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Landfill Site Selection for Solid Waste Management in Karu Lga, Nasarawa State, Nigeria

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Abstract: Solid waste disposal is a crucial problem in the urban and rural areas because most solid wastes are not dumped in the suitable areas. Karu LGA has the challenge of solid waste dumping site identification. The specific objectives of this study were to: map and identify the existing landfill site and dump sites in the study area and to identify potential suitable landfill site(s) in the study area. The main data used for this study were SRTM image with a spatial resolution of 30m spatial resolution, Landsat 8 OLI imagery, google earth imagery and ground control point (GCP) collected by ground point survey (GPS). The maps were prepared by overlay and suitability analysis of geographic information system (GIS), remote sensing techniques and multi criteria analysis methods. The potential suitability map was prepared by overlay analyses on Arc map and suitability levels as high, moderate, less suitable, and unsuitable sites of the study area were determined. The results indicate that 37.7% of the study area is unsuitable for solid waste dumping; 44.29% less suitable; 14.97% moderately suitable; and 3.0 % most suitable. The GIS and remote sensing techniques are important tools for solid waste site selection. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will reduce the risk contacting diseases and improve the aesthetic look of the environment and cut down cost of constructing a landfillin the study area.

Keywords: *Solid waste; Landfill; AHP; Weighted overlay*

I. INTRODUCTION

A. Background to the study

In the last two decades, towns and cities in Nigeria have being growing in number, physical size and in population. In the words of Onibokun and Kumuyi (1996) "Nigerian towns and cities are exploding — growing in leaps and bounds. The problems and challenges posed by this rapid urban growth are immense. One of which is solid waste generation and management. Solid wastes could be defined as non-liquid and nongaseous products of human activities. Urban solid wastes are made up of a variety of materials including vegetable matter, food fragments and remnants, papers, rags, and large quantities of dust and soil material from the sweeping of streets and surroundings of residential buildings (Arlosoroff, 1982: Leton and Omotosho, 2004). These materials are heaped together as dumps in various parts of urban centers and cities in the country.

One of the means used to solve the problem of refuse disposal commonly used everywhere in Nigeria is the utilization of landfill. Landfill is an engineered method of disposing of solid waste on land in a manner that protects the environment, by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with compacted soil by the end of each working day or at more frequent intervals if necessary. Sanitary landfill are and will continue to be the principal method of urban solid waste (U.S.W) disposal because of the relatively inexpensive equipment required to operate and the possibility to reuse the site once the landfill has been sealed and shut.

However, the selection of suitable locations for landfill has always been the greatest challenge due to its multi-objective nature that is very tasking. Hence, this has resulted to disposal of refuse on unsuitable areas such as borrow pits and vacant plots of land both inside and outskirts of cities and state capitals such as Keffi metropolis in Nasarawa State, Nigeria. Many methods exist for site selection but acceptable and suitable landfill site identification is very much challenging and are completely lacking in towns and cities in the country

B. Statement of the Problem

Studies are numerous on waste problems and management in Nigeria and elsewhere in developing countries. These studies cover cities of various sizes and different ecological, climatic, cultural, religious and economic regions in the country. Some of the studies emphasize solid waste problems and how it has defiled different government policies at various time (Rosenbaum 1974; Uwadiegwu et al., 2013; Shuaibu, 2015). Other looked at solid waste as an unofficial measure of prosperity since wealthy nations produce more wastes than poor ones (Omuta, 1988). Other studies argued that what causes waste problem is not volume produced but the degree of effectiveness of solid waste management. The uncharted volume of wastes that are visible along almost all the roads and streets of our urban centers is an indication that the adopted strategies to cope with the inevitable byproducts of development are ineffective (Uwadiegwu et al., 2013). Other studies centered mainly on classification of urban solid waste (Ekwueme and Achikanu, 2000), while some studies examined the environmental impacts and consequences of solid waste generation and recycling of mixed waste plastic products (Nyeenenwa, 1991;Chukwu, 2007).

Missing from these studies are the issues of landfill and selection of landfill for waste management. In addition, none of these studies examined landfill site selection using remote sensing (RS) and geographic information system (GIS). Therefore, it becomes essential to focus search light on landfill site selection using GIS and multi criteria analysis.

C. Aim

The aim of the study is to locate potential landfill site for waste management in Karu Local Government Area, Nasarawa State, Nigeria, with the view of reducing environmental consequence of urban waste in the state and the country.

D. Objectives of the Study:

The specific objectives of the study are to:

i. map and identify the existing landfill site and dump sites in the study area;
ii. identify the potential suitable landfillsite(s) in the study area

E. Research questions

i. Where are the locations of the existing dumpsites and landfill?
ii. Where are the suitable sites for landfill sitting in the study area?
iii. How efficient is GIS and Multi criteria techniques for landfill site selection?

F. Justification

Solid Waste disposal is a very serious problem particularly in Karu LGA of Nasarawa state because of its proximity to the federal capital territory and its increasing population. Therefore there is need for an effective sitting and selection of landfill for the disposal and management of solid waste generated in Karu LGA, Nasarawa state.

G. Scope

The scope of the study is limited to Karu LGA of Nasarawa state and the research focused on selection of new landfill for effective management of solid waste generated by Karu dwellers. This research did not address the effect of illegal solid waste disposal on the health of the residents in the study area.

II. STUDY AREA AND LOCATION SETTING

Karu is a Local Government Area in Nasarawa state, Nigeria. It lies between between Latitudes 9° 25” 4’ and 8° 38” 37’ N and Longitudes 8° 6” 45 and 7° 33” 26’ E . The Study area shares its western boundary with the Federal Capital Territory Abuja, the southern boundary with the Nasarawa Local Government area, the eastern boundary with Keffi Local Government Area and northern boundary with Kaduna State. It has an area of 2,427km^2 with population of 205,477 (population census, 2006) and it is the second most populous local government area in Nasarawa after Lafia, the State capital. Karu LGA headquarters is in the town of Karu.

A. Climate

Nasarawa State is characterized by a tropical sub humid climate with two distinct sea sons. The wet season lasts from about the beginning of May and ends in October. The dry season is experienced between November and April. Annual rainfall figures range from 1100 mm to about 2000mm ((NASEEDS Document, 2004).

About ninety per cent of the rain falls between May and September, the wettest months being July and August. The rain comes in thunder storms of high intensity, particularly at the beginning and towards the end of the rainy season. Temperatures are generally high during the day, particularly between the months of March and April. The mean monthly temperatures in the state range between 20^{O}C and 34^{O}C, with the hottest months being March/April and the coolest months being December/January.

B. Soils

The major soil units of Nasarawa State belong to the category of oxisols or tropical ferrugi nous soils (Nyagba, 1995). The soils are derived mainly from the basement complex and old sedimentary rocks. Lateritic crust occurs in extensive areas on the plains, while hydromorphic soils (humicinceptisols) occur along the flood plains of major rivers. Loamy soils of volcanic origin are found around the volcanic cones of Awe. The hilly areas carry shallow skeletal soils. Many parts of the state are ravaged by both sheet and gully erosion. The major urban centres, particularly Lafia and Keffi, are heavily gulled. Since most of the inhabitants of the state are farmers, extensive areas in the countryside are also cleared for farming, thus exposing wide areas of land to sheet erosion.

C. Geology and Relief

The southern landscape of the state forms part of the low plains of the Benue origin. Other parts of the state are composed of undulating lowlands and a network of hills developed on granites, migmatites, pegmatites and gneisses. Around the saltmining village of Awe are a number of worn volcanic cones.Most parts of the state that lie within the Benue valley are composed of sandstones. However, around the salt bearing districts of Awe, Keana and Akiri, are detached synclinal areas formed by localized folding. The brine springs of Awa, Azara and Bomanda are associated with anticlinal axes along which salt bearing beds within the synclines approach the surface.

The high land areas of the state are found towards the north, notably in Wamba, Nasarawa t Eggon and Akwanga Local government Areas. The Eggon rolling hills for example, rise to an average; height of about 1,200m. The Maloney Hill in Keffi is of historical significance.

D. Vegetation

Nasarawa State falls within the southern guinea savanna zone. However, clearance of vegetation for farming, fuel wood extraction for domestic and cottage industrial uses and saw milling has led to the development of regrowth vegetation at various levels of development. Dense forests are few and far apart. Such forests are found in lowland areas, particularly where population pressure is less on the land. Gallery forests are common along major streams and pronounced depressions. Forest reserves are being developed mostly near major urban centres like Lafia, Nasarawa, Keffi, Akwanga and Wamba. The vegetation on the hilly parts of the state is composed mainly of grasses and isolated trees. Trees of economic value, including locust bean, shea butter, mango, citrus and banana are scattered across the state, particularly the lowland areas and southern parts of the state

E. People

Nasarawa State, in terms of ethnic composition, is Nigeria on a mini scale. Not only are the ethnic groups numerous, they are also thoroughly intermingled and overlapping in their geo- graphical locations, to the extent that the areas of dominance of each group cannot be easily separated. The major ethnic groups include Eggon, Tiv, Alago, Hausa, Fulani, Mada, Rindre, Gwandara, Koro, Gbagyi, Ebira, Agatu, Bassa, Aho, Ake, Mama, Arum and Kanuri. While English and Hausa are widely spoken in the state, all the ethnic groups indicated above also have their own languages or Traditional religions are widespread.

However, the two leading religions (Christianity and Islam) have made a greater impact among the people. Although cultural artifacts are scattered among the cultural groups all over the state, no collection has yet been made as at now. A museum is yet to be built. Among the many cultural activities are, for example, the Umaisha and OyooreKeana festivals in Toto and Keana local government areas respectively. Others are observed within the course of the practice of the peoples' economic and social activities such as farming, fishing, as well as marriage, naming ceremonies and burial activities which reflect the varied cultural realities of the people. These manifest also in the commercial and recreational spheres of their lives. Dyeing, weaving, carving and blacksmithery are among the traditional industries of the people. Thus items of art and crafts, such as baskets, carved wooden implements like ladles, pestles and mortars, besides iron implements like knives, cut lasses, hoes, etc are a common sight in the local markets. Pottery and calabash carving also represent items of art and crafts, produced for either domestic purposes or as items used for carriage of goods, such as the Bassa and Gbagyi are often seen carrying on their shoulders.

F. Population

Nasarawa State had a total population of 1,863,275 as at the 2006 head counts (NPC, 2006)

G. Rural Settlements

Rural settlement pattern of Nasarawa state is largely influenced by the prevailing economic activities and, to some extent, historical and physiographic factors, Historically, Nasarawa constitutes part of the Middle Belt zone of Nigeria which is known to have been depleted of its human population during the period of the slave trade, although the exact degree of the impact of this historical event is not known. The majority of the rural people are engaged agriculture and are known to be sparsely settled ire the countryside. The current average population density is about fifty four persons per sq. kilometer Individual farmsteads, particularly towards or southern parts of the state, are highly dispers30 with population densities ranging from fifteen of twenty five persons per sq. km. More nuclear rural settlements are found towards the north, local government areas of the state where, countryside is much hillier and not too productive for agriculture. Hill top settlements were common in the northern parts of the state a now being relocated by the roadsides at the foot or the hills. It is common to find isolated compounds fence with corn stalks. In some cases, houses are built very closely and the spaces between them closed up so as to provide the needed security as well as protection from harsh weather conditions. Most rural dwellings are built of mud and are in the form of round huts with thatched grass roofs.

H. Urban Settlements

Urbanization in this area started with the advent of colonial administration. The need to establish provincial and Native Authority headquarters in each of the Provinces and Divisions gave rise to the beginning of most of what we know today as urban centres in Nasarawa State. The 1976 Local Government Reforms further enhanced this situation and today we have Lafia, the State Capital, Keffi and Akwanga as the biggest settlements. Other nucleated settle ments include Wamba, Nasarawa, NasarawaEggon, Kaderko, Awe, Keana, Gudi and Karu.

In fact all local government headquarters are officially designated urban areas in line with the urban policy in the country. In addition, the state has also includedGudi, Kaderko, Agyaragu and Assakyo as urban areas apart from local government headquarters. Urban settlements in the state can be categorized according to their size. First, we have those between 50,000 to 75,000 people. These include Lafia and Keffi, while the second category which includes Nasarawa, Akwanga, and NasarawaEggon and Karu range between 25,000 to 40,000 people. The rest of the designated urban centres fall under the 25,000 mark. Because of its status as the state capital Lafia is now growing quite fast. The same applies to Karu and Keffi which are close to Abuja (the Federal Capital) and Akwanga to some extent. Karu and Keffi play the role of 'new towns,' taking off some of the pressure on Abuja in terms of accommodation and shops for building materials. Due to lack of finances, the development and planning of these centres is not coming up as expected and the result is the increase in the number of environmental problems that are commonly associated with urban growth in most Third World cities. These include the problems of refuse management, pollution, and drainage and erosion control (**http://www.onlinenigeria.com/Nasarawa-state/?blurb=324**)

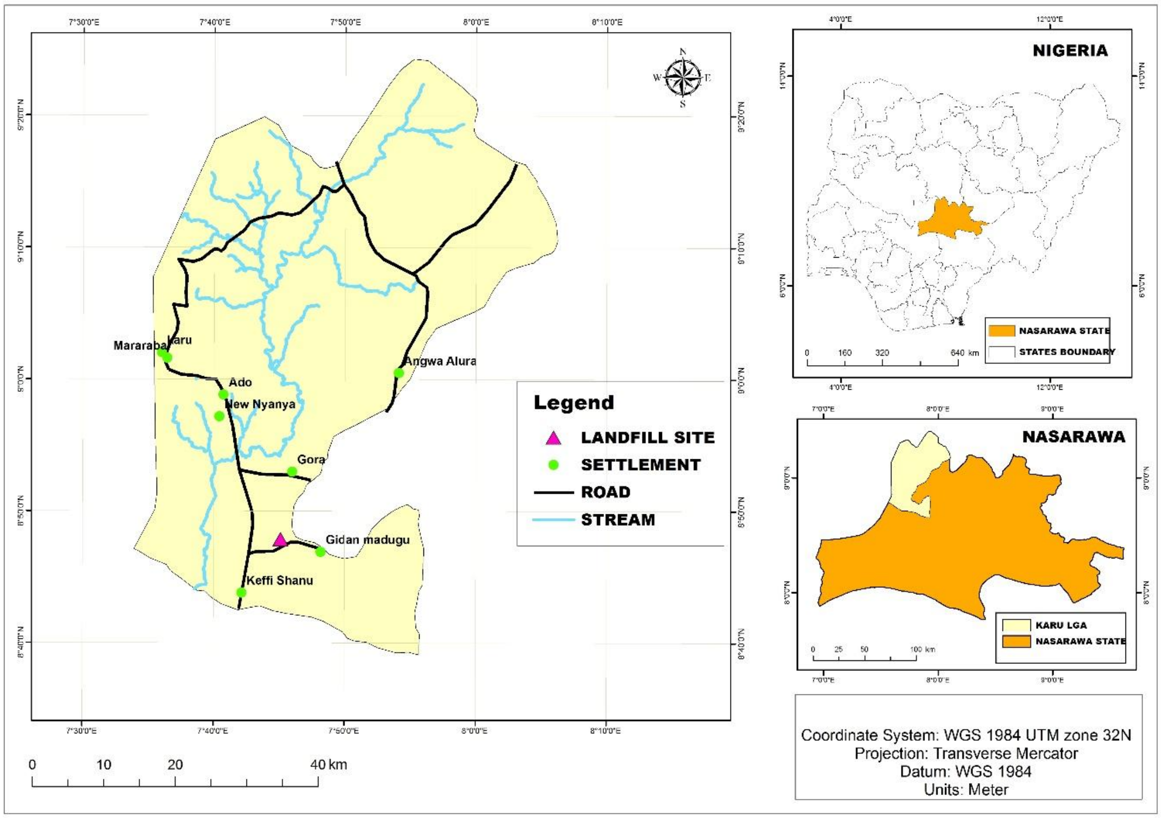

Figure 2.1 Map of the study area

III. METHODOLOGY

A. Materials and Methods

This chapter presents the methodology that was adopted for the study. It includes the strategies for data collection and the techniques used to analyze the datasets.

B. Data Type and Source

Primary and secondary data were used for this study. The primary datasets were collected from the field survey and personal observations. The primary data sets include the location coordinates of landfill and dumpsites. The location coordinate points of these sites were tracked through the are made up of location coordinate of the existing landfill. These were obtained through the use of Global Positioning System (GPS).

The secondary data used for this study were made up of Landsat 8 OLI satellite image, Shuttle Radar Topographic Mission (SRTM), Soil map of Nasarawa State and Geology map of the study area. The satellite imageries sourced from United States for Geological Survey (USGS) website http://glovis.usgs.gov/. Table 3.1 presents the summary of the secondary data used.

In addition international criteria for sitting landfill were extracted from the publications of Environmental Protection Agency (EPA) and used to determined landfill site in the study area (see Table 3.2).

Table 3.1 Characteristics of Satellite image data and analoque data

S/N	TYPE	FORMAT	SCALE	PATH/ROW	RESOLUTION	AVAILABLE BANDS	DATE/ SOURCE
1	Landsat 8 OLI	Digital		188/55	30m		2016
2	SRTM	Digital			90m	1	DEC. 2014

3	Geological and mineral resource map of Nasarawa	Analogue	1:500,000				COPINE
4	Dominant soil map of Nigeria	Analogue	1:1,300,000				1997/COPINE

Table 3.2 Landfill selection criteria according to Environmental Protection Agency (EPA)

No	Item
1	The site should be 7000m away from an urban area
2	The site should be 3000m away from forest area
3	The site should be 3000m away from forest area
4	The site should be 2000m away from water source i.e. running stream in order to prevent leachate passage
5	The site must be 2000m away from road for easy access
6	Leachate collection point should be built within the landfill site
7	Construction of bole hole for time to time monitoring to detect contamination of water
8	The landfill must be fenced and an office attached to security purpose
9	The site must be in stable environment i. e soil should not be porous but loamy clay
10	A good drainage system
11	The slope should be less than $\leq 12^{o}$
12	The geology of the site should have a good hydraulic conductivity and the permeability level should be moderate.

C. Software Requirement

Different GIS and non- GIS software packages will be used to integrate the different datasets considering the set objectives of this study. These software include: ArcGIS, Envi, Microsoft word, Microsoft power point, Microsoft Excel and Vision extension. Below are the characteristics and uses of the software as shown in table 3.3

	SOFTWARE	VERSION	APPLICATION
1	ENVI +IDL	4.7	For image classification
2	ArcGIS	10.3	BandComposition, Reclassification,Georeferencing, Digitizing, Hillshade, Euclidean Distance, Raster Calculation, weighted overlay and maps layout

3	Google Earth Plus	2016	For validating satellite imagery

D. Satellite Image Data Preparation

The ArcGIS version 10.3 software was used to perform band composition and Pan-sharpening to enhance its spectral resolution for more detail. Color composite of bands 5, 4 and 3 and the study area was clipped using karushapefile. Figure 3.1 show the workflow of the implementation of the study.

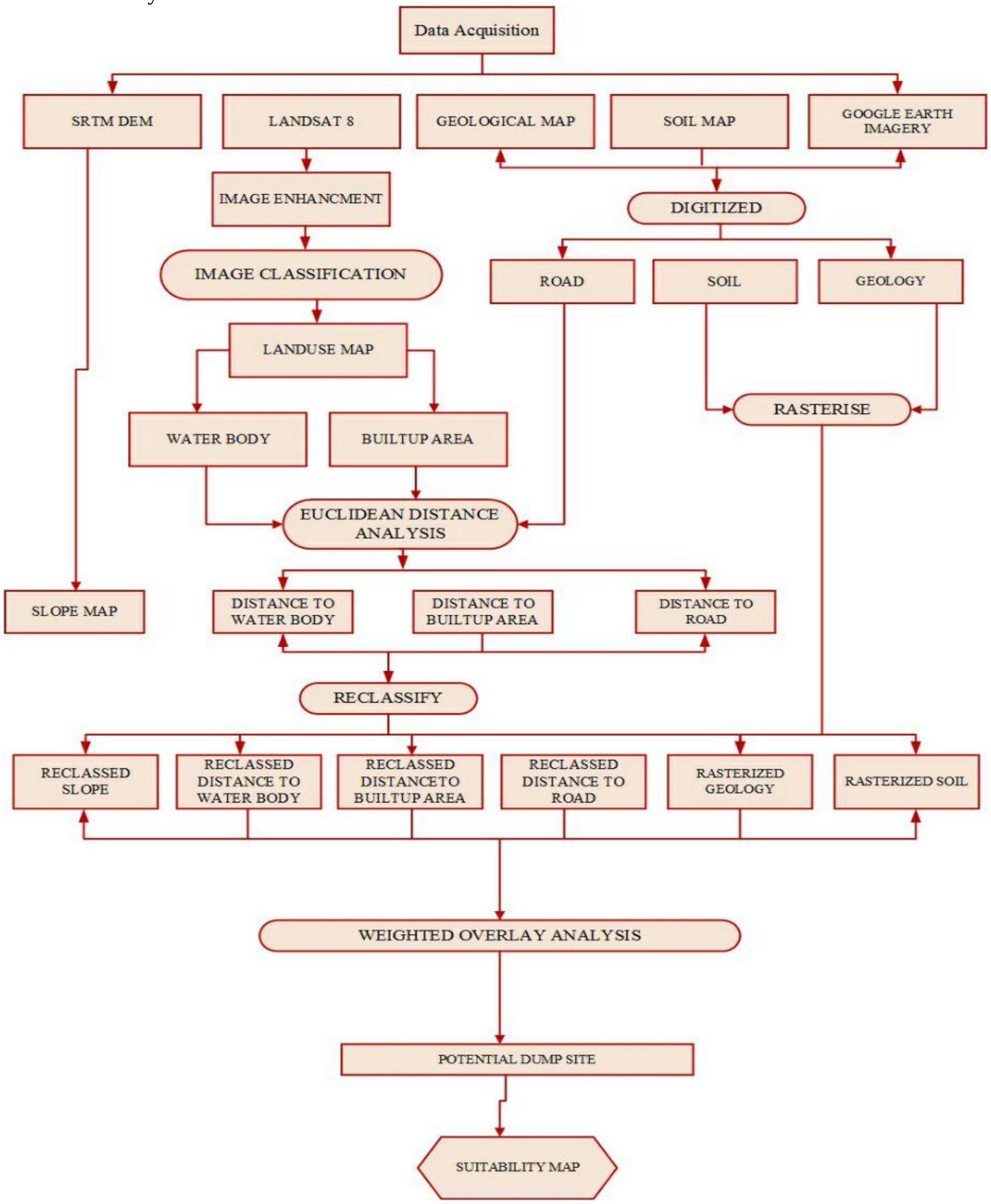

Figure 3.1 Flowchart of the study

E. Satellite Images Processing

Image processing is applied to compensate data errors and geometric distortions, to enhance and extract features related to thematic subjects being under investigation and to suppress redundant information. In this study, standard tools of image processing have been used for digital processing of the satellite data. Digital image processing was used to enhance and extract features that indicate targets of interest in the data. In this study, the digital image processing processes were conducted in the following steps:

1. Image Enhancement

Image enhancement is the modification of an image in order to alter its impact on the viewer (Sabins, 1987). Generally, image enhancement changes the original digital value and it should be carried out after geo-referencing. The purpose of image enhancement is to make the images more interpretable for specific applications. The general aim of image enhancement is to highlight features of thematic interest (lineament, soil surface features, etc.) and to suppress redundant information.

Image enhancement technique applied to image data in order to effectively display or record the data for subsequent visual interpretation. The Landsat 8 OLI image was enhanced by carrying out different types of image enhancement process such as:

i. Geometric correction

Geometric correction is a process by which points in an image are registered to corresponding points on a map or another image that has already been rectified. In attempt to rectify any error introduced into an image by the geometry of the curved earth surface and movement of the satellite.

The goal of geometric correction is to put image elements in their proper plan metric (X and Y) position, and also to make sure that they are in the same projection to allow overlaying of the images and other layers which can be extracted from them.

ii. **Panchromatic Sharpening**

Panchromatic sharpening is a remote sensing technique that effectively doubles the resolution of 30-meter resolution of Landsat 8 images. The technique is very easy to do in Photoshop. It requires Band 8 consisting of grayscale panchromatic data representing the red, green, and blue portions of the visible spectrum. The technique uses the grayscale values in Band 8, which have a ground resolution of 15 meters, to give the impression of greater detail in lower resolution 4-3-2 Landsat 8 images.

2. Image Mosaic

ENVI 4.7 software was employed to mosaic the SRTM satellite image which cover the study area by using a geographical mosaicking method. The aim is to generate new images which cover the study area.

3. Geo-referencing

The Satellite images used in this project were geo-referenced to Universal Transverse Mercator (UTM), (WGS-84 ZONE 32 N).

F. Image Classification

Image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised. For the purpose of this the image was classified using supervised classification and maximum likelihood.

1. Maximum likelihood

The tool considers both the variances and covariance of the class signatures when assigning each cell to one of the classes represented in the signature file. With the assumption that the distribution of a class sample is normal, a class can be characterized by the mean vector and the covariance matrix. Given these two characteristics for each cell value, the statistical probability is computed for each class to determine the membership of the cells to the class (ArcGIS 10.3 help).

The image was classified into five classes: settlement, Natural vegetation, waterbody, Rock-outcrop and farmland.

G. Data Analysis

1. Identify the Suitable Areas for Solid Waste Disposal in the Study Area

The following criteria and techniques were used to identify area suitable for landfill, solid waste disposal site.

2. Field Survey

Constraint criteria for the selection of the suitable site acquired from NASARAWA STATE URBAN DEVELOPMENT BOARD (NUDB), Karu LGA. The criteria are as follows:

Location Constraint Criteria

1. The site should be 7000m away from an urban area
2. The site should be 3000m away from forest area
3. The site should be 2000m away from water source i.e. running stream in order to prevent leachate passage
4. The site must be 2000m away from road for easy access
5. Leachate collection point should be built within the landfill site
6. Construction of bole hole for time to time monitoring to detect contamination of water
7. The landfill must be fenced and an office attached to security purpose
8. The site must be in stable environment i. e soil should not be porous but loamy clay
9. A good drainage system
10. The slope should be less than $\leq 12^{o}$

11. The geology of the site should have a good hydraulic conductivity and the permeability level should be moderate. Geological units with permeability $Kf<1\times10^{-7}$ m/s are considered impermeable(Kontos et al. 2003, Simsek et al. 2006).

3. Euclidean Distance Analysis

Euclidean Distance is a tool that gives the distance from each cell in the raster to the closest source. This process was used to determine the distance of road, urban settlement, rural settlement and stream. The table below shows the classes and their corresponding distances;

4. Reclassification

Reclass is a tool under spatial analyst tools that takes input cell values and replace them with new output cell values (ESRI GIS Dictionary). This was done so as to assign values of preference, sensitivity, priority, or some similar criteria to the raster.

H. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty (1977 and 1994). The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. AHP allow some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value. The table 4.4- 4.7 shows the derivation of the weight assign to the seven (7) criteria used for this study.

I. Weighted overlay

Weighted overlay is a tool in spatial analyst tools that Overlays several raster datasets using a common measurement scale and weights each according to its importance. The reclassified raster were overlaid together in order to produce a suitability map identifying areas suitable. For the weighted overlay operation to be successful, the raster dataset must be in integer. Figure 4.24 shows the result of the weighted overlay after the reclassification of the factors.

IV. RESULT AND DISCUSSION

A. Introduction

This chapter presents the results of various processing and analyses carried out as earlier stated in chapter three.

B. Existing Landfill site and Dumpsites in the study area

The existing landfill in Karu LGA, the study area, is the only landfill inKaru LGA and Nasarawa state in entirety. The landfill was established by the World Bank in collaboration with Nasarawa State government to serve as a prototype for the establishment of other landfill in the state. The landfill has a lifespan of 2 to 3years. Presently, the site is filled up and from field observation, more waste are being dumped on regular bases without sealing up the landfill.

In addition, due to the remoteness of the landfill from the settlements, scavengers are totally absent from the site. Figure 4.1 shows the map of the existing Landfill in AutaBalefi, Karu LGA. Several dump sites coordinates were collected during the field survey (Figure 4.2). These sites are not properly used as shown in plates 4.1 to 4.6. The dumpsites are sited along the roads of Mararaba, Masaka, Gwadara, Auta-Balefiareas of Karu LGA. Plates 4.1 to 4.6 shows that waste are dumped indiscriminately on major roads and any available public spaces.

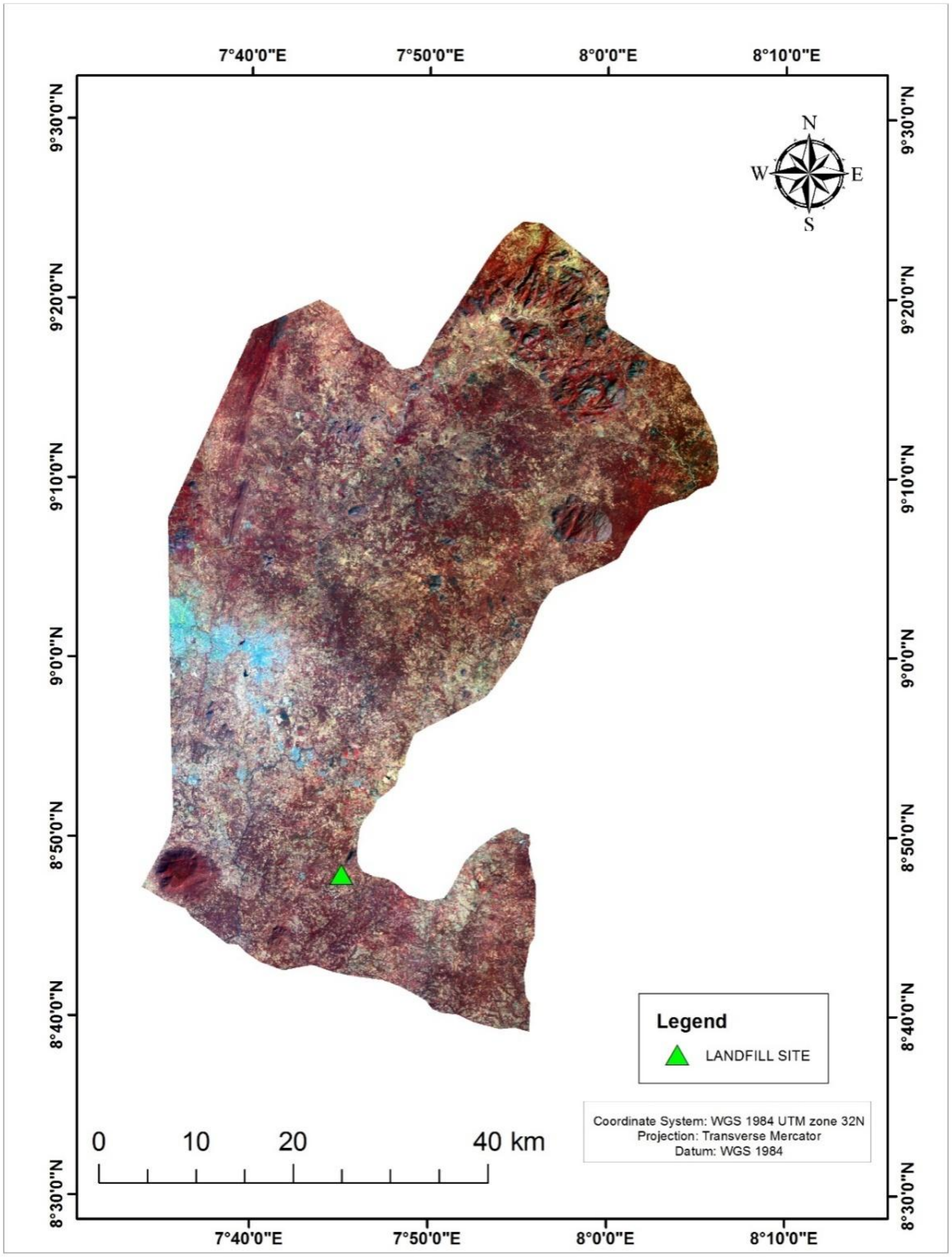

Figure 4.1 Existing Landfill in the study area

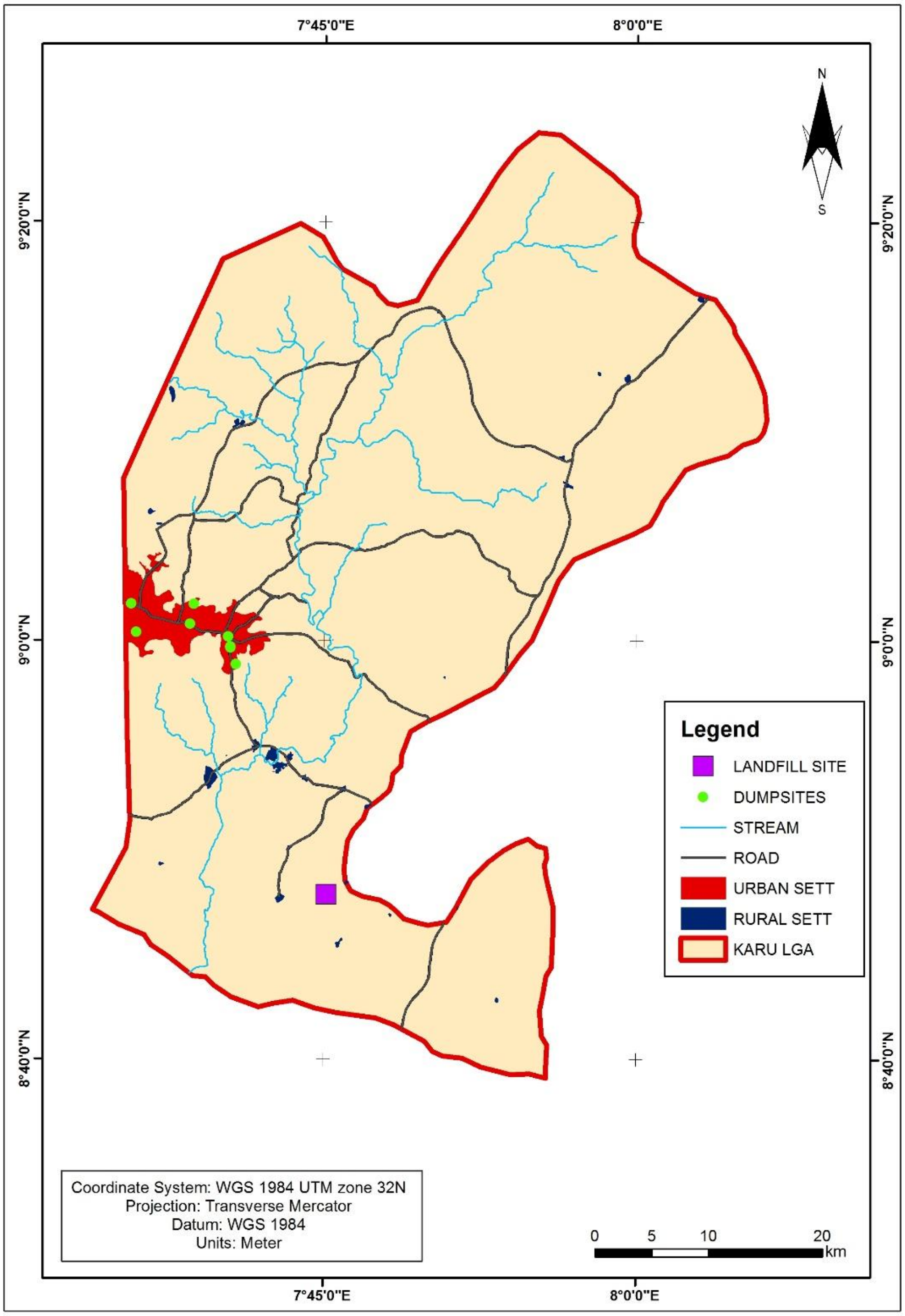

Figure 4.2 shows the spatial distribution of existing dumpsites and landfill sites in the study area. Fromthe figure above, the waste are being dumped right at the center of the urban settlement.

Plate 4.1 Dump site along Masakaroad
Source: Field work, 2016

Plate 4.2 A pile of solid waste along AutaBalefiroad
Source: Field work, 2016

Plate 4.3 A pile of solid waste along Gwadararoad
Source: Field work, 2016

Plate 4.4 A pile of solid waste along Mararaba road
Source: Field work, 2016

Plate 4.5 A pile of solid waste along Mararaba road
Source: Field work, 2016

Plate 4.6 A mass of solid waste along Mararaba road
Source: Field work, 2016

B. Identify the Suitable Areas for Solid Waste Disposal in the Study Area

Analyses of each of the seven criteria used in landfill site selection are presented in this section

1. Slope

Slope is needed to get a good drainage system to prevent leaching of waste water and other soluble from landfill into underground and surface water. It is also important because it affects the ease of construction and susceptibility to land sliding (Dai et al. 2001; Kolat et al. 2006; Sumanthi et al. 2008). The study area slope map (figure 4.3) was generated from SRTM data using Universal Traverse Mercator WGS 1984 Zone 32 and reclassified into four classes of 1 to 4, highly suitable, moderately suitable, less suitable and unsuitable. Figure 4.5 & 4.6 showing the area coverage of each suitability classes in kilometer square and percentage (figure4.5 and 4.6). Details of the slope suitability classes and areas covered in kilometer square and percent can found in table 4.1. The table shows that an area coverage of 270462 km^2(74.77%). Hence, the study area is said to be more or less flat in topography.

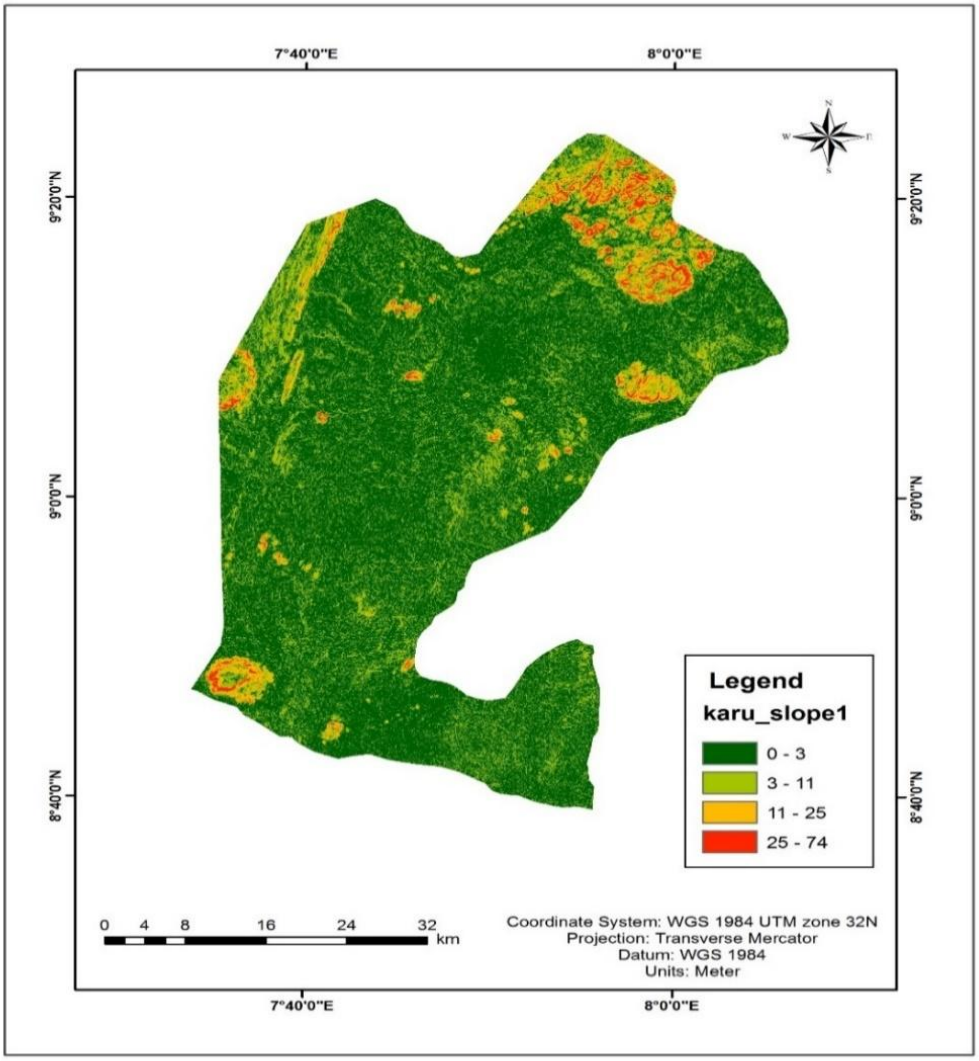

Figure 4.3 slope map of study area

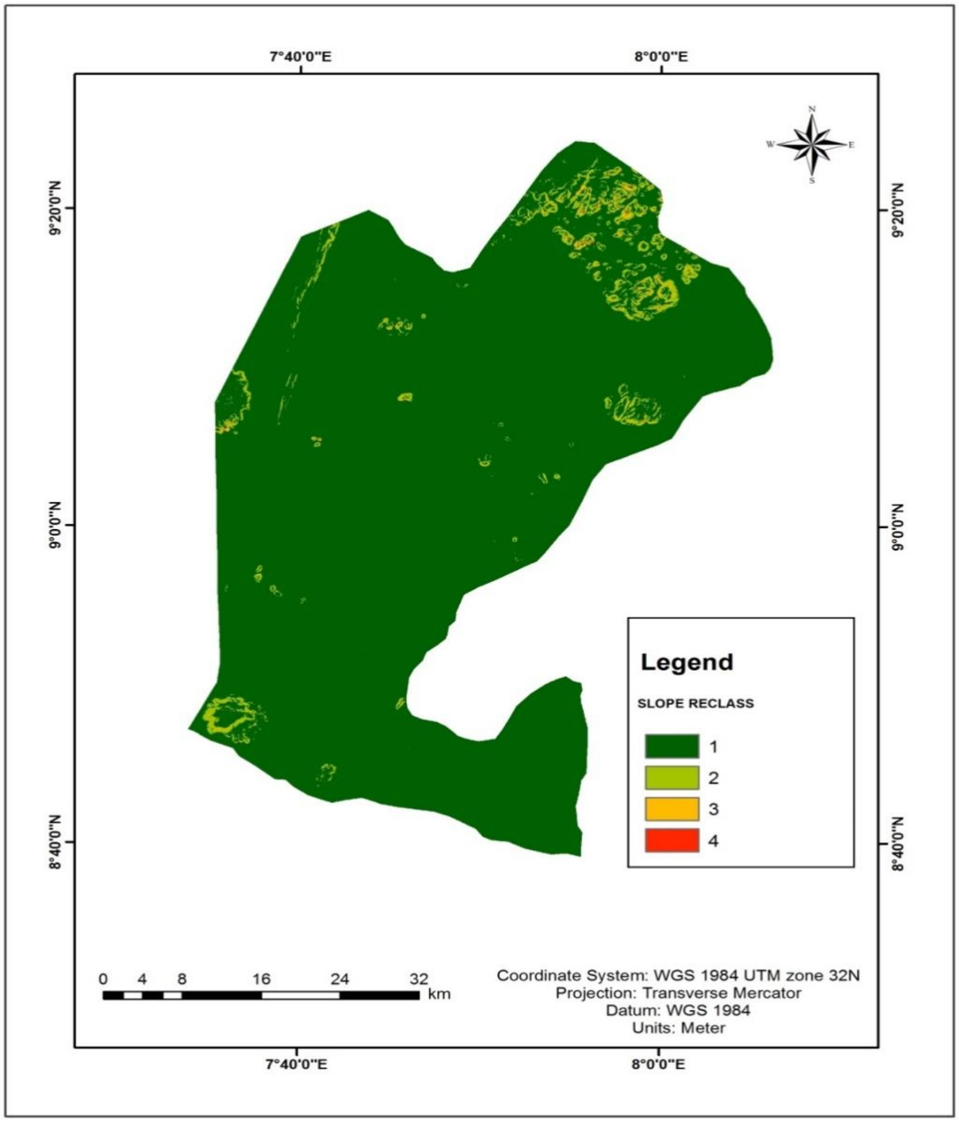

Figure 4.4 Reclassified slope of the study area

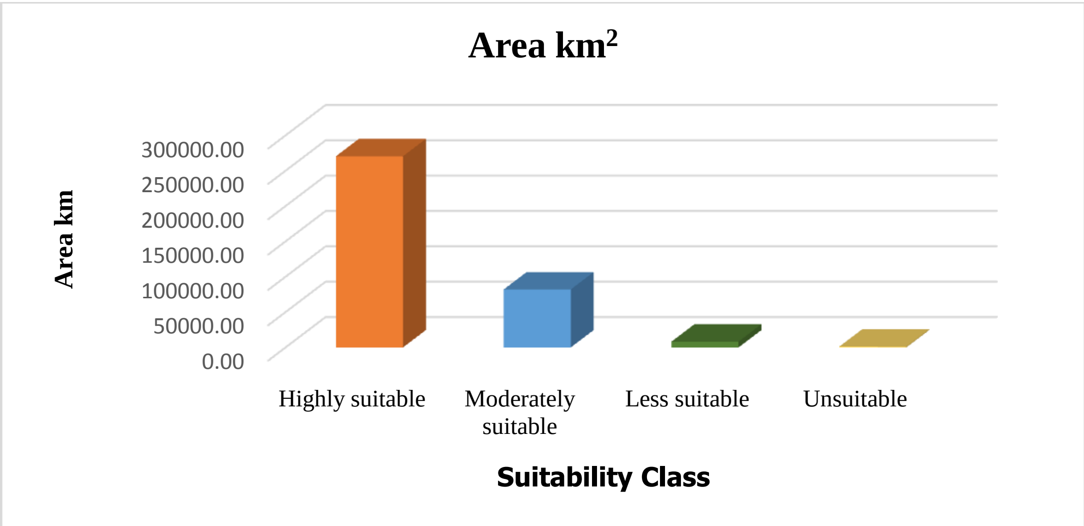

Figure 4.5 Slope Suitability Levels Area

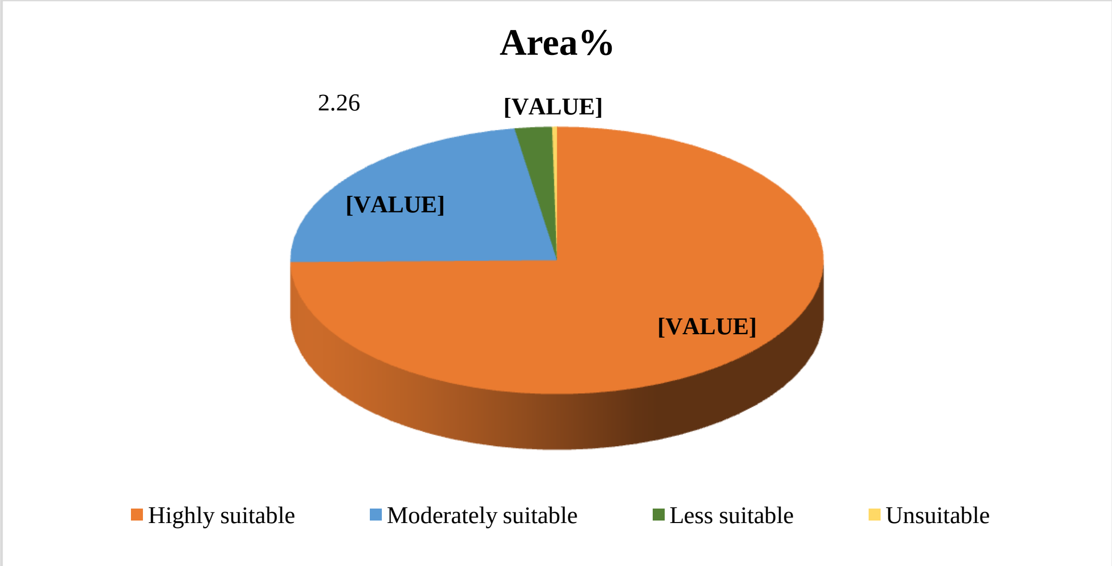

Figure 4.6 Slope Suitability Levels Area

Table4.1 Slope class with their respective suitability levels.

Slope %	Level of Suitability	Value	Area	Total Area (%)
0-3	Highly Suitable	1	270462	74.77
3-11	moderately suitable	2	81987	22.26
11-25	Less Suitable	3	8179	2.26
25-74	Unsuitable	4	1074	0.30

2. Road

Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. According to NUDB, (2016) landfills shall not be located within 100 m of any major highways, city streets or other transportation routes. To assess site suitable for landfill based on road network, shapefile of the study area was superimposed on Google earth image so as to digitize the roads network.Euclidean distance analysis of 2000m was then performed and reclassified as unsuitable road within 500 m, low suitable between distances from 500 to 1000m, distance from 1000m up to 1500mas moderate suitable, and distance between 1500-2000 m as highly suitable.InFigure 4.7, the study area road was reclassified into four classes, the reason is to determine the most suitable distance from residential area. Figure 4.8 and 4.9 shows the area coverage of the study area as 618802, 34036, 289046,114,172 and 58.60, 27.37, 10.81 and 3.22 in meters and percentage respectively. The most suitable area is 3.22% and covers an area of 114.172.

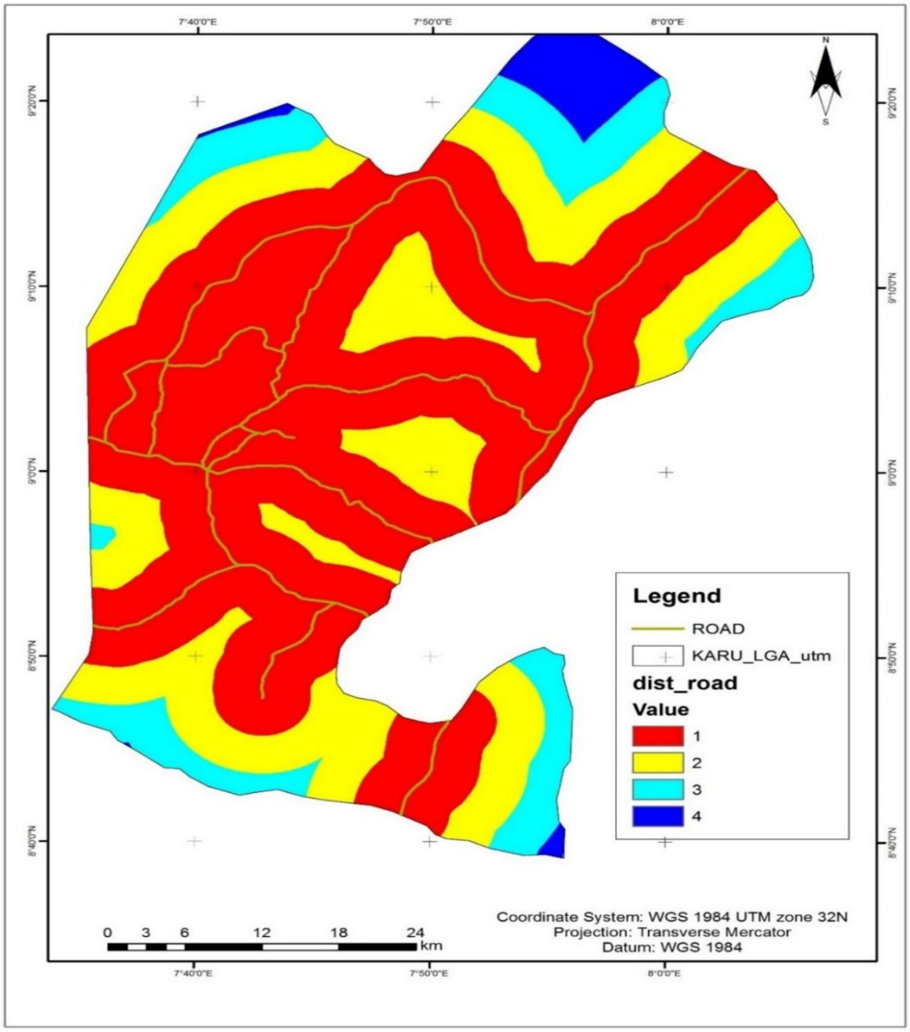

Figure 4.7 Reclassified Road of the Study Area

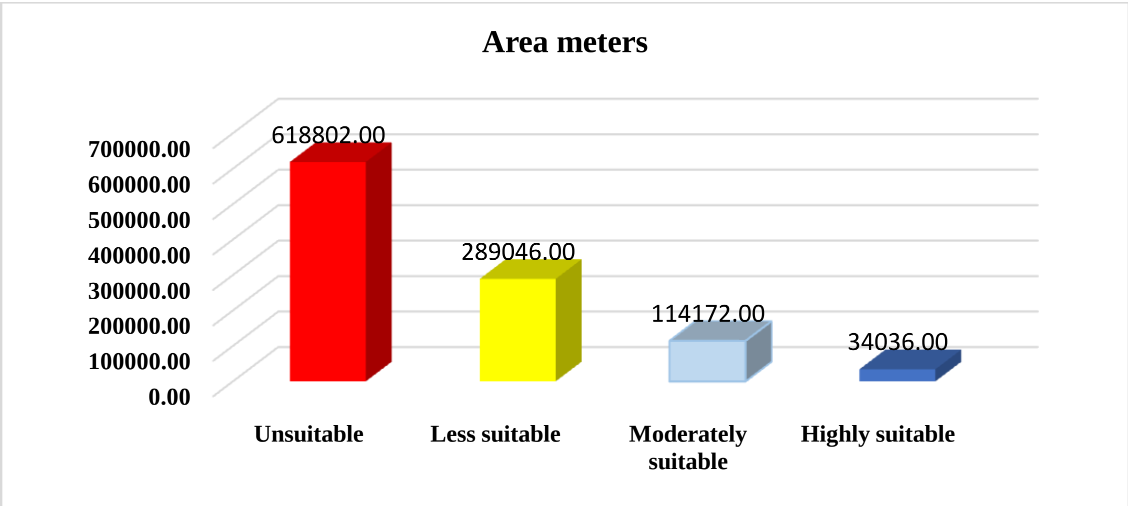

Figure 4.8 Road suitability levels area in meters

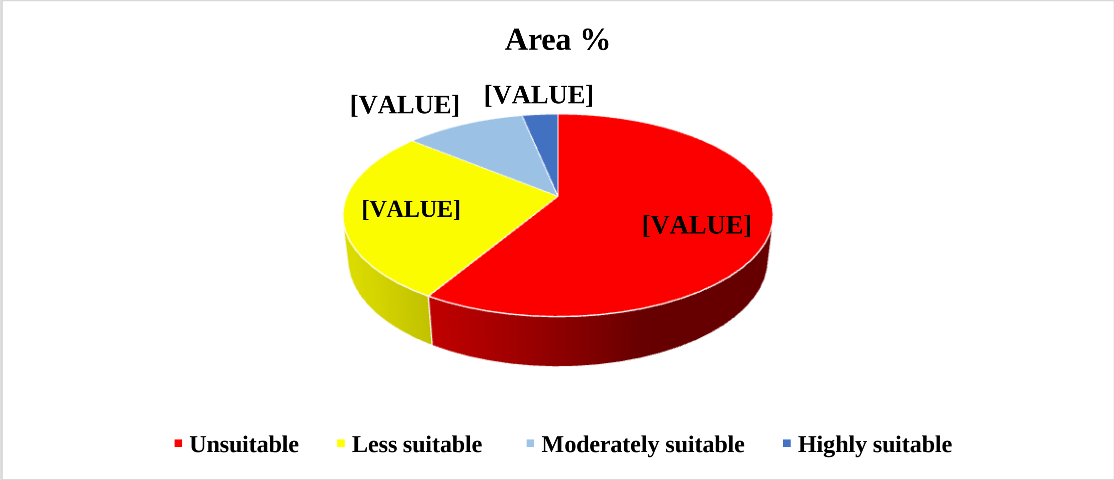

Figure 4.9 Road suitability levels area%

Table 4.1 Road class with their respective suitability levels.

Slope %	Level of Suitability	Value	Area (m)	Total Area (%)
0-3	**Highly Suitable**	**1**	**34036.00**	**3.22**
3-11	**Moderately suitable**	**2**	**114172.00**	**10.81**
11-25	**Less Suitable**	**3**	**289046.00**	**27.37**
25-74	**Unsuitable**	**4**	**618802.00**	**58.60**

3. Geology

There were four different lithology (Muscovite Schist, Porphyritic Granite, Undifferentiated Schist and undifferentiated older Granite) in the study area but they were mainly composed of Igneous and Metamorphic rocks. Geology characteristics are important for selection of suitable sites for landfilling and special consideration must be given to the underlying foundation soil and bedrock features: geologic structure, existing fractures etc. these aspects affects the waste and leachates containment characteristics of the sites, Sadek et al (2001). One main characteristic of these rock types is that they all contain fracture, and allow water percolation but they differ slightly. Hence the purpose of reclassifying the geology.

4. Soil

The study area comprises of different soil types mainly Acrisols, Arenosols, Leptosols, Lixisols and Rocks. According to Food and Agriculture Organization (FAO),lixisols and acrisols are both rich in clay and can retain water. Though, acrisol has low fertility and toxic amount of aluminium which poses limitations to its agricultural use thereby making it a better option for landfill site selection. Atkinson et al., 1995, in his work, said that certain characteristic of soil promote a safer and more economically feasible implementation and operation of a landfill. Furthermore, considering soil permeability, effective porosity and workability are also very important. Figures 4.11, 4.12 and 4.13, show the soil map of the study area, charts of area covered by different soil types in square kilometer and percentage respectively. Among the soil types identified in the study, acrisols has more clay and covers 1% of the total study area, Karu LGA. Therefore, soil in the study area that has good amount of clay like the acrisols are preferred.

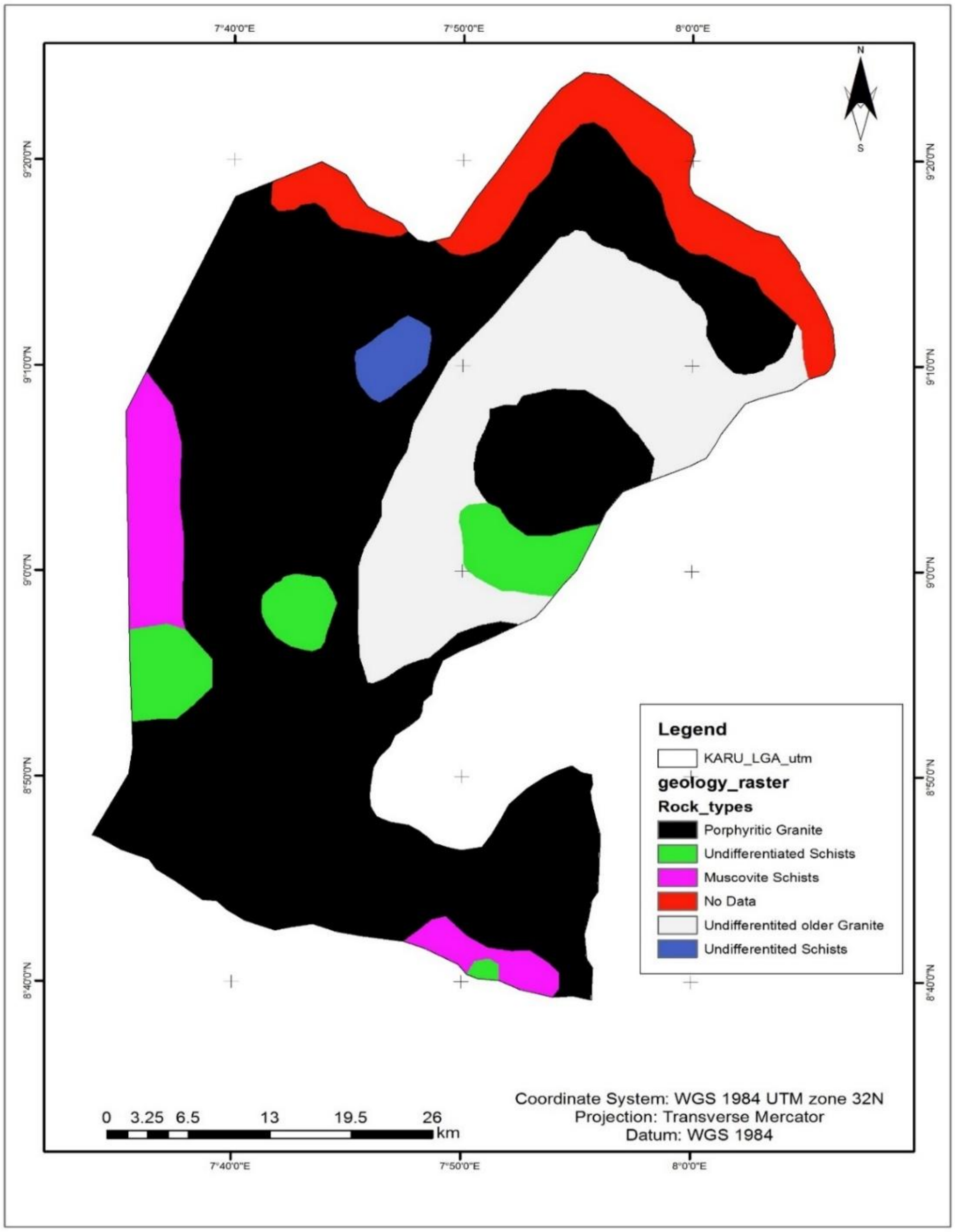

Figure 4.10 Geology Map of Study Area

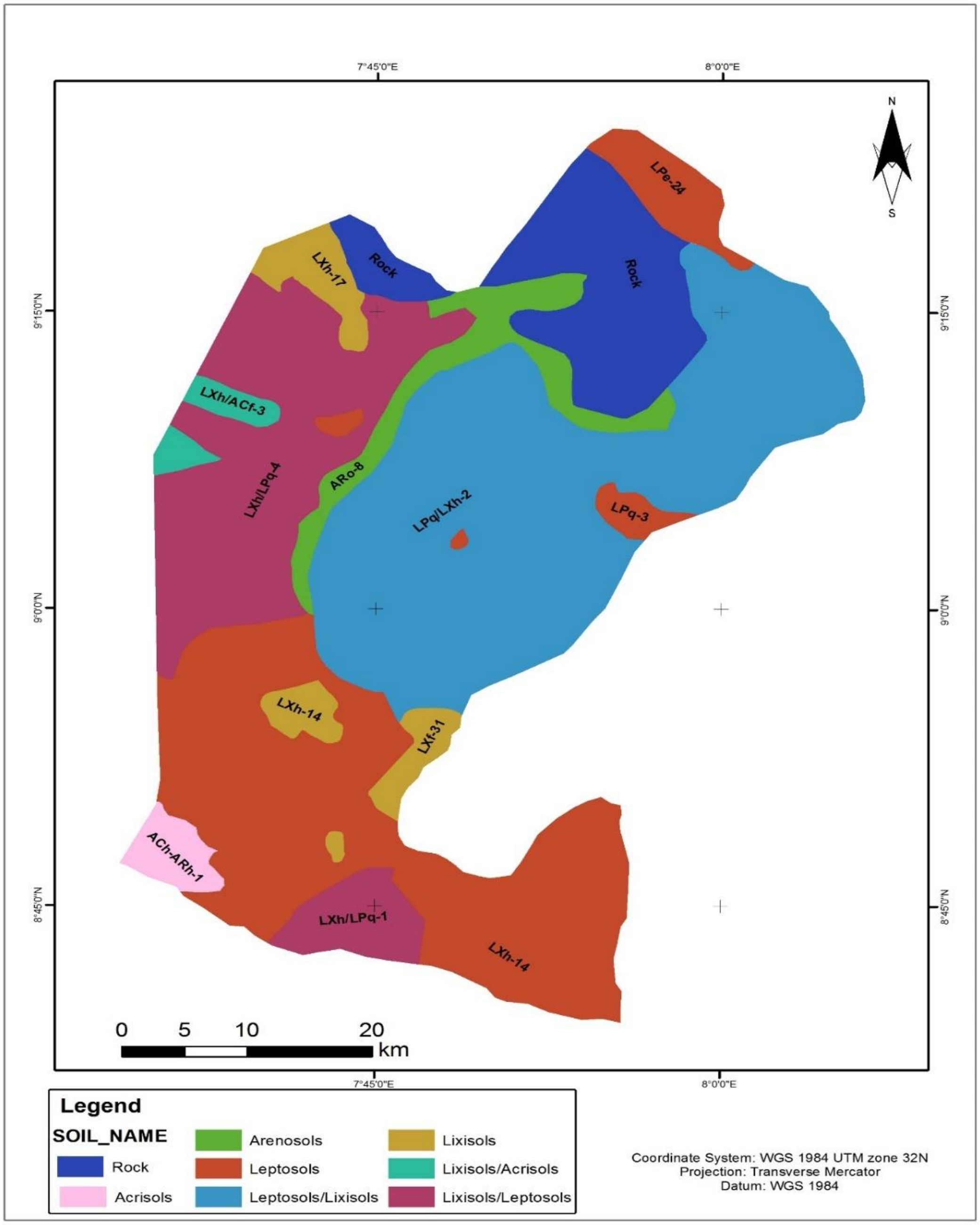

Figure 4.11 Soil map of study area

Table 4.2 Soil types and Area covered

Soil Name	Area covered (sq km)	Area %
Rock	**238.149471**	**9.15**
Lixisols	**108.036269**	**4.15**
Acrisols	**38.99135**	**1.50**
Lixisols/ Acrisols	**32.891236**	**1.26**
Leptosols/ Lixisols	**1343.731615**	**51.61**
Leptosols	**718.0274**	**27.58**
Arenosols	**123.891848**	**4.76**

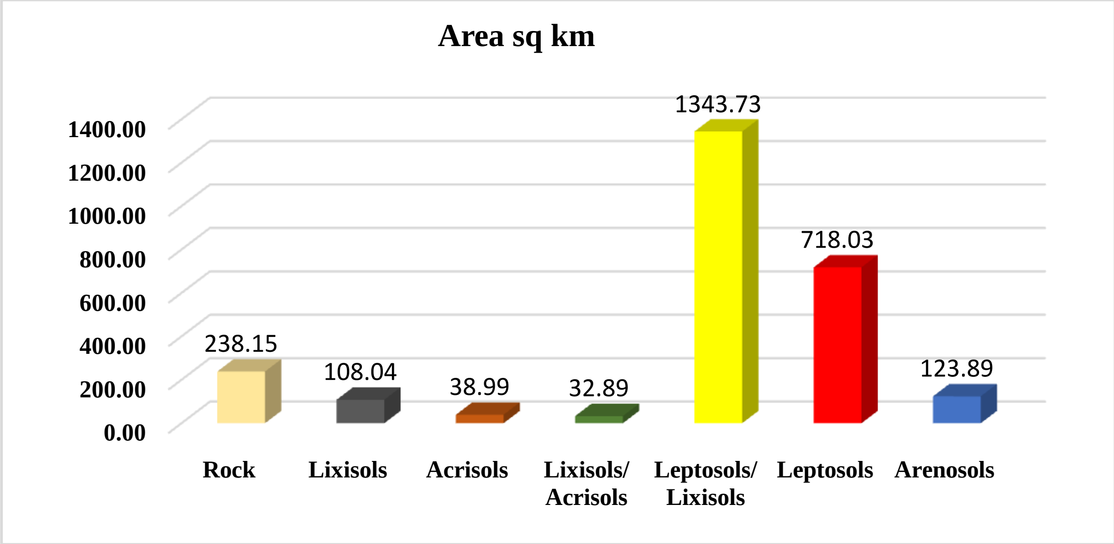

Figure 4.12 soil types and area covered in sq km

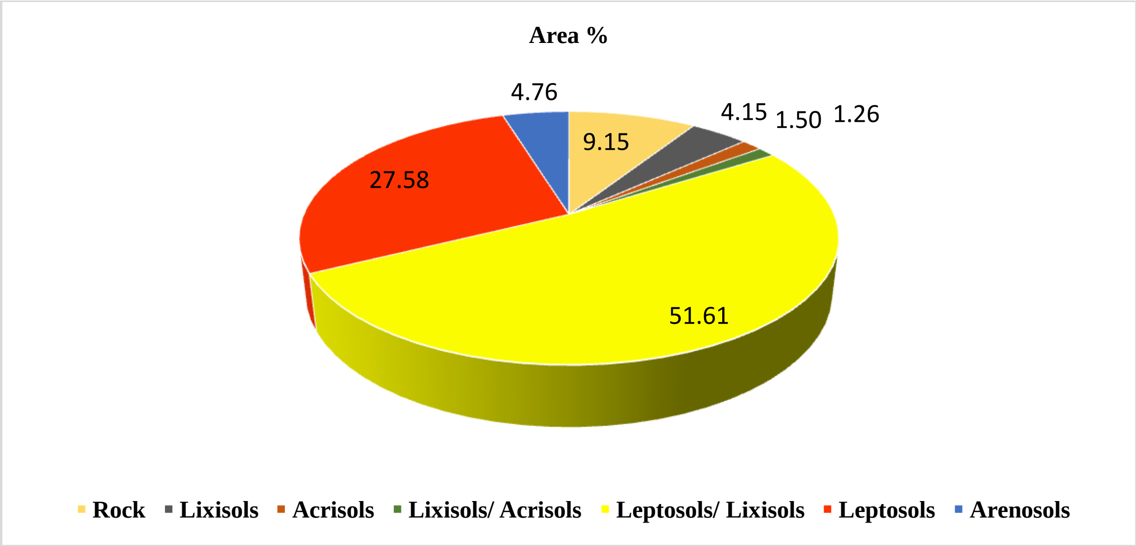

Figure 4.13 Soil types and area%

5. Surface water

Streams were generated from SRTM data using Log10 and Con 10 in Raster calculator tool, this was done in order to include hydrological information (surface water criteria), and Euclidean distance of 2000m and reclassification was carried out. From the result of the analysis, the most suitable distance from stream has an area coverage of 167.64km^2(6.35%) which implies that the farther the distance the more suitable it becomes.

Table 4.3 Distance cover by stream settlement and suitability levels

Distance from stream	Level of Suitability	Value	Area (km^2)	Area (%)
0-500	**Unsuitable**	**1**	**1896.96**	**71.88**
500-1000	**Less**	**2**	**426.87**	**16.17**
1000-1500	**Moderate**	**3**	**148.53**	**5.63**
>2000	**High**	**4**	**167.64**	**6.35**

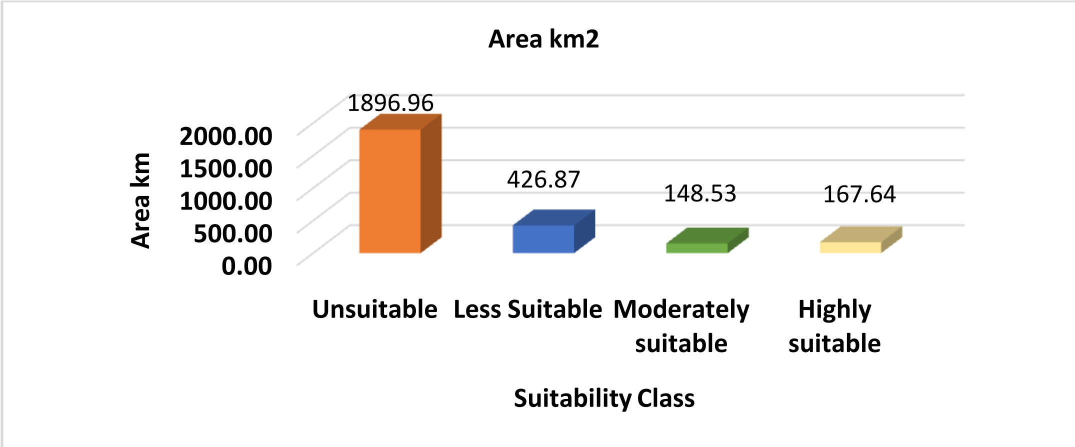

Figure 4.14 Stream level of suitability in km^2

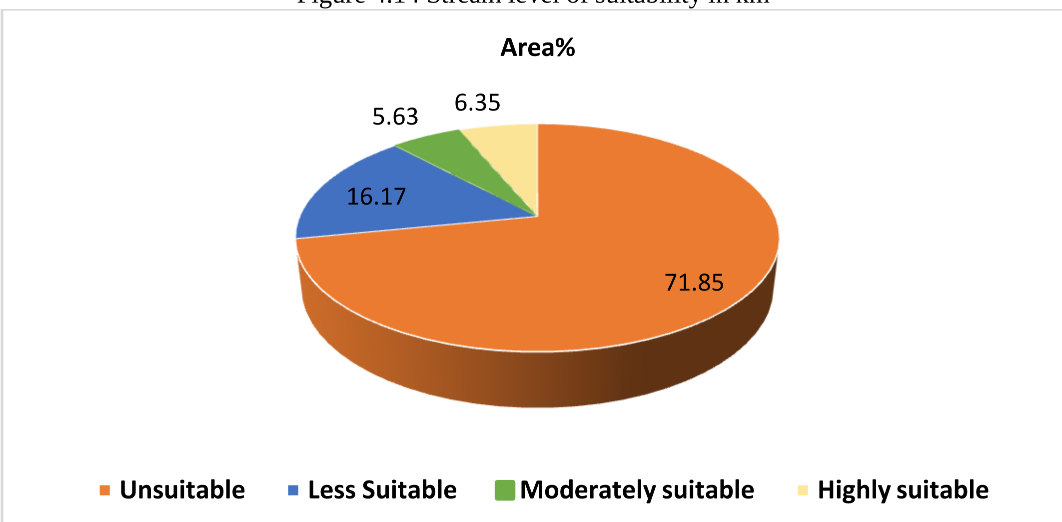

Figure4.15Stream level of suitability in Area

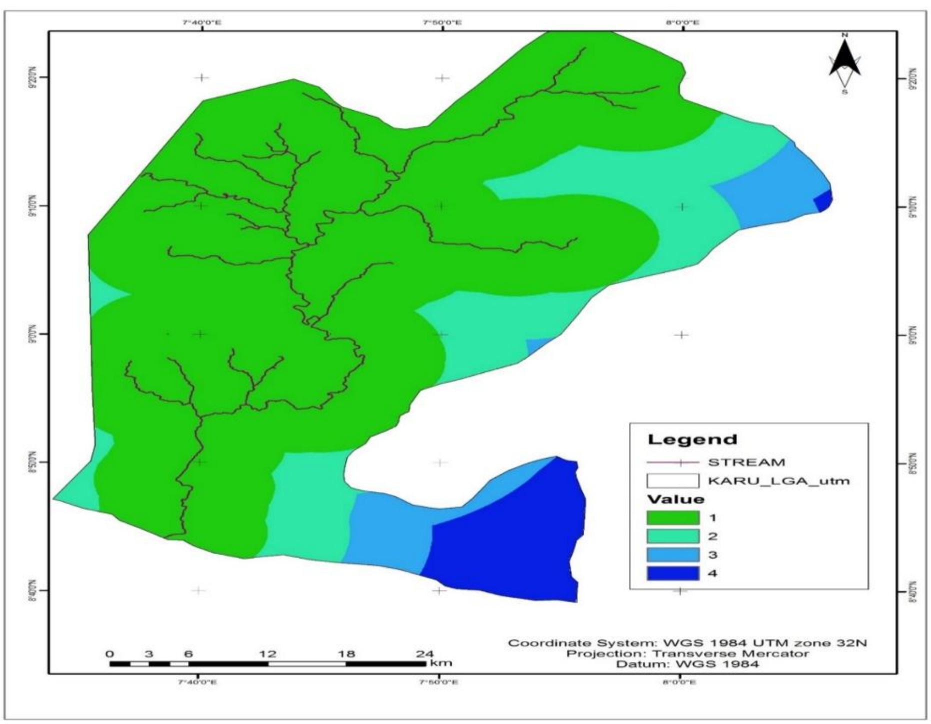

Figure 4.1 Stream Map of Study Area

6. Settlement

The safe distances from settlements are determined as 7000 m for urban centers and 3000 m for rural villages. Like other criteria, settlement areas were classified according to their suitability. The study considered the reclassified distances as unsuitable from 0 to 2500 m, less suitable between 2500 and 4500 m, suitable from 4500 to 5500 m and most suitable from 5500 to 7000 m for the urban areas. And for rural settlement according to Akbari (2011) 3000 m were put as criteria around the rural settlement. This distance was reclassified as unsuitable, 0 to 500 m, less suitable, 500-1000, moderate suitable from 1000 to 1500 m and most suitable area from 1500 to 2000 m. This study used 2000m for it analysis and the result is presented in Figure 4.17 and 4.20, urban and rural settlement were reclassified into four (4) classes. This was done so as to further simplified the their level of suitability and table 4.4 and 4.5 shows the suitability levels of settlement in urban and rural area, this was also done to determine area suitable for sitting landfill. The most suitable area in urban settlement covers an area of 509.54km^2 which is 19.32% of the total study area while rural settlement covers an of 69.13km^2, 2.62% of the total study as well. This shows that distance from settlement area differs from one place to another.

Table 4.4 Distance covered by urban and suitability levels.

Distance from urban	suitability Level	Value	Area	total area (%) settlement
0-2500	Unsuitable	1	874.66	33.13
2500-4500	Less suitable	2	696.27	25.62
4500-5500	Moderately	3	579.24	21.94
5500-7000	Highly	4	509.54	19.32

Table 4.5 Distance cover by rural settlement and suitability levels.

Distance from rural	suitability Level	Value	Area	total area (%) settlement
0-750	Unsuitable	1	1464.32	55.47
750-1500	Less suitable	2	806.94	30.57
1500-2250	Moderately	3	299.64	11.35
2250-3000	Highly	4	69.13	2.62

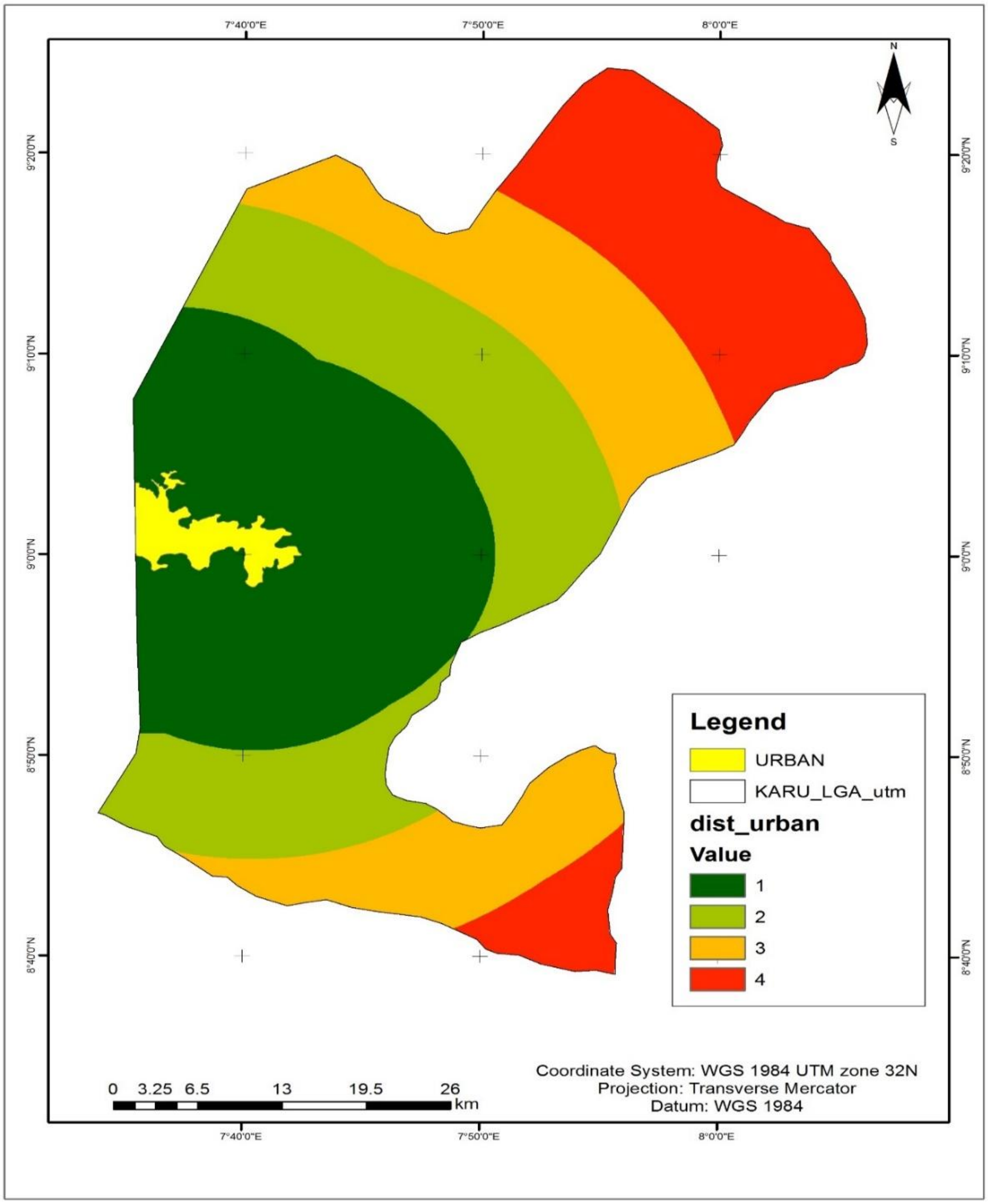

Figure 4.17: Reclassified Urban settlement of study area

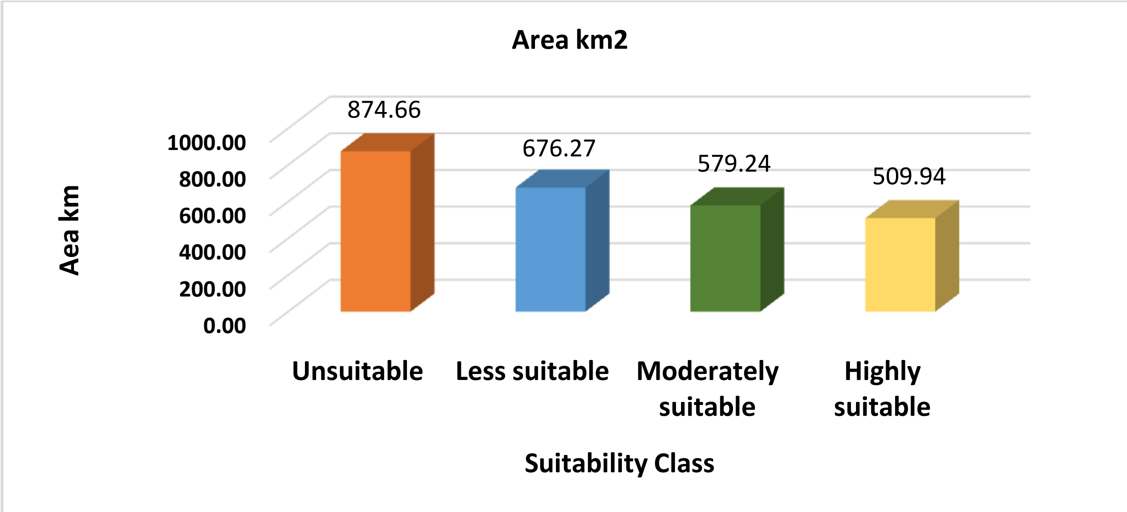

Figure 4.18 suitability level of urban area km^2

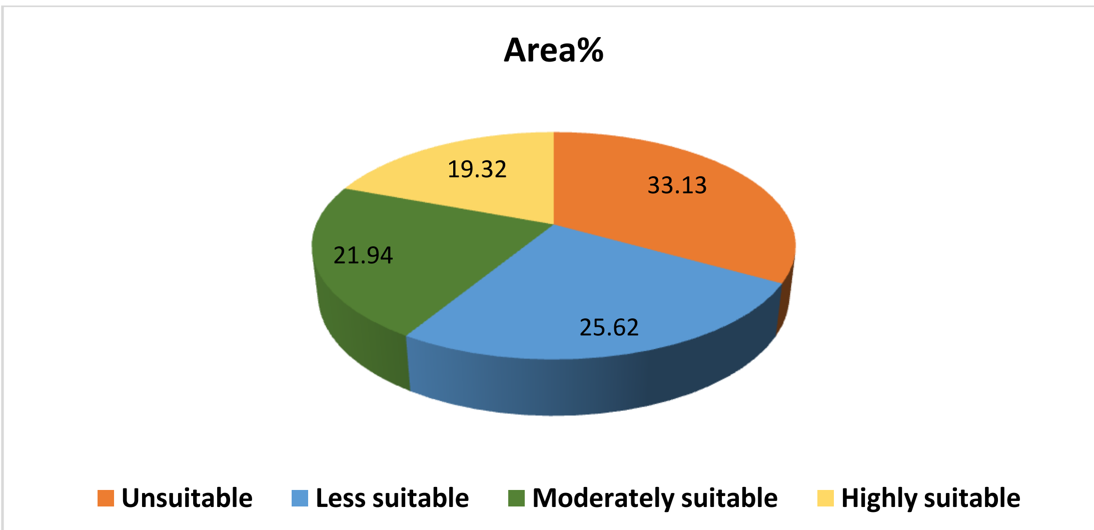

Figure 4.19: Suitability level of urban area %

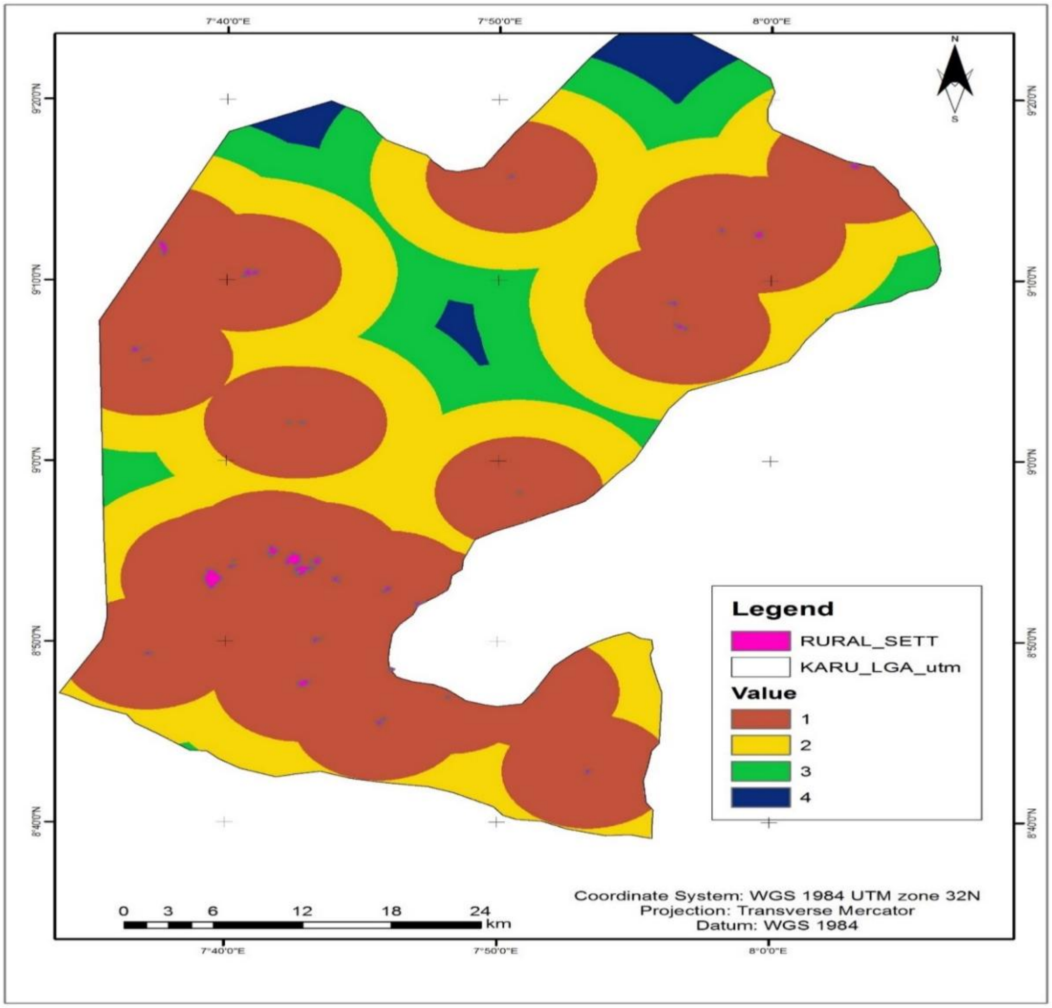

Figure 4.20 Reclassified Rural settlement of study area

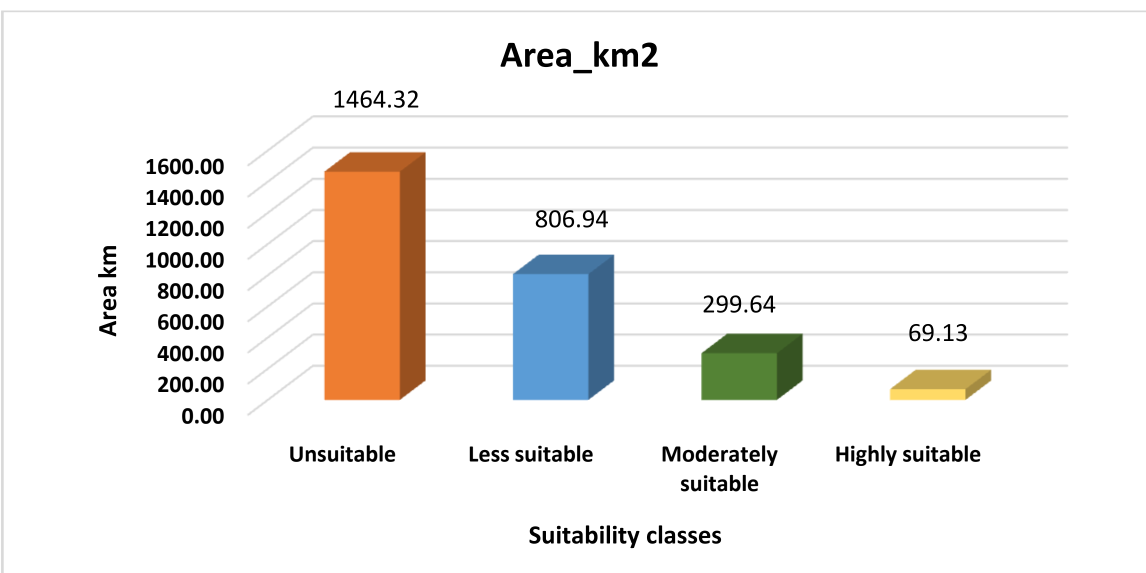

Figure 4.21 suitability level of rural area km^2

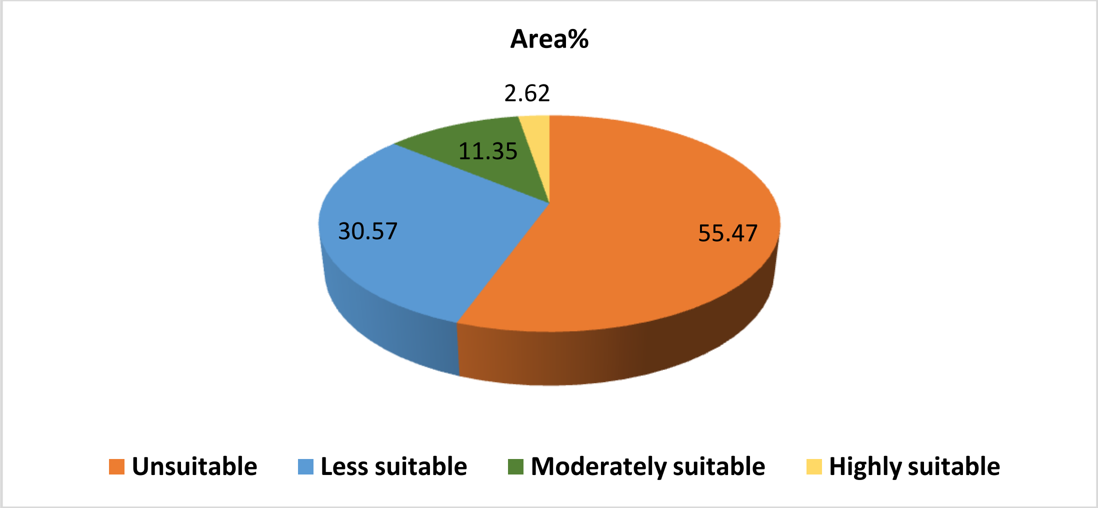

Figure 4.22suitability level of rural area %

7. Overlaying and identifying suitable sites

The suitable site selection for solid waste disposal dumping site involves comparison of different options based on different environmental factors experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility. The weights were developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by Saaty (1980) under the Analytical Hierarchy Process (AHP). Weight rates were given based on pair wise comparison 7 point continuous scale (Table 4.6). These pair wise comparison were then analyzed to produce of weights that sum to 1 (Table 4.7). The factors and their resulting weights were used as input for the multi criteria evaluation (MCE) module for weighted linear combination of overlay analysis. In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 (value 1 = unsuitable (restricted), value 2 = less suitable, value 3 = moderately suitable, value 4 = highly suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map. The factors and weights are summarized in (Table 4.9). According to the degree of importance, they have the role of selecting suitable solid waste dumping site. Suitable solid waste site was produced after the overlaying all the given factors. Below is the factor map and potential Suitability map of study area with four different colors each representing various level of suitability with four (classes) , Figure 4.24) has four colors (classes): Orange, blue, green and yellow. The most suitable site for landfill site selection is marked by yellow color (class 4) and it covers about 80.10 km^2(3.03%) of the total area of the study area. The green color represents moderate suitable area (class3) and it cover an area of 37.97% (395.28 km). The area with blue color covers 1169.70 km2(44.29%) representing less suitable class and the unsuitability classcovers an area of 995.78km^2 (37.71%)under the class 1.

Table 4.6Scale of relative importance using Pairwise comparison in 7 point Scale (according to Saaty (1980))

	Urban	Rural	River	Road	Geology	Slope	Soil
Urban	1	3	5	5	7	9	7
Rural	01-Mar	1	3	5	5	7	3
River	01-May	01-Mar	1	5	5	7	3
Road	01-May	01-May	01-May	1	1	3	01-Mar
Geology	01-Jul	01-May	01-May	1	1	3	01-Mar
Slope	01-Sep	01-Jul	01-Jul	01-Mar	01-Mar	1	01-Mar
Soil	01-Jul	01-Mar	01-Mar	3	3	3	1

Table 4.7 Pair wise comparison (according to Saaty (1980))

	Urban	Rural	River	Road	Geology	Slope	Soil
Urban	1.00	3.00	5.00	5.00	7.00	9.00	7.00
Rural	0.333	1.00	3.00	5.00	5.00	7.00	3.00
River	0.2	0.33	1.00	5.00	5.00	7.00	3.00
Road	0.2	0.7	0.2	1.00	1.00	3.00	0.33
Geology	0.14	0.2	0.20	1.00	1.00	3.00	0.33
Slope	0.11	0.14	0.14	0.33	0.33	1.00	0.33
Soil	0.14	0.33	0.33	3.00	3.00	3.00	1.00
	1	1	1	1	1	1	1

Table 4.8 Weights derived by calculating the principal eigenvector of pair wise comparison matrix (according to Saaty (1980))

	Urban	Rural	River	Road	Geology	Slope	Soil	Eigen vector
Urban	0.47	0.57	0.50	0.24	0.31	0.27	0.46	0.40
Rural	0.15	0.19	0.30	0.24	0.22	0.21	0.20	0.22
River	0.094	0.063	0.10	0.24	0.22	0.21	0.20	0.16
Road	0.094	0.038	0.02	0.049	0.044	0.090	0.022	0.05
Geology	0.066	0.038	0.02	0.049	0.044	0.090	0.022	0.07
Slope	0.052	0.026	0.014	0.016	0.014	0.090	0.022	0.033
Soil	0.065	0.063	0.033	0.14	0.13	0.030	0.066	0.075

Table 4.9Weights derived by calculating the principal eigenvector of pairwise comparison matrix (according to Saaty (1980)).

Landfill site selection criteria	**Eigen vector(weight)**
Urban	**40%**
Rural	**22%**
River	**16%**
Road	**5%**
Geology	**7%**
Slope	**3%**
Soil	**7%**

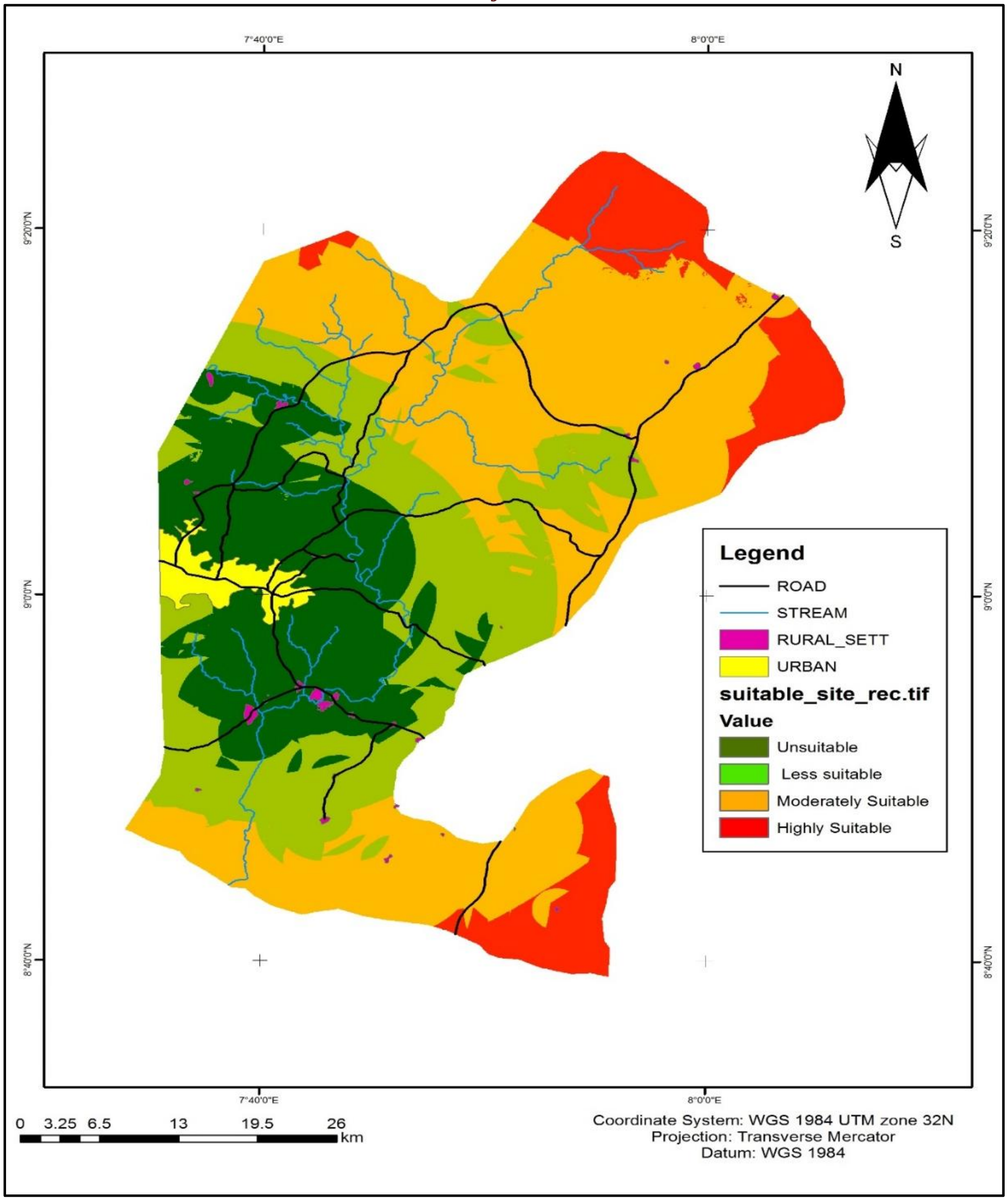

Figure 4.23 Potential Suitability Map of the study area

Table 4.10 Final suitability table of the study area

Level of Suitability	Range of Score	Area (km^2)	Total Area (%)
Unsuitable	Class 1	995.78	37.71
Less	Class 2	1169.70	44.29
Moderate	Class 3	395.28	14.97
Highly	Class 4	80.10	3.03

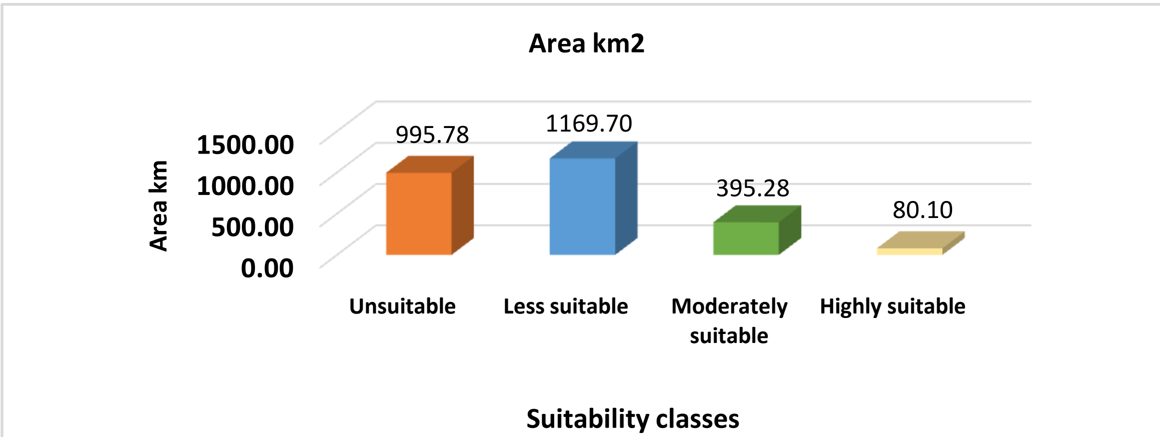

Figure 4.24potential suitable area km2

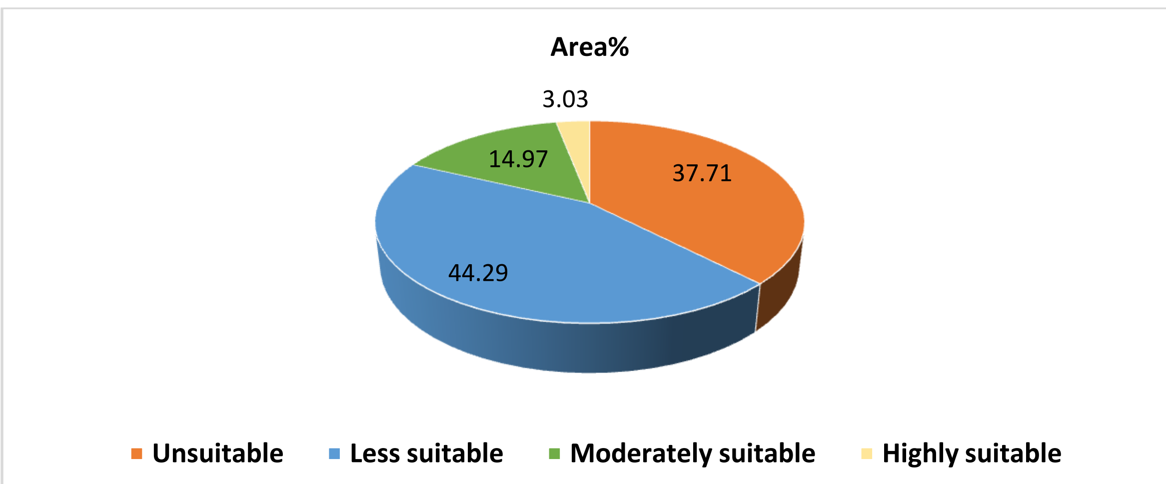

Figure 4.25 potential suitable area%

V. IMPLICATIONS AND RECOMMENDATIONS

The implication of the finding on the number of landfill sites in the study area is that the only site is grossly inadequate for the quantum of waste generated in the LGA and the entire state. Hence, there is a strong need for additional landfill to be established in the state especially in the area identified as most suitable.

In addition, the study revealed total absence of management at the landfill site. Therefore adequate management and control of the use of the existing one need to be improved upon so as not to create the same state of condition exhibited by the existing landfill in the study area -that is filled up without proper maintenance. Furthermore, the study revealed that the government policy on ground is not effective enough to curb the indiscriminate disposal of these solid wastes in the study area.

Lastly, the study revealed that the only 3.03% (80.10 km^2) of the total study area is the most suitable for potential suitable landfill sites which is not big enough but with proper maintenance, the available site (s) will go a long way in reducing the indiscriminate disposal of solid wastes in the study area.

Based on the study findings, the following are recommended to the government in order to manage waste disposal adequately in the study area:

i. Government should improve and implement the existing policy for the management of solid waste in the study area.
ii. Government should sensitize the people on the importance of a cleaner environment.
iii. Government should endeavor to construct an additional landfill to support the existing one so as to prevent waste being dumped near residential area and along the roads.
iv. The people should be made to be responsible for the indiscriminate disposal of the solid waste they generated.
v. The local waste disposal agent in the community should be ordered not to dumped waste anywhere they deem fit else they pay a certain amount of fine.

CONCLUSION

In this study, criteria necessary for siting suitable area for landfill in study area, Karu LGA were examined and weighted using AHP. The weighted criteria were then overlaid using weighted overlay analysis to get the most suitable areas for siting landfill in Karu LGA, Nasarawa state. The study concludes that the application of GIS and weighted overlay using AHP could provide better decision for locating suitable areas for siting landfill.

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