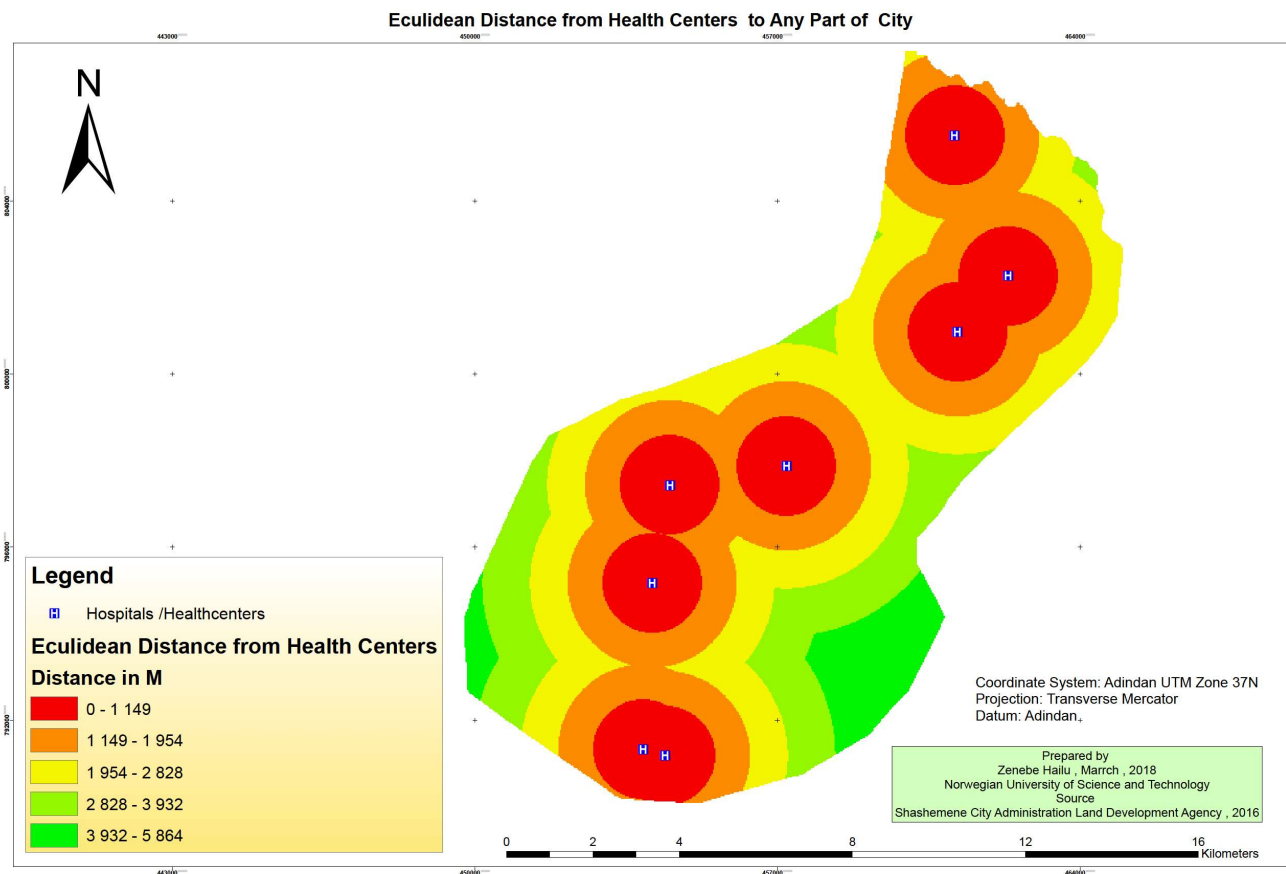
5.6 Reclassification of Factor Maps

Reclassification is a process of converting the floating, continuous datasets into discrete and integer values. In other words, to reclassify a data means replacing the input cell value with new output cell value according to their importance (Meaza 2009). Once datasets such as slope, distance to road network, distance to school, distance to rivers, distance to wells and health centers and the land use /land cover map are derived from the input maps, the next step was reclassifying the datasets in to common number of classes. From the above definition therefore, it is fair to understand reclassification of the factor map as a task of giving suitability scales to each class values in that particular factor map. There are different suitability scales have been on practice today. The most common suitability scales are either three (ranging from highly suitable, moderately suitable and not suitable) to five suitability classes, which are most commonly used suitability scale in land use classification. For this particular thesis however, the United Nations Food and Agricultural Organization's (FAO's) standard scale of suitability classification is applied. The FAO's classification model for suitability is widely used in the studies of land suitability assessment in China

(Dai 2003). This model is based on two general suitability orders (suitable and not suitable) which are subdivided into five suitability classes.

Table 5.1   FAO's Land Use Suitability Classification

Land Suitability Orders	Land Suitability Classes
Suitable	Highly Suitable (S1)
	Moderately Suitable (S2)
	Marginally Suitable (S3)
Not Suitable	Currently Not Suitable (N1)
	Permanently Not Suitable (N2)

(FAO 1993)

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 was calculated. The reclassification values used ranged from 0 to 5, with 1 being the most suitable for sites for landfill development, 4 and 0 are listed as least and not suitable for locating a landfill site respectively.   The higher class value, the lower 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.
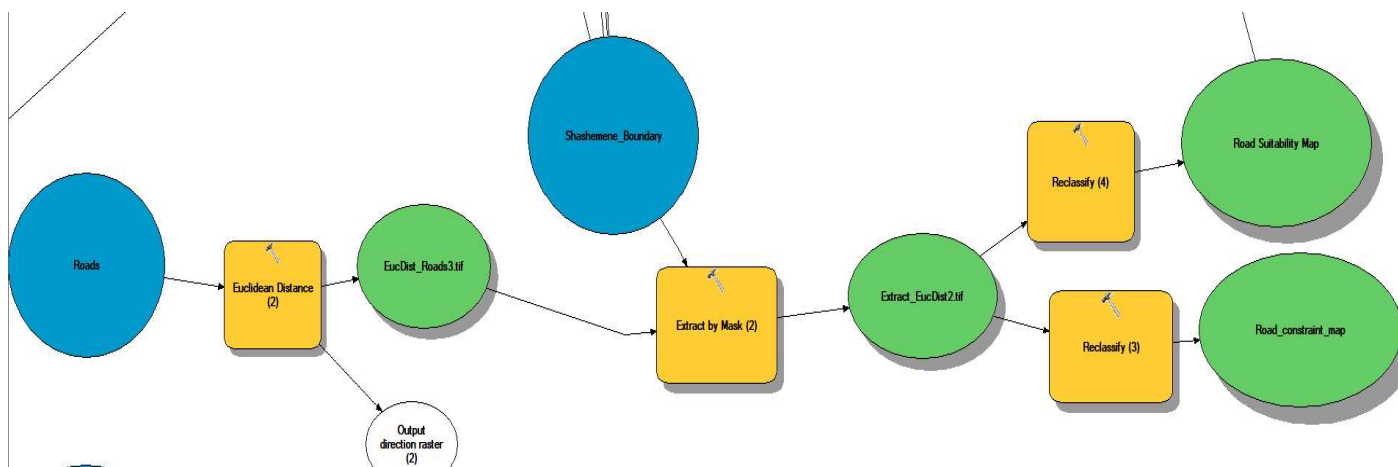
5.6.1 Road Suitability map

5.6.1.1 Reclassifying Distance to Main Roads Data

The road map which was prepared through on screen digitization from the structural map of the city, was then measured distance from the roads to all parts of the city's boundary using the Euclidean distance extension of the spatial analysis tool. The resulted map however, was not ready for overlaying with the other parameters. Therefore, to make it ready for overlaying, the buffered road data had to get reclassified so that it would match and had have equal number of suitability class with other maps for overlaying process.

Here below is a workflow of how a road constraint and suitability maps have been created on a model builder wizard. While Blue colored symbols are input data for processing yellow colored symbols area operations (processing tools) to obtain the green colored symbols which are the outputs in the modelling process.
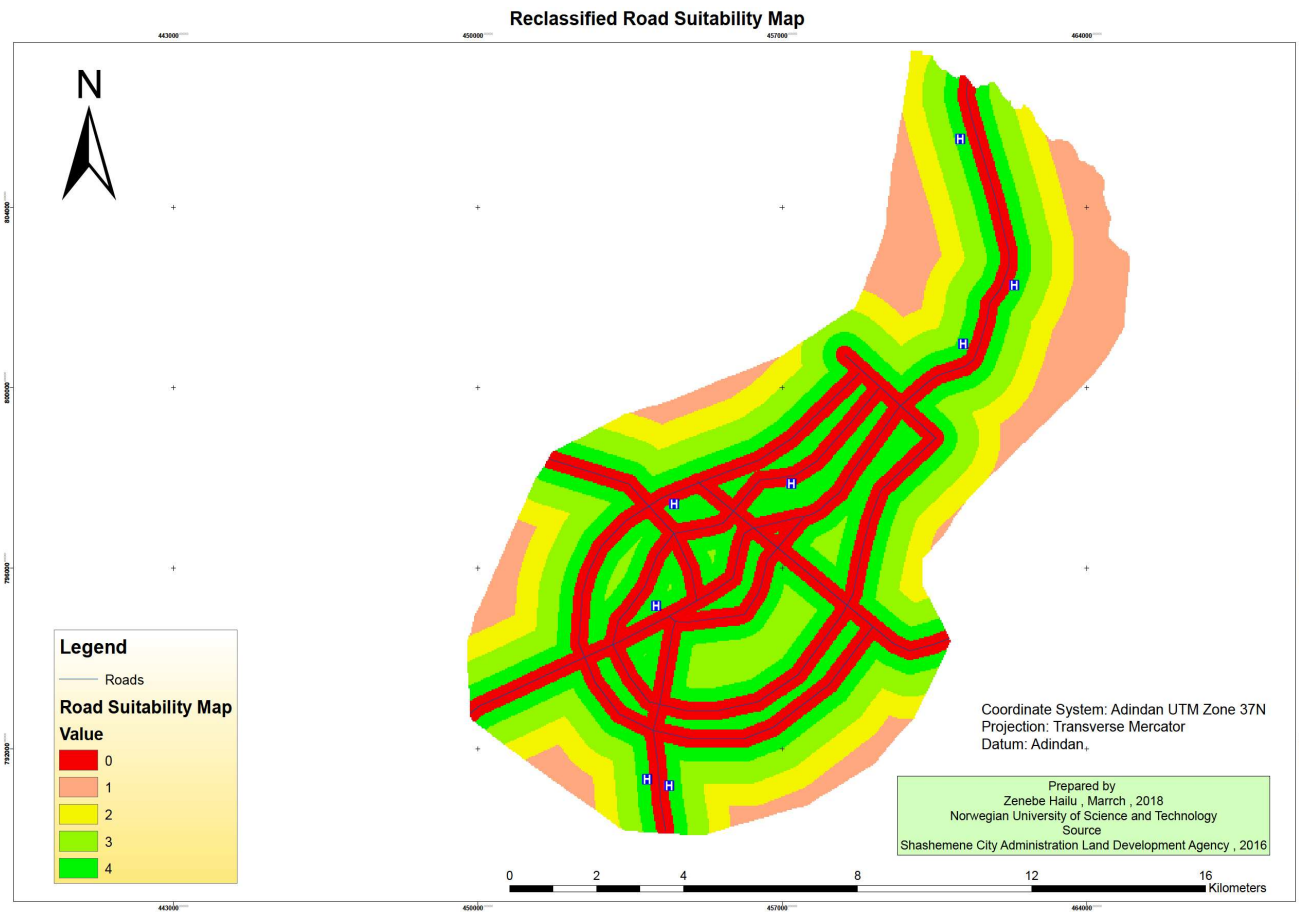
The road data obtained from the structural (master plan) map of the city was measured Euclidean distance and the output Euclidean distance data is clipped (cropped) based on the extent of shashemene city's boundary using the extract by mask operational tool from spatial analysis tools in the arc tool box. Finally reclassify tool have been used to create a road constraint and suitability map for a landfill site. Figure 5.14 below shows step by step procedures of creating constraint and suitability map for road data in this thesis work.

Figure 5.14 Road Constraint and Suitability Map Workflow in Model Builder

As a result higher values have got higher suitability scale and vice versa. See figure 5.14 below.

Figure 5.15 Roads Suitability Map in Shashemene

Reclassified Road Suitability Map

Legend

Roads

Road Suitability Map Value
- 0
- 1
- 2
- 3
- 4

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan,

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Source
Shashemene City Administration Land Development Agency , 2016

0   2   4   8   12   16
Kilometers

5.6.2 Slope Suitability Map

5.6.2.1 Reclassification of Slope Map

The slope map of the study area was by default classified in to 5 class values with an interval of approximately 3 degrees. This had to be reclassified in to 5 discrete class values for the sake of maintaining a common measure scales with the rest datasets. As a result, the slope is reclassified in to 5 class values with an interval depending on their steepness.

Slope constraint and suitability map is created on a model builder wizard, where Shashemene DEM data have been used as an input for generating slope data of the study area. Finally reclassify tool have been used to create a slope constraint and suitability. The slope data have then been reclassified in further to create constraint map (having just suitable and unsuitable areas) and suitability classes (having more than two a suitability classes). See figure 5.16 below for details.

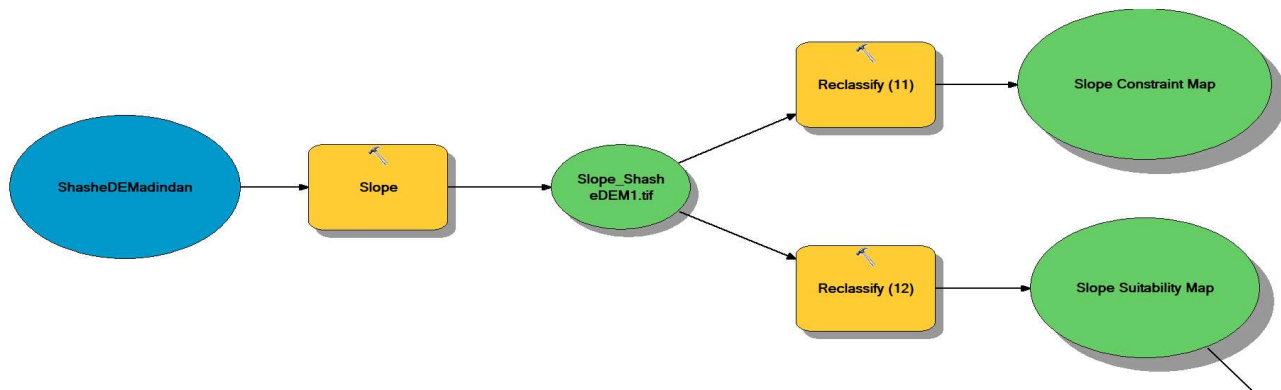Figure 5.16 Slope Constraint and Suitability Map Workflow in Model Builder
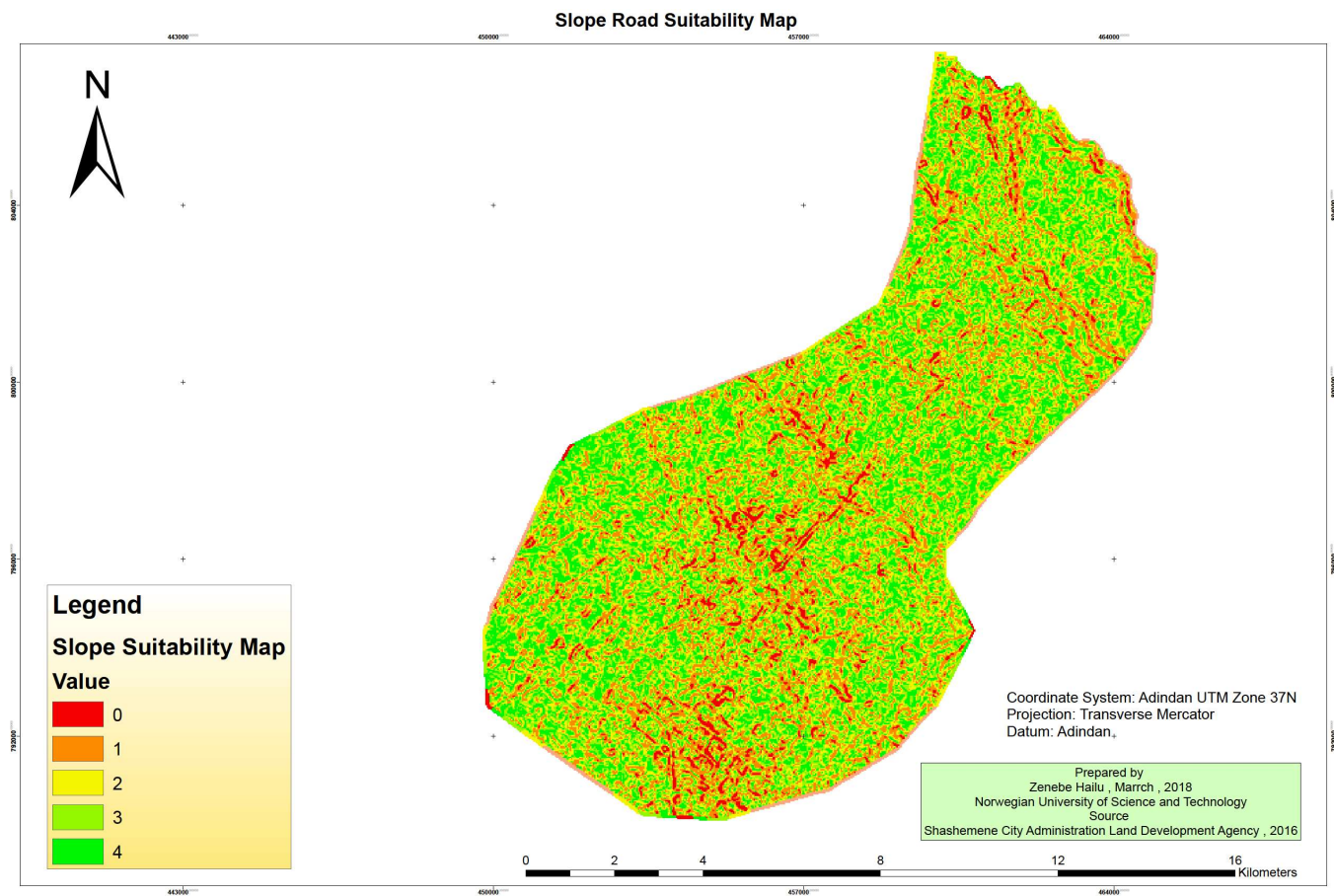

Figure 5.17 Slope Suitability Map in Shashemene City

The suitability scale is given higher for higher class values and vice versa. Unsuitable areas that have some sort of constraint have been ignored from analysis and shaded with red color on a map. In general, slope steepness between 0-5 degree are given the highest suitability value i.e. four and three respectively while those areas lying on a slope steepness between 5-12 degree are accepted as medium and those having steepness of higher than 12 degree are categorized as least suitable for selection of optimal landfill site (Nas et al. 2010). Therefore, areas in a relatively flat topography, having a gentle slope are given higher suitability scale values while the rest are given lower.

5.6.3 Well and Reservoir Suitability Map

As it is show on a map 5.16 below, suitable areas for a landfill are located outside a buffer distance of 300m from the existing well and reservoir while areas inside this buffer distance are accepted as unsuitable for landfill. As a result, distance to existing well and reservoir data is reclassified and assigned a number zero to four, where value number four, one and zero represents the highest, lowest and unsuitable areas respectively. This is due to the fact that the more nearer the landfill to a reservoir, the higher the possibility pollution of drinking water to occur.

Like roads and slope map of the city, a point reading locating a well/reservoir site have been buffered with Euclidian distance measurement to get a buffered point data of a well/reservoir site. Since some parts of the buffered data lie outside the city's boundary, it was then clipped based on extract by musk tool from spatial analysis tools in Arc Tool box. The clipped output data in green color have then been reclassified twice to get a constraint and suitability map of well/reservoir in landfill suitability analysis. This have resulted in creation of suitability classes for a well/reservoir. Below diagram shows the step by step procedures in model building process.

Figure 5.18 Distance to Well Constraint and Suitability Map Workflow in Model Builder
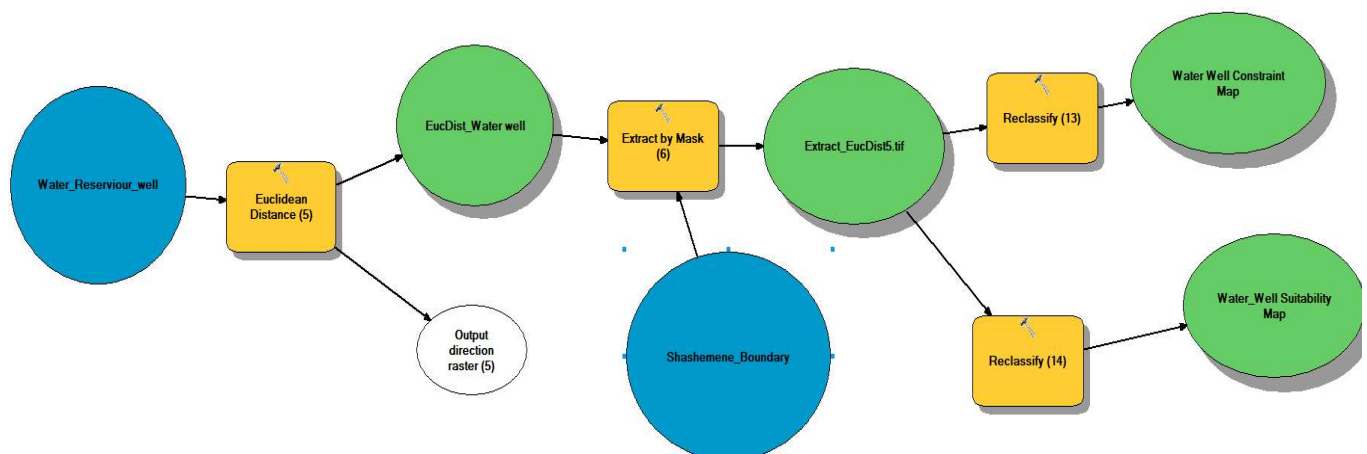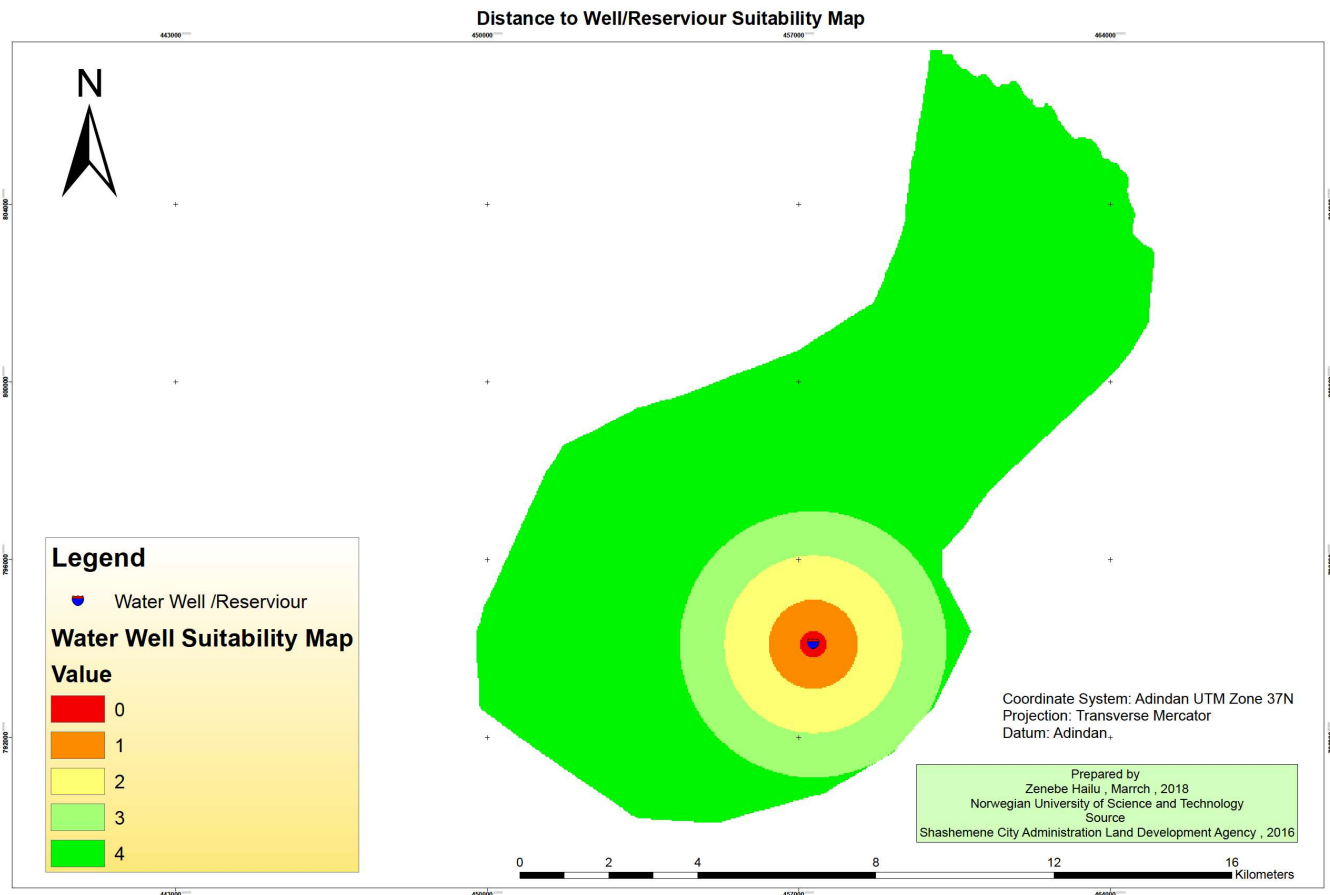
Figure 5.19 Distance to Wells Suitability Map

Distance to Well/Reserviour Suitability Map

Legend

Water Well /Reserviour

Water Well Suitability Map
Value
- 0
- 1
- 2
- 3
- 4

Coordinate System: Adindan UTM Zone 37N
Projection: Transverse Mercator
Datum: Adindan,

Prepared by
Zenebe Hailu , Marrch , 2018
Norwegian University of Science and Technology
Source
Shashemene City Administration Land Development Agency , 2016

As it is clearly shown above, value number 4, 3 and 2 represent highly suitable, moderately suitable and marginally suitable areas while value number 1 and 0 represents least and unsuitable areas respectively. This is obtained after selecting reclassify option in spatial analysis tool, choosing defining intervals, assigning 5 class values and checking the reverse new values option.

5.6.4 Land use Suitability Map

5.6.4.1 Reclassification of Land Use/Land Cover Map

The land use/ land cover of the city is classified in to eight land use /land cover classes. This data had to be converted in to numeric suitability scales. Therefore, the land use /land cover map is reclassified in to five classes based on similarity in use. So as to overlaying a land use data with other factor maps, the land use ma which was in feature data have been converted in to a rates using a convert feature to raster tool from spatial analysis tools in Arc tool box.The resulting raster dara have then been reclassified (divided in to suitability classes) to identify a land use type that are suitable and have some constraint for location of a landfill site. Details of the steps is shown below under figure 5.20.

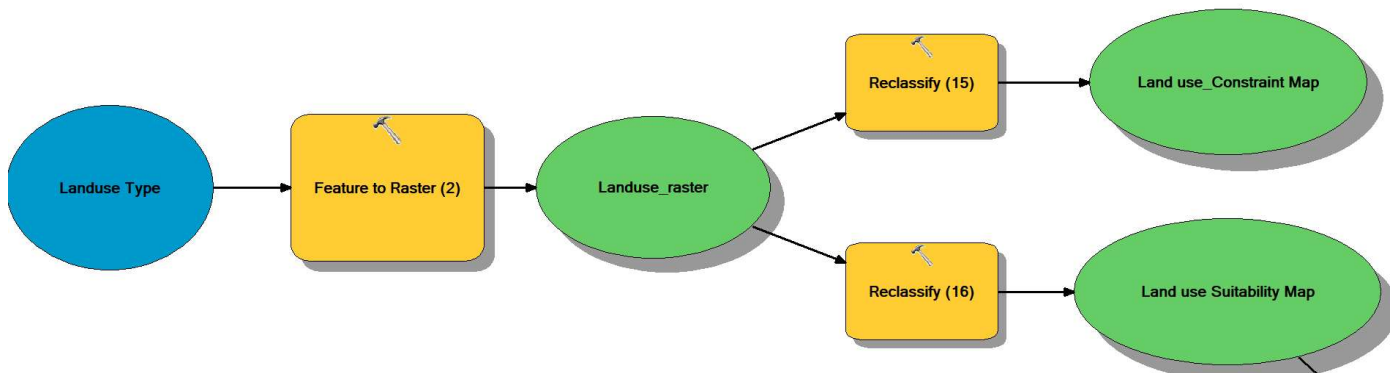Figure 5.20 Land use Constraint and Suitability Map Workflow in Model Builder
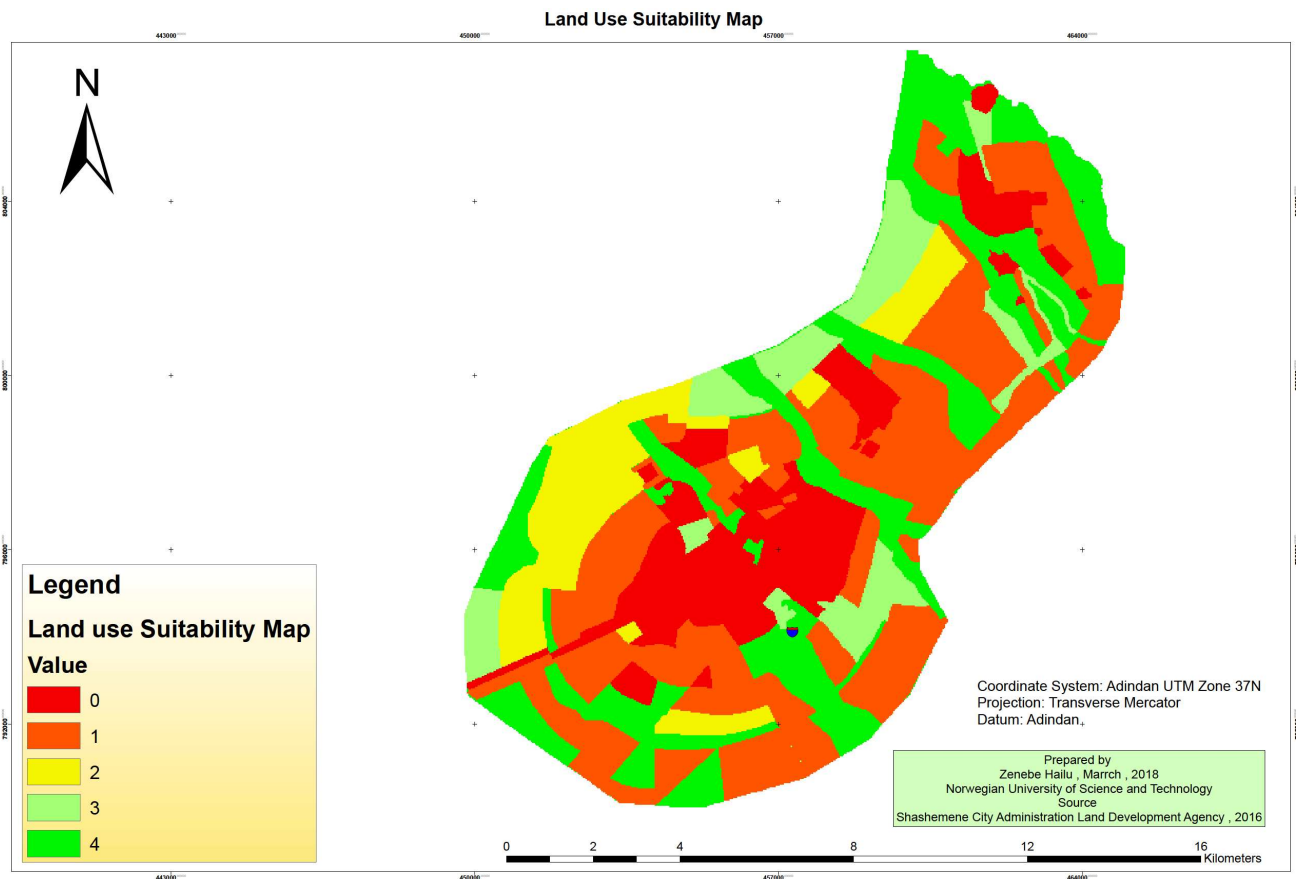

Figure 5.21 Land use /Land cover Suitability Map in Shashemene City

Accordingly, about eight land use/ land cover classes are obtained through on screen digitization method namely, agricultural and green areas , commercial area, existing residential mixed use area, forest, manufacturing and investment areas , open area, proposed mixed use residence and protected , market and reserved areas. Based on their similarities and suitability scales all these land use/land cover types would be grouped and merged together in to five suitability classes in this thesis. While Commercial sites and existing residential mixed use areas are ignored from further analysis due to their major constraint in landfill construction, forest area, open area, agricultural and

green area and investment area have got a higher suitability scale of 4, 3 and 2 respectively. The higher the suitability scale, the higher the suitability value they have for a landfill location. The rejected values (missing data) have a 0 suitability scale covering the most central part of the city where commercial and residential activities are common.

5.6.5 Rivers Suitability Map

The stream data which have been obtained from the structural plan of shashemene city has been used as a factor affecting the location of landfill site in the city. So as to overlay the stream with other factor maps and investigate its contribution to site suitability analysis, the buffered stream data have been reclassified in to five suitability class. Keeping the rejected values constraint, as in the analysis process, four suitability classes have been identified depending on how far each class values apart from the proposed landfill site. Unlike in the other factor maps, the nearer the location to the streams the more the suitable for choosing a dumping site (Nas et al. 2010).

So as to generate a constraint and suitability maps for stream data, the input river data (in blue color) have been buffered with Euclidean distance measurement from spatial analysis tools and then clipped based on the city's boundary extent to obtain a stream buffered data. This stream data have then been reclassified as those having constraints and those rivers with suitability for a landfill development. This step by steps procedure is show on figure 5.22 below.

Figure 5.22 Stream Constraint and Suitability Map Workflow in Model Builder
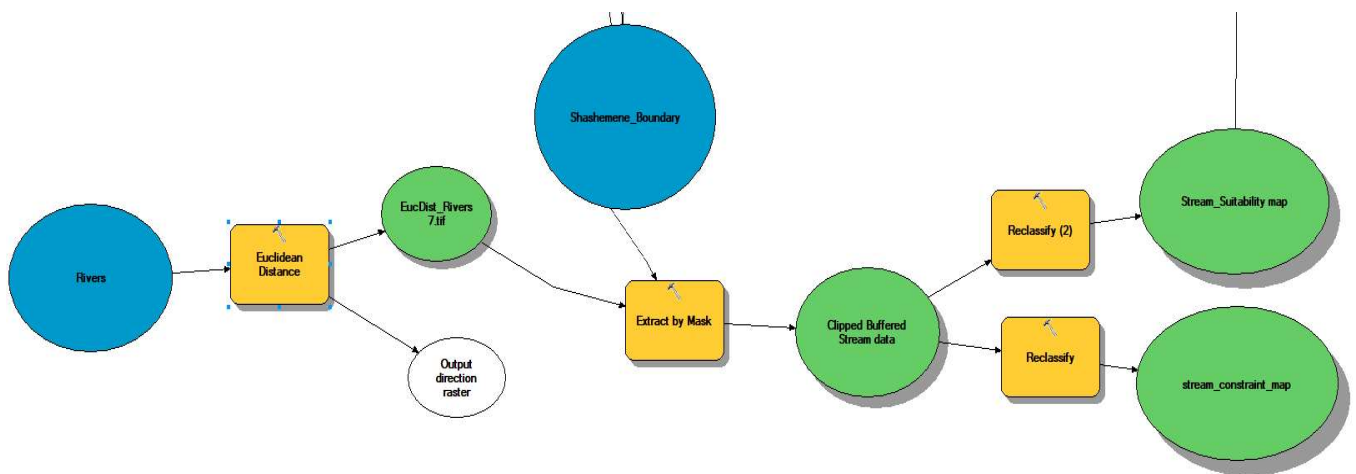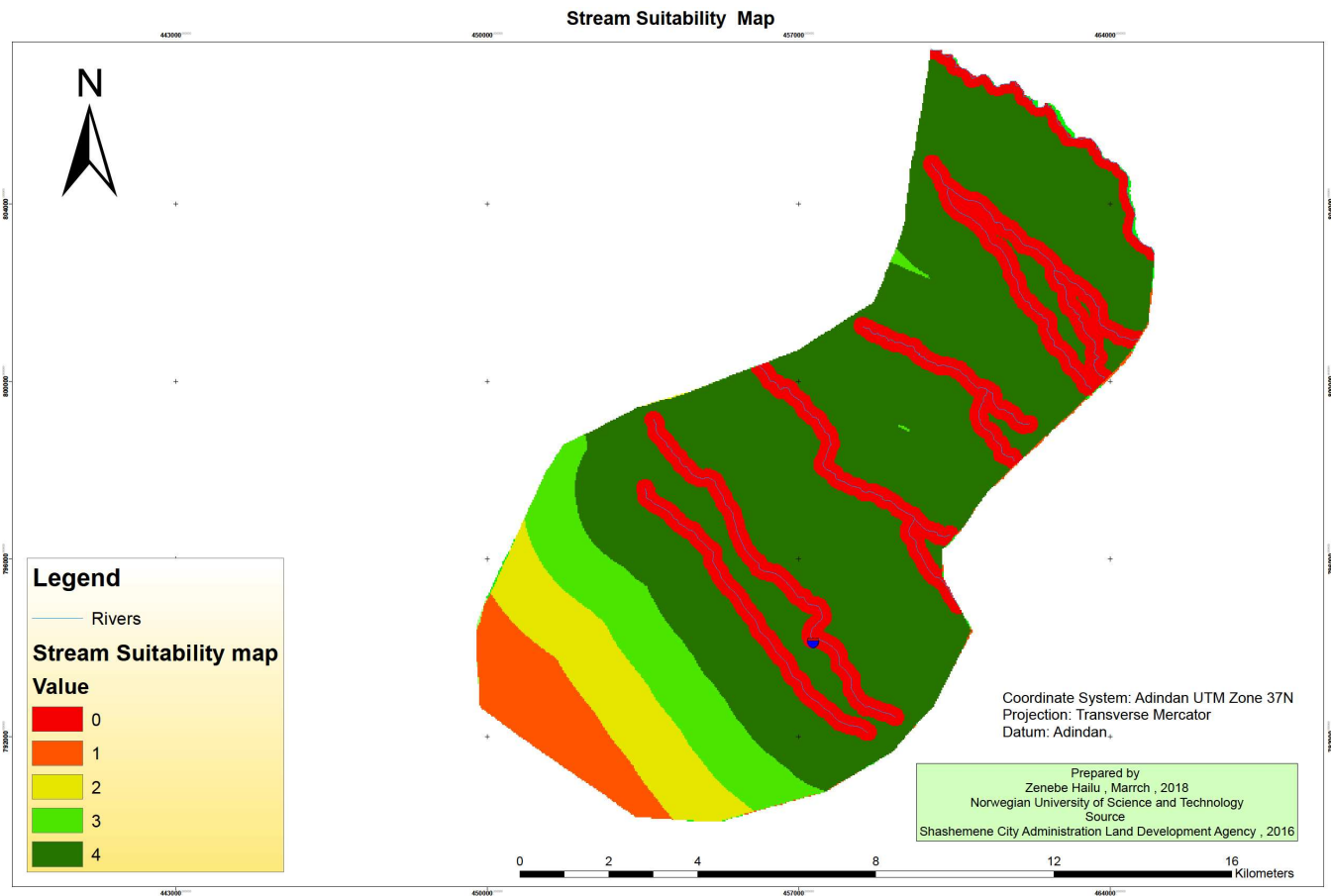
Figure 5.23 Stream Suitability Map in Shashemene City

As it is shown on the map 5.18 above, most part of the city's area falls within a buffer distance of 200m-1573m, which is represented by suitability scale of four covering the light green area on a map. This means in other words that, most central and northern half of the city is drain by rivers than the southern part of the city. As result for this particular map, suitable areas would be towards northern half of the city, keeping the influence of other factor constant.

5.6.6 Schools Network Suitability Map

Suitability of a given land for a dumping site can be influenced by different factors. One of these is its distance to the existing school network .The more nearer to schools; the lower suitability and the more distant the a given land to schools, the higher its preference for selection. Similar studies have been conducted in different parts of the country. Generally areas within a buffer distance of 300m from the existing social services are not suitable for landfill site development while areas located at a distance greater than 300m are suitable for the selection of appropriate landfill site (Berisa & Birhanu 2016).

The point data representing the location of schools are buffered with Euclidean distance measurement and clipped based on the study areas boundary extent. Once buffered distance from schools data was obtained the next task was to reclassify in to suitability scales and constraints.

Figure 5.24 Schools Constraint and Suitability Map Workflow in Model Builder
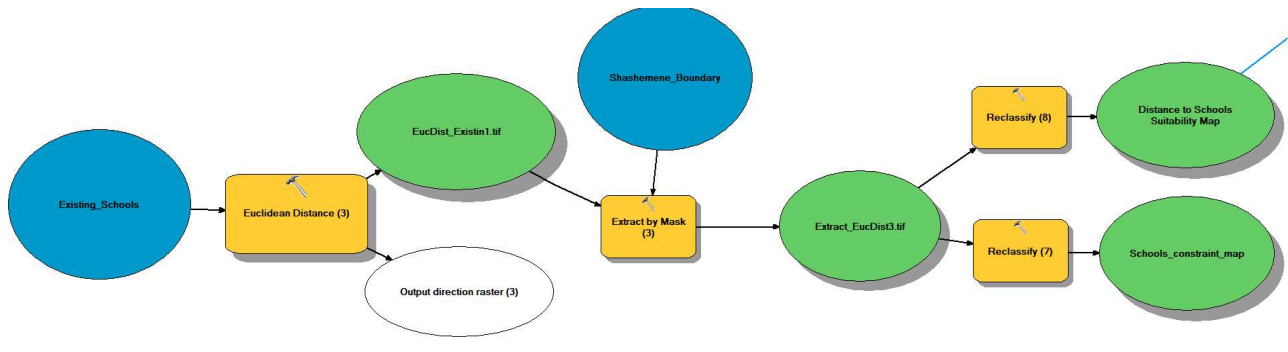
Therefore, distance to a proposed landfill and suitability are directly related, the more apart schools and a landfill site is located, the higher the suitability of a given land. Figure 5.19 shows, remote areas bordering the city are highlighted as more suitable than those located in the central part of the city.
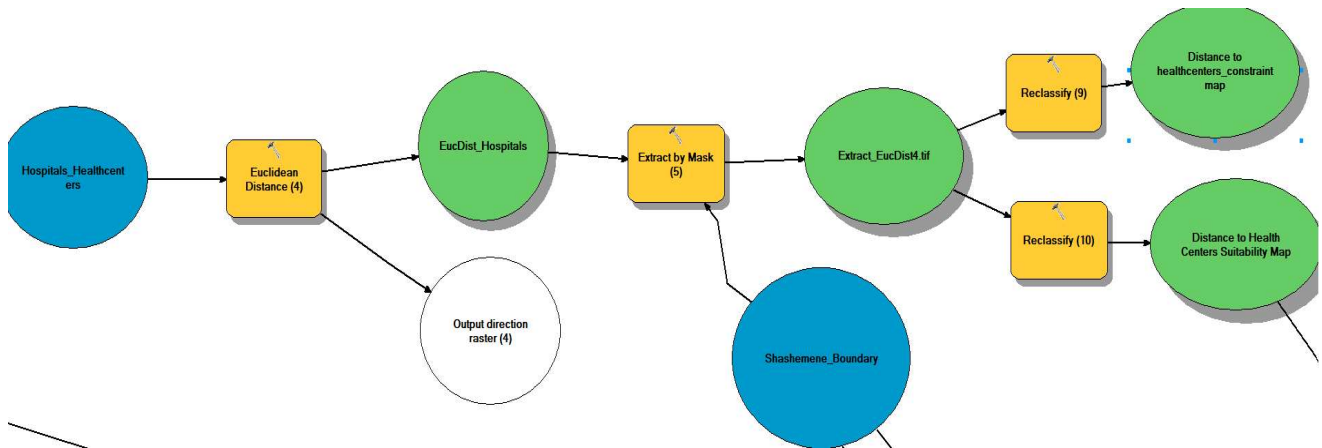
Figure 5.25 Suitability Map of Distance from Schools Network in Shashemene
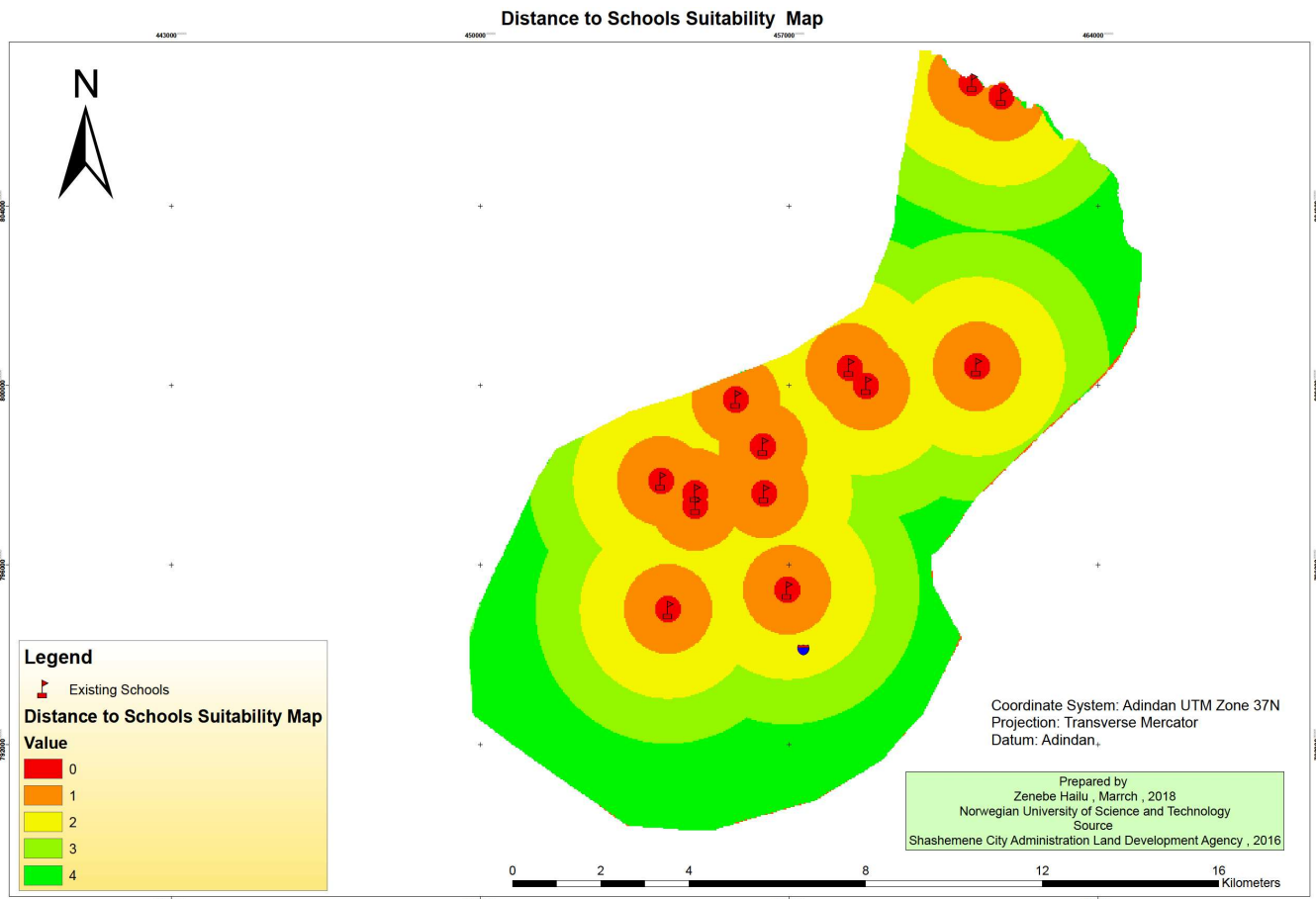
5.6.7 Health Centers Suitability Map

As shown in figure 5.20 below, health center are unevenly distributed in Shashemene town. The distance from each health centers to any part of the town is measured using the Euclidean distance measurement from spatial analysis tool. But this map has to match with the other layers for carrying out a weighted overlay analysis. So as to make suitable for overlay with other layers, distance from health centers map has also been reclassified in to five suitability classes with interval of 1000m meters from the already defined constraint distance to the rest part of the city's boundary. As the gap between a landfill site and health centers gets higher, suitability preference of the land will get higher. Similar steps have been followed for a point data representing health centers in the modelling wizard. Buffering the point data with Euclidean distance measurement , extracting by musk the output with shashemene city's boundary and reclassification operations have been done to obtain a constrain and suitability map of distance to health centers data for landfill site selection process. Each steps have been show on the figure 5.26 below.

Figure 5.26 Distance to Health Centers Constraint and Suitability Map Workflow in Model Builder

See figure 5.27 below for details.

Figure 5.27 Suitability Map of Distance to Health Centers in Shashemene City
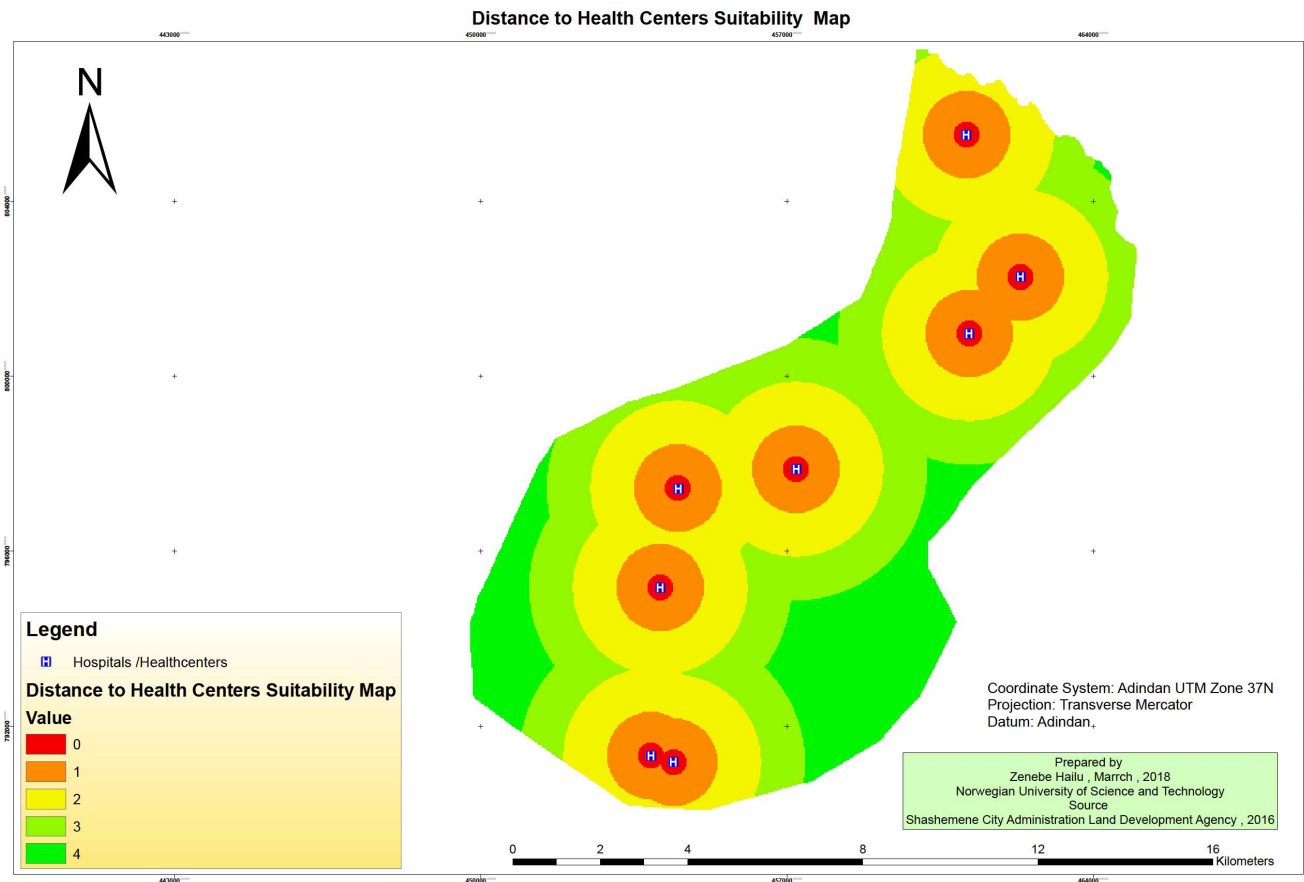
Areas very far to health centers are highly suitable for locating a landfill sites and therefore are given a higher scale value (Value number four) whereas areas located near to health centers are given lower scale value (value number one). Here like for schools, the distance and suitability have a direct relationship.

5.7. Ranking, Rating and Weighting Factor Maps

The suitability model in this thesis included three steps: identify site selection constraint and suitability factors, rating and ranking the suitability factors, and weighing the factors selected and finally implementing the suitability model. Rating, ranking and weighting are the remaining procedures discussed below.

5.7.1 Ranking

After Euclidean distance calculation, reclassification of the raster layers has been carried out. Reclassification is indirectly refers to putting the suitable values (ranks) in their suitability order. This was done simultaneously during the reclassification process (Meaza 2009). Arranging entities and

their attributes is not arbitrary made. Ranking and specifying the suitability class values have been made based on document analysis and experts comment and suggestions during the field work. The ranking of suitability classes are grouped in to five suitability classes namely high suitable, moderately suitable, marginally suitable, and currently not suitable and permanently not suitable areas. Accordingly, permanently not suitable areas, area that are rejected from consideration are ordered with suitability rank of zero while suitability class 4 , 3,2 and 1 are ranked as high suitable , moderate suitable , marginally suitable and not suitable respectively. See figure 5.14 – 5.27 under reclassification part of this thesis.

5.7.2 Rating

Once the suitability classes are ranked in order, the next step was to numerically value a given factor based on extent of strengthen or weakness of influencing a given variable in comparison with the others. Rating is refers to an evaluation, usually expressed in numerical terms, of how suitable a site is supporting a specific land use (Meaza 2009). Numeric scores to a total of five (one as least and five as most suitable) are assigned to each factor attribute class. Comparisons between classes were based on their level of suitability with respect to the choice of optimal site selection for a landfill. Since environmental factors for each specific study areas are different with others, there is no uniform standard for rating factors. For this thesis however, factors are rated based on the situation of study area, review of literatures and suggestion from experts. For example, a site having a slope over 12 degree is assigned a rating of zero (rejected area) while area with slope steepness less than 3 degree is rated one (highly suitable) for the location of a landfill site. This is related to cost of construction, transport and accessibility issues.

5.7.3 Combining and Weighting Factor Maps

In practice, it is usually unsuitable to give equal importance to each of the criteria being combined. This is because evidence needs to be weighted depending on its relative significance. Hence, each attributes are evaluated according to weighted criteria, resulted in a ranking on a suitability scale (Saaty 2003).

First ranks are given and based on their rank, their rate of influence or weights are determined using the software. Finally, the resulted weights are converted in to percentage, which is mostly named as normalized weight. Normalized weight is obtained after dividing the weight of each factor by their total weight. Weight of factors and variables were determined depending on the importance of each

variable in comparison with the others in the same factor group as well as between environmental factors. See the table 5.2 below for details.

Table 5.2 Ranks and Resulted Weight of Factors in Percentage

S.N	Factor	Weight	Weight in Percent (%)
1	Distance to well	0.20	20
2	Distance to rivers/streams	0.20	20
3	Distance to Schools	0.15	15
4	Distance to Health Centers	0.15	15
5	Distance to Main Roads	0.10	10
6	Land Use /Land Cover	0.10	10
7	Slope	0.10	10
Total			100

As a point of departure, in this thesis work, priorities, ranks, rates and weights are given based on reviewing different literatures, personal judgments and including experts' idea. Distance from wells, drinking wells, ground water and rivers, should get similar weights but higher than others influencing factors in landfill site selection process due to their sensitivity to pollution and health problems followed by social and infrastructural services and a land use (Nas et al. 2010). As much parts of the city area has a relatively gentle slope and flat topography, slope have been given lower weight in influencing the landfill selection process. The following table describes the details of the ranking, rating and weighting of factors in landfill suitability assessment in the city of Shashemene.

5.8. Weighted Overlay Analysis

Giap et al. (2003) has defined Weighted Overlay as a technique use to integrate and combine different factor maps with common measurement scale values to produce one final integrated output.

''Geographic Problems often require the analysis of many different factors using GIS. For instance , finding optimal site for irrigation requires weighting of factors such as land cover , slope , soil and distance from water supply'' (Giap et al.2003).

The Weighted overlay Process allows us to set weights for as many different factors as we want to analyze. The weight establishes the relative importance of the factor under consideration. The sum of the weights must equal to 100 percent. Using the Weighted Overlay tool found under spatial analysis tools, the values of each dataset can be weighted and combined at one time (Giap et al.2003).

So as to fit and overlap different factor maps, however, all inputs in the Weighted Overlay tool must contain discrete, integer values. Land use is already categorized into discrete values; for example open area with a value of four being the highest suitable land use type for a landfill selection while commercial areas, existing residence and protected areas are rejected from consideration as they are permanently unsuitable for landfill site development. Therefore it was simply to adding this datasets directly into the Weighted Overlay tool and assign each cell a new value on the common measurement scale of five. It was now ready to combine the derived datasets and land use to find the most suitable locations. The values of the derived datasets representing slope, distance to Health centers, distance to main roads , distance to wells , distance to rivers and distance to schools have all been reclassified to a common measurement scale (more suitable cells have higher values). The land use dataset is still in its original form because we can weigh the cell values for this dataset as part of the weighted overlay process. If all datasets were equally important, we could simply combine them, giving each equal influence; however, based on the already collected data and predefined ranking and rating, factor maps have different percent of weight. Therefore, weights for each factors is shown on table above have been discussed below in details. There weights results are inserted on the weighted overlay table .The higher the percentage, the more influence a particular input (factor map) would have in the suitability model. As a result the weight for each parameter is assigned as follows.

With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of the results to yield a suitability map (Equation 3).

$$S = W_i X_i \text{ (3) Where:}$$

S= suitability

W_i= weight of factor i

X_i= criterion score of factor i.   Javaheri et al. (2006)

To prioritize the influence of these factor values, weighted overlay analysis uses evaluation scale from 1 to 9 by 1. For example, a value of 1 represents the least suitable factor in evaluation while, a

value of 9 represents the most suitable factor in evaluation. Determining the weights is, however, quite controversial and is basically accomplished by decision-makers through reviewing the criterion and their relative importance concerning the objective to which they contribute (Siddiqui et al.1996).

Reclassified distance to wells suitability map …………………..20%

Reclassified distance to Rivers suitability map ….......................20%

Reclassified distance to schools suitability map…………………15 %

Reclassified distance to Health centers suitability map………….15 %

Reclassified distance to Main Roads suitability map …………...10 %

Reclassified Land use suitability map …………..………………10%

Reclassified slope map suitability map …………………..…...10 %

As it is indicated above, slope map have been given smaller weight .i.e 10%. This is because the study area lies in relatively flat topography and based on observational experience a landfill can be located in almost all parts of the city's boundary with exception of few areas in south central and northern parts of the city. The influence of the slope is clearly visible on the weighted final map where most unsuitable areas are on built up, commerce and residential sites than in higher slope   areas.

About 96 % of the city's land has a slope steepness of less than twelve (12) degree. This amount of steepness is still acceptable for a landfill development project. Therefore the slope map of the city has a minimal role in determining the city's suitability assessment for optimal dumping site selection. On contrary, distances to drinking water well and rivers have been given the highest weight. This was because unlike other factors, how far or near a proposed landfill to these locations considered more than the others factors. Whatever the flatness of a topography or suitable land use exist in a given location if a landfill is situated around drinking water wells or rivers, the life of the people living in that particular area would be under serious situation. Therefore, they are given the highest weight. i.e 20 % for distance from water well/reservoir and rivers respectively followed by distance to social service facilities such as schools and health centers 15% each.

Land use, distance from main roads and slope steepness have been given the smallest influencing weight constituting 10 % each. Having finished ranking, rating and weighting these factor maps, the

weights in decimal are normalized and change in to percentage. Finally, a weighted overlay tool from spatial analysis tools have been used and factor maps are inserted in accordance of their weighing in weighted overlay wizard in model builder.

Since the main objective of this thesis is to assess the suitability of landfill site in the city of Shashemene, all areas in each factors maps having constraint are made restricted and the rest are given a suitability scale from the highest four to the lowest one suitability scale. The weight in percentage are applied against each factors. See resulting map in figure 5.28 below.

Figure 5.28 Final Suitability map for a landfill Site Development in Shashemene City
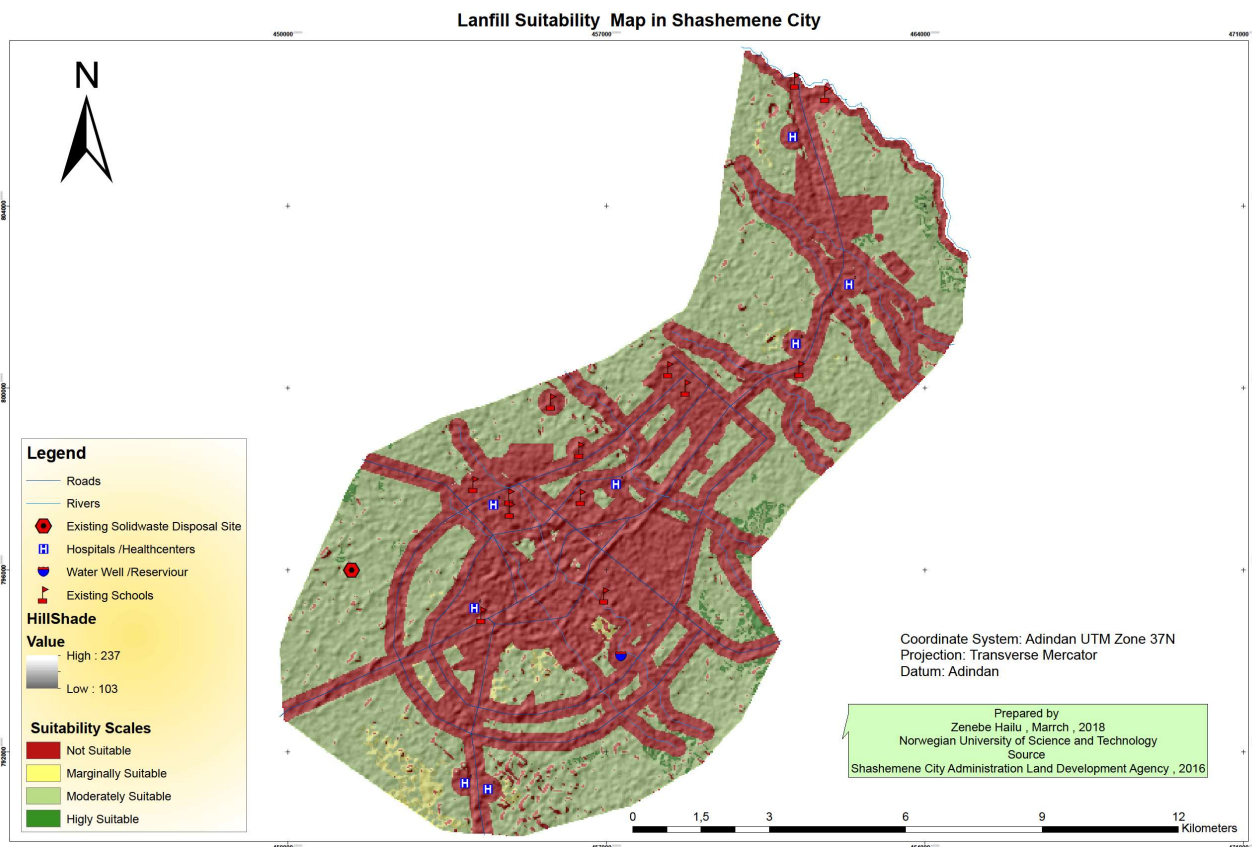
As it is shown above on figure 5.28, suitability of a land increases with the value. The higher the value the more the suitability for a landfill development in this thesis analysis. Therefore least and no suitable areas are shaded with a red color and are given low suitability scales while suitable areas are given higher suitability scale and shaded with green colors. Highly suitable areas for a landfill development cover very small area and are represented by a dark green color on a final suitability map. They are located along the south eastern, north eastern and south western borders of the city, constituting approximately 1.1% of the total area of the city while unsuitable areas cover the central and wider area of the city of Shashemene, constituting approximately half of the city's areal coverage.

South central and northern parts of the city where there exist built up and services facilities areas are shown as unsuitable for a landfill site development. Due to some constraints, the area that lie on commercial and residential land uses are made restricted during the weighted overlay process. The details of which suitability scale covers what portion of the city is show on the table 5.3 indicated below.

5.8.2 Proportion by Area of Suitable Sites

Table 5.3 Proportion by Area of Suitability for a landfill

Factor	Value	Count	Area in Hectare	Proportion (%)
Weighted Overlay Map	0 &1 (Not suitable)	65245	58720,5	49 %
	2 (Marginally Suitable)	1886	1697,4	1.4%
	3(Moderately Suitable)	64397	57957,3	48.5%
	4 (Highly Suitable)	1614	1452,6	1.1%

As can be seen from table 5.3 above, suitability scale values 4, 3 and 2 are identified as suitable for the selection of a landfill site in Shashemene city. Approximately about 61107.3 hectare of the city (51% of the total area) is identified in general as suitable for a proposed landfill site location while the remaining 58720, 5 hectare (about 49%) of the area is both currently not suitable and permanently not suitable for landfill development.

Chapter Six

6. Conclusion and Recommendation

6.1 Conclusion

Now a day, many cities and towns are growing rapidly in our country, Ethiopia. Among the fast growing towns and cities, Shashemene is probably the prominent one. Its strategic location and lying along the ancient long distance trade route has made the city to be the primary choice for investment and trade center in southern parts of the country. This postiontional advantage has been resulting in rapid growth of urban population and expansion of a number of industries, factories and service sectors such as hotels, restaurants, small and micro enterprises in the city.

This development however has been at the expense of human health and the natural environment. As the city grows, so does the amount of waste production specially the solid hazard waste. Even though Shashemene city is growing at faster rate, there exist a number of problems especially in the down town area. Large volume of waste production, improper disposal of waste, overcrowdness, expansion of slums and illegal settlements are some of the major problems in the city's municipality is facing.

Due to lack of adequate finance and organization problems, the city's municipality is unable to handle and manage the large volume of waste production and the rapid urban population growth, which in turn is resulting in sanitary related problems in the city. Because of Improper waste management practices and limited public and community toilets, people are being forced to dispose their wastes in any open.

So as to reduce if possible avoid these problems, the application of Geo-information systems on landfill site suitability assessment have been done play a vital role in addressing the problem and effective management system in this thesis. Although the city has already one solid waste disposal site located in South Western part of the city, it has not been chosen properly and not even being used wisely. So as to fill the existing gap and forward solution, GIS based assessment of optimal solid waste disposal site have been carried out in the city.

Although many factors can influence the selection of best sites for a landfill in the city of Shashemene, due to time and financial limitations , the researcher have focused on factors of slope, land use , distances from social service, distance from main roads, distance to water well and stream network data.

In general, the assessment process has passed through a number of steps. After the data creation i.e. obtaining GPS points, land use map and road map, euclidean distance have been calculated to identify the nearest and farthest areas from the roads, rivers , water well and GPS points. Similarly, identify

the suitability scales of the resulted values, reclassification was mandatory and reclassification processes have been executed. Having reclassified each parameters, weighted overlay tool from spatial analysis tools was used on model builder. Weight of each factor maps is determined, where ranks are given and the rate of influence of each factor maps determined based on their rank. The weight for each criteria map was however given based on reviewing literatures, personal filed experiences and judgements and including experts idea.. Among the factors, distance to water well and stream data have been given 20% of weight each while distance to health centers and schools have 15 % each. Land use, distance from main roads and slope steepness have been given the smallest influencing weight constituting 10 % each. This was due to their lower determining role in landfill suitability assessment in the study area.

As a result, highly suitable areas for a landfill development cover very small area in southeastern, northeastern and southwestern borders of the city, constituting approximately 1.1% of the total area of the city while unsuitable areas cover the central and wider area of the city of Shashemene, constituting approximately half of the city's areal coverage.

Approximately about 61107.3 hectare of the city (51% of the total area) is identified in general as suitable for a proposed landfill site location while the remaining 58720, 5 hectare (about 49%) of the city's area is both currently not suitable and permanently not suitable for landfill development. Most parts of South central and northern parts of the city, where there exist built up and services facilities are shown as unsuitable for a landfill site development. Due to some constraints, the area that lie on commercial and residential land uses are made restricted during the weighted overlay process

6.2 Recommendation

So as to cope up with the large volume of waste produced from manufacturing industries and service sectors such as hotels, restaurants, small and micro enterprises , Shashemene city's municipality need to exercise good governance in its Waste management system. Democratization of the system and working in closer with the local administration office (kebeles) and even down to community and household level is crucial to solve the problems of improper collection and disposal practices. Public awareness and participation, as some of the core principles of integrated waste management system, are required to be give much emphasis in the city's waste management agenda. This is because lack of public awareness and improper waste disposal practices are among the most challenges the residents are complaining.

Households as the pillars of the large community needs to be give much attention and focus during all phases of waste management processes starting from wastes collection ,sorting treatment and final disposal phase.

Financial problem is another challenge the city municipality is facing today. This problem could be solved through democratizing the system and involving local community, and planning and practicing different fund raising programs. Once these problems are solved at their initial level, the next big challenge .i.e the optimal landfill site can be overcomed through modernizing the system and applying GIS technologies to carry out site suitability assessment for an optimal landfill site.

Therefore, in order to have effective planning, there is a need to carryout Site suitability analysis for hazard waste disposal and management of sanitary problems in the study area. Even though the results of the suitability assessment in this thesis have been seen as accurate and successfully accomplished with in the given time frame, more accurate and better than this result can be achieved if researchers or other concerned bodies try to include others factors maps in addition to the factor maps used during this thesis work. Finally, the researcher recommends if other interested individuals scarify their time and cost to study the suitability of the town from different angles. 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 city of Shashemene.

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