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Suitability Studies of Some Selected Dumpsites for Solid Waste Disposal in Zaria, Kaduna State, Nigeria, using Geographic Information System

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ABSTRACT

Given that most solid waste dump facilities are not situated in acceptable areas, disposing of solid waste presents a significant difficulty in built-up areas. Using the Geographic Information System (GIS), this study conducted a suitability analysis of selected dumpsites in Samaru, Zaria, Kaduna State, Nigeria. The research made use of information from a spot picture with a spatial resolution of 5 m, elevation models, with a spatial resolution of 30 m, a control point acquired through the Global Positioning System, and a map of the region. Geographic Information System and multi-criteria analysis techniques based on land-use/land cover, suitability of slope, distance to water body and road were used to do an overlap analysis of remotely sensed data to prime the maps. Following a systematic sampling of eight dumpsites, the results showed that four (50%) of the sampled dumpsites are located in moderately suitable areas within the study region, while the other dumpsites are less suitable. Around 65% of the study area has already been built up and hence not suitable for location of dumpsite, though more than half of the study areas had slope of less than 10% which is within the acceptable range for dumpsite location. It was revealed from this research that GIS is an invaluable resource for general suitability analyses. The waste management policies of the Governments in the study area need to be considerably implemented.

Keywords: Dumpsite, Environmental pollution, Geographic Information System, Health hazard, Solid waste management.

INTRODUCTION

Waste is any material that is thrown away at every stage of daily human activity, having a negative impact on both human health and the environment [1]. Solid waste consists of food scraps, paper, metal scraps, discarded clothing, carcasses, excrement, debris from building and demolition projects, hospital waste, and household appliances [2, 3]. In today's world, waste is a major cause of environmental pollution, especially in emerging and less developed nations. Waste generation is increasing due to population growth, economic expansion, and improved living standards in society [4, 5]. In Africa, the rate of solid waste generation far supersedes that of urbanization itself [6]. This is definitely not unconnected with the fast urban growth that has occurred in the continent since the 1960s resulting in sustained pressure on land resources within the areas adjoining cities and has correspondingly led to increase in waste generation. The problem is intensified by the waste management practice of open dumping in the slum areas of most African cities [7]. The huge quantity of solid wastes that is commonly observed in most of the roads and streets of major cities in Nigeria is a pointer to the fact that the current strategies to deal with the bye products may not be as effective as first construed [6]. Adequate solid waste management facilities in urban areas are a vital investment that serves to safeguard the health and well-being of the populace in cities and towns as well as the environment [8].

An essential component of any waste management plan is the disposal of solid waste, which requires careful planning to prevent both environmental pollution and health hazard [9-11]. The majority of trash dumps are located on the edges of developed communities, often near roads, farms, and bodies of water. These areas are conducive to the growth of disease-carrying organisms such as parasites, rats, and flies [12]. When this waste is improperly disposed of, it can pollute water sources through leachate, contaminate soil through constant contact with waste, and contaminate the air through the practice of waste incineration. It can also spontaneously release methane gas when it breaks down in the absence of oxygen [13-15]. Discarding solid garbage carelessly also leads to irritation, pollution of water and land resources, and disturbances to the environment's aesthetic qualities [13].

The primary challenge in managing solid waste is locating appropriate places for the disposal of this material as well as appropriate landfill sites away from residential areas [16,17]. Getting rid of trash in carefully designed, constructed, and maintained landfills is a smart strategy for secure containment [18]. Site selection analysis can be improved by using Geographic Information System because it has the capability to manage large amount of spatial data that comes from various sources [19]. Nigusse *et al.* [20] hinted that large amount of spatial data can be analysed using GIS and which conserves time that would ordinarily be spent in choosing an appropriate site. While James [21] claimed that GIS is an eventual method for maiden site selection as it efficiently stores, retrieves, analyses and displays information according to user-defined description. However, GIS can be limited by the existing sources of data needed in siting analysis.

Using the Geographic Information System and remote sensing to pick landfills requires integrating a number of elements to make an informed choice [22]. Surface and ground water, soil type, slopes, settlements, reserved areas, land use and land cover, and accessible road networks should all be taken into consideration when creating selection standards. Birkie [8] studied the solid waste management practice and dumpsite suitability analysis using GIS technology in Debre Markos town, Ethiopia, and concluded that 58% of the dumpsite were less suitably located. In the same vein, Geidam [6] carried out spatial analysis of suitable waste dumpsites in Damaturu, Yobe State, Nigeria, and discovered that majority of the dumpsites were not suitably located in the area.

Information on several spatial criteria, such as land use and land cover, drainage density and pattern, and slant angle, is provided by remote sensing [21, 23, 24]. In order to facilitate the comprehension of landfill selection criteria, digital geospatial datasets are created through the use of geographic information systems [25]. To choose an appropriate dumpsite location, layers of data from remote sensing and GIS are methodically evaluated in a multi-criteria evaluation [22]. With the goal of reducing risks to the environment and public health, this research evaluates the appropriateness of current dumpsites using remote sensing and GIS techniques. It is aimed at creating a GIS map of the selected dumpsites at Samaru, Zaria, in Kaduna State, Nigeria, towards conducting a GIS-based dumpsite location suitability analysis in the study area.

METHODOLOGY

Study Location

The study was conducted in Samaru urban community, which is located in Sabon Gari Local Government Area of Zaria Metropolis, Kaduna State, Nigeria. The Local Government area has a total of eleven political wards; Anguwan-Gabas, Basawa, Bomo, Chikaji, Dogarawa, Hanwa, Jama'a, Jushi, Muciya, Samaru, and Zabi [26] . Its coordinates are latitude 11^0 12' North and longitude 07^0 37' East at an altitude of 550-700 m (Figure 1). It lies within the savannah environment of northern Guinea. According to the National Population Commission (NPC) estimates, its population is 50,000 [27]. Its eastern boundary is shared by the Industrial Development Centre and the Nigerian Institute of Leather and Science Technology (NILEST). Its borders are the Basawa Military Barrack to the north, the Institute of Agricultural Research (IAR) to the west, and the main campus of Ahmadu Bello University to the south.

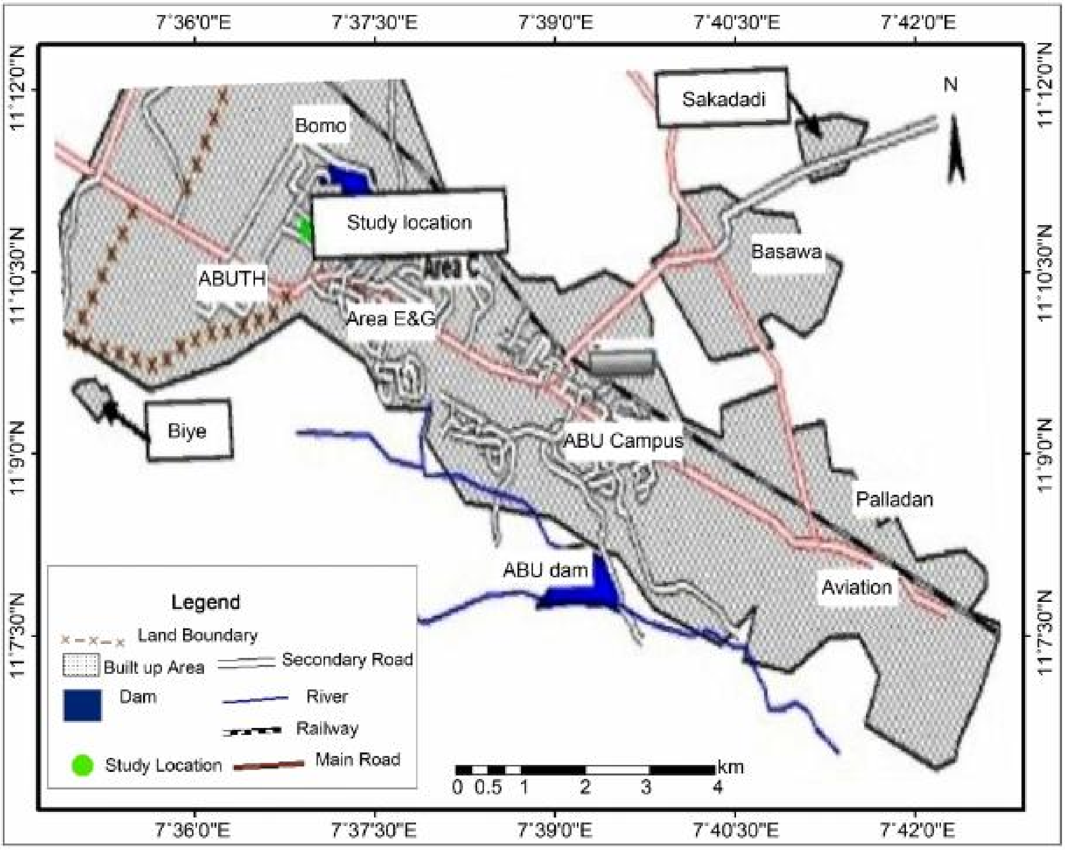

Figure 1: The geographical coordinates of the study location

Study Materials

The materials used in this research include a handheld geographical positioning system (GPS), a topographic map of the area, and personal protective equipment (PPE) like safety boots, a nose mask, and hand gloves. Applications used include ArcGIS 10.1 software and Google Earth.

Study Approach

The primary data from the field study and information from first-hand field observations were gathered to answer the present study question. Supplemental materials were obtained from the internet, published books, newspapers, articles, and magazines. Among the geographical data sources and data types were Ikonos satellite imagery from RECTAS with a resolution of 4 m, coordinate data from the GPS receiver Garmin eTrex 10 acquired during the field survey, and individual field measurements from the field study.

The strategy used in this study includes obtaining spatial and attribute data from the coordinates of the chosen dumpsites by field inspection. Additionally, a Garmin eTrex10 hand-held global positioning system receiver, Ikonos satellite imagery of the Samaru region at a resolution of 4 metres, and a base map/goggle earth picture map of the region displaying the road networks were used. The acquired pictures were digitalized and geo-referenced to display the sample points' locations. With the help of ArcGIS 10.1, the database, shape files, and on-screen were produced. Layers were used for classification, and values ranging from most appropriate to inappropriate were assigned. After which, layers were reclassified into 1's, 2's, 3's, and 4's recording systems, where 1 denoted unsuitable, 2 less suitable, 3 moderately suitable, and 4 highly suitable.

Selection of Dumpsites

The dumpsites were randomly selected based on significant volume of waste and closeness to built-up areas within the study area. This was done by using a basic hand-held GPS device (eTrex 10) to obtain the coordinates of the chosen dumpsite in the research region. The coordinates were meticulously recorded in a record book for appropriate presentation when precise readings were obtained.

GIS Map of the Study Area

The GIS map of the study area was achieved with the coordinates of eight selected dumpsites which were overlaid on a topographic/goggle earth map of the area to generate the GIS map. Google earth was used in generating the picture map.

Dumpsite Suitability Analysis

The parameters considered were in accordance with those in the literature [25-28] which were used before drawing conclusion on the suitability of the selected dumpsites. They include land-use/land-cover, distance from road, suitability of slope (slant angle), and distance from the river. The integrated data used include satellite image from Google Earth for the extraction of road networks, ASTER-GDEM from USGS for elevation and slope generation. The datasets were integrated into the GIS environment using Multicriteria evaluation in ArcGIS 10.7.

Tables 1-4 provide the multi-criteria groups used in determining the suitability of dumpsites to include land-use/land cover, distance to road, suitability of slope, and distance to river respectively.

Table 1: Land Use and Land Cover [28]

Land cover	Level of Suitability	Value
Built-up Land	Unsuitable	1
Farmland	Less Suitable	2
Bare land	Moderately Suitable	3
Vegetation	Highly Suitable	4

Table 2: Distance to Main Road in meters [29].

Distance to Road (M)	Level of Suitability	Value
0 – 500	Unsuitable	1
501 -1000	Less Suitable	2
1001 – 1500	Moderately Suitable	3
1501 – 2000	Highly Suitable	4

Table 3: Slope of the Study area [30]

Slope (%)	Level of Suitability	Value
>20	Unsuitable	1
16 – 20	Less Suitable	2
11 – 15	Moderately Suitable	3
<10	Highly Suitable	4

Table 4: Showing Distance to River in meters [31]

Distance to River	Level of Suitability	Value
0 – 500	Unsuitable	1
501 -1000	Less Suitable	2
1001 – 1500	Moderately Suitable	3
1501 – 2000	Highly Suitable	4

RESULTS AND DISCUSSION

Coordinates of Selected Dumpsites

The coordinates and suitability level of each of the selected dumpsites are presented in Table 5.

Table 5: Location coordinates and suitability of each dumpsite selected

S/No.	Location	Coordinates	Level of Suitability
1	Sai'id Primary school	N 11 º 09.977 E 007 º 38.751 H 2255 feets	Less Suitable
2	Behind Saint Mary's	N 11 º 09.733 E 007 º 38.711 H 2229 feets	Less Suitable
3	Sakafa	N 11 º 09.000 E 007 º 39.175 H 2212feets	Less Suitable
4	Basawa Road	N 11 º 09.945 E 007 º 39.314 H 22215 feets	Less Suitable
5	LEA Mamman Nura Road	N 11 º 09.995 E 007 º 39.622 H 2193 feets	Moderately Suitable
6	Pensioner Quarters	N 11 º 09.833 E 007 º 39.708	Moderately Suitable

		H 2199 feets	
7	Hayin Danyaro Dumpsite A	N 11 º 09.644 E 007 º 39.895 H 2159 feets	Moderately Suitable
8	Hayin Danyaro Dumpsite B	N 11 º 09.629 E 007 º 39.871 H2158 feets	Moderately Suitable

GIS Map of the Study Area

The GIS map of the study area is presented in Figure 2. It can be seen that most of the dumpsites are located in the eastern side of the map followed by the Western part a possible indication that there are more generating activities taken place in the eastern side hence more waste been generated and discarded.

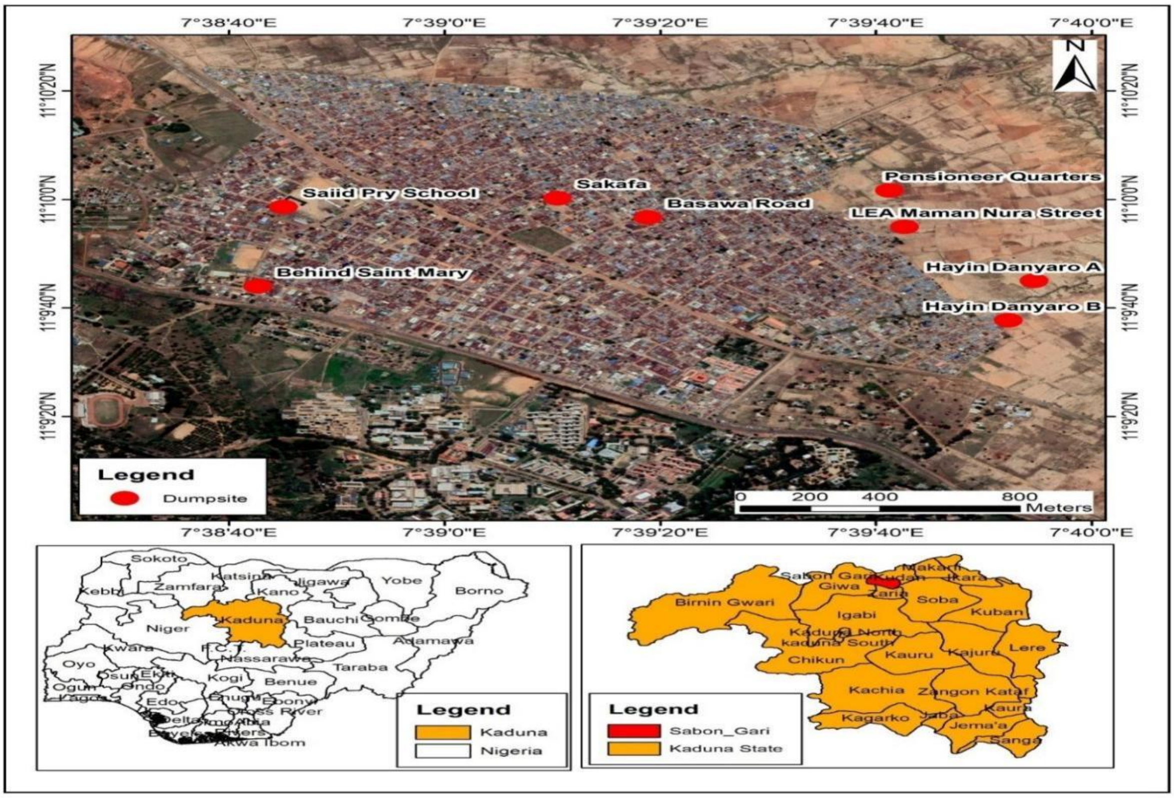

Figure 2: The GIS map of the study area

Dumpsite Suitability Analysis

- **Land-Use/Land-Cover**
- Figure 3 displays the land-use map of Samaru town, which includes naturally occurring vegetation, bare land, built-up areas, and farmland.

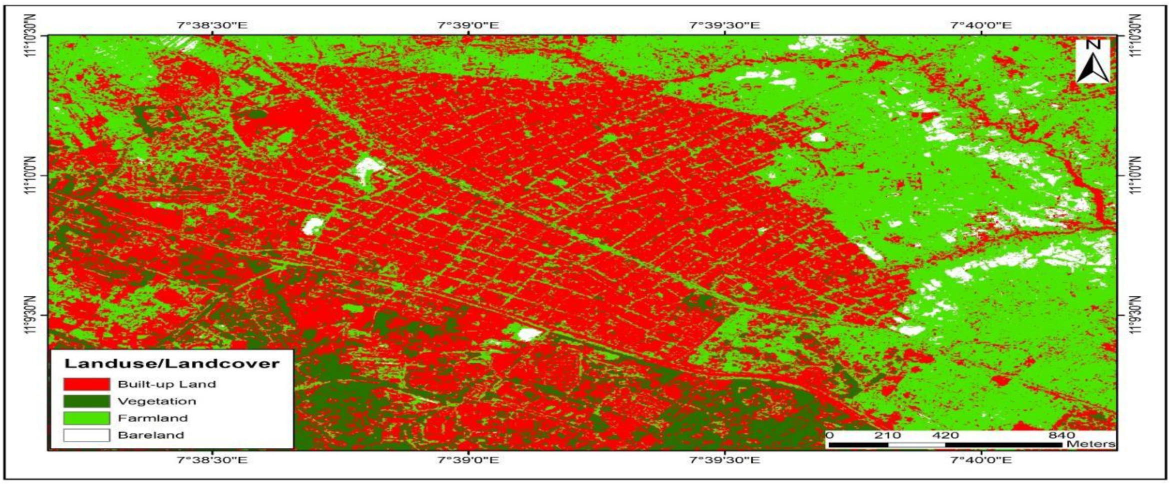

Figure 3: Land-Use and Land-Cover Suitability of study area

It can be seen from the map that the majority of the areas to the South and East are made up of buildings. The study area's built-up land is categorised as unsuitable denoted by the red coloured parts of the map (around 65%) of the study area has already been built up and hence not suitable for location of dumpsites, though more than half of the study had slope of less than 10% which is within the acceptable range for dumpsite location. The sparse vegetation within the built-up area is also less suitable for dumpsite location while farmlands and bare lands as seen towards the North-western part of the map denoted with light green and white colour are more suitable [28]. These parameters are expected to be taken into consideration before determining which of the selected dump sites are most appropriate for the overall goal. Dumpsite are to be located away and far from populated centres of the city, as it causes aesthetic depreciation as well as bad odours and also depreciation of land worth of the surrounding area [32].

Distance from Road

Aesthetic contemplation would be of good practice for good preparation and based on this opinion, waste dumpsites should not be located within 1000 meters of any major highways, city streets or other transportation routes [29]. The ease of access to a dumpsite is crucial and should be considered in establishing suitable areas for the dumpsite. The dumpsite should be easily accessible from either new or existing roads in order to reduce the cost of transportation to the site. Olanibi and Emmanuel [33], also opined that dumpsite should be cited inside a 1 km buffer from the roads. Considering the present study, a distance north of 1000 m from roads is ideal. The recommended distance of dumpsite to road in accordance to Ghoutum*, et al* [29] is presented in Table 2.

The buffering analysis performed according to worldwide standard recommendations [29] is shown in Table 2. Lands that are much farther away from protected areas are more desirable than those that are closer to them. Disposing of solid garbage near a busy road might have negative health effects.

In Figure 4, four categories of dumpsites were identified in relation to the major road.

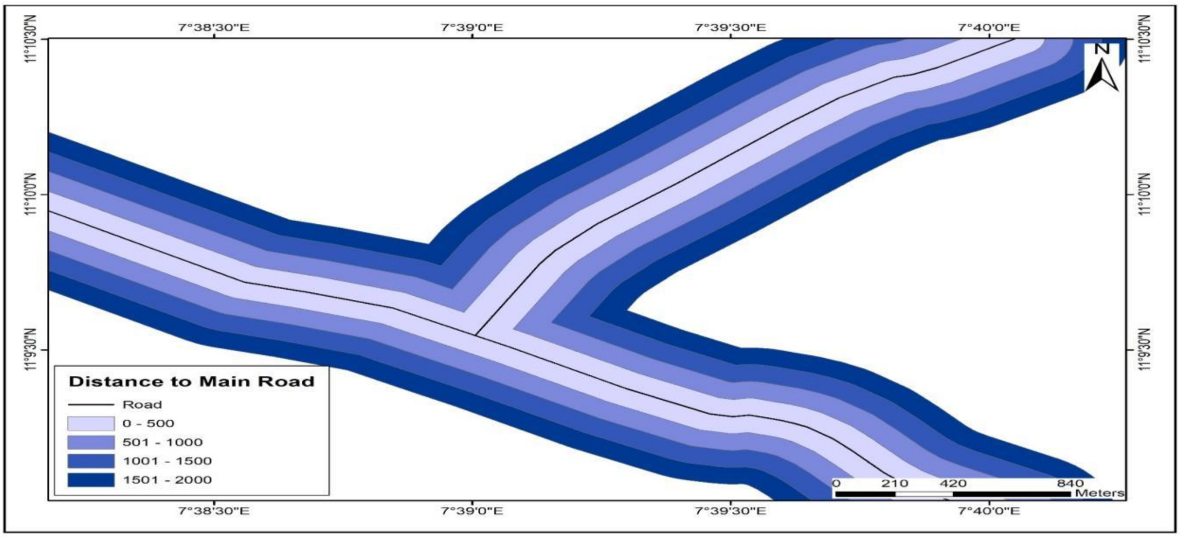

Figure 4: Suitability distance of dumpsite from the main road

In Samaru town, areas ranging from 0 to 500 m were deemed unsuitable for disposing of solid trash; 501 to 1000 m were less acceptable; 1000 m to 1500 m were fairly suitable; and 1500 m to 2000 m were extremely suitable.

Suitability of Slope

As shown in Table 3 and Figure 5, the areas covered by slope, which goes from 0-9%, is 90.7%. Sener et al [31] state that land with a slope of less than 10% is perfect for dumping of solid garbage. Slopes reduce the need for earthmoving and helps in attaining the correct leachate drainage [34]. Hence, the bulk of the area presents an excellent location for the construction of a solid waste disposal facility as more than halve of the study area has slope of less than 10%. This is explained by the flat terrain of Samaru town.

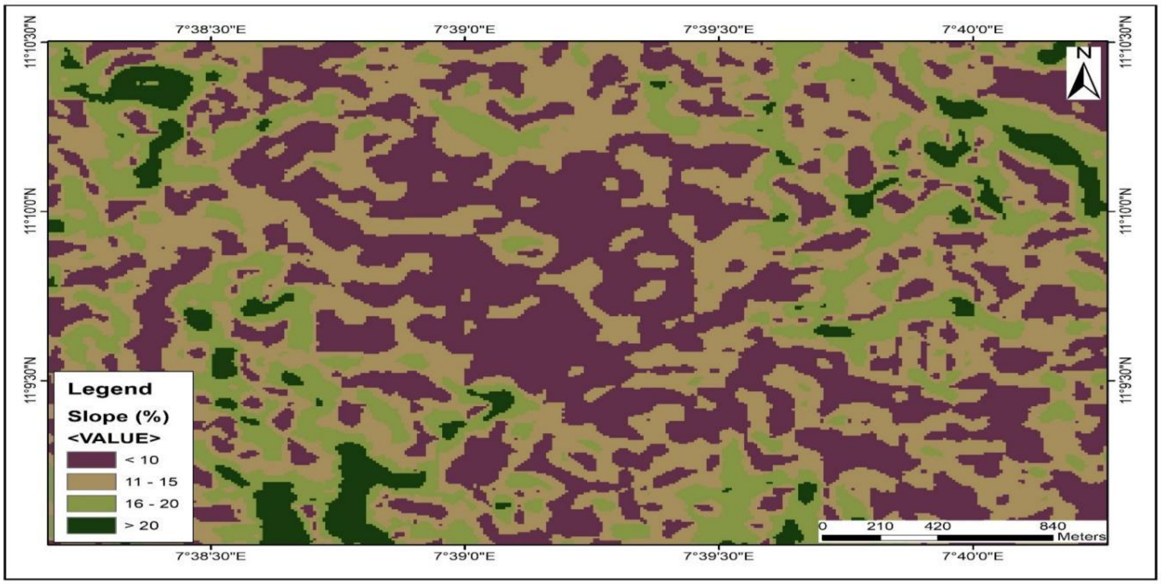

Figure 5: Map showing the variability in slope of the study location

Distance to River

Solid garbage disposal near rivers can have negative effects on the environment, agriculture, and public health [30]. Like other elements, the river map was centred on the Hayin Danyaro River and was divided into four groups. In a study by Mussa and Suryabhagavan [35], areas with a percentage distance of 0-500 m were deemed undesirable, 501–1000 m were deemed less suitable, 1001–1500 m were deemed moderately suitable, and 1500–2000 m were deemed extremely suitable for the disposal of solid waste as seen in Figure 6 and Table 4. Water bodies such as surface streams and wetlands are one of the major factors to be considered when siting waste dumpsite. Also, proximity to wells and other underground water reservoir is an important standard to be considered when locating suitable waste dumpsite [36].

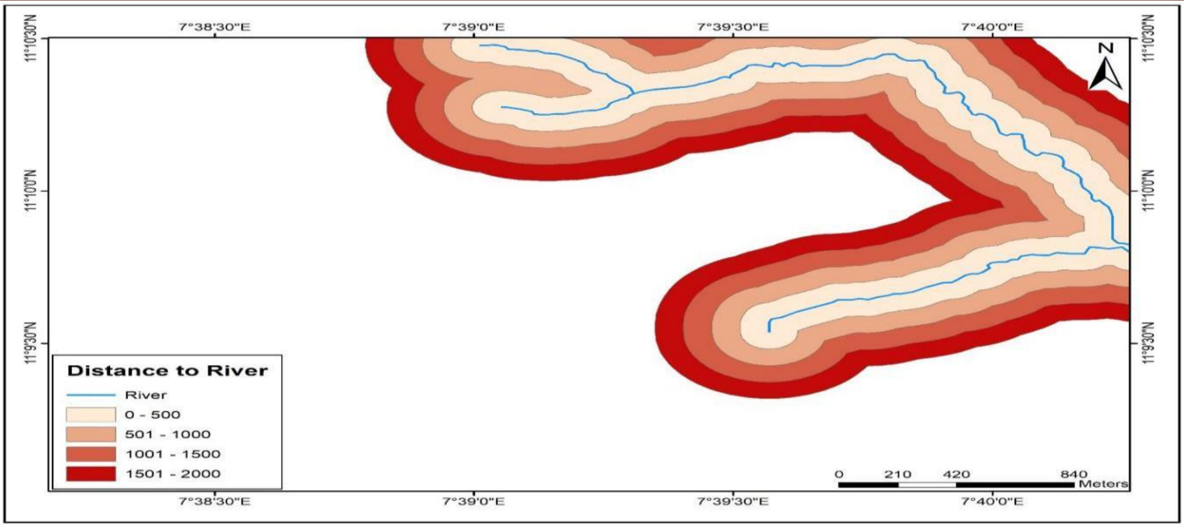

Figure 6: Map showing the distance of dumpsite to river

Suitability Map of the Dumpsite in the Study Area

To develop a suitability map of the selected dumpsites in the study area, all aforementioned criteria were considered and combined. Figure 7 combined all parameters earlier considered above which are; slope, distance to main road, distance to river in producing a suitability map of Samaru.

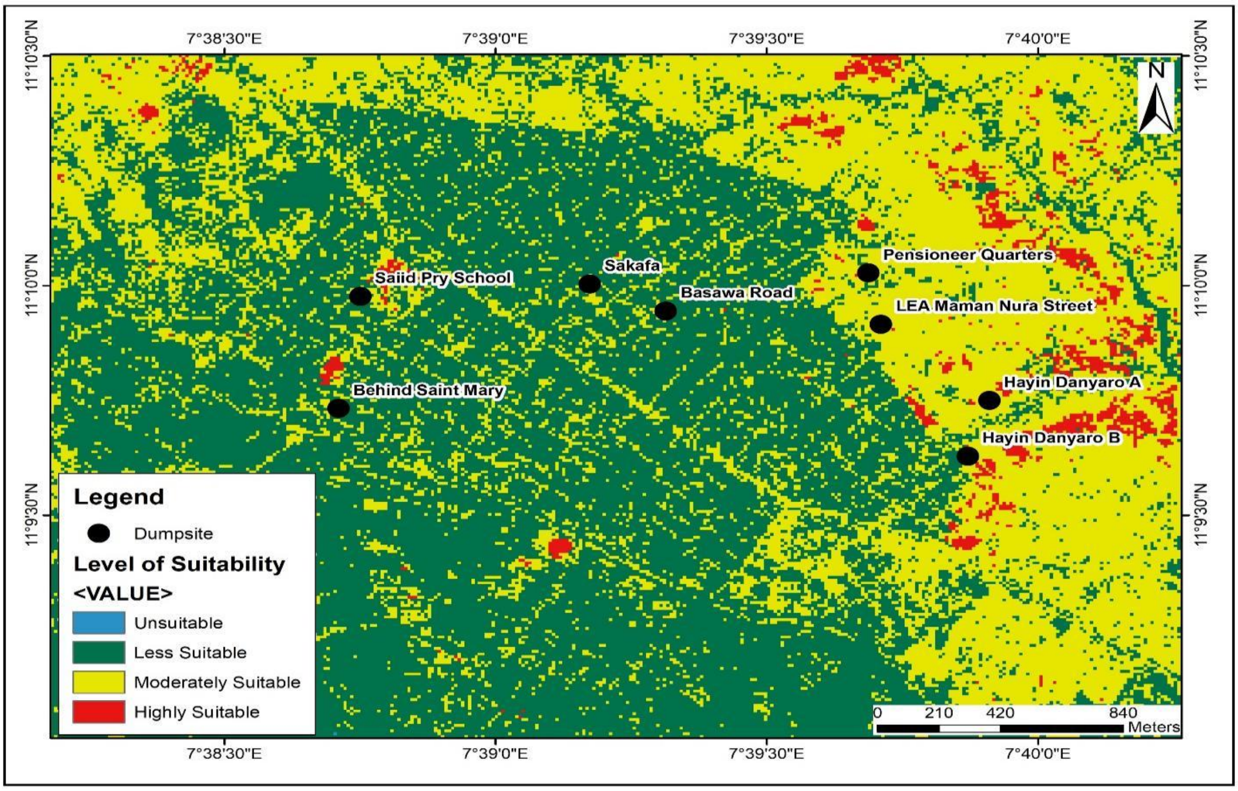

Figure 7: Suitability Map of the Selected Dumpsite in Samaru

Based on this Figure, dumpsites to the west of the map are less suitable while east of the map are more suitable. This information is presented in a tabular form in Table 5.

Findings of the research revealed that dumpsites to the Central-Western portion of Samaru are not suitable because they fell short of standard set for the location of dumpsite [25-28]. While those to the Eastern part of the study area were generally more suitably located as they pose minimal threat to man and the environment in the short-run, though they have significant potential deleterious consequences on human population in the future due to the expected increase in human population and development. Based on this research, none of the existing dumpsite is highly suitable for solid waste disposal in Samaru town but half of them is within the moderately suitable category which presents a variant to findings by Burkie *et al* [8] and Geidam and Isa [6] were less than half of the dumpsites in the sample area were suitably located. This research also proves the dexterity of GIS in spatial analysis of dumpsite location.

CONCLUSION

While some considerations may have been made for roads, and residential areas, same cannot be said for rivers and slope. Dumpsites here fell between two extremes of no area being entirely unsuitable and highly suitable. The dumpsites at LEA Mamman Nura Road, Pensioner Quarters, Hayin Danyaro Dumpsite “A” and Hayin Danyaro Dumpsite “B” pose serious threat to the river/underground water in the area. There is need to enforce existing policies on waste management by concerned authorities, from waste generation to waste disposal. Around 65% of the study area has already been built up and hence not suitable for location of dumpsites, though more than half of the study area had slope of less than 10% which is within the acceptable range for dumpsite location. Also, GIS and Remote Sensing application should be maximised in environmental issues so as to minimize risk to the environment.

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