University of Nairobi

School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

Use of geospatial technologies in selecting suitable site for solid waste disposal in Kajiado North Constituency – Kajiado County.

BY

Mercy Ngunju Rienye

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Declaration

I, **Mercy Ngunju Rienye**, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

…………………………………………………… 28/07/2022

Mercy Ngunju Rienye Date

This project has been submitted for examination with our approval as university supervisor(s).

………………………………… 28/07/2022

MR. P.C. Wakoli Date

Dedication

I sincerely devote this project to the almighty God for the strength and guidance. I also dedicate it to my Parents and husband Maloi who have been very supportive during my educational journey and have given me word of motivation in pursuit of my master's degree.

This reservation also goes to my two daughters Nina and Nasha. May this project be an inspiration to passionately pursue education, and grow to be ladies of value and achieve your ambitions.

Acknowledgement

I would like to express my sincere gratitude to the Almighty God for being my strong pillar throughout this project. It’s for his love and mercies that am able to complete my Project. I would like to recognize my supervisor Peter .C Wakoli for the guidance, encouragement, support and counsel during the Research period.

Credits to Mr. Martin Nyoro for provision of DEM data from Geomaps Africa and to Mr. Job Maloi for his technical assistance.

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ABSTRACT

Poor solid waste management is among the factors considered as environmental health harzards. One of the ways of managing solid waste in an urban area is by disposing the same at a carefully selected land-fill site in or around the area. Because of the tremendous impacts on the economy, biodiversity, climate, and public health, site selection is a serious problem in the urban planning phase (Abu Albert Mornya).

Ngong Town in the constituency has a solid waste disposal problem that adversely affects its inhabitants. The aim of this project was to use geospatial technologies to identify a suitable site for disposal of solid waste in Kajiado North Constituency. As of 2019, the constituency had a population of 306,596.

The methodology of the study involved data acquisition, creating a model that buffered the criteria according to their factors, the creation of criteria analysis maps and performing a weighted overlay analysis using the criteria analysis maps to come up with a suitability analysis map. The data used included; Satellite imagery, County spatial data, Development plans and Digital elevation model.

The project entailed identifying and weighting the factors that influence the choice of a suitable waste-disposal site, carying out multi-criteria analysis and producing an overall site-suitability map. The map was then used to evaluate the appropriateness of the waste disposal locations that the local government had already chosen.

As per the research criteria used in the analysis, the study was able to come up with suitable sites for solid-waste disposal. It further established that the current dumpsite lies within the unsuitable areas and therefore it is unsuitably located. The results indicated that there were several areas that were suitable for landfill and could be used. It is therefore recommended that the dumpsite be relocated to one of the more suitable areas, such as Kibiku. Due to scarcity of land as years go by, need for identifying sites vertically instead of horizontally is important. A quarry site could be considered on this since in Kenya only few fill-up of the quarries is done.

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CHAPTER 1: INTRODUCTION

1.1 Background

The amount of waste generated has increased dramatically as a result of the increasing population, urbanization, and industrialization. Solids, sludge, liquids, gases, and any combination of these can be formed as waste. Some waste can degrade into harmless products depending on their nature and source of generation, while others may be non-degradable and hazardous.

The collection, storage, and disposal of garbage and other waste materials is referred to as solid waste management. All trash generated by human and animal activity that is normally dumped as undesired waste is defined as solid waste. The word "solid waste" refers to a diverse collection of residential, agricultural, manufacturing, and mineral wastes. Waste is generated in several areas, some of which include: residential, industrial and even commercial areas. Most solid waste may be categorised as organic, metal, glass, plastic and paper waste.

Environmentally sound waste management entails making all reasonable steps to guarantee that trash is managed in a manner that human health and the environment are protected from the waste's possible detrimental effects. (Kenya Gazette, 29th September, 2006).

A society that is active in terms of lifestyle, poor waste management practices and outdated production technology leads to accumulated waste deposits. Improper waste management contributes to Climate Change and makes pursuing sustainability more difficult. Solid waste, among other things, is a source of greenhouse gases that contribute to climate change.

Solid waste can be managed by different methods which include: Incineration, Recovery and recycling, Composting, Pyrolysis and finally disposal. The incineration method involves the use of high temperature to burn solid waste. Temperatures are usually not so high so this method could be used by institutions, ordinary people and even municipalities. The most common and well-known method is the recovery and the recycling method. In this method, waste to be disposed is usually reused to manufacture other products. Before manufacturing or recycling, the waste is usually cleaned and processed.

The composition method is purposely for the biodegradable wastes where by it is used to form manure used for agricultural purposes. Pyrolysis is a method that encourages the burning of solid waste chemically without the presence of oxygen. The burnt solid waste is transformed into small quantities of liquids, gases and solid residue.

In industrialized countries, the problem of solid waste has been effectively addressed through waste reduction, reuse, recycling, and effective disposal. One of the world's most pressing urban challenges is the lack of space for waste disposal, as well as restricted landfill sites and rapid population growth. Landfills are an essential part of any solid waste management plan. The world is always looking forward to go green, clean and ensure an environment that is suitable. From the early days, solid waste had continued to rise since it comprised of all the unwanted products from human and animal day activities.

The selection of a waste disposal site is a complex problem that requires several parameters to be considered. The parameters include: Slope, Elevation, Land use, accessibility to roads, vicinity to settlement areas, Proximity to rivers and water bodies. (Süleyman Sefa Bilgilioğlu, 2014)

There have been efforts to manage the waste around Kajiado North Constituency and the only progress made was recycling and reuse of some of the waste like plastics. According to (Dr. Lewis Sitoki, 2018), The County Government had chosen the “Vet Farm” site in Kerarapon (Embulbul) to host the planned solid waste treatment facility.

Kajiado North Constituency experienced an increase in population, which has resulted in a rapid rise in solid waste production. Waste disposal in the area has become a major problem to the residents and finding a solution is tending to be more difficult (Habiba Ibrahim Mohammed1 , 2017. Waste reuse and recycling is the waste disposal method used in Kajiado North Constituency by a company that separates the non-biodegradable materials from the degradable. The non-biodegradable waste was reused and recycled while the remaining waste was left lying around the area. This method was not able to handle every type of solid waste, and this leads to the question of where the rest of the waste would go.

1.2 Problem Statement

Solid waste Disposal around the globe was recognised as an important activity in the society. Although Kenya's Vision 2030 had prioritized five cities and towns (Mombasa, Kisumu, Eldoret, Nakuru and Thika) for implementation of sustainable solid waste management systems, those strategies were to be applied countrywide (World Bank, 2019). In recent times, researchers have used GIS and Remote Sensing in conjunction with Multi-criteria Decision Analysis to determine the locations of suitable sites for land fills.

Landfilling is the most ancient and widely used method of disposing solid waste in most nations throughout the world, in which a suitable location is chosen and a big hole is constructed to dispose and compress the solid waste. The main reason for selecting an appropriate landfill site is to ensure that the location selected has the minimum negative impact to the population and the environment. In order to achieve this, an evaluation process needs to be carried out and the selected location should comply with the existing Government regulations.

The problem facing Ngong Town is that a proper solid waste disposal site had not been selected based on any scientific criteria. This project aimed to undertake research on the most appropriate site for solid waste disposal based on scientific criteria. It will guide the Kajiado county government on selection of a suitable dumping site for Kajiado North constituency. It is of great concern that the existing dumping area which is in Ngong Township has become such a nuisance to the residents since it stinks and renders the environment untidy. It also poses critical health hazards to the residents of that area. It was selected depending on distance to settlement but no scientific criteria were used. There was a proposal to locate the site at Bulbul which is in the suburbs of Ngong town where solid waste will be sorted and recycled. A previous project analyzed the areas suitable for putting up a land fill and proved the proposed areas were the right landfill site as per criteria (Star, 21st September 2019).

This study involved a suitability analysis to select the best location to develop a waste management system, using Geographical Information Systems (GIS) to show the options separate from the ones identified before. Kajiado North Constituency in Kajiado County was considered to be the area of interest.

Figure 1. 1: Showing the current dumping site located within Ngong Township.

1.3 Objectives

The main objective of this study was to use geospatial technologies to select suitable sites for solid waste disposal in Kajiado North Constituency in Kajiado County.

1.4 Specific Objectives

i) To identify site-selection criteria and their respective weights.
ii) To produce site suitability maps based on each criterion.
iii) To carry out multi-criteria analysis culminating in the production of a final site-suitability map.
iv) To evaluate the suitability of the existing dumpsite and the ones proposed by the local authorities

1.5 Justification for the Study

Through research, the solid waste disposal problem in Kajiado North Constituency will be addressed and a solution on a suitable site selection identified. Moving the Ngong centre landfill site to a more convenient location will enable the County government to reclaim the land which is considered prime with regards to its location. The land is considered prime since it is on a good road network and close to the central business district of the town. It is also the only open land which is close to the Ngong stadium and when reclaimed can be used for parking and/or other activities.

Since Kajiado County government is not new to the idea of relocating the dumpsite the purpose of this research was to show the importance of implementing the relocation of the landfill site as soon as possible due to the damages it is causing and also its alarming growth rate. The research will bring in the factor of time, the best suitable locations for relocation and the benefits of the new landfill site. With Ngong having a poor urban plan, an open additional space will be advantageous since it will be used to locate some of the planned avenues.

Due to the harmful impact of the present landfill site, the Kajiado North constituency will be the first to benefit from this research. The county government will also benefit since this will be a positive move towards planning its town's hence proper revenue collection and improved County government services to its population.

1.6 Scope of work

The study confines itself to selecting sites suitsble for solid waste disposal in Kajiado North Constituency. The study explores on the criteria used in selecting the most suitable site. It also discusses how GIS technologies are used in determining the suitable dumping site in Kajiado North constituency. In this study, the analytical hieracial process was used in weighting the criteria and mapping them in order to determine the most suitable site for disposal. Due to the broad study of solid waste management, the study was not able to deal with other effective and efficient waste management methods but limited to selection of a suitable site. There were a variety of parameters to be utilized in site selection, but the research only employed six: distance from settlement, distance from the road network, distance from water bodies, distance from the railway, vegetation, and slope.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Waste has always been a major issue for mankind, and it has grown exponentially in recent years, becoming a major source of concern for every nation on the planet (Science), April, 2015). Waste generation is rising globally and has overstretched in the past few decades. There have been some shortcomings in managing solid waste and this has led to its voluminous accumulation. Cities throughout the world produced 0.74 kilos of solid garbage per person per day in 2016. Yearly garbage generation was predicted to increase by 70% from 2016 levels to 3.40 billion tonnes by 2050, due to continuous population expansion and urbanization.

'According to the U.S. Environmental Protection Agency' some regulations and restrictions were provided to regulate environmentally unfriendly projects, with landfill site requirements being one of them, and several agencies in various developed countries adapted it (Authority N.E, 2016). Solid waste production in terms of rate and quantity vary across Africa. It is connected to the industrial development, Lifestyle and waste management system in each country (Mohee, 2012). Residents in emerging nations, especially in urban areas, are more severely affected by unfeasible waste management than residents in developed nations.

Approximately 90% of waste in nations with a low income is disposed to unbridled dumps or burned in open. This has great consequences for one's health and the environment. Disease vectors thrive in waste that has not been adequately handled. It also emits methane, which contributes to global warming, and it has the potential to increase urban crime. (World Bank, 2019).

With the application of Geographic Information Systems and Multi Criteria Decision Analysis, a lot of research has been done on landfill site appropriateness assessments over the years. Researchers have widely used the above methods to create a suitable landfill site for garbage disposal and the preceding approaches were used in many nations (Habiba Ibrahim Mohammed, 2017).

To improve the cities and ensure they are sustainable and livable, well-managed waste is essential. For many developed countries and cities, this continues to be an issue. Waste management is costly, accounting for between 20% and 50% of municipal expenditures.

Operating this vital municipal service allows for the creation of appropriate, advantageous, and long-term integrated systems. (World Bank, 2019).

2.2 Future of solid waste management

In most large cities in Africa, solid waste management is a major environmental issue. If the continent is to stay up with worldwide advancements and standards in Mass Solid Waste management, alternative applications such as composting, separation and recycling may help transform waste into assets by generating employment and income. There is still a myriad of obstacles that Africa must tackle in order to do this. They include improving current waste collection and disposal methods. To overcome this problem, more investment in solid waste management and technology is essential. However, how well waste is handled and disposed is a measure of how well the local government system is functioning. Waste is no longer a burden on the state in industrialized countries, but rather a resource that has been incorporated into energy-generation systems. As this brief demonstrates, waste management and re-use in Africa seem to need significant change through the implementation of cutting-edge technologies (Mohee, 2012).

2.3 Solid waste disposal in Kenya

In Kenya, there are few dumping sites which require to be increased as per county. Due to the high growth of the population, the sites need to meet environmental and public health considerations. According to (Africa.net, 2016), virtually half of the Solid waste produced (1500 tons per day) is uncollected. Moving the local stinky dumpsite will have economic benefit to the residents of Kajiado North Constituency and they will soon get a breath of fresh air.

Many factors must be taken into account when deciding where to place a landfill, according to a case study conducted in Ethiopia by (Genemo Berisa, 2016), GIS was suitable for this type of research on accounts of its potential to manage substantial quantities of geographical data from a variety of sources. For the study of landfill site suitability, the technique used involved GIS to assess the whole town based on certain assessment parameters.

The criteria were later chosen based on the characteristics of the study field. The key sub criteria employed in the geographical analysis were major highways, high tension lines, surface water, residential areas, notable buildings, soils, boreholes, and reservoirs. To extract acceptable criteria for the landfill site selection process, national and international standards were applied.

2.3.1 Locating a disposal site

Provision of a solid waste disposal site is among the public health concerns. Given the increasing rate of urbanization, long-term land use planning in the outskirts should be taken into account when deciding where the disposal area should be located.

In addition, existing and potential garbage truck traffic should be considered. When it comes to finding a waste disposal location, there are numerous factors to consider. The type of land chosen for this purpose has a direct impact on the design, use, and equipment required for a successful operation (Science) G. B., 2015). Accessibility of landfills in the region to handle the garbage,vicinity to residential and industrial sectors, and distance to and from the city are all important considerations. The proximity to road access, the atmosphere of the region, the irrigation system of the area, which includes both ground and surface water, and finally the land use of the area are all factors to consider. The factors can also be referred to as a site selecting criteria to be used in selecting an appropriate location.

Constraint criteria indicated inappropriate sites according to legislation, whereas factor criteria improved landfill placement within an area. For each of six requirements, restriction criteria maps will be generated in accordance with various regulations. To construct the final factor map, all constraint criteria maps will be overlaid (Genemo Berisa, 2016).

During the site selection process, the landfill's life expectancy and potential demand for landfill space should be taken into account. Proponents should analyze the types and amounts of waste produced in the landfill's service area, existing trash disposal routes, estimated quantities and types of garbage that will need to be disposed of, and the remaining landfill capacity at existing dump sites servicing the region. Landfills need to be built with enough space to meet the community's existing and potential waste disposal needs for the near future (Science) G. B., April, 2015).

2.4 Application of GIS technologies in solid waste disposal.

According to (Ms. Priyanka S. Deshmukh, 2017), The selection of a landfill site is often a difficult and complex process that necessitates a variety of parameters as well as large amounts of bio-physical, environmental, and socio-political data (Basnet and others 2001). Geographic information systems (GIS) are useful for early research because they can handle large quantities of spatial data from several sources. (Sener and others 2006). Since GIS allows users to enter, store, manipulate, analyze, and view vast amounts of spatial data, it can help with spatial decision-making and planning (Congalton and Green 1992). Because of this complimentary feature, multi-criteria analyses included into GIS can include correct manipulation and data display with clear ranking based on a variety of aspects that could affect the analyses. As a result, spatial data, legislation, and acceptance requirements are critical in selecting a solid waste disposal site, and there must be a strong link between them (Süleyman Sefa Bilgilioğlu, 2014).

According to (Dragoljub J. Sekulović, 2016), GIS technology enables a wide range of geographical studies by combining spatial data (maps, photogrammetric images, topography, and satellite imagery) with quantitative, qualitative, and descriptive datasets. The research includes the identification of areas suitable for the development of a landfill using GIS and the AHP. In order to compile spatial statistics and group the most appropriate areas, as well as to manage vast volumes of spatial data gathered from different sources, GIS is used. The AHP on the other hand provided for the solution of complex problems involving a variety of variables.

Analytical Hierarchical Process (AHP) has several principles used to arrive to the final product/ decision. The principles include: A definition of alternatives, a definition of problem and criteria, prioritizing the criteria using pairwise comparison, consistency checks and finally getting the relative weights used for decision making.

In accordance to the aim of this project the alternatives were defined as unsuitable, less suitable, suitable and highly suitable in that increasing order respectively. In the definition of problem and criteria, the problem is a combination of sub-problems, where breaking down the sub-problem, criteria to evaluate the solutions emerges. The criteria used in this project are: Zones (Land Use Land cover), the road network, forest, waterbodies, slope and Railway network. The problem is the current location of the dumpsite with respect to the criteria used. The next principle is creating a matrix using pairwise comparison in order to prioritize on the most suitable site.

After comparison the next step is checking the consistency, which involves whether all the criteria used have all the alternatives given in the initial stage. ArcMap will use the formula to do a mathematical calculation derived from the data and assign relative weights to the criteria: The formula is:

$$\boldsymbol{A_{WSM} = max\sum_{j=1}^{N} a_{ij}w_j}$$

Where; A_{WSM} is the Weighted Sum Model score of the best alternative.

N is the number of decision criteria

a_{ij} Is the actual value of the ith alternative in terms of the jth Criterion and;

w_j Is the weight of the jth Criterion

According to (Şule Tüdeş, 2017) According to the research, limited areas account for 67.0 percent of the territory, with 11.0 percent having low suitability, 6.1 percent having moderate suitability, 5.9 percent having high suitability, and 10.0 percent having very high suitability. The end result included an overview and assistance in resolving waste management issues. According to the research, limited areas account for 67.0 percent of the territory, with 11.0 percent having low suitability, 6.1 percent having moderate suitability, 5.9 percent having high suitability, and 10.0 percent having very high suitability. The study concluded that GIS-based MCDM enabled decision makers to make proper decisions in the context of difficult decision-making environments relevant to urban areas using GIS technology and APH. As a result, the model developed after the study could be used in other similar analyses with different parameters and scales. The study's model consisted of selecting a solid waste landfill site while taking into account geo-environmental factors. The research may also provide useful guidanceto waste management and site selection, plus a proposal for various purposes and decisions.

After analyzing previous works, it was clear that the analytic hierarchy process (AHP) was a decision-making method created by Saaty (1977, 1980, 1986). Its main purpose was to provide solutions to multivariate decision and estimation problems. The AHP organizes priorities, requirements, and sub criteria in a hierarchical system to determine priority weights for alternatives (Michele Bernasconi, 2009). GIS is used for spatial analyses and worked hand in hand with the multi-criteria decision-making analysis which is APH. Land usage, distance from surface waters, distance from cities, distance from road networks, aspect, slope, and elevation were the eight parameters used to conduct the study.

CHAPTER 3: METHODOLOGY

3.1 Area of Study

The area of study as shown in figure 3.1 is Kajiado North Constituency in Kajiado County. It consists of six wards namely, Ngong, Olkeri, Oloolua, Ongata rongai, keekonyokie and Nkaimurunya.

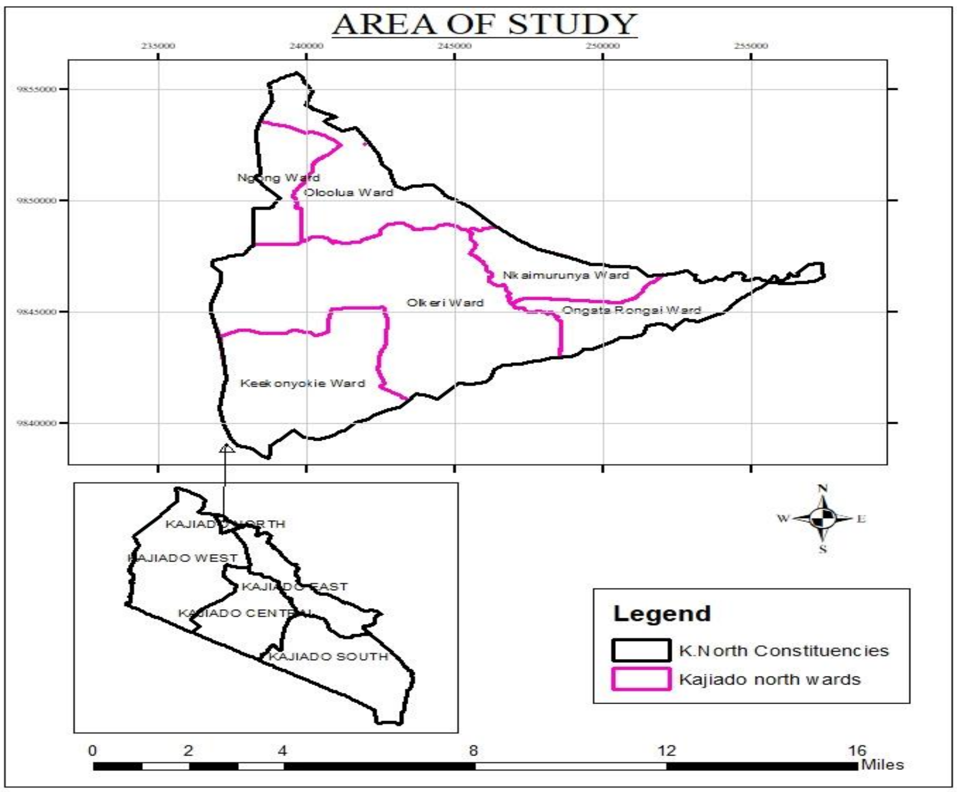

Figure 3. 1: Location map of the Study Area

3.2 Data and Data Sources

Data collection was one of the major activities that spearheaded this project. Table 3.1 shows the sources from where data was collected in order to be used in GIS software.

Table 3. 1 The Geospatial data types used in the study

Data	Description	Source	Format
Satellite Imagery	They show the rapid change and growth of the dumpsites.	USGS	Raster format
County spatial data	They show the vector data required.	UON Lab and ILRI	Shape files
Development plans	They show land use data for the towns within Kajiado North	County Planning Office	Raster format
Digital Elevation Model	To extract contours for Slope analysis	Geomaps Africa	Raster format

3.2.1 Software Requirement

The software used in this project included:

- ArcGIS Software
- MS Word

3.3 Work flow and Methodology

The methodology of this research was based on the main objective of the study which was to select a suitable site for solid waste disposal using the GIS software. The scope involved data acquisition, creating a model that buffered the criteria according to their factors, the creation of criteria analysis maps and performing a weighted overlay analysis using the criteria analysis maps to come up with a suitability analysis map.

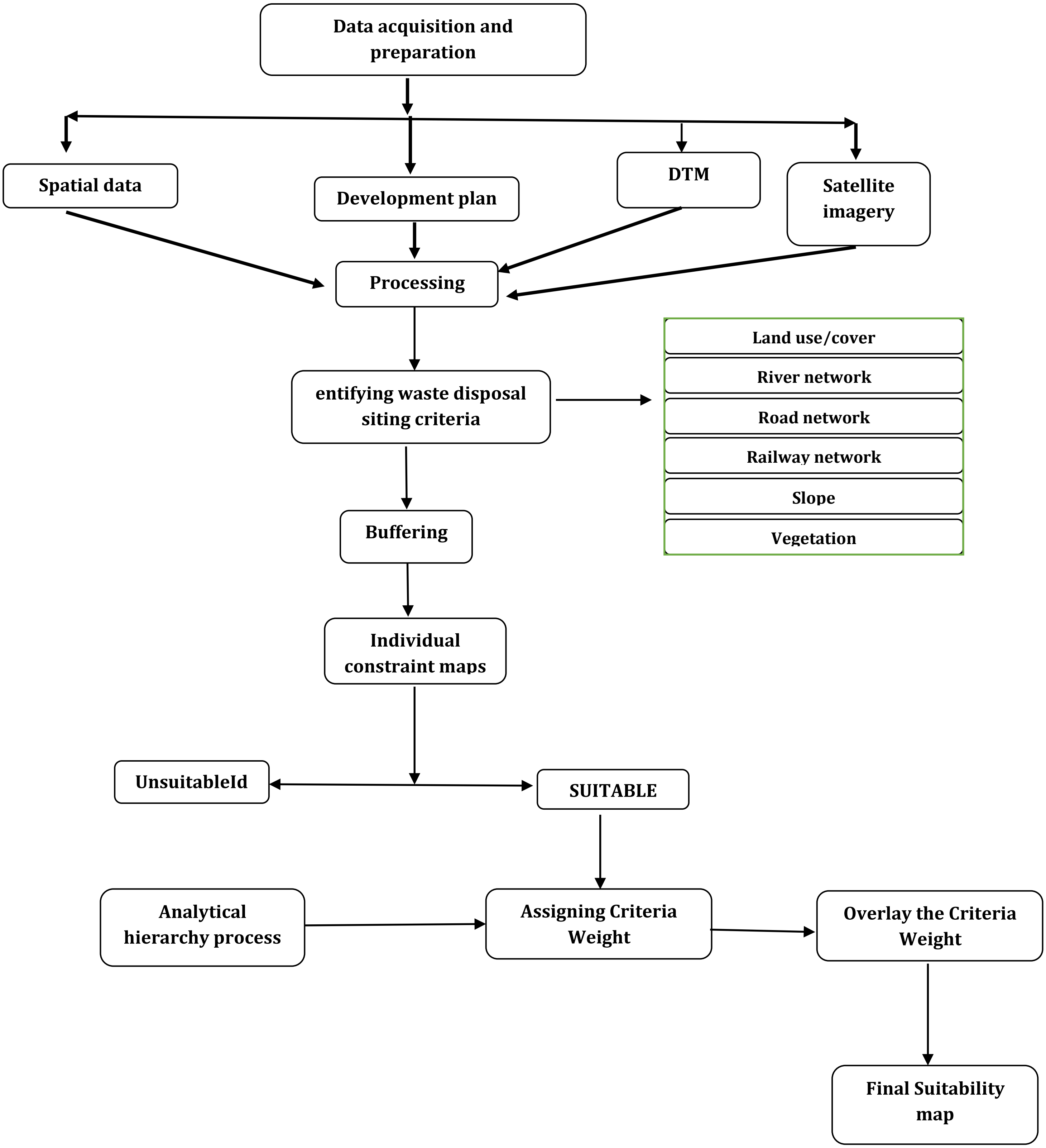

Figure 3. 2: Methodology flow chart

3.4 Data Preparation

In this study, there were various criteria used in selecting suitable landfill sites. The criteria included distance from settlement areas, road network, railway, water bodies, vegetation and slope. Map layers were imported and analyzed for each criteria to confirm that they had a same coordinate reference system.. In the ArcGis environment, the data was prepared to ensure quality data analysis. For every criterion data, clipping was undertaken to ensure they were within the area of study. The data input was rasterised for the purpose of weighting analysis.

3.5 Site Selection

By balancing all the multi criteria factors used in the study, a suitable site selection was acquired. The criteria were all important but they had to be used according to those with high preferences. The values were attributed in the ArcGIS environment putting into consideration their preferences and used for analysis.

3.6 Data Analysis

The data acquired from data acquisition was manipulated, evaluated and analysed in the ArcGIS environment. The software was primarily used for data processing.

3.6.1 Slope Analysis

The DEM data was obtained from the Regional Center for Mapping of Resources for Development (RCMRD) Portal. The study area was used to clip the DEM, and two-meter contour interval was extracted.

The contours were used to create a Triangular Irregular Network (TIN) which was then converted into raster. Under the spatial analysist tool in ArcGIS, the slope tool was used to create a slope map. The slope map was reclassified to change old raster values to new values that were unique and controlled the numerical precision of reclassification value.

The raster data was later converted into a polygon and the grid code in the attribute table used to categorize the slope interval.

3.6.2 Proximity analysis

The first analysis for the criteria land use (zones), road network, forest and reserves, waterbodies (rivers and dams) and railway, is proximity analysis. Under the proximity analysis the multiple ring buffer was used to give the appropriate distances as per the international and UNEP standards.

Table 3. 2 Dataset Standardization for Buffer Analysis

The table 3.2 below indicates a weightage computation which was formulated using analytical hierachy process (AHP) to give the categories values respective to their influence in site selection.

CRITERIA	BUFFER DISTANCE	SUITABILITY	RANKING
Land Use (ZONES)	0-200M	Unsuitable	1
	200-500M	Less Suitable	2
	500-1000M	Suitable	3
	>1000M	Highly Suitable	4
Road Network	0-500M	Unsuitable	1
	500-1000M	Less Suitable	2
	1000-1500M	Suitable	3
	>1500M	Highly Suitable	4
Railway Network	0-200M	Unsuitable	1
	200-500M	Less Suitable	2
	500-1000M	Suitable	3
	>1000M	Highly Suitable	4
Water Bodies (River, Dams)	0-300M	Unsuitable	1
	300-700M	Less Suitable	2
	700-1500M	Suitable	3
	>1500M	Highly Suitable	4
Slope	21°-28°	Unsuitable	1
	14°-21°	Less Suitable	2
	7°-4°	Suitable	3
	0°-7°	Highly Suitable	4
Vegetation	0-300M	Unsuitable	1
	300-700M	Less Suitable	2
	700-1500M	Suitable	3
	>1500M	Highly Suitable	4

Table 3. 3 Normalized pairwise comparison matrix (6 layer) developed for AHP based landfill site selection

Table 3.3 below shows a matrix computation using the weighted sum model formula to show weights of each criterion.

FACTORS/CRITERIA	Zone (LuLc)	Roads	Forest	Waterbodies	Slope	Railway	**Weight**
Zone (LuLc)	6	5	4	3	2	1	0.40
Roads	6/2	5/2	4/2	3/2	2/2	1/2	0.20
Forest	6/3	5/3	4/3	3/3	2/3	1/3	0.13
Waterbodies	6/4	5/4	4/4	¾	2/4	1/4	0.10
Slope	6/5	5/5	4/5	3/5	2/5	1/5	0.09
Railway	6/6	5/6	4/6	3/6	2/6	1/6	0.08
TOTAL							1

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Criteria identification and respective weights.

Table 4.1 below shows the criteria used in the project and their assigned weights.

Table 4. 1 Weights assigned for different landfill site parameters in the present study

FACTORS	WEIGHT	RANK	OVERALL WEIGHTAGE
Land Use (Zones)	40	1	40
		2	80
		3	120
		4	160
Road Network	20	1	20
		2	40
		3	60
		4	80
Forest	13	1	13
		2	26
		3	39
		4	52
Waterbodies	10	1	10
		2	20
		3	30
		4	40
Slope	9	4	36
		3	27
		2	18
		1	9
Railway	8	1	8
		2	16
		3	24
		4	32

4.2 Site suitability maps based on each criterion.

4.2.1 Distance from the road network

Major, minor, and street roadways connected the research region.. Accessibility was important during site selection and was considered first before selecting the most suitable site. To facilitate garbage transfer, the land fill location should not be too close to the road or too far away. The disposal site should be conveniently accessible from both existing roads and available pathways. This will reduce greatly the cost of transportation of the waste. The roads were buffered using the criteria obtained and the constraints were 0-500m which represented the unsuitable areas; 500-1000m was for the less suitable, 1000-1500m was suitable and >1500 was highly suitable. This range was chosen to aid transportation, better accessibility and cost effectiveness to the land fill site.

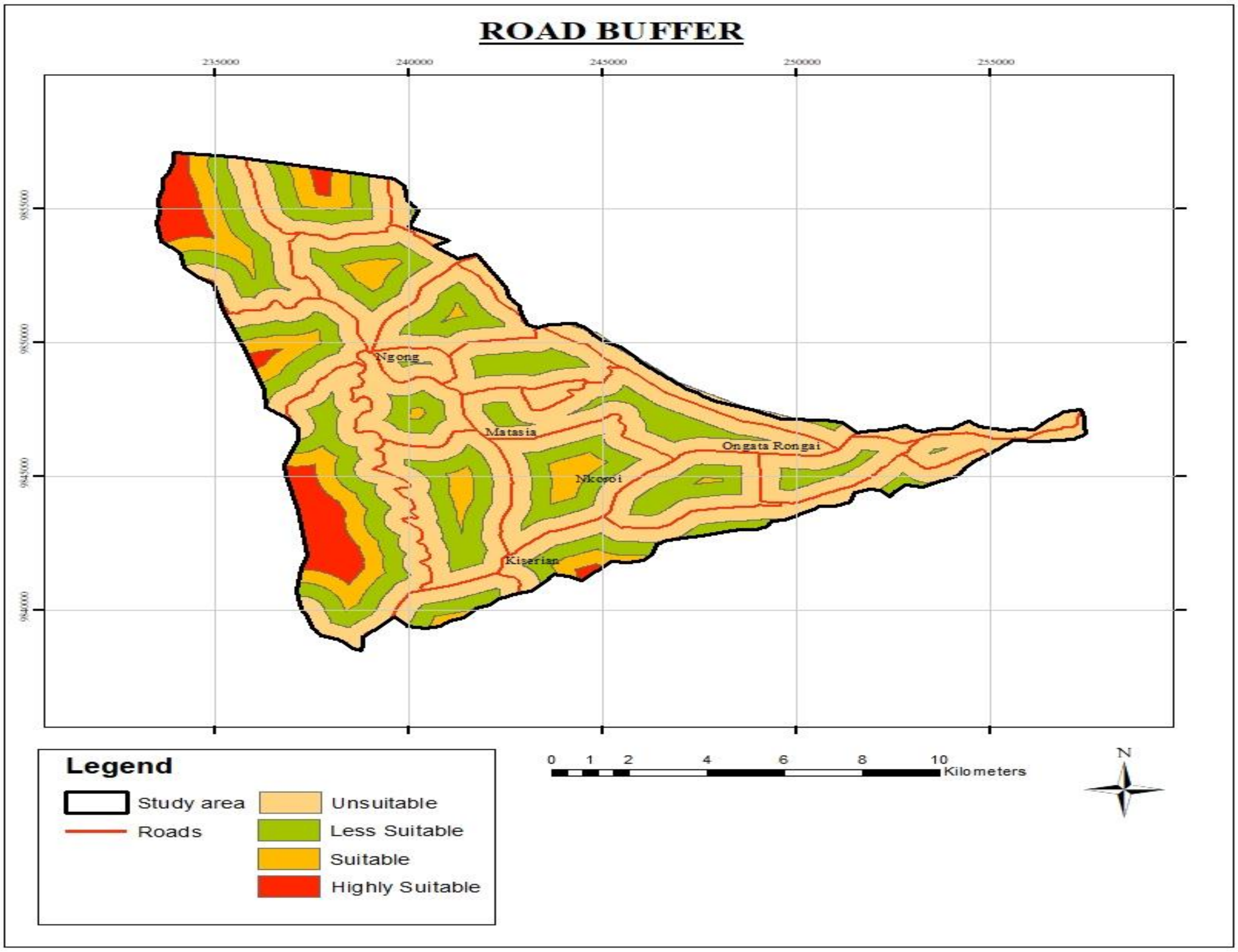

Figure 4. 1: Buffer analysis for road network

4.2.2 Distance from settlement (LuLc)

A landfill should not be located close to settlement or any land use land cover area. The Kajiado Noth Constituency has other land uses which include urban/built up areas, bare land, graze lands and agricultural land. The zones were classified as, residential, commercial, public utilities, Educational and Industrial areas which were used for buffering. Figure 4.2 shows buffers used according to the standards set. As indicated, 0-200 was unsuitable areas, 200-500M was less suitable, 500-1000M was suitable while >1000M was highly suitable. These zones were taken into consideration to avoid pollution, ecological disturbances and other health related issues.

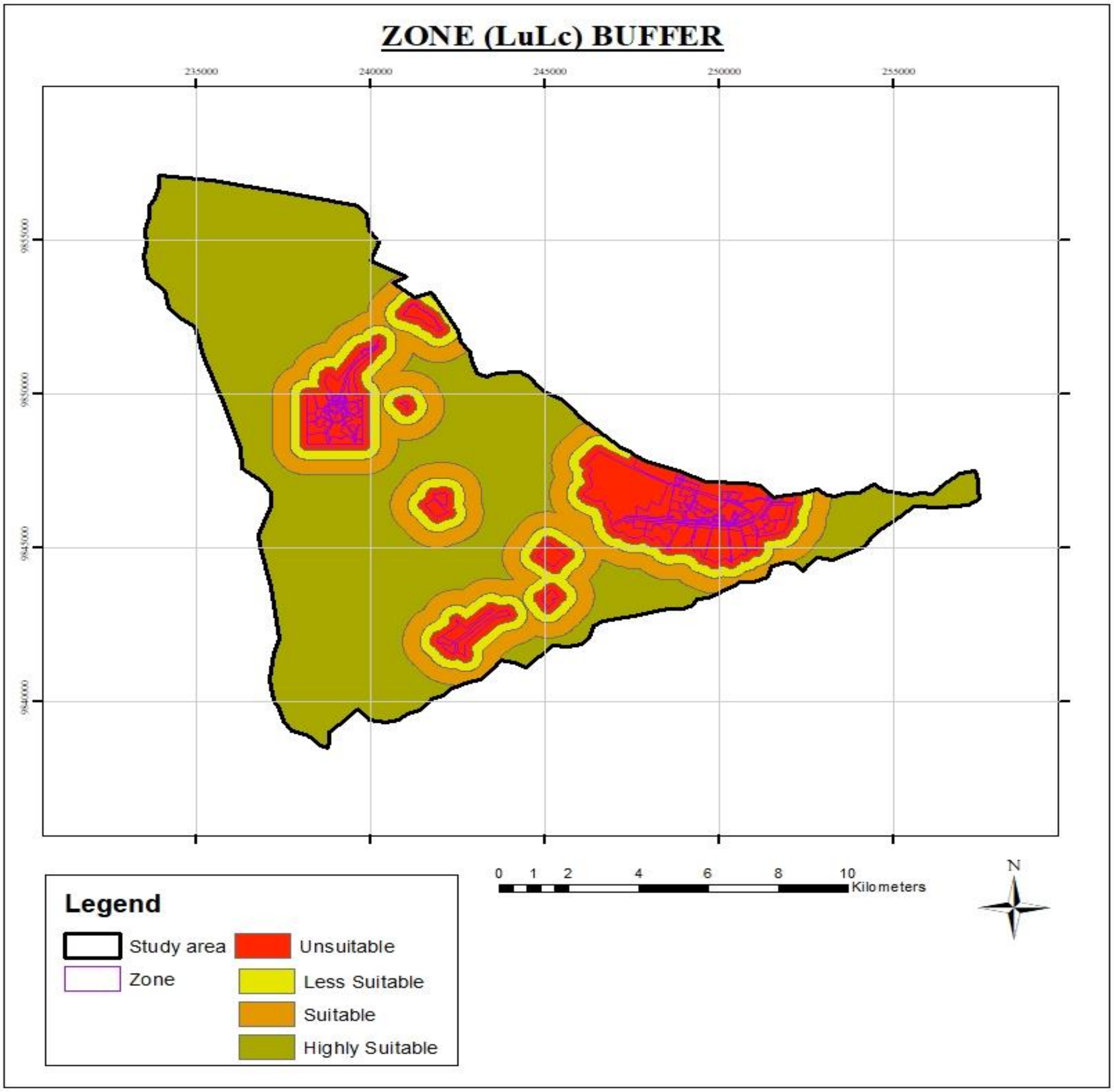

Figure 4. 2: Land use Land cover constraint map

4.2.3 Slope Analysis

Slope map was extracted from the Digital Elevation which represented the whole world. Lands with slopes >21° were seen as unsuitable while 14°- 21° were less suitable. According to the international standards 7°- 4° were the suitable slope which were required.

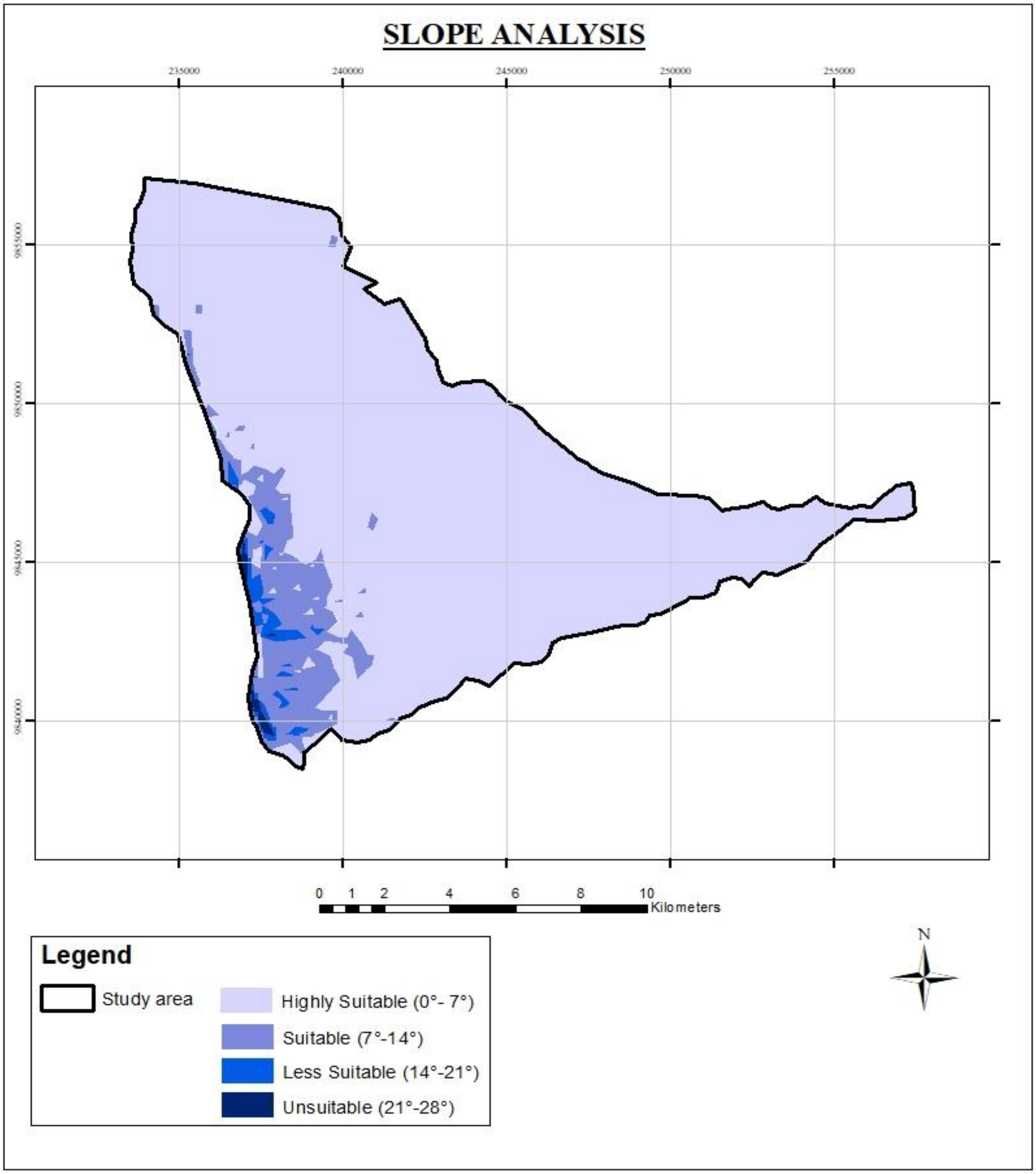

Figure 4. 3: Buffer analysis for Slope analysis

4.2.4 Vegetation

Vegetation cover included forest and any protected zones with vegetation or wild habitat. Less than 300 meters buffer was considered to be unsuitable, 300 -700 meters was less suitable, 700 - 1500 meters was suitable while >1500 meters was highly suitable.

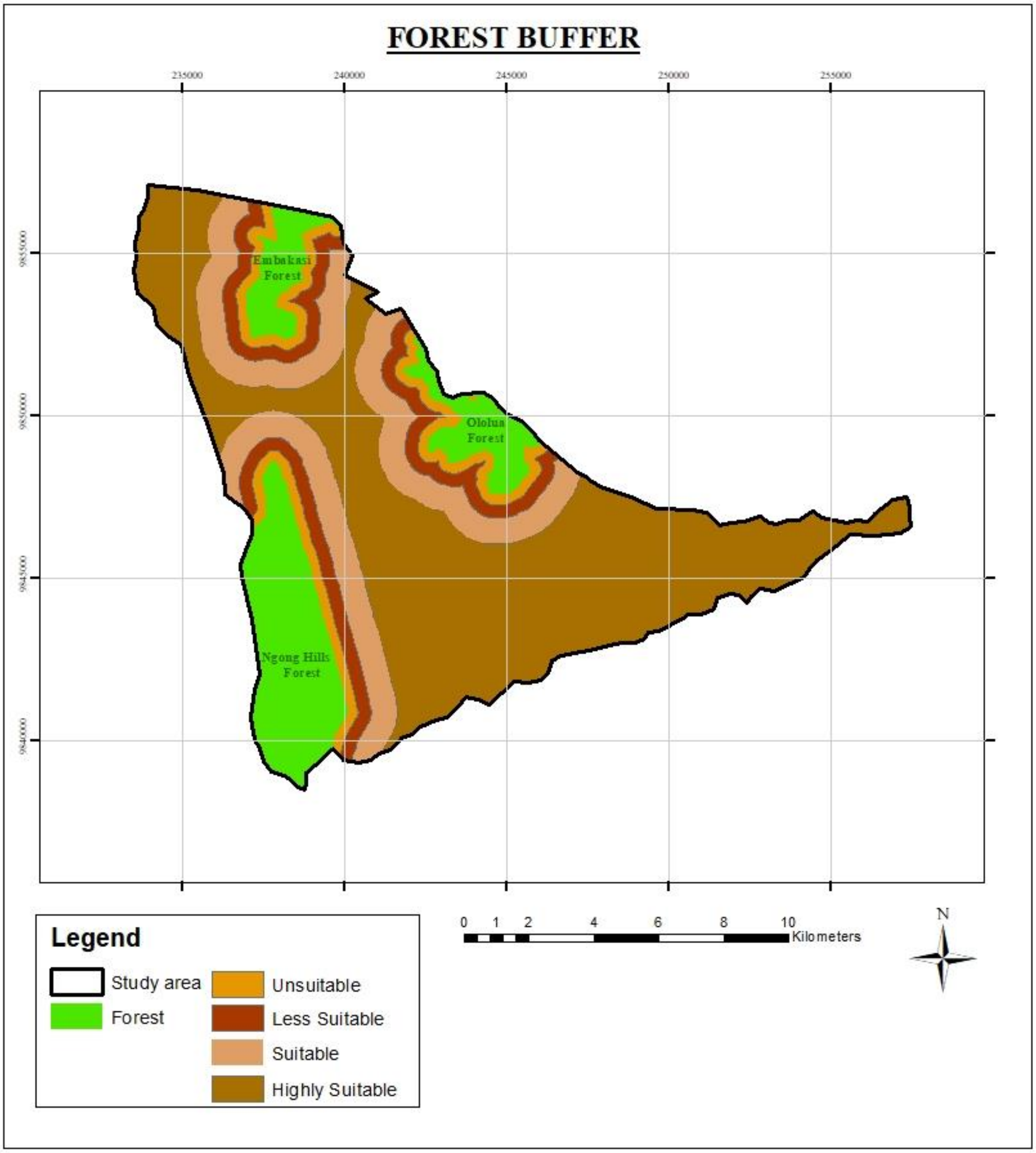

Figure 4. 4: Buffer analysis for vegetation

4.2.5 Distance from water bodies

The water bodies considered during the study included dams, streams and rivers in Kajiado North Constituency. There are no lakes within the Constituency. A land fill site should be located away from any water body to ensure no contamination of ground and surface water bodies. Less than 300 meters buffer was the unsuitable, 300 - 700 meters was less suitable, 700 - 1500 meters was suitable while >1500 meters was highly suitable.

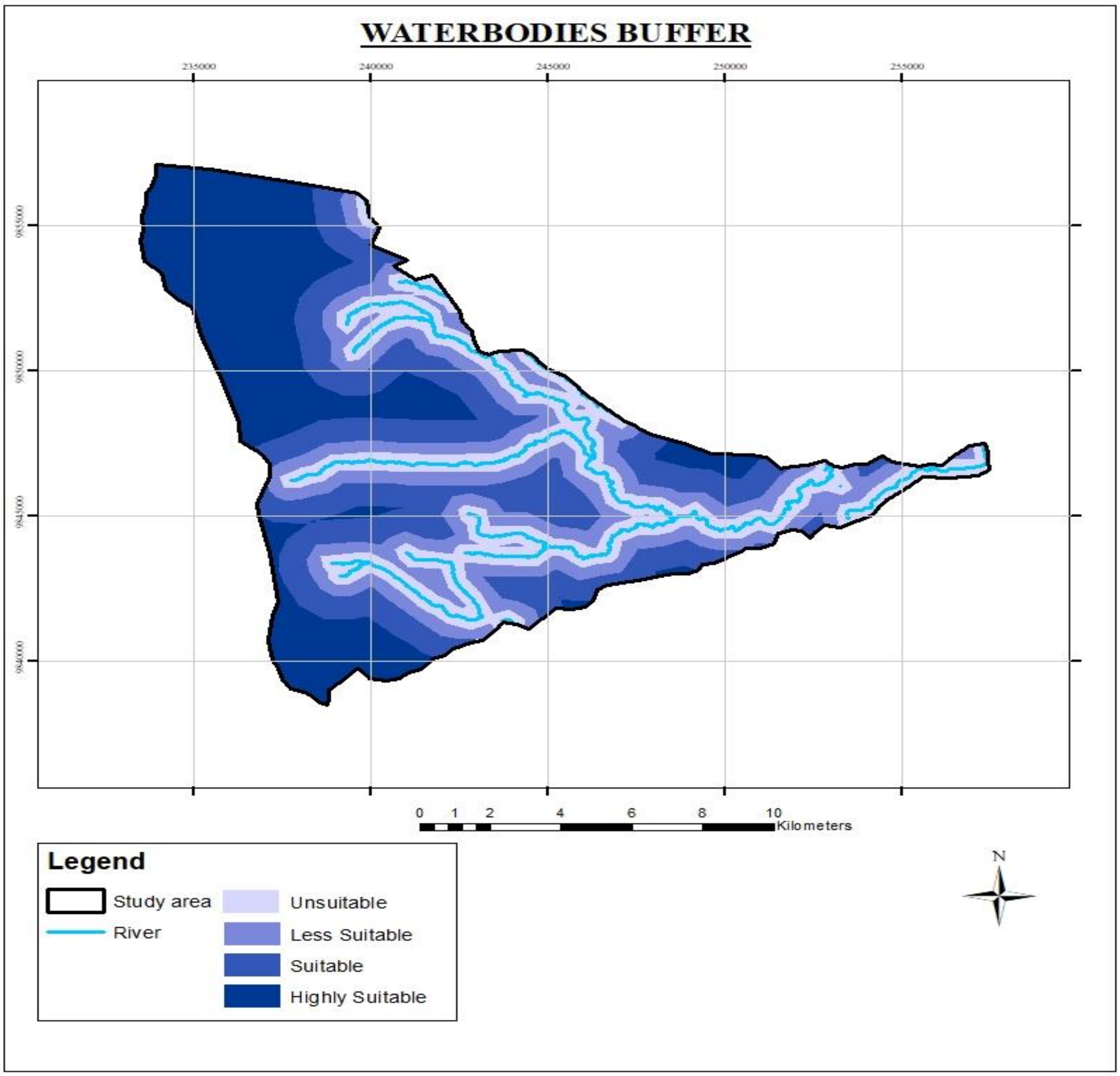

Figure 4. 5: Buffer analysis for waterbodies.

4.2.6 Distance from the Railway

The standard Gauge Railway was taken into consideration since it crosses the kajiado north Constituency. A landfill site should be located at least 1 kilometer away from the railway line. The buffer distance of less than 200 meters is unsuitable, 200-500 meters is less suitable, 500-1000 meters were the suitable areas and finally >1000 meters was highly suitable.

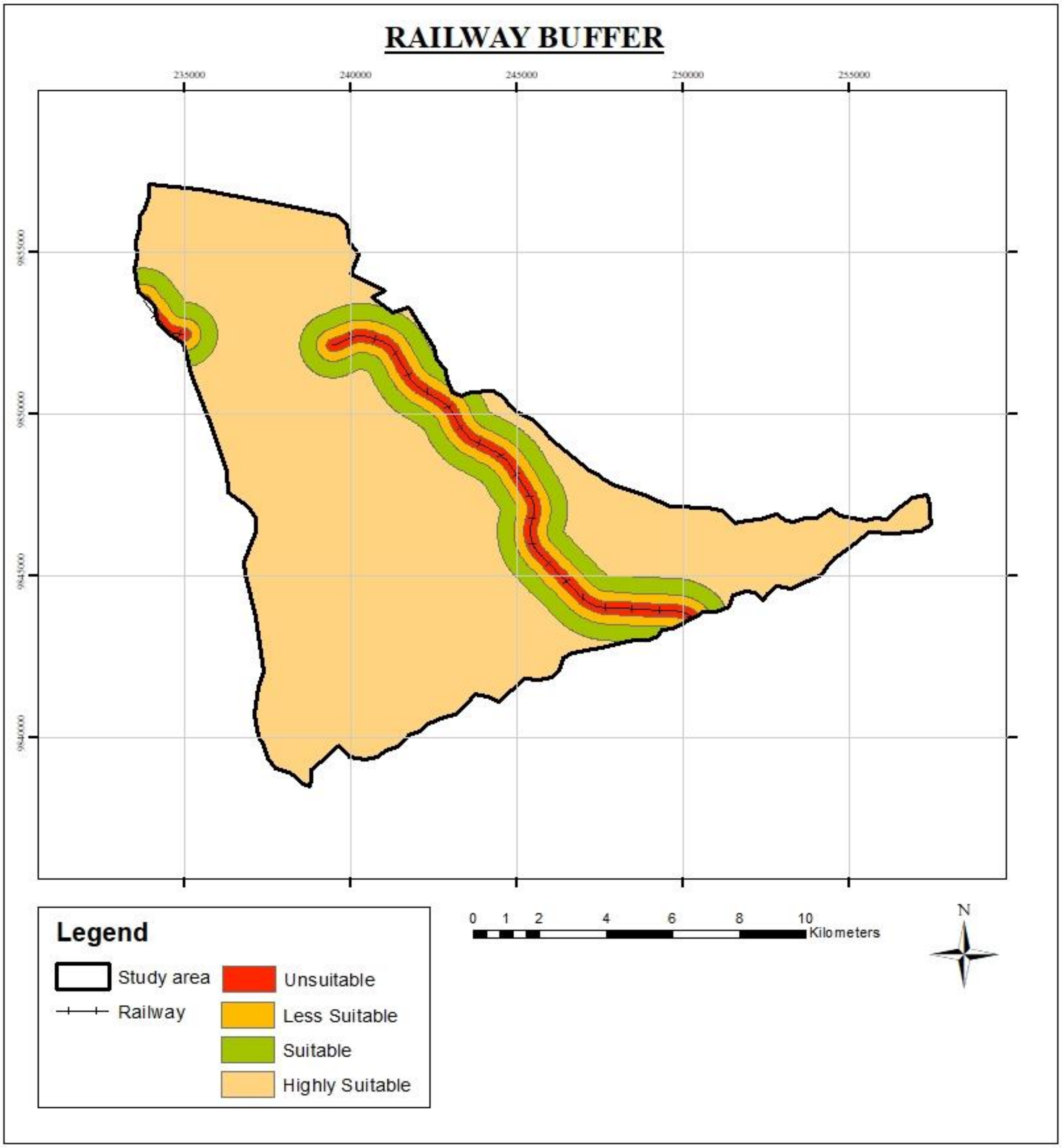

Figure 4. 6: Buffer analysis for Railway

4.3 Overall site suitability map

The figure 4.7 below shows the final map after overlaying all the criteria used for the study. This combination of criteria gives a clear analysis and result of the most suitable area to place the dumping site. Suitable areas are identified and represented by green, according to the final overall suitability map.

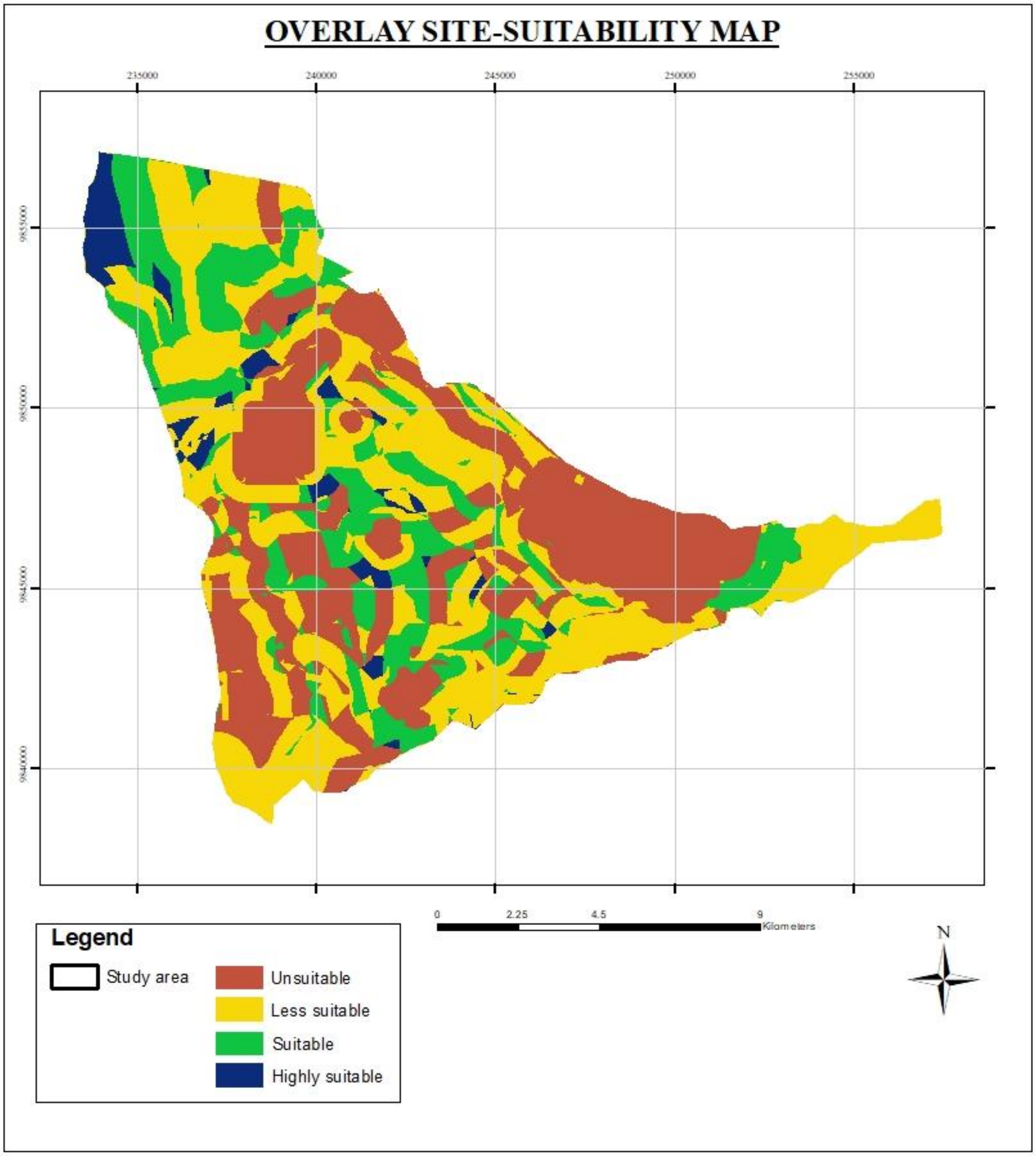

Figure 4.7: overall site suitability map

4.4 Dumpsite Selection

The current dumping site in Kajiado north constituency is located in Ngong Township. It has occupied 2.18 Ha. The suitability site selection analysis was undertaken based on distance from settlement,distance from the road network,distance from the railway, distance from any water bodies, vegetation and slope. This leads to a final decision on the most suitable site to locate the landfill.

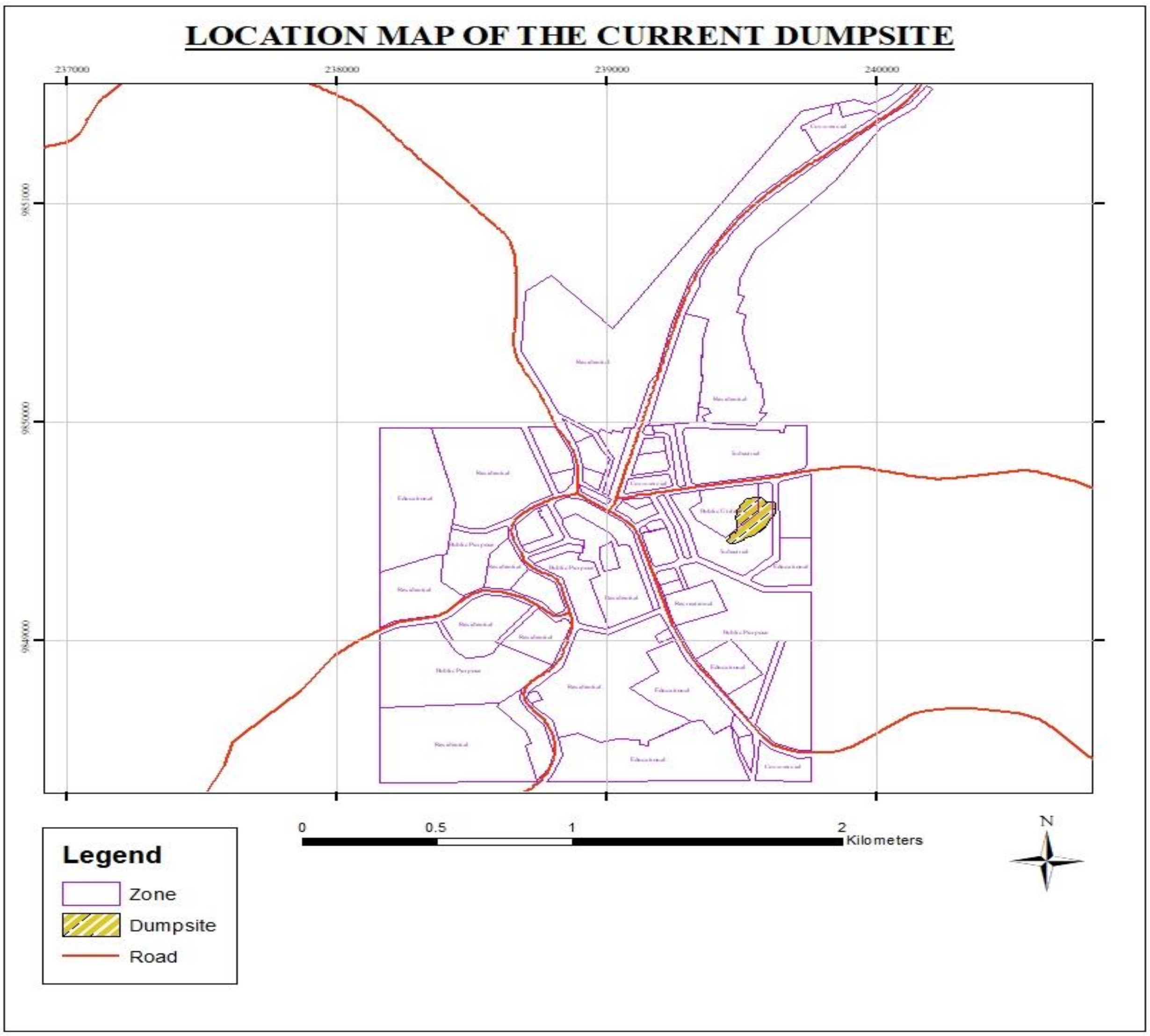

Figure 4. 8: The location of current dumping site

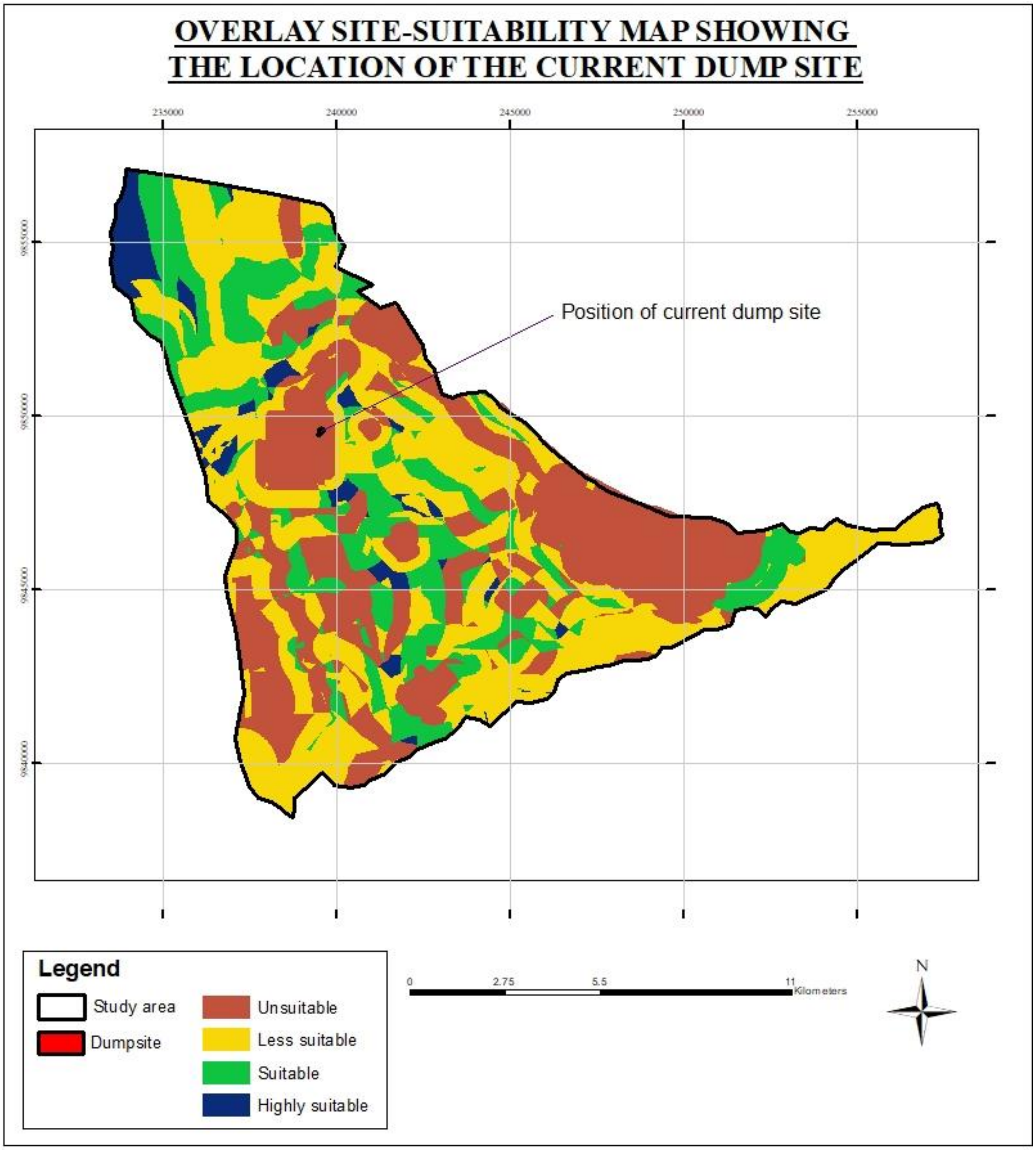

Figure 4.9 The location of current dump site overlaid on the site suitability map

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The results indicated that there were several areas that were suitable for landfill and could be used. Although from the results the largest area is unsuitable, there is a number of areas that are suitable and could be used in selectin a suitable site. It is clear from the results that the current dumpsite is located in the unsuitable area. Kibiko however was identified as the most suitable site as per criteria used. It is considered more suitable than the others because of its location and also the size. There is government land close by which is “Vet” and a piece could be secured for a landfill site.

Within the Kajiado North constituency, there are different types and quantities of waste identified and the location at which they are disposed. A geographical analysis has been devised to aid in the identification of the best site for solid waste disposal. It has also been identified that the current dumping site within Ngong Township is not suitable as per criteria used. The County Government would have to take the initiative in project implementation.

5.2 Recommendations

Solid waste management is an important activity for every urban centre. The following recommendations were suggested from the findings:

- Policies should be formulated to support waste management by the County government. A policy where by the government will initiate a scientific analysis of sites before identifying them as suitable land fill sites.
- The current dumping site located in Ngong Township tends to be harmful to the people settles around it. This site could be put to better use in accordance with the approved development plans of the county.
- Kajiado North being a metropolitan county, rapid growth is being reflected and this calls for need of rapid action in moving the current dumpsite.

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