Midlands State University

Established 2000

Our Hands, Our Minds, Our Destiny

DISSERTATION

FOR

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BSc

HONORS DEGREE

IN

GEOGRAPHY AND ENVIRONMENTAL STUDIES

TITLE:

A GIS and Remote Sensing based modelling for landfill site selection. A case of City of Gweru, Midlands Province, Zimbabwe.

ABSTRACT

The aim of this study was to determine suitable sites for locating a landfill in Gweru city. The study also sought to analyze the social impacts of the current disposal site to the local residents. Interviews with the City of Gweru and EMA were used to get the results on the social impacts of the current disposal site. Questionnaires and observations were also used to complement the interviews. The impacts of the disposal site on soil quality was determined in this research. GIS and remote sensing were the major methods used in mapping the suitable areas as well as determining sampling points for soil quality tests. Multi criteria evaluation and weighted overlay analysis methods were used in landfill site selection process. Factors used for landfill site selection were: rivers, settlements, road, railway, airport, slope and soils. Results of the study shows that social problems such as diseases, odors, deterioration of living standards and reduction in the value of land are prevalent in woodlands park residential area as a result of the disposal site. Soil sample results shows that there is high concentration of chemical substances (lead 66.93 ppm, cadmium 1.27 ppm and sulphides 89.53 ppm) at the disposal as compared to the control sample concentration (lead 0.01ppm, cadmium 0.1ppm and sulphides 20.02ppm). A suitability map was generated showing 5 sites that are suitable for landfill siting in Gweru. Suitable area occupied only 2.7% whilst 97.3% of the land is unsuitable. It was recommended that Gweru city council should consider terminating its existing disposal site for an improved site from the possible suitable sites established by this study.

DECLARATION

The research was carried out in Gweru City, Gweru District in Midlands Province. This research was done in collaboration with Midlands State University under the supervision of Mrs Mupfiga. The research presented in this dissertation represents original work done by authors. The research has never been submitted to any University or Colleges in any form. The Author acknowledges work done by authors through referencing in the text.

DEDICATIONS

I would like to dedicate this dissertation to my parents, brothers and sisters as well as my niece. There is no uncertainty in my mind that without their continuous support and guidance I could not have accomplished this process.

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My appreciations go to my dissertation supervisor Mrs. Mupfiga for assisting me throughout the research process. My sincere gratitude goes to the members of the Department of Geography and Environmental Studies, Midlands State University for their assistance during the course of the undergraduate period through supervision. I owe my thanks and appreciation to my brothers, sisters and the family for their guidance and support. They also encouraged and motivated me during the course of my learning period. My special gratitude also to my mother M Mabvure for her constant prayers. All would not have been possible without the divine intervention of the almighty God.

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ACRONYMS

AHP	Analytical Hierarchy Process
CA	Constancy Ratio
CGIAR-CSI	Consultative Group for International agriculture Research
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
EMA	Environmental Management Agency
FAO	Food and Agriculture Organisation
GIS	Geographic Information System
GPS	Global Positioning System
LULU	Locally Unwanted Land Use
MCA	Multi Criteria Evaluation
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
MSW	Municipal Solid Waste
UNEP	United Nation Environmental Protection
USA	United States of America
USGS	United States Geological Survey
WHO	World Health Organization
ZMA	Zimbabwe Military Academy

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Landfill siting is currently, a challenge in urban centers of the world resulting in the accelerated rate of illegal disposal sites. Sharif (2009) indicated that a rapid population increase and cumulative per capita income have added in the accumulation of municipal solid waste, causing a severe hazard to the environment and people. This is predominantly significant in third world countries where bulky amounts of municipal solid waste (MSW) disposed without taking serious cautions about the environment and people, thereby putting burden on threatened land, air and water. The challenge of landfill siting is causing more harm to the people as some municipal solid waste dumped at disposal sites that are not properly lined and sited. The impacts of such negligence cannot be tolerated more when GIS presents opportunities for a better landfill siting techniques.

Municipal solid waste disposal in developed world is a responsibility of both the local authorities with the help of the private individuals. Waste is becoming a resource in developed countries as experienced in Netherlands importing tonnes of waste to recycle. Type of waste produced in developed countries ranges from electronic, metal, plastics and solid waste but only few ends up in landfills. Developed countries such as USA, Canada and Japan have set standards that they use in locating the landfills so as to reduce the implications associated with these detrimental facilities. Recycling and Reuse are regarded as best practices in waste management in developed countries.

On contrary, developing countries struggle to manage their Municipal solid waste as the local authorities' budgets will dwell much on development than of waste management. Utilization of every area in developing countries in a major cause results in the problem of improper waste management. As city's population increases, more land is being utilized for infrastructure development and industrial resuscitation neglecting the issues of waste management and other related issues.

Some developed countries are using methods such as incineration and recycling, but because of the costs associated with the above mentioned methods, developing countries adopt the method of landfill siting as the best and cheapest method. However, this method is associated with heath risks and environmental problem if not properly sited according to the set standards.

Sthami etal (2008) and Kontos (2005) postulates that, improper siting of landfills mostly affects the well-being of humans, especially the vulnerable poor communities without adequate health access and proper sanitation.

Assessment has been done that about 80 percent (%) of the municipal solid waste produced around the world is ending up in landfills. However, according to (Zimstat 2005) the amount of municipal solid waste that is disposed accelerate to 95% because of lack of technological advancement. Nas etal (2010) highlighted that the structure of land filled municipal solid waste is not uniform henceforth differs considerably amongst countries of different socio-economic backgrounds. The composition of municipal solid waste is usually organic as well as inorganic matter. According to Downmore etal (2011) the issue of solid waste management in Zimbabwe ranges from collection to disposal of waste. Of great concern for this study is Gweru municipal disposal site, which is now becoming more of a problem than a solution to municipal solid waste.

The rain water filtering through Gweru disposal site's diverse disposed materials, ranging from factory waste to car batteries, becomes a poisonous solution which end up into the Gwenoro Reservoir, Gweru municipal water supply. Current disposal site is also not in line with EMA standards as indicated in statutory 6 of (2007) and has been condemned several times as illegal by the Environmental Management Agency Zimbabwe. Therefore, the research sets out to explore the impacts of the current disposal to the environment and the local people.

1.2 Statement of the problem

In the present day world, locating a landfill for waste disposal is a noteworthy problem faced by decision makers. Developing countries are facing this challenge mainly because they are not integrating landfills in the pre-planning of their urban centers. In most cases landfills will be located after human habitation causing more harm to the urban populace. In Zimbabwe this challenge is prevalent as most of the cities have disposal sites that are associated with hazards to the local people. Gweru city council is one of the towns with this major problem as it is currently using the disposal site at woodlands residential area 25m away from settlements and 1.6km away from Mtapa residential area for waste disposal. However, the current disposal site has been regarded as unsuitable as it is not in line with International and national standards on waste disposal. As the City of Gweru is expanding the disposal site ended up located in built up areas. The disposal site normally catches fire in summer as a result of deliberate action of

the squatter residents and or combustion from rotten matter. According to Chadenga (2017), at nights and still days, the smoke from Gweru disposal site spreads slowly across Woodlands, Mtapa, Infill, Ascot and Mkoba housing areas creating a health hazard to the residents. The disposal site is posing hazards as runoff water comes from the area (Jerie 2005). Therefore, this research intends to do a suitability analysis so as to find an optimal landfill site with no limited effects to the environment and the people sing GIS and remote sensing.

1.3 Justification of the study

The study presents an opportunity to the City of Gweru and the affected people (Woodlands, Infill, Ascot, Mtapa and Mkoba Residents) in relocation of the disposal site that is currently located near woodlands residential area. The current disposal site is causing health risks to the people through air pollution and water pollution respectively (Jerie 2007). This study will assist the responsible authorities to select an optimal landfill site with minimal effects to the environment and the people.

In the social sector, amenities such as landfills are essential as part of the contemporary societies solution to solid waste. In this regards, their location in relation to any development needs to be wisely planned in order to satisfy the needs and wants of the people in as much as waste management is concerned. In most cases, factors such as distances from the rivers, settlements, road, rail, shops and other related developments need to be taken into consideration. Therefore, using GIS and Remote Sensing town planners will be assisted to place a landfill where social, economic and ecological concerns are minimized.

This study is also an important measure in solving environmental problems associated with current disposal site in Woodlands suburb. Landfills has been known by impacting negatively to the environment and the surrounding community, so this study is imperative as it will explain the environmental and ecological impacts that are associated with the current disposal site and also proposing on what can be done to reduce these impacts.

The legitimization of this study, after recognizing basic methods for siting landfills, is to come up with an optimal landfill siting method employing Geographic information system. The demonstrate will be tried in City of Gweru municipal boundary with the intension to be connected in all other cities as before long as this investigate demonstrates to be valuable and imperative.

1.4 Objectives of the study

1.4.1 General Objective

- ✓ The general objective of the study is to determine the location of landfill site using GIS and Remote Sensing.

1.4.2 Specific Objectives

- ✓ To identify social impacts associated with Gweru City disposal site.
- ✓ To evaluate impacts of Gweru city disposal site to soil quality.
- ✓ To determine suitable locations for a landfill site for Gweru City.

1.5 Description of the study area

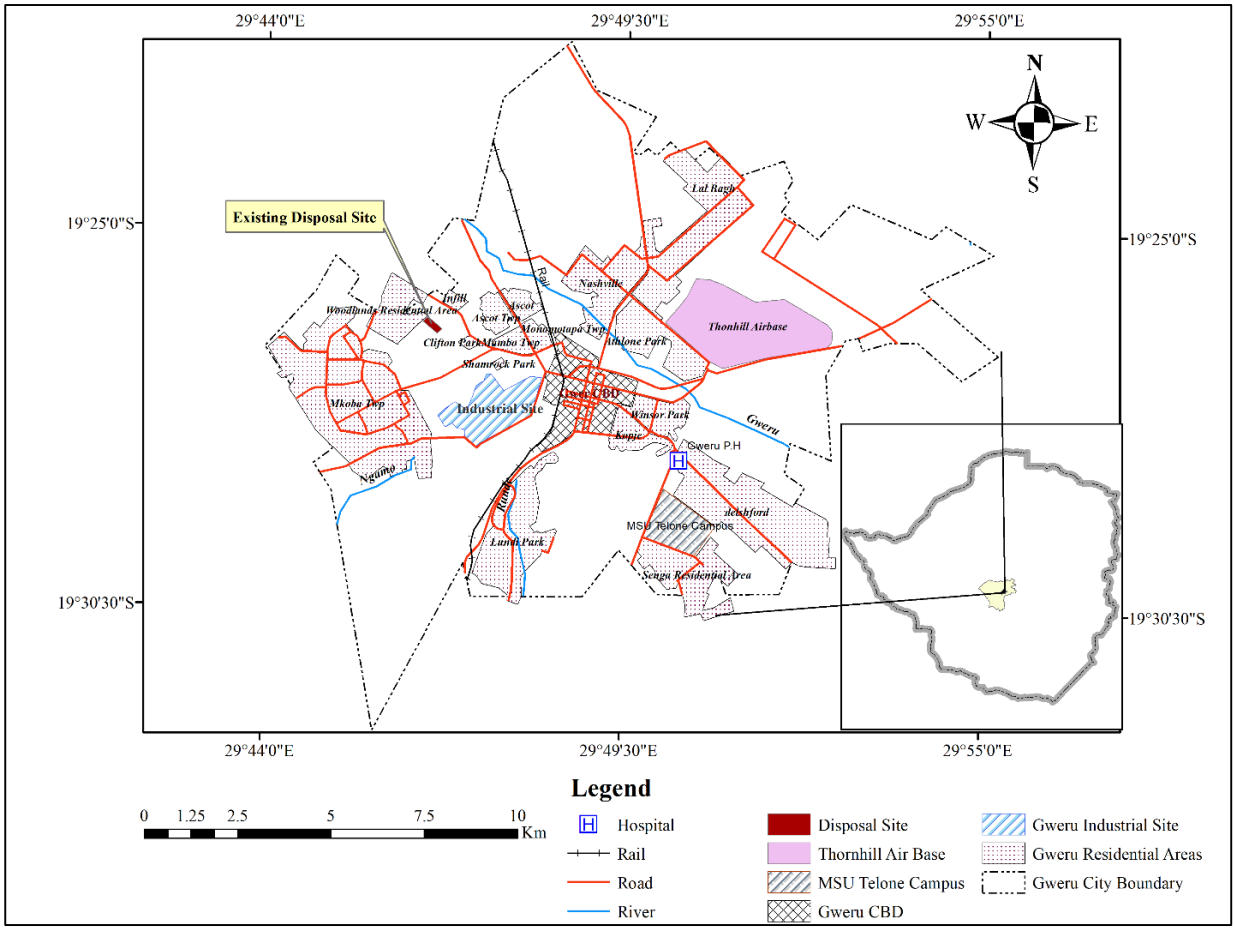

Figure 1.1: Study Area Map

(Source: Author)

1.5.1 Physical characteristics of Gweru City

The Area under study is Gweru City in Midlands Province. Hydrologically, the area under study falls within Sanyati catchment and is generally drained by Lundi, Ngamo and Gweru River. Drainage in the area is generally dentritic and follows a south-east trend. Elevation ranges from about 1300 m to 1400m that makes it a highland.

Geologically, Gweru city is dominated by Fersiallitic soils. Nyamapfeni (1991), depicted these soils as Fersiallitic soils which are inferred from stone and are basically found in districts where mean annual precipitation is around 650mm and they include by distant the biggest range of granite-derived soils in Zimbabwe. The Fersiallitic soils span a range which envelops Normal Locale II to IV. Glang (2002) moreover portrayed soils found in these zones as tolerably filtered soils of the Fersialittic group. These soils range from the sandy soil to clay in other regions. They are susceptible to erosion due to poor particle grading and weak consolidation. They, therefore, require high input use and good conservation in establishment of landfill sites.

1.5.2 Socio-economic description of the study area

It is key subject in carrying out any planning activity, having knowledge of population size of any urban centre is very important. Gweru urban district has an estimated population of 48 459 as of the year 2012 (ZimStats, 2012). The proportion of male and female population is 23 703 and 25 265 respectively. Gweru is the major city in the midlands province, offering services such as retail, manufacturing, education and residential. Rates of migration in the province are relatively high because people will be highly mobile to the city in search of the above-mentioned services offered by the city.

High rates of immigration have led to the emergence of other suburbs and expansion of the city in the past years. Although the services are increasing as well as the population of the city one has to realize that issues of waste management are fairly remaining constant and eventually posturing hazard to the well-being of the people especially residents of Mkoba, Mtapa, Ascot and Woodlands.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

Chapter 2 examines the foremost significant literature found within the sources that are related to the issue of improper landfill siting and how it can be addressed. Problems related with urban waste disposal and contemporary waste management procedures in third world countries nations are moreover talked about. This chapter will too clarify the use of geographic information system in waste management and variables that are connected to decide optimal landfill site. Besides, the circumstance of the Zimbabwe disposal sites is looked into.

2.1 Waste management in urban areas

Solid waste is any fabric which is not in fluid shape and has no esteem to the individual dependable for it (Clarke 2015). According to Rikalovic, Cosic, and Lazarevic (2014), municipal solid waste alludes to waste from roads, workplaces, houses, and clinics, which are exceptionally regularly the obligation of municipalities or other government authorities. According to Moeinaddini (2010), disposal of solid waste is a major challenge facing most of urban areas because of urbanisation.

Collection, exchange and transportation of waste have been for the most part expected by municipalities in developing nations. The arrange shifts, be that as it may, as in most urban zones, deny is collected by an administrative office or private temporary worker, and this constitutes a fundamental and anticipated government work in such settings (Eskandari, Homaee, Mahmodi 2012).

Municipality solid waste disposal has hence gotten to be a major stress of concern for numerous under-developed countries, particularly as populaces increase. Gbanie etal (2013) states that, the issue of municipal solid waste management is compounded as numerous countries proceed to urbanize quickly. For example, 30-50% of populace in most under-developed nations is urban (Thomas-Hope, 1998) and in numerous African nations, the development rate of urban ranges outperforms 4% (Senkoro 2003).

2.2 Current situation in developing countries

Unlike the global north, most of the third world nations are exposed to challenges in managing municipal solid waste. While urbanisation in the third world countries is a major contributory factor in wealth accumulation, its impacts on the health of the people in the waste management sector cannot be undermined. The challenge is more prominent in most third world nation's cities where poor design, rapid urbanization, limited utilisation of recycling activities, inadequate management of hazardous and health care waste, lack of adequate resources and lack of legislation and policies for realistic long term planning exist.

As issues of waste are a responsibility of government environmental institutions, collection and disposal still lies in the hands of Municipalities. Involvement of the local people in waste management practises is now being adopted in some parts of the developing world where community based organisations are now doing recycling projects and earning money at the same time. Awareness programmes are being done but the issue of waste disposal remains fairly constant with the majority of people launching complains about waste collection and disposal. Incineration, composting and recycling are some of the alternatives that are used in the developing countries of the world. However, incineration is widely used in Hospitals and on hazardous waste. On the other side composting is only used when small quantity of biodegradable waste is generated. The majority of developing countries use land filling method of waste disposal. Waste separation at source is still a major challenge in most of developing countries resulting in the hauling of mixed type of waste comprised of bottles, plastics and steel to the landfills. Hazardous waste is also being transported to the disposal site results in the leaching of hazardous chemicals into underground water storage.

Although advanced methods of waste management are now used in countries such as China, Japan, South Africa and Egypt, most of developing countries still use landfill method as their way of managing municipal solid waste. This is because of the advantages associated with this method such as cheap to maintain and easy way to dispose waste. However, this method is also associated with several problems when factors such as proximity to settlements, proximity to water sources and geology are not concerned. This problem in most cases is because, waste management is regarded as a minor issue henceforth concentrating more to issues such as wars, political instability, diseases, hunger etc.

2.3 Applications of geographic information system in waste management.

According to Campell (1996), remote sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth's surface. Its multispectral capability provides appropriate contrast between various natural features where as its repetitive coverage provides information on the dynamic changes taking place over the Earth surface and the natural environment (Adeofun et al., 2011).

The use of remote sensing in the environmental studies is significantly increasing. In the contemporary world, no serious research of the environment performed without advanced image processing and analysis. One of the most important applications of remote sensing can be found in the case of solid waste landfill site selection where satellite images are used for extracting most of the site selection criteria used for siting landfill (Oštir et al., 2003) time and cost effectively. Moreover, remote sensing can provide digital data as an input for GIS.

GIS is a computer-based innovation and technique for collecting, preparing, overseeing, analyzing, displaying, and showing geographic (spatial) information for a wide range of GIS and applications (Eldrandaly et al., 2003). The part of GIS in solid waste disposal is exceptionally key and critical as numerous angles of its arranging and operations are exceedingly subordinate on spatial information. In common, GIS plays a key part in maintaining account information to encourage collection operations. In this way, highlights such as client benefit; examining ideal territories for exchange stations; planning headings for vehicles transporting waste from private, commercial and mechanical clients to exchange stations and from exchange stations to landfills; finding modern landfills and observing the landfill, are critical. GIS is a method that decreases time in finding a suitable site only, but it also offers a computerized information database for pending checking program of the location forthcoming monitoring programme of the site (Jerie and Zulu 2017).

2.4 Multi-Criteria Decision Analysis for landfill site selection

Decision analysis is a series of precise strategies for analysing intricate decision problems. These strategies incorporate separating the choice issues into smaller more justifiable parts; analysing each part; and joining the parts in a coherent way to produce a significant solution (Malczewski 1999). The main objective of MCDA is the plan of numerical apparatuses to back

the subjective assessment of a limited number of choice alternatives under a limited number of criteria in arrange to discover the most excellent decision (Pournamdarian 2010). Multi criteria decision analysis (MCDA) procedures can be utilized to recognize a single most preferred choice, to rank choices, to short-list a constrained number of alternatives for ensuing point by point evaluation, or essentially to recognize worthy from unsatisfactory conceivable outcomes. Multi criteria decision analysis has gained popularity both in the developed and developing countries after realisation that dealing with contemporary challenges needs all the factors applicable to be examined separately and incorporated jointly in decision making.

As a replacement for, it helps in decision-making to the stakeholders because they can organize accessible data, think on the results, investigate their claim prerequisites and resistances and minimize the credibility for a post-decision disappointment (Belton and Stewart 2002). Analytical Hierarchy Process (AHP) is one of the foremost commonly utilized MCDA method. Analytical Hierarchy Process is used especially when generation of weights is needed. This is further analysed sing weighted overlay analysis. According to Lunkapis (2010), these two methods complement each other as both acts towards determining suitable sites for a landfill location.

2.4 Factors for landfill site selection.

2.4.1 Proximity to water sources

Clarke (2015) postulates that landfills create detrimental gases and leakage that make them unfitting to be in proximity to surface waters. Since landfill is characterised by several types of waste, it pollution capabilities is high. Henceforth to avoid pollution of rivers and transmission of hazardous chemicals into underground water which can lead to bio accumulation of chemicals in the enact species, a landfill must be located far away from the streams, rivers and water reservoirs. Landfills that are located near water surfaces has resulted in the death of aquatic life and also health implications to the people who depends on surface water sources domestic use.

2.4.2 Geomorphology

Most of the developing nations use boreholes and wells as their home-use water, groundwater pollution issues are a main alarm. According to Kharlamova etal (2016), geologic physiognomies of a location are important consideration when situating a landfill. A key factor in diminishing the potential for pollution is largely depended on the geological characteristics

of the area. Soil textile with low hydraulic conductivity, low dynamic porosity, and high withholding of unsafe substances are incomparable for landfill areas.

2.4.3 Slope

Topography is a serious concern when siting a landfill (Matsa 2005). Preferred topographical surfaces must be gentle to reduce the accelerated rate of pollution to the areas far away from the disposal site. Steep slopes must be termed unwanted areas because they have the potential of polluting the surrounding areas of the disposal sites henceforth the gentle slope are suitable for locating detrimental facilities. It is also costly for the local authorities to construct a landfill on a steep slope and to avoid such costs the location must be restricted to gentle slopes. Slopes of less than 12% inclination are considered as the most suitable when locating a landfill.

2.4.4 Soil characteristics

Properties of soils is major concern in as much as landfill siting is concerned. Effective porosity, workability and permeability are traits of soil characteristics that must be taken into consideration when siting a landfill. Soils must be analysed and classified according to texture and selected accordingly. High clay and silts soils protect groundwater from contamination and these soils can be compacted easily. However according to Jerie and Zulu (2017) even if these soils are not present at the site, they can be hauled to the site by means of transporting them or substituted with geosynthetic system.

2.4.5 Proximity to residential areas

Socio-political antagonism to siting a landfill has been designated as the single greatest impairment to positively locating landfills (Rikalovic, Cosic, and Lazarevic 2014). The ‘not in my backyard’ phenomenon is both a significant deliberation and a challenge to landfill siting. The problems that are associated with landfills often resulted in them being unwanted more and not acceptable without considering the advantages associated with them.

Noxious smells, congestion and noise, transportation and deterioration of property values are some of the major problems professed by the urban populace. The costs problems associated with the siting of landfills are perceived in a proportional way that the increase in distance between the landfill and the human populace resulted in the reduction of the problems. As the distance from the landfill increase the perceived costs reduces, it is of great significance to consider the distance from population centres when siting a landfill site.

2.4.6 Airport

Airport and airbase have to be considered as critical factors when siting landfills. According to Eskandiri (2015), the airport factor though not significant in all the towns in developing countries, it has to be considered as important. The nature of airports/airbase is that aeroplanes are volatile in nature and if the landfill burn as a result of combustion several people will be affected.

2.4.7 Roads and railway

Roads and railway are also major transport mediums that have to be considered critical and important. Landfills must be located far away from the rail and roads. However, they must not be located very far away from the road so as to minimise transportation costs.

2.5 GIS projects in landfill siting

According to Kahila-Tani etal (2016) methods of landfill designing were established more than thirty years ago with maximum use in developed countries than in developing countries. Projects of landfill siting maximise use of GIS and remote sending techniques because it takes into consideration aspects to do with spatial data. In Zimbabwe, although the technology and knowledge of GIS and remote sensing is now widely spread, its application is not widely seen (Kharlamova, Mada and Grachev 2016). The Environmental Management Agency has long back condemned the use of disposal site advocating for Landfills but in cities like Gweru and Harare they are continually using ancient disposal site despite the harm they are causing to the environment. Nyarai, Willard, Moses and Ngezile (2016) indicated that waste management in Zimbabwe is still a challenge which needs to be solved with Geographic information systems.

International world GIS based projects has been carried out resulted in the proper siting of detrimental facilities. Parameters are set based on the location and available land and resources. For developing countries in landlocked countries they have their own unique parameters so as the water locked countries. This study will embrace the parameters and criteria that has been widely used in landlocked developing countries.

According to Jerie and Zulu (2017), GIS and remote sensing must be adopted in Zimbabwe. In their study on Banket landfill site selection, they indicated advantage of using GIS to manual selection of suitable site. Conflicts that usually come with the challenge of poor siting arouse from planning for the site henceforth if the site is properly planned, these might be eliminated. GIS and remote sensing is now regarded as a way to go when siting landfills. Although the

criteria vary from country to country, there are a lot of similarities along the use of GIS that can be embraced internationally.

Multi-Criteria Evaluation, Analytical Hierarchy process and Fuzzy integration are some of the methods of analysis that most of GIS projects used in location of landfills. All these processes and methods require constraints and factor data that has to be subjected into form of analysis before the final analysis (Jerie and Zulu 2017). The analysed data will then give results to suitable areas and unsuitable areas respectively.

According to Teta and Hikwa (2017), unlined landfills results in heavy metal contamination of ground water. In most cases unlined landfills are usually as a result of poor planning of landfills and they are called disposal sites. In Zimbabwe, most cities are using such phenomenon of disposal sites neglecting the usefulness of landfill sites. GIS has been applied in countries like Namibia, Botswana and now it has been adopted in Zimbabwe henceforth critical to analyse its applicability in Gweru City.

2.6 Knowledge of gap

Applications of GIS and Remote Sensing in decision making are still a challenge in developing countries and some of the parts of the world. Gweru city waste management strategies have been taken into consideration in a social manner where the impacts are only evaluated without giving proper recommendations on where exactly is it supposed to be sited. Several scholars have analysed the disposal site's effects and yet the site to locate the landfill was not proposed. According to Jerie (2007), there is need to come up with technical solutions to deal with the issue of integrated waste management programme. This gap led to this study as it intends to propose the optimal site for land filling for Gweru City.

2.7Summary

The location of disposal sites in the Zimbabwean towns is a challenge as most of these sites are against the Environmental management agency of Zimbabwe standards. EMA (2005) regarded most of the disposal sites in Zimbabwe as highly unsuitable and they need to be relocated and the local authorities were given a mandate to relocate this disposal site and come up with engineered landfill sites. Due to this challenge on waste disposal in Zimbabwean towns it is important to use GIS and remote sensing modelling that can assist to help in finding an optimal landfill in the Zimbabwean town of Gweru.

CHAPTER 3: RESERCH MATERIALS AND METHODS

3.0 Introduction

Internationally, municipalities and government institutions have put in place several criteria in selecting a landfill site for detrimental facilities. Procedures and strategies act as instruments used to safeguard the environment as well as minimizing nuisance to the nearby communities. This chapter therefore intends to explain procedures that were taken in analyzing the impacts of the current disposal site to the people and soil. Methods used in selecting optimal suitable locations for siting a landfill are also explained.

3.2 Research design

Collective approach method (Quantitative and Qualitative techniques) research design was used in this study. GIS and remote sensing methods were moreover utilized to form an outline of the reasonable landfill sites. Geographic information system and remote sensing were used in geographical data capturing, control and introduction. Quantitative techniques through the use of graphs, tables, Boolean logic calculations and map algebra were then complemented by descriptive analysis that was qualitative in nature. The use of these two methods allows the research to be comparatively strong with synergetic analysis being taken into consideration.

3.3 Sampling procedures

Determination of sample location was done using Fishnet ArcGIS tool. According to Mankin, DeAusen, and Barnes, (2002), fish net is a tool that can be used to select sample size randomly in ArcGIS. Randomly the households in Woodlands Park were selected. 10% of approximately 500 households in woodlands park phase two suburb were selected to err their views concerning the current disposal site. Purposive sampling method of snowballing was also used when selecting the organizations to ask information concerning landfill relocation. Gweru City council and Environmental Management Agency (Midlands Province) were regarded as affected institution on the same cause. EMA is an environmental body that deals with issues that are environmental related such as detrimental facilities. Gweru city is the local authority responsible in collecting and disposal of waste henceforth selected to air their views in this study.

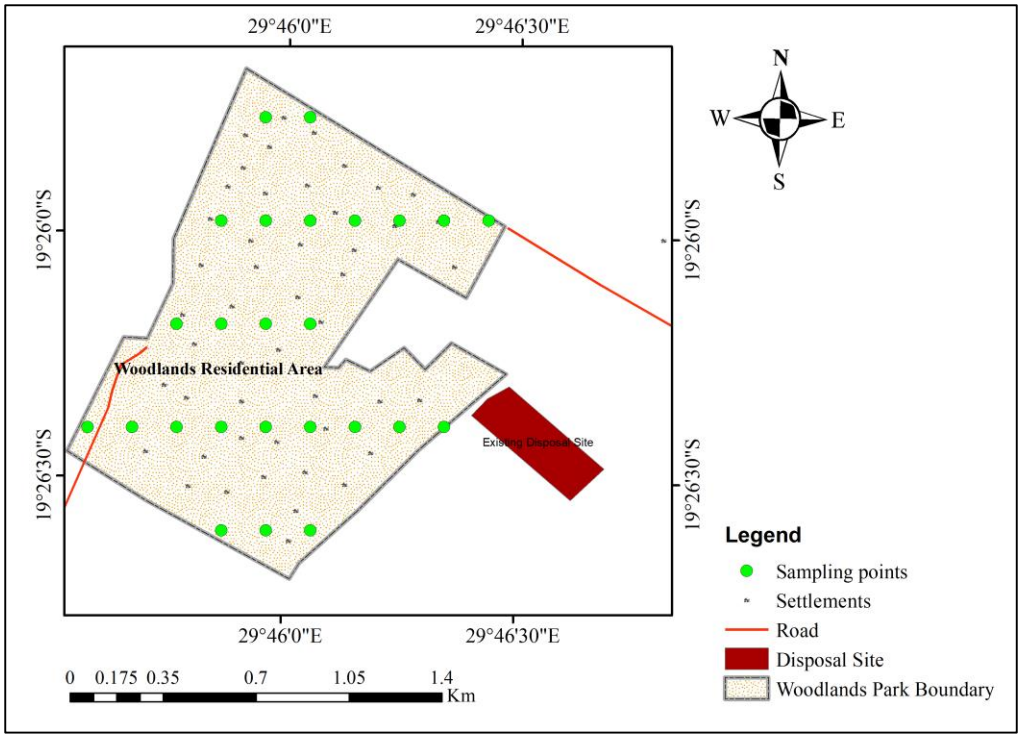

Figure 3.1 Sampling points in woodlands park residential area

3.4 Research instruments

In this study, primary and secondary data was collected and subjected to analysis. A strategy that was used in selecting a landfill was based on the assessment criteria for suitability analysis. The movement of a transfer location must be defended with the negative wellbeing and natural impacts related with it. A case study approach was utilized in distinguishing the social and natural impacts related with Gweru City transfer location.

3.4.1 Primary data sources

Field survey approach was one of the main pillars of data acquisition in this research. Data in terms of accessibility and proximity of the current disposal site was done through this method. Face-to-face interviews and observations were also part of data collection methods.

3.4.1.1 Field survey approach

Field survey was comprised of the use of kobo collect (Electronic data collection tool) when obtaining information from the local people and observations of the current landfill site effects. Interview questionnaires were drafted on an online kobo collect account (See appendix 1), sent to a server and retrieved at the mobile phone through Kobo collect application. The interviewee with the assistance of the interviewer then fills in the blank form in the field and save the

information. Data was then sent back to the server for retrieval. The researcher downloaded the results in excel format and analyze them respectively. In the field, data collection through the use of physical observations and digital camera to capture pictures at the disposal site were used. A Global Positioning System (GPS) was used to get the geographic location of the area affected by the current disposal site.

3.4.1.2 Face-to-face interviews

Informants' interviews were done to those who had firsthand experience of the Gweru disposal site. Gweru City council, Environmental Management Agency (Midlands Province) and local people in Woodlands Park residential area were interviewed. Interviews were helpful in understanding the social and ecological impacts that are being caused by the current disposal site to the people and environment. Interviews were conducted with the selected participants using an interview guide with semi-structured questions. Apart from sticking to the semi structured questions, participants were asked if they had any questions or comments to add to what they had been interviewed about. This assisted in closing down the interview as well as getting extra information, which would have been missed by the interview questions.

3.4.1.3 Soil sampling

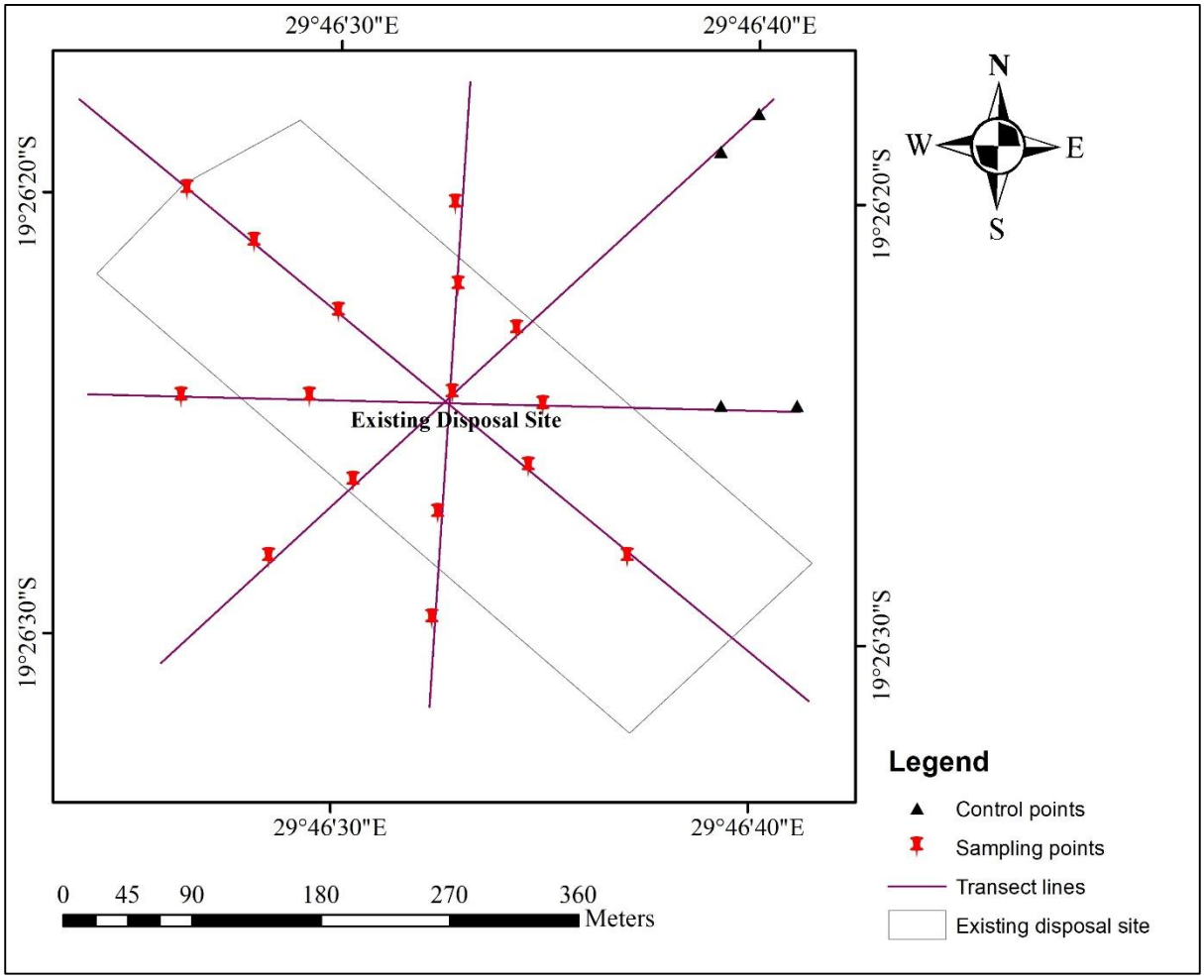

Figure 3.2: Sampling point map of the disposal site.

(Source: Author)

100 g soil samples were taken from 16 randomly selected points around the disposal site. Transect sampling was done and two points were systematically selected along transects to determine concentration of each chemical from one point to the other. 3 randomly selected points were taken soil samples. 3 control points' samples were taken in areas that are 800 meters away from the disposal site along windward side (north eastern part of the disposal site). Chemical concentrations were determined using Leco machine tests and this was only applied when testing sulphides. Testing of lead and cadmium was done using the atomic absorption spectrometer.

3.4.2 Secondary data sources

Since landfill-siting phenomenon using GIS and Remote Sensing is international in origin, data acquisition through secondary sources was of prime importance. Data that was collected was

used to produce digital format maps, define criterion and helped in coming up with suitable sites for landfill siting.

Table 1: Datasets used and their sources of acquisition

Shape file	Source
Digital elevation model	USGS
Gweru city wards	http://hundata.org/dataset
Gweru city rivers	DIVA-GIS (www.diva-gis.org/datadown)
Gweru city roads	DIVA-GIS (www.diva-gis.org/datadown)
Soils	FAO
Gweru settlements	Google Earth (2017)
Gweru Rail	Google Earth (2017)

Settlement is a critical issue in as far as landfill siting is concerned. Settlement data was acquired through digitising Google earth images and creation of shape files that were exported to ArcMap 10.5 for mapping purpose.

DEM was needed to calculate slope of the study area. Slope is a critical factor when siting a landfill because if it is sited on a steep slope, it may have resulted in pollution of the areas surrounding the landfill. Economically it is not reasonably safe to site a landfill on a steep slope. Gweru wards data shape files were downloaded and imputed into Arc Map so that the boundary of the area under study will be easily denoted. Gweru Rivers, roads and rail shape files were acquired through DIVA-GIS so as to compute distance analysis using Analytical hierarchy process and Multi criteria evaluation. Soil map was downloaded from FAO as indicated in Table 1. Soils with high sediment and clay divisions give groundwater assurance and are financially cheaper implies to build a landfill liner.

Table 2 Characteristics of Digital Elevation Model (DEM) of Gweru City.

Size of the tile	3601 x 3601 (1 x 1)
Size of the pixels	1 arc-second
Projection: Geographic Coordinate System	Geographic latitude and longitude
Output format of the Digital Elevation Model	GeoTIFF, signed 16-bit, in units of vertical meters Referenced to the WGS84/EGM96 geoid

The slope for Gweru city was generated using the Digital elevation model of 30m by 30m resolution. The digital elevation model was then converted to slope sing ArcMap 10.5 spatial analyst tool.

Table 3: Criteria and defined buffer zone

Criteria	Buffer zone	References
Rivers	1 000m	(Mlczewski 2004)
Settlements	1 000m	UNEP (2011), Allen (2002)
Railway	1 500m	Rikalovic, Cosic and Lazarevic (2014)
Road Network	1 000m	Kharlamova, Mada, Grachev (2016)
Airport	2 000m	Sumathi, Natesan and Sarkar (2008)
Soil	Clay	Jerie and Zulu (2017)

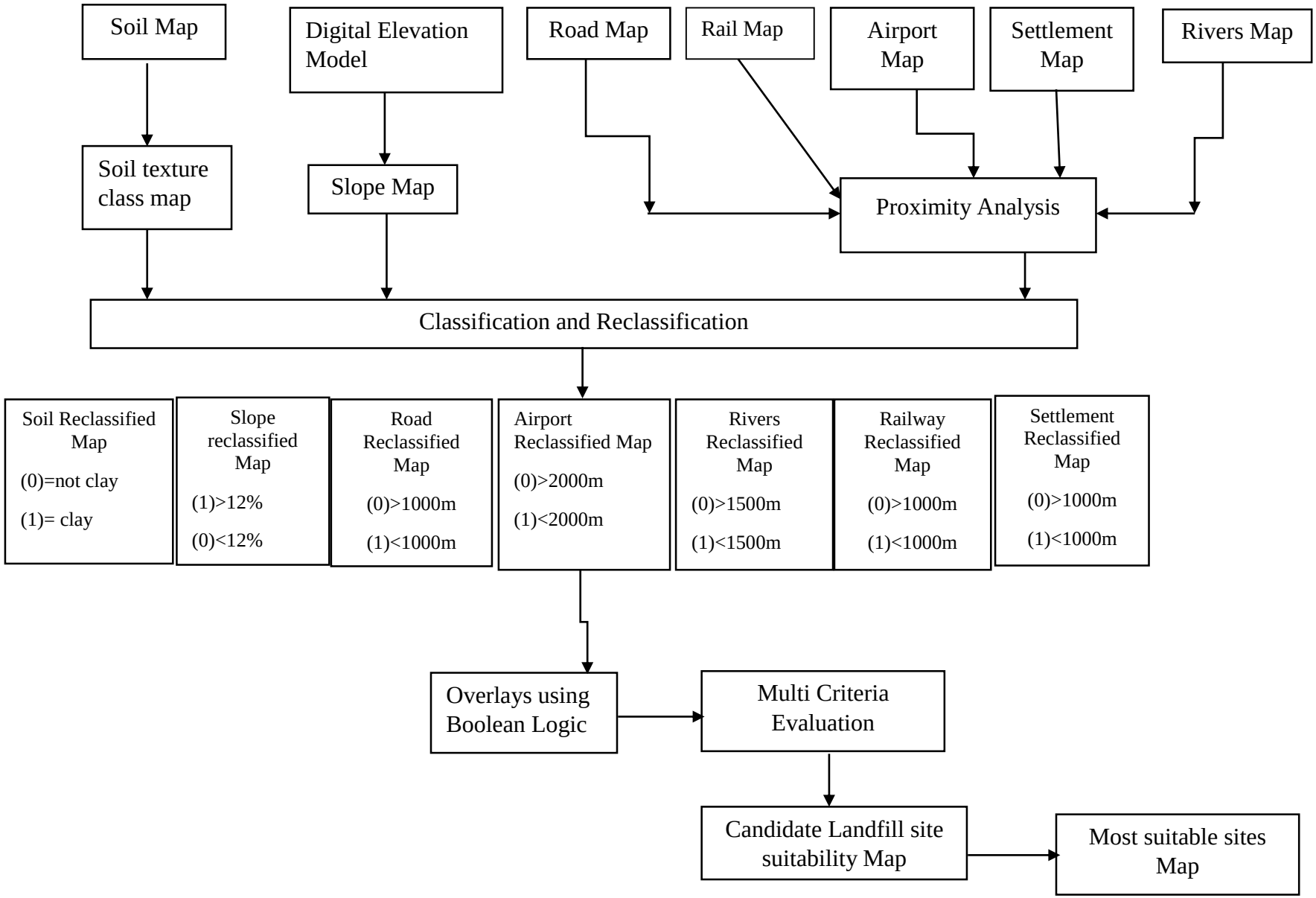

Figure 3.2: General Methodology flow chart (source author)

3.5 Suitability analysis methods

3.5.1 Multi Criteria Evaluation

In this study, a comprehensive database involved 7 input outline layers, including settlements, roads, railroads, airport, slope, rivers and soil were obtained and arranged inn ArcMap 10.5. These layers were then changed from vector to raster data sing ArcMap conversion tools. After characterizing the parameters for landfill location determination, examination was done in two stages where unacceptable packages of land for siting a landfill were isolated. The recognized reasonable packages of land after the disposal method were assessed using the analytical hierarchy process.

The converted layers were subjected to classification where individual raster layers attained 9 classes pending to reclassification. Criteria that deals with distances such as settlements, roads, rail, river and airport were classified sing Euclidean distance under spatial analyst tools in ArcMap 10.5. On the other hand slope criterion was classified sing surface tool under spatial analyst tool.

Classified raster layers were then reclassified according to the criteria in Table 4. Reclassification was done so as to come up with two distinct areas on each single raster map indicating the suitable and the unsuitable sites. Reclassification was done sing spatial analyst tools and binary numbers “0” and “1” were assigned to the two classes “0” representing unsuitable and “1” suitable parcel of land.

Reclassified raster maps showing areas of suitable and unsuitable were combined sing Boolean logic process “and”. This computations combined all the reclassified raster maps by the means of calculations. All the maps were combined and the “0” s for unsuitable area were multiplied by zero to project a class of zeros in all the mas reflecting unsuitable areas. All reclassified areas of “1” were also multiplied by one to project an area of one representing suitable area. A candidate landfill sites map was produced using this method of multi criteria evaluation

3.5.2 Analytical Hierarchy Process (Weighted overlay analysis)

Weighted overlay analysis was also used in further analysis complementing Multi criteria evaluation process. The analytical hierarchy process pair-wise comparison scale was further used in coming up with landfill sites for Gweru city. The 9-point scale used in normal analytic progression studies ranges from 1 (similarly favored) to 9 (supreme significance). This pairwise

evaluation permits the decision maker to evaluate the part of each role to the objective autonomously, in this manner streamlining the decision-making handle factor as appeared in Table 3.

Table 4: Scale of pairwise comparison scale for AHP preferences

Number	Priority
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred

Pairwise comparison scale in Table 4 was used to generate pairwise comparison matrix. The consistency ratio was used according to Saaty (2005) standards. The criterion of most significance attained highest vale as compared to other criteria of lowest significance. The Consistency ratio was computed and it was <0.10.

The calculation of weights was done on an online pairwise comparison matrix page. Factors such as settlements, rivers and slope were assigned highest vales because they do not have substitutes. However, factors such as roads and rail were assigned lowest vales and the results for online pairwise comparison matrix are presented in table 5.

Table 5 Matrix for pairwise comparison

Criterion	*i*	*ii*	*iii*	*iv*	*v*	*vi*	*vii*	Weight
I	1	1	2	3	5	6	7	0.259267
Ii	1	1	2	3	5	6	7	0.259267
Iii	0.5	0.5	1	3	3	3	4	0.147988
Iv	0.33	0.33	0.5	1	2	3	4	0.106635
V	0.2	0.2	0.33	0.5	1	2	2	0.056883
Vi	0.16	0.16	0.33	0.33	0.5	1	2	0.04244
vii	0.14	0.14	0.25	0.25	0.5	0.5	1	0.033049

i, settlements; *ii*, river; *iii*, slope; *iv*, soil type; *v*, distance to airport; *vi*, distance to roads; *vii*, distance to railway.

After generation of weights for individual criteria's, weighted overlay analysis was done in were individual reclassified raster maps were assigned a certain weight according to the results of the pairwise comparison matrix. A map showing areas that are most suitable to most unsuitable was generated using weighted overlay analysis.

Weighted overlay analysis map was then combined with candidate landfill site map of multi criteria evaluation. Areas that are most suitable according to weighted overlay analysis were

combined with areas that were identified as suitable according to multi criteria evaluation to produce a final suitability map.

3.6 Research ethics

The research was obedient to the system of principles overriding morality and standard conduct. The research takes into consideration the law and maintained confidentiality and anonymity at all levels of the research. When conducting interviews, permission was first sought from the local authorities to conduct interviews in their area. Briefing of the interviewee about the project being carried out and the reasons why they were being interviewed was done. Anonymity and confidentiality of participants was respected; interviewees were assured that information they will deliver would not be drawn back to them in any form of broadcasting.

Principalities governing acquisition of secondary data was observed and respected during this study. Referencing of secondary literature was done so as to acknowledge work done by other scholars. When downloading the Digital Elevation Model for Gweru city at USGS, an online account was created and all the procedures were followed.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.0 Introduction

Chapter 4 took into account the results, findings and analysis of the current disposal site impacts to the environment as whole, in this chapter, the results on the suitable site for landfill sites selection are also presented and analysed.

4.1 Impacts associated with Gweru City disposal site.

The current disposal site has been located using unrefined strategies since it was built up long back some time recently the sanctioning of the Environmental Management Act of Zimbabwe that presented environmental management strategies and waste management arrangements to municipalities. According to the Environmental Management Agency, the disposal site is not in line with the Environmental Management Act regulations on hazardous waste management. Environmental Management Agency also testified to the fact that the current disposal site is not in line with the Statutory Instrument 7 of 2007 and causing serious threats to Woodlands residents resulting in several complaints coming from local committee. The city of Gweru indicated that, the disposal site was located when Woodlands residential area was a farm by then. The director of health indicated that the disposal site was relocated from Mkoba to Mtapa and later on to woodlands area. These stakeholders accept the fact that it had been located using crude methods without taking into considerations the future development.

4.1.1 Social impacts

The residents living close to the disposal site uncovered the natural and health impacts that affects them as a result of the disposal site. The impacts emerging from the current disposal site ranges from illnesses, smells, clamour and visual interruption. 100 percent of the residents met were concerned around the wellbeing impacts related with the current transfer location. The whole number of the concerned inhabitants appears that the larger part of the individuals living close the transfer location recognize that it is causing negative impacts to them from now on calling for its movement.

4.1.1.1 Diseases

The survey result shows that diseases are a social concern that is attributed to the proximity of the disposal site to settlements. Of the interviewed residents 35 % are not connected to Gweru City water reticulation system henceforth using wells as their source of water. Some of the wells they are using are not protected and they complain of stomach problems as flies and underground water pollution is prevalent. The type of waste that was noted by the respondents

supported their notation of high prevalent of diseases. The majority of respondents postulated that waste meat from restaurants, abattoirs and Bata attract flied at the site which later on spread the pathogens in woodlands suburb. The Gweru city council testifies this challenge indicating that not all of the Woodlands suburb phase 2 stands are connected to Gweru city water. In such a scenario high spread of diseases is prevalent and it is a case of concern to relocate either people or the dumpsite to minimise the impacts associated with it.

4.1.1.2 Odours

The survey indicated that, Gweru city disposal site is comprised of waste in form of hospital waste, metal, plastics, wood, electronic waste, and solid waste. The interviewed residents indicated that this mixed bag type of waste results in offensive smells spreading through Woodlands residential area causing inhalation problems. During the field survey it has also been testified that a bad smell is generated at the disposal site. Most of disposed waste is not biodegradable henceforth it remains at the site. At the disposal site, there are so many plastics that are not compacted. The local residents testified that plastics are blown by the wind to the residential area reducing the aesthetic value of their land. The composition of waste at the disposal site demonstrated that there is no separation of waste before it is disposed at the site. This persistence type of waste is contributing to air pollution if it is burnt.

4.1.1.3 Dust and smoke

It has been noted that, the disposal site usually resulted in fire outbreaks due combustion and sometimes caused by the squatters who live at the disposal site. The majority of the interviewed residents confirmed that when the disposal site is burning, the area is not habitable as smoke will be covering every part of Woodlands Park residential suburb. The smoke from the disposal site is associated with inhalation problems, chest problems and lung cancer as indicated by the respondents. Although 75% of the respondents identified this to be a challenge they face in woodlands park residential area, by the time of field visits there were no traits of such a problem.

4.1.1.4 Noise

As council trucks dispose waste at woodlands disposal site, the nearby residents indicate that they are affected by noise that comes from the site. Since some houses are located within the radius of 25 meters, the residents launched a complaint that the council must avoid disposing waste closer to residential areas. From the observations, it has been noted that the council trucks can reach closer to residential areas when they compact waste as well as when they dispose waste. The residents indicated that, although they launch complains about the problems they

are facing non is being done to reduce these impacts. However, some of the respondents highlighted road construction and medical assistance as measures that the city of Gweru is taking as a corrective measure to the problems faced.

4.1.1.5 Pests

Flies and mosquitoes were also noted as a key social problem that is related to the Gweru city disposal site. Malaria was highlighted by the respondents as one of the prevalent disease affecting Woodlands residents. 85% of the respondents professed that the presence of pools and gullies at the disposal site act as the breeding grounds for mosquito and this resulted in the spread of Malaria in the area. 7 of the 43 respondents highlighted that their fields have been destroyed by pests and they suspect these pests to emanate from the disposal site. The pools were also mentioned to be a hazard to the residents since the area is not protected. Issue such as the death of an infant at the disposal site was raised as critical and a point of consideration to the responsible authorities.

4.1.1.6 Visual intrusion

People pass through the dumpsite on their way to and from Woodlands Park residential suburb. As they are passing through, there is risk of carrying pathogens from the dumpsite to their respective houses. The disposal site is located within 20 meters from residential areas. There are also squatter settlers that are located within 10-meter radius of the disposal site. With the odour produced at the disposal site, people are likely to be affected by the Gweru City disposal site.

4.1.2 Impacts of the disposal site on soil quality

Gweru city disposal site is currently a major threat to soil quality as indicated by concentration tests in Table 6. The Environmental Management Agency and City of Gweru admitted to the fact that, soil quality deterioration is one of the challenges that can be attributed to the disposal site. Residents in woodlands park residential area also indicated that, their fields closer to the disposal site are not producing anything and suspected that the disposal site might be the case. Table 6 summarises the results of soil tests that were taken at the site.

Table 6: Concentration of toxic substances within and around the disposal site

Toxic substance	Average within disposal site(ppm)	Average around disposal site (ppm)	Recommended in soil near residential areas (ppm) (WHO, 2006)	Control sample concentration (ppm) (800m from dump)
Lead	66.93	9.37	0.04	0.01
Cadmium	1.27	0.6	0.1 – 1.0	0.1
Sulphides	89.53	75.25	0.10	20.02

*ppm stands for parts per million

It was detected that the concentration levels for lead, cadmium and sulphides are considerably ($p<0.05$) greater within the disposal site than around the disposal site. Table 6 also shows that the concentration levels of these toxic chemicals are far beyond what is recommended by WHO. This shows that the disposal site is the cause of highest toxic substances as sustained by the normal control sample outcomes which show low concentration levels for these substances to be well below both samples from within and around the disposal site as shown in Table 6.

The identified toxic chemical concentration levels are subjected to several health problems. Being exposed to hazardous chemicals such as cadmium results in dangerous health problems include cancer and flue. It has been reinforced by the woodlands phase 2 residents who mentioned flue as one of the problems they face in the area.

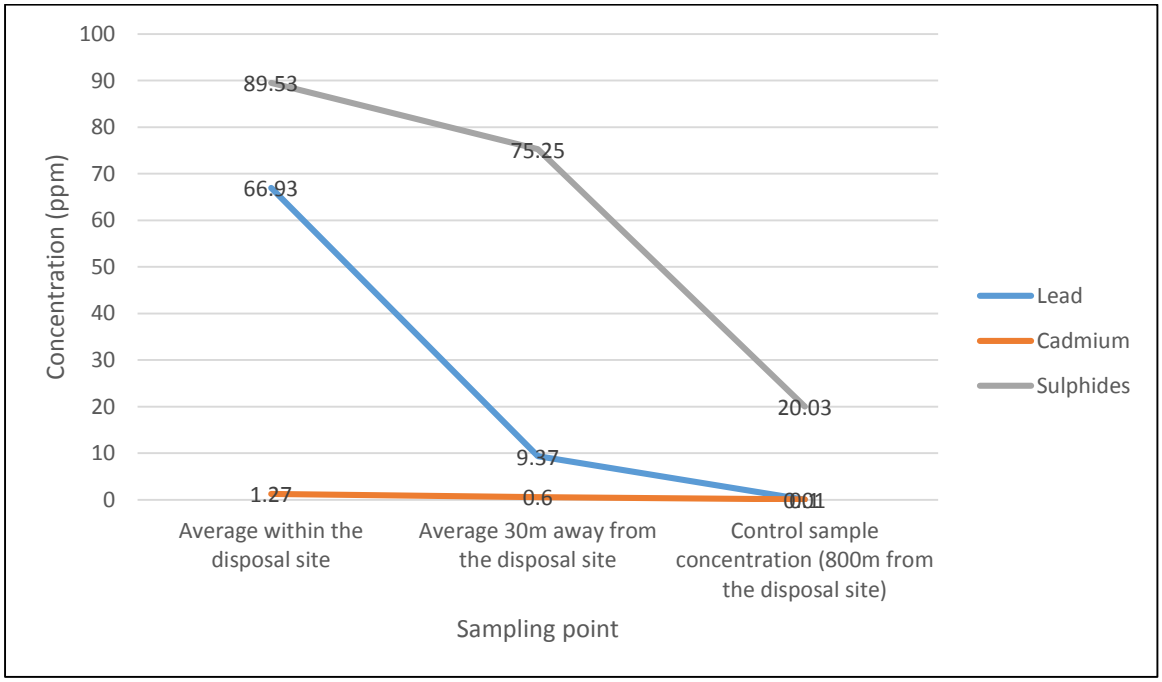

Figure 4:1 Graph showing concentration of lead, cadmium and sulphides as one moves away from the disposal site.

Concentration of toxic substances decreases as one moves away from the site. This shows that the disposal site is responsible in the pollution of the site as the control points has the lowest value as compared to the value of the concentrations at the disposal site. Geology has been taken into consideration and it has been realised that the disposal site is characterised by clay soils that has highest retention capabilities therefore minimise the rate of pollution in distances of 800m.

4.2 Determination of suitable landfill site

4.2.1 Suitability maps

Figure 4.2 – 4.9 presents the reclassified suitability maps that were used in multi criteria evaluation to determine suitable landfill sites.

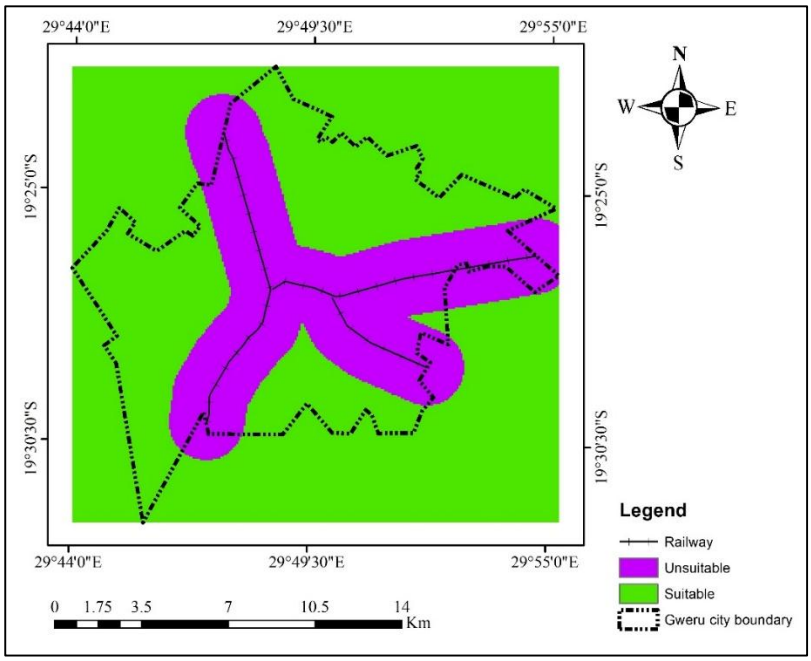

Figure 4.2: Rail reclassified map

(Source: Author)

Fig 4.2 show that, the railway reclassified map is 23.5% unsuitable and 76.5% suitable. This is because the rail track in Gweru is not so much congested with one from Dabuka Marshalling yard to Harare and the one from Gweru city to Mvuma and lastly a track from Gweru city to Zvishavane. So the areas affected according to the criteria of rail are smaller as compared to the unaffected areas.

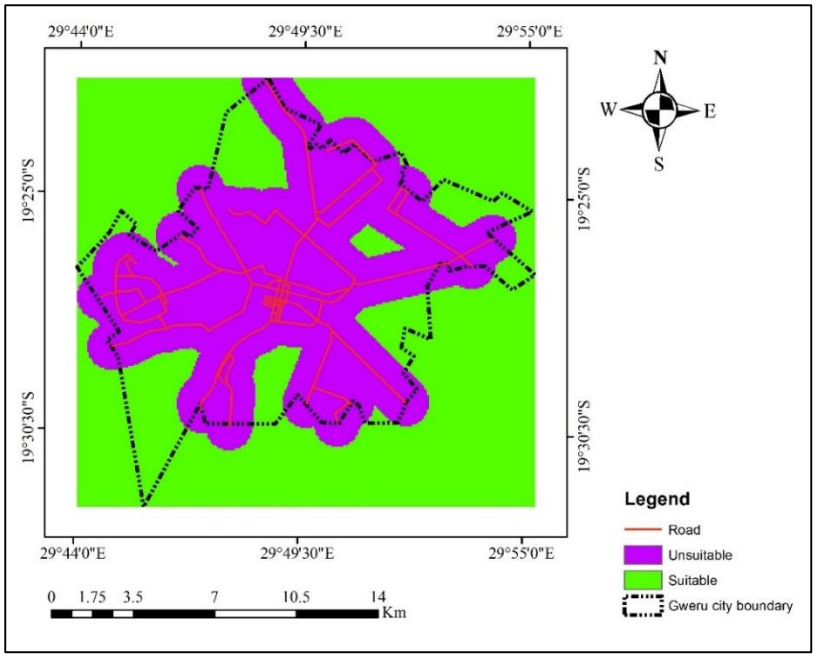

Figure 4.3: Roads reclassified map.

(Source: Author)

Figure 4.3 shows the roads reclassified map. The results show that in Gweru city the area that is suitable according to this criterion was 15 % and 75% is not suitable for landfill site. This is because, Gweru city is expanding and most of the areas are being developed.

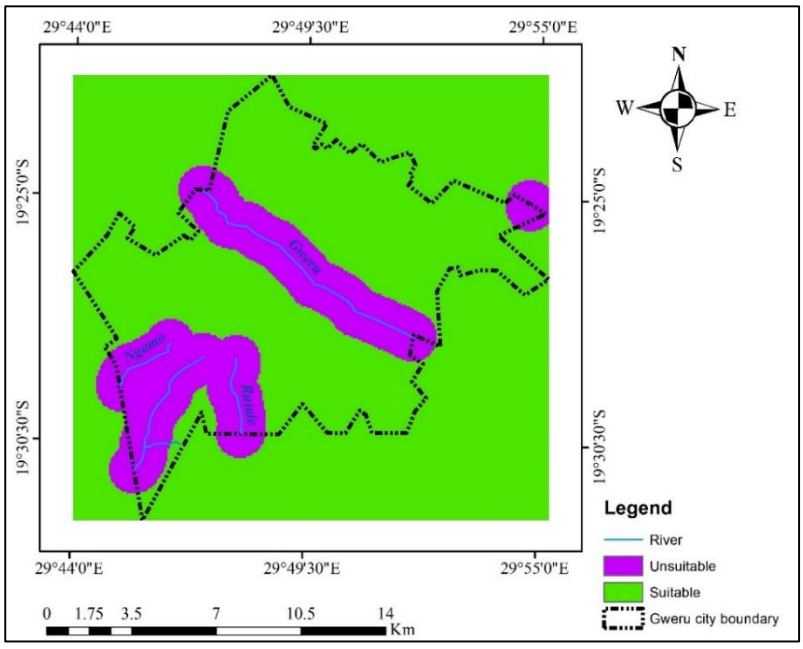

Figure 4.4: Rivers reclassified map

(Source: Author)

Rivers that pass through Gweru City are Ngamo, Gweru and Lundi. Figure 4.4 shows that, after performing Boolean logic operation "And" the areas that were found to be suitable constitute 80% whilst 20% was unsuitable.

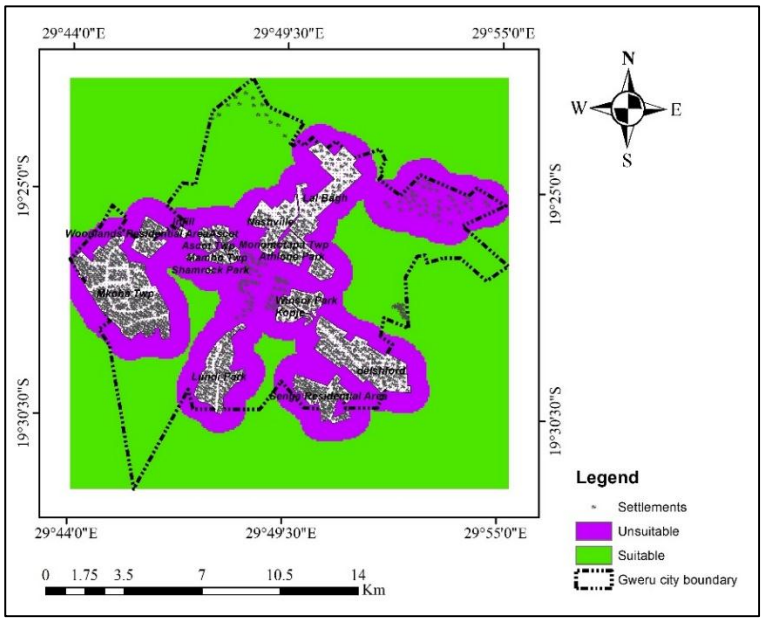

Figure 4.5: Settlements reclassified map. (*Source: Author*)

The settlement map was reclassified according to the criteria assigned and figure 4.5 shows that in Gweru city areas that are suitable are 12 % and 88% is not suitable.

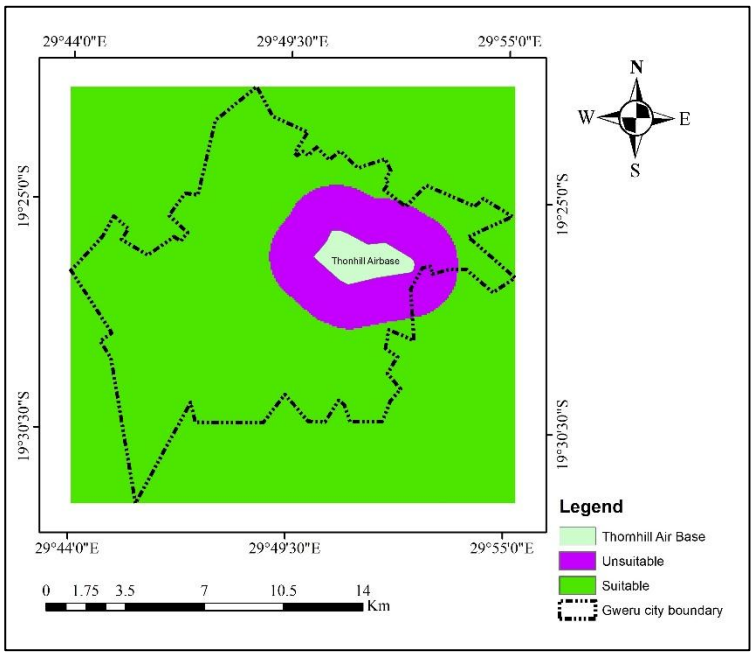

Figure 4.6: Airport reclassified map. (Source: Author)

Gweru city only have a military airbase known as Thornhill airbase. No major airports have been identified in the city besides Thornhill airbase. The reclassified map for Thornhill airbase shows that only 25 % is unsuitable and 75% of the area is suitable according to this criteria.

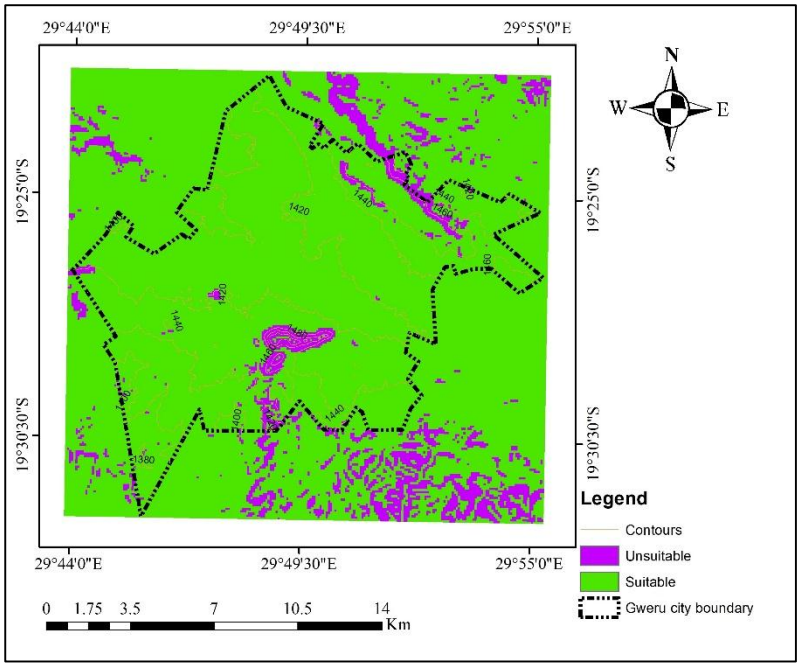

Figure 4.7: Slope reclassified map

(Source: Author)

Figure 4.7 shows that the slope for Gweru city is relatively flat with the highest percentage suitable for landfill site selection. Slope for more than 12% was identified near kopje and along Bulawayo road near Zimbabwe Military Academy (ZMA). Unsuitable area according to this criterion is 10% and 90% is suitable.

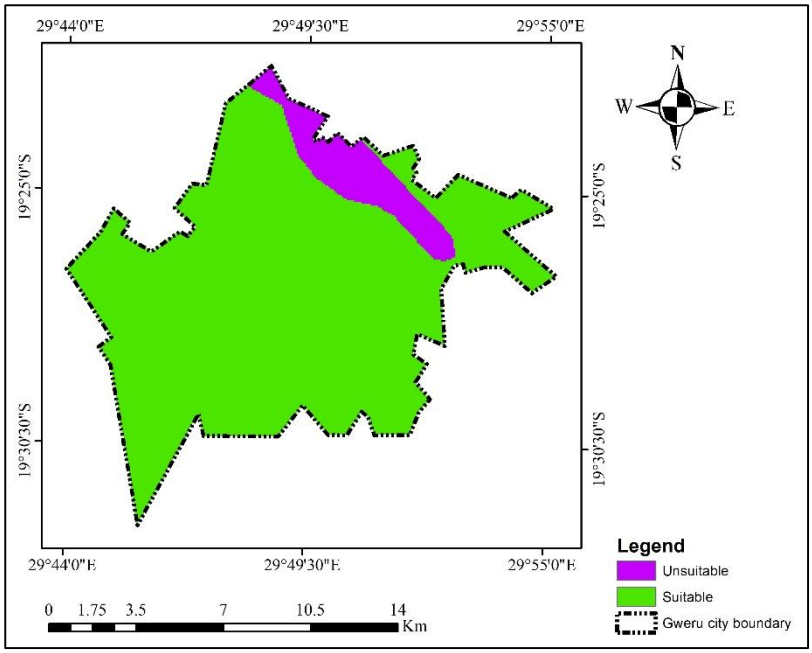

Figure 4.8: Soil reclassified map

(Source: Author)

Soil reclassified map in Figure 4.8 shows that Gweru city is characterised by more clay soils in the class IV and V according to soil classification. The area that is covered by clay soils was considered suitable and it accounts for 85% of the total area. Only 15% of the total area was considered unsuitable according to this criteria.

Table 7 Table comparing percentage and area for the suitable and unsuitable reclassified maps.

Criteria	% suitable	% unsuitable
Settlement	12	88
River	20	80
Airport	75	25
Slope	90	10
Road	25	75
Rail	76.5	23.5
Soils	85	15

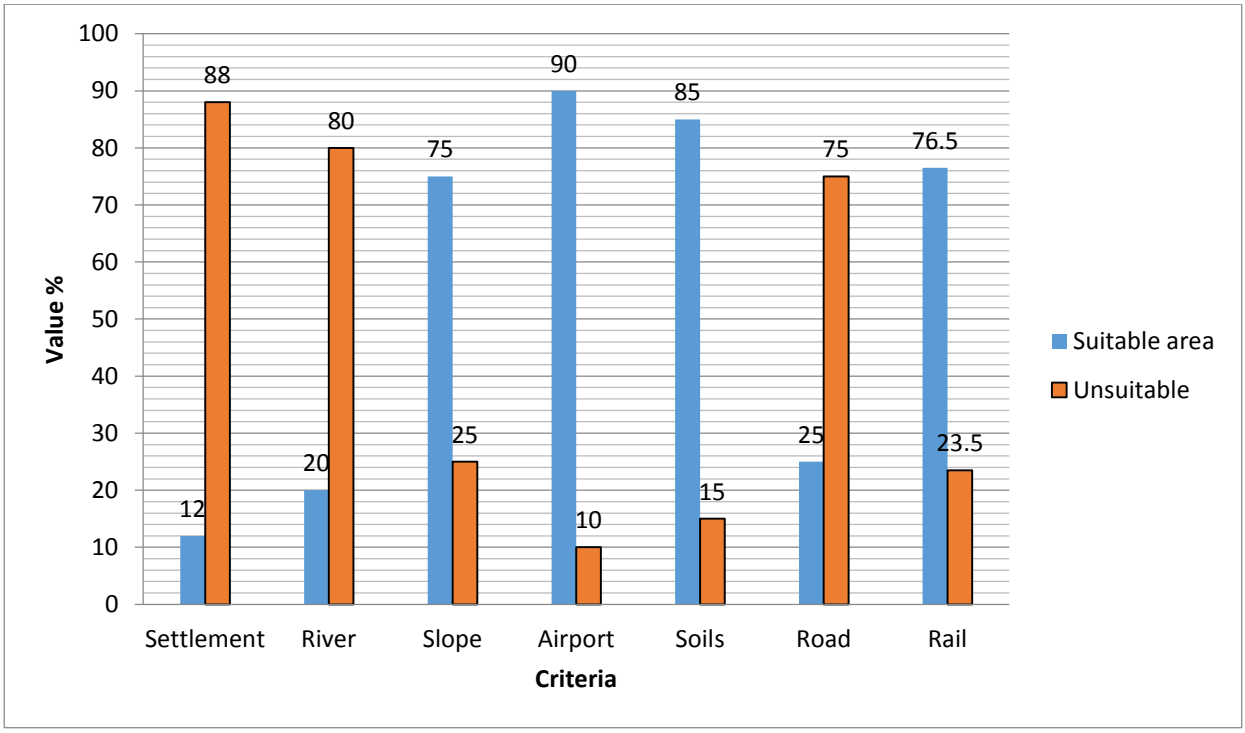

Figure 4.9: Graph showing the percentage of areas that are suitable as compared to the unsuitable area on reclassified maps

Figure 4.9 shows that Airport reclassified map have highest percentage of suitable and the lowest unsuitable percentage. On the other hand, settlement reclassified map has the least percentage area that is suitable and the highest percentage unsuitable. This is because there is only one airport base in Gweru and there are so many settlements in Gweru which contributed to the differences in terms of their suitability.

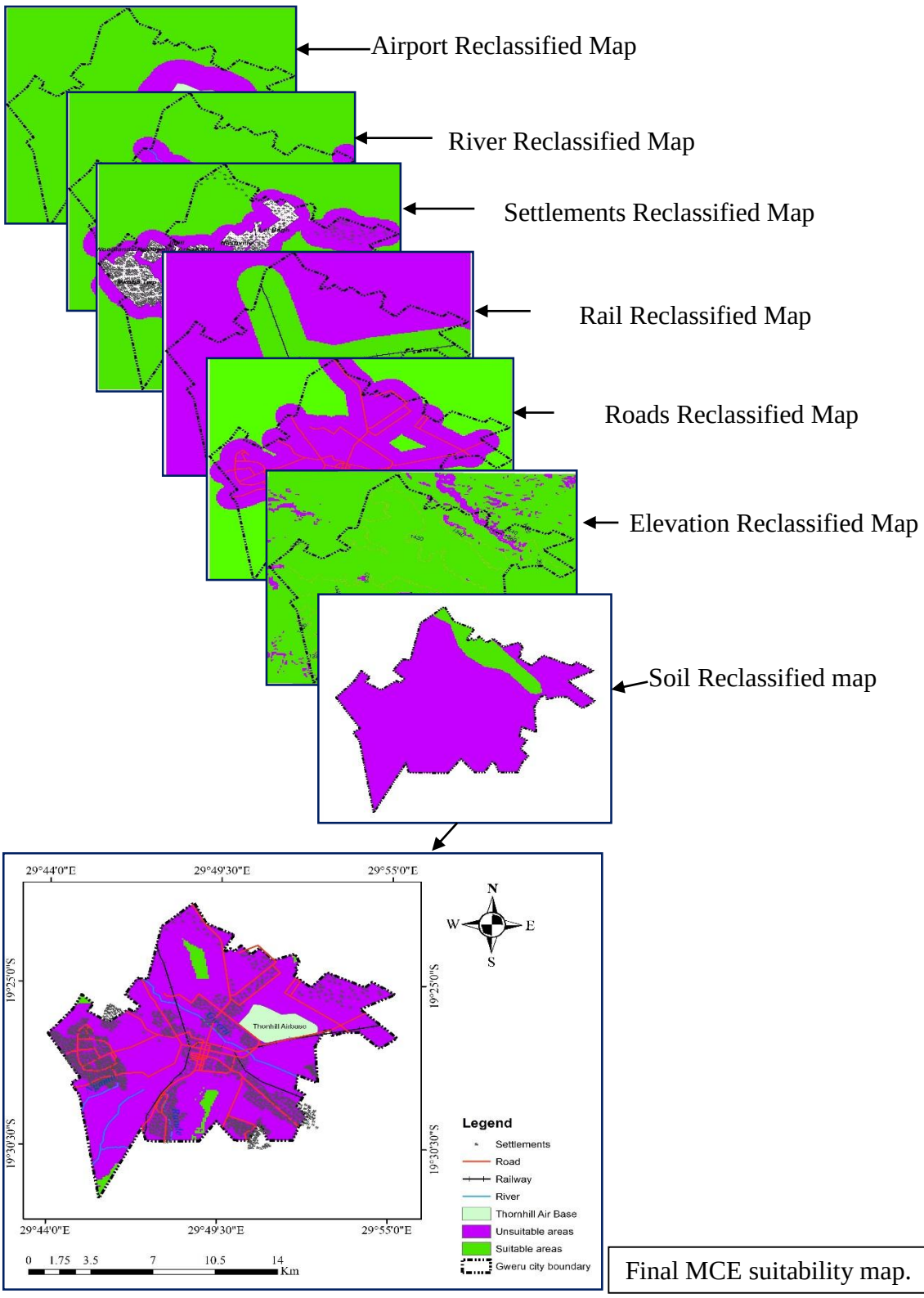

Figure 4.10: Overlays of reclassified maps.

(Source: Author)

Figure 4.10 shows the process that was followed by this research in combining reclassified maps to come up with the candidate landfill sites. The results from the Multi criteria evaluations show that there are 5 suitable sites in Gweru city. The sites vary according to size, shape and

location. However, although the sites are regarded as suitable, there was need for ground assessment where the predefined criteria will be analysed basing on what is at the ground.

4.2.2 Weighted Overlay Analysis using AHP

The results from Boolean integration of reclassified raster layers shows that the bigger area in Gweru City is unsuitable and only a smaller percentage is suitable according to the predefined criteria. However, it is not always the case that we find unsuitable and suitable sites treating each criterion as equally important. All classified raster layers went through weighted overlay technique where weights were assigned to each reclassified layer and then integrated to produce final suitability map with areas ranges from least suitable to most suitable site. Figure 4.11 shows the areas that are suitable according to weighted overlay using analytical hierarchy process.

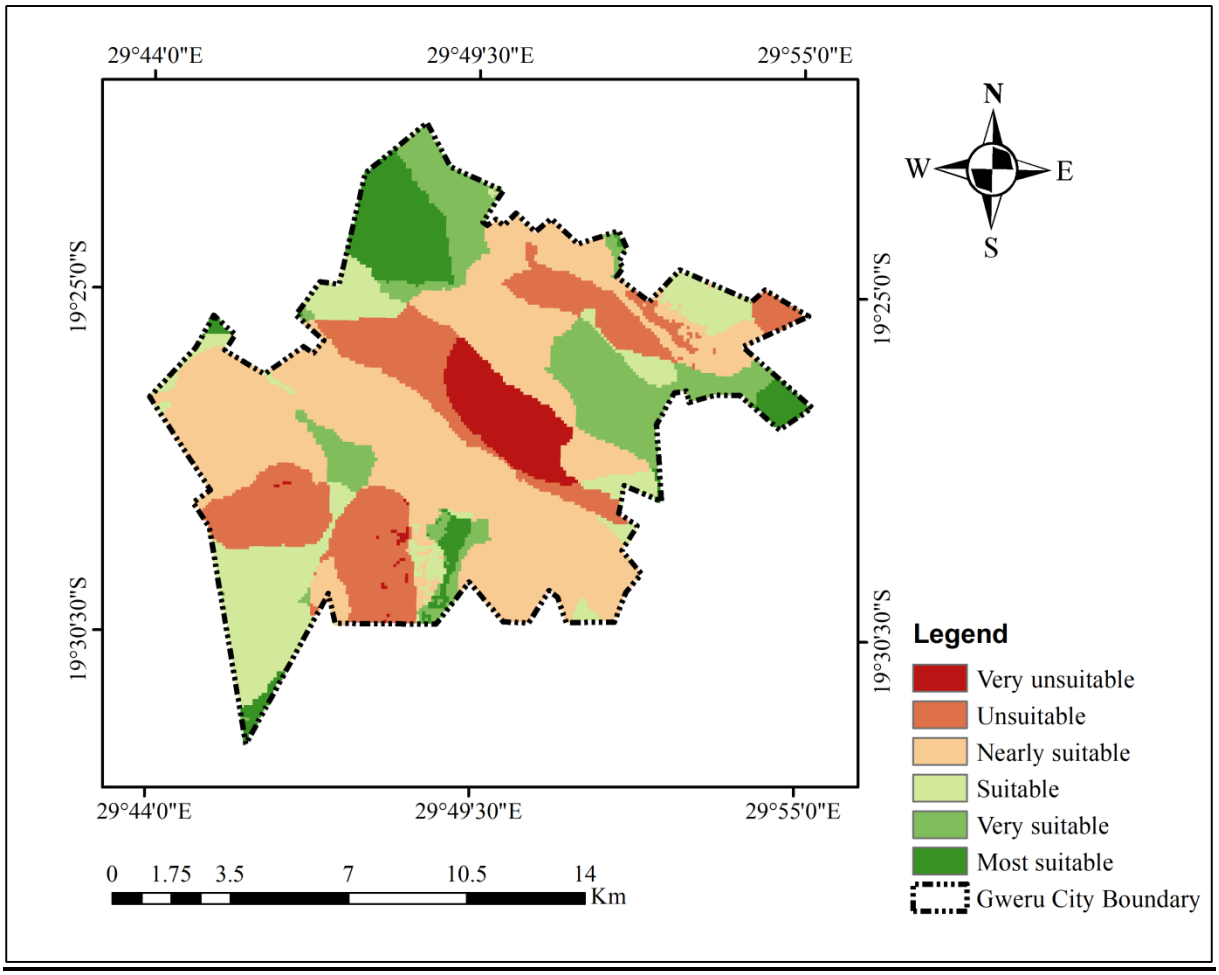

Figure 4.11 Final weighted overlay analysis map.

(Source: Author)

Results in figure 4.11 indicates that suitability for landfill site depends on array of factors that needs to be analysed extensively to come up with what can be recommended as the best site for locating a landfill. The results also prove that, given a range of factors as a standard for locating a suitable site, they are not equally important to each other henceforth need to be ranked and assigned a certain weight that will be used to produce a final map. The final map that was produced indicated areas that are not suitable, suitable, fairly suitable, and moderately suitable.

Weighted overlay analysis resulted in more areas regarded as suitable and only a smaller percentage most suitable. Further analysis was done so that the most suitable areas were combined with the suitable areas that were found through Multi Criteria Evaluation. Boolean logic operator and was used in combining Candidate landfill sites from Multi criteria evaluation and the weighted overlay analysis suitability map and the final suitability map with 5 suitable sites in Figure 4.12 was produced. The final suitability map shows that 2.5% of Gweru city is suitable for landfill site and 97.5% is unsuitable. The breakdown of the 5 sites was done and presented in Figure 4.13 and Table 8 respectively.

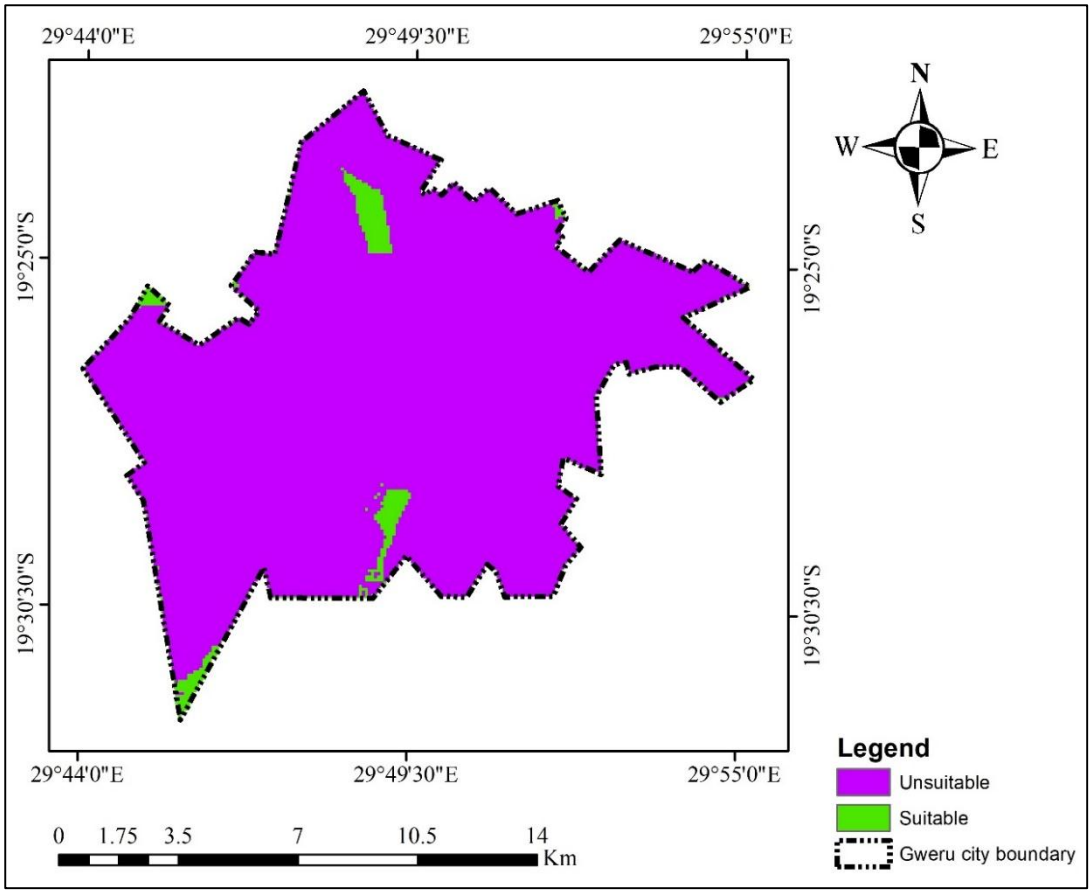

Figure 4.13: Final suitability map after multi criteria evaluation and weighted overlay analysis.

Source: Author

Further analysis was computed by converting final suitability map (Multi criteria evaluation "and" weighted overlay map) from a raster layer to a polygon and then viewed in Google earth to see if there are no developments at these areas. Three of the four identified suitable sites are located at the edges of Gweru city boundary which might cause conflicts with Gweru rural council. Figure 4.14 shows the Google image indicating suitable sites that has been identified using Multi criteria evaluation and weighted overlay analysis.

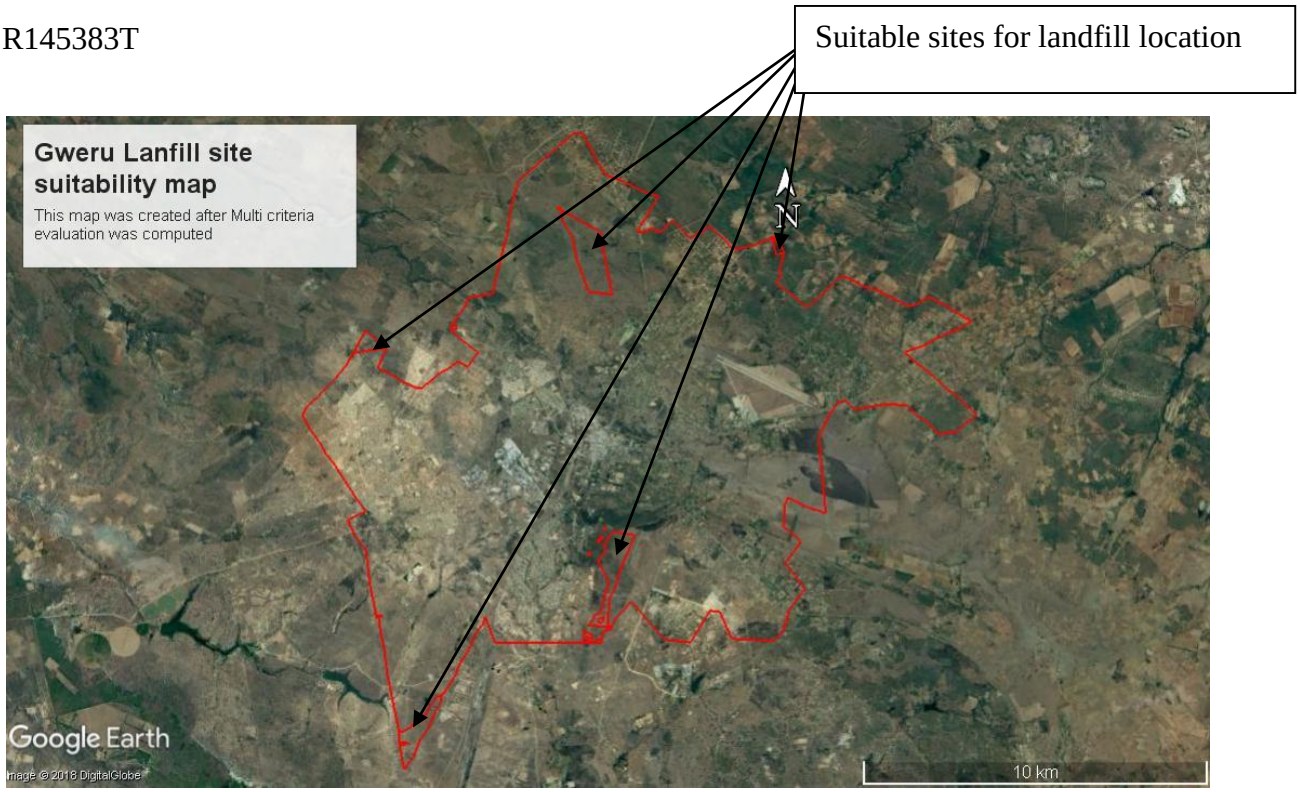

Figure 4.14: Google Earth image showing suitable sites in Gweru City

Source: Google Earth image 2017.

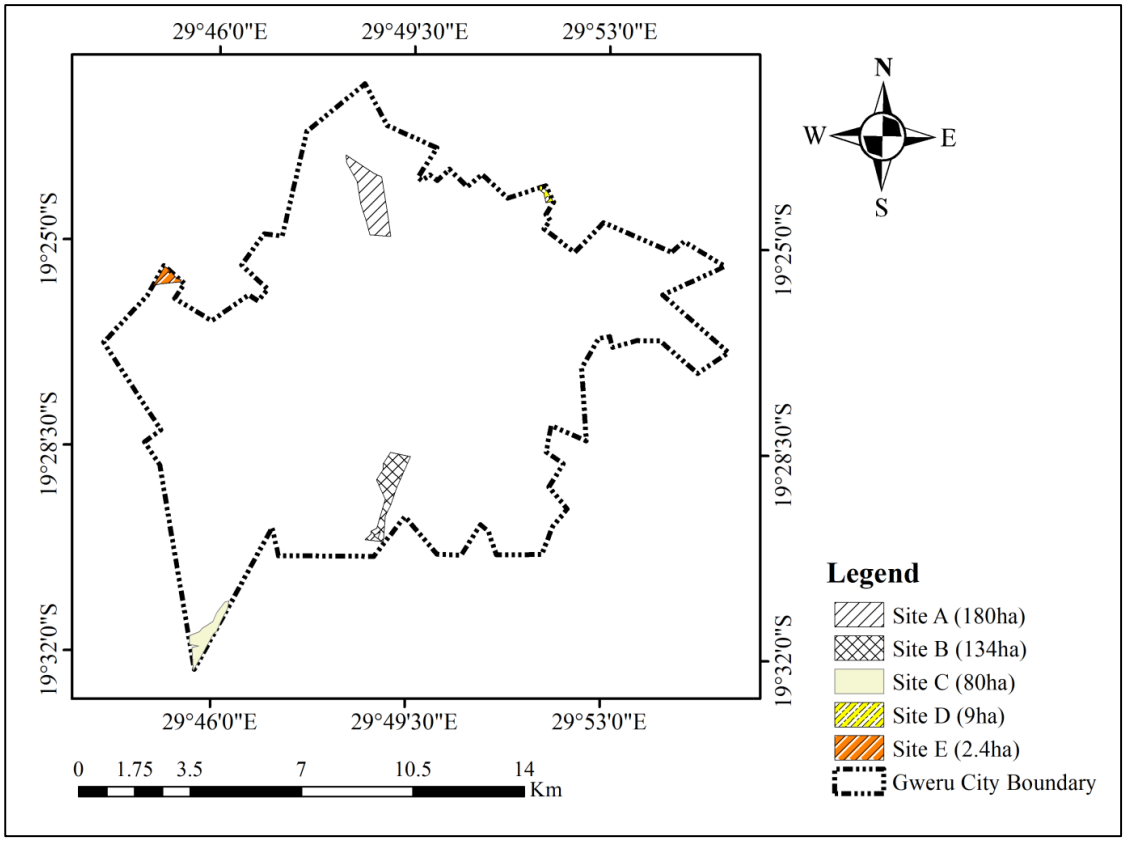

Figure 4.15 Suitable landfill sites in Gweru urban.

Source: Author

Table 8 Site location and the area

Site location	Area (ha)
A	180
B	134.4
C	80
D	9
E	2.4

Figure 4.15 and Table 5 shows that, there are 5 sites suitable for landfill site in Gweru urban. However, these sites are not equally the same in terms of shape, size and location. The sites were ranked into 5 classes from most suitable to least suitable area. The most suitable site was indicated in Figure 4.24 which is located near Ridgemond residential area. The area is not densely vegetated, have highest area as compared to the other four and is isolated it had met all the criteria for landfill siting. The identified suitable sites were compared with City of Gweru master plan and realised that although there were plans for the northern site which is the first site priority in terms of size, the other sites which were also identified by the residents to be suitable are not yet developed or planned for.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.0 Conclusions

Management of waste in Gweru City remains an issue of concern as they are using a disposal site instead of a landfill. The disposal site they are using is far from ideal site with associated with social impacts. The problem is accelerated by the type of waste being disposed which includes clinical waste, industrial waste, liquid waste, electronic waste, metal waste and glass. Most of the waste being disposed is not bio degradable henceforth continuously polluting the environment. The issue of proximity to land use is not also being taken into consideration as houses are located within 25m radius from the disposal site. The disposal site produces noxious smells, odour, breeding grounds for mosquito and flies which is also accountable for diseases such as cholera, malaria and cancer that have been alluded to by the consulted parties.

The disposal site is causing soil pollution as indicated by the results in this study. Concentration levels of lead at the site was 66.93 ppm as compared to 0.01 control sample concentration. Cadmium have been also tested and the results show that the level of concentration at the disposal site is high indicated by a value of 1.27 ppm within the disposal site and 0.1 control sample concentration. Sulphides were tasted and the average concentration within the disposal site was 89.53 as compared to 20.02 control sample concentration. This explained the view that, the current unlined disposal site is causing soil pollution at the disposal site and the pollution levels reduces as one moves away from the disposal site.

To solve the challenges associated with the current Gweru city disposal site, GIS and remote sensing modelling was part of this research. The study resulted in optimal sites being identified, analysed and weighted. A criterion that was used based on factors such as water sources, settlement, slope, airport, soil, road, rivers and boundary. The criterion was given a set standard that was used to create buffers that were then integrated using two methods of Multi criteria evaluation (Boolean logic “and”) and Weighted overlay analysis (Analytical Hierarchy Process). The two methods resulted in two suitability maps being produced. Multi criteria evaluation produced a map with two classes: suitable and unsuitable. Weighted overlay analysis produced a map with a range of classes’ ranging from unsuitable to most suitable areas. Final suitability map showing 5 suitable sites was created using Multi criteria evaluation map and the weighted overlay analysis final map and presented in this research.

5.0 Recommendations

Government of Zimbabwe, private sector and local authorities needs to integrate GIS and remote sensing when locating detrimental facilities. GIS and remote sensing therefore reduce the effects associated with these landfills. Some approaches can be discussed below.

- It is recommended that the city of Gweru municipality must take corrective measures to minimise the impacts of the current disposal site. The disposal site area must be fenced as the area is heavily polluted by substances such as cadmium, lead and sulphides.
- The City of Gweru must select a new landfill site based on the results presented in this research. The site must take into consideration social, economic and ecological factors.
- The residents in woodland park residential area must be advised not to pass through the disposal site or to practise farming in the areas closer to the disposal site because it can result in health effects.
- The Environmental Management Agency must come up with a strategy of revising the projects that were enacted before the establishment of the Environmental Management Act 20:27 so as to counteract the problems that may be associated with these projects.
- Waste management strategies such as recycling and rese are recommended so as to reduce the amount of waste that is ending up in the disposal site.

REFERENCE LIST

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APPENDICIES

Appendix 1	Kobo collect questionnaire
Appendix 2	Interview guide to EMA
Appendix 3	Interview guide to the city of Gweru

Appendices 2: Interview guide for Environmental Management Agency

1. What are the social impacts associated with Gweru city disposal site?
2. Are there any measures that are being practised to reduce the impacts?
3. What are ecological impacts associated with Gweru city disposal site?
4. What measures are you implementing as the Environmental regulatory authority to ensure that effects of the disposal site to the environment are minimised?
5. What can be done to ensure a sound waste management of waste in Gweru city?

THANK YOU

Appendices 3: Interview guide for Gweru city council

1. What are the impacts of the current disposal site to woodlands community?
2. What challenges are you facing in relocating the disposal site?
3. What had led to the siting of the disposal closer to residential area?
4. Are there any plans for relocating the disposal site and if there are there where?
5. What can be done to ensure effective waste management of waste in the city of Gweru?

THANK YOU