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APPLICATION OF GIS AND MULTI-CRITERIA DECISION ANALYSIS FOR LANDFILL SITE SELECTION IN ABEOKUTA NORTH LGA OF OGUN STATE

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ABSTRACT

This study is based on site selection for Solid Waste dumpsite in Abeokuta North LGA, Nigeria using Geographic Information Systems (GIS) and Multi-criteria Decision Analysis (MCA) techniques. Five criteria were used for the study. This criteria were classified in to two: the constraint criteria (buffers). While the factor criteria involves road types, soil, elevation, slope and land use. The study was divided in to three phases. In the first phase the constraint criteria were standardize using Boolean logic, a score of 0 was assigned to the restricted area, while 1 to unrestricted area. Then all the five criteria were overlaid to generate a restriction map. For the second phase, factor criteria were standardize using fuzzy membership, with a range of numbers from 0 –1. The factor criteria were then weighted using Analytical Hierarchical Process (AHP) and then overlaid, to get a suitability map. The final phase combine the result of the first and second phase to get most suitable sites for landfill. The result revealed Six different sites; the Highly Unsuitable site occupy 64.64Km2 (8%), Very Unsuitable site occupy 290.88 km2 (36%), Unsuitable site covered 56.56 km2 (7%), Suitable site covered only 161.6km2 (20%), Very Suitable site covered 24.24km2 (3%) and then Highly Suitable site covered 21.08% (26km2). Some communities within the Very Unsuitable sites are Atapa Ikoyi, Ogoye, Ijale Orile, Ijale Papa; those within unsuitable sites are, Aiyetoro, Imala, Olohunda; those within suitable sites are Idi Emi, Abeokuta south; those within very suitable sites are Idiya, Adimo,Igbo Aje; those within Highly Suitable sites are Gbopa ehin, Igbasa, Owode.

KEYWORDS: ***Decision Criteria, GIS, Landfill, Suitability, Waste***

1.0 INTRODUCTION

Population growth, urbanization, the emergence of new technologies, and changes in lifestyle and consumption patterns on the one hand, and restrictions on the use of natural resources have, on the other hand, led social, economic, and even environmental conflicts in addition to creating a variety of complex problems regarding the quality of human life (Monazzam et al, 2014). One of the aftermaths of the increasing population with its increasing consumption rate has led to increased waste generation.

The goal of siting a sanitary landfill is to provide long-term environmental protection that is economically efficient and complies with applicable regulations. Very few potential landfill sites are ideal. But the landfill's design phase allows managers to overcome site deficiencies using proven engineering techniques. A good location of a well-developed landfill will make construction, operation and closure less technically difficult and more cost-effective by using GIS techniques.

Using GIS for locating landfill sites is an economical and practical way as they have capabilities of producing useful, high quality maps for landfill site selection in a short period of time. This technological evolution, driven by significant advances in computer technology and the availability and quantity of data informed the use of GIS in this study. For proper identification and selection of appropriate sites for landfills careful and systematic procedures need to be adopted and followed. Wrong siting of landfill many result in environmental degradation and often time public opposition (Babalola & Busu, 2011). Thus in order to satisfy the needs and wants of the population their spatial location needs to be carefully planned. Most often, social concerns such as distance from urbanized areas (residential or commercial) and distance from historical, cultural, or natural/recreational sites need to be addressed.

Therefore there is need for planners and government organizations to ensure that facilities are placed where it will not result in the deterioration of the quality of human life, with long-term impact on future generations of particular concern.

In a research by Yi, et al., (2019) to investigate the use a novel hybrid MCDA-GIS technique to evaluate Flood Susceptibility Mapping, which is constructed by ensemble of DEMATEL, ANP and IRN technique in the case study at Shangyou County, China. The final susceptibility map was obtained which can be considered promising since the reliability and stability of the ranking results are checked.

This work aimed at using GIS cut edge tools and Multi-criteria Decision Analysis to identify the appropriate area that is most suitable for Landfill site in Abeokuta north LGA in Ogun State. This aim is achieve through a number of objectives as follows:

i. identifying existing land use in the study area
ii. obtaining input data required for the analyses
iii. determining factors and important criteria for locating a landfill site
iv. develop a model as a siting tool in landfill site selection process using criteria in (ii) above
v. identify the most suitable location for the landfill site

1.1 The Analytic Hierarchy Process

One of the most well-known and often used multi-criteria procedures is the analytical hierarchy process (AHP), developed by professor Saaty in 1980. This method integrates the procedures of assessing alternatives and aggregating them to locate the most pertinent ones. The method is used to rank a set of alternatives or to choose the best option from a set of alternatives. Rankings and selections are made in light of a broad objective that is broken down into a number of factors. For instance, in a research, Analytic Hierarchy Process (AHP) for a Landfill Site Selection in Chachapoyas and Huancas (NW Peru) by Jhonsy , et al., (2022). The study provides a management tool for identifying suitable sites for landfills through the integrated use of the analytic hierarchy process (AHP), geographic information systems (GISs), and remote sensing (RS). Three sites were selected out of twelve highly suitable sites that were identified, based on their shape and the minimum area required for the operation of the landfill until 2040

In another development, Samra, et al., (2021) compared Landfill site suitability assessment using AHP and Fuzzy AHP Methods were several environmental, socio-economic, and infrastructure factors such as groundwater level, soil type, slope, land cover, distance to settlements, railways, roads, surface water sources, airport, power lines, wells, and protected areas were used as predictors. Relative Operation Characteristic (ROC) analyses performed gave results of 0.77 and 0.86 for the suitability maps of AHP and Fuzzy AHP, respectively and the resulting suitability map showed the best suitability that could be implemented to resolve the fundamental landfill siting problems in other cities of Pakistan.

2.0 MATERIALS AND METHODS

2.1 Materials

i. Land cover/land use map
ii. Digital Elevation Model (DEM)
iii. Shapefiles explaining Administrative maps of the area showing (roads, built up areas, water bodies etc).

2.2 The study Area

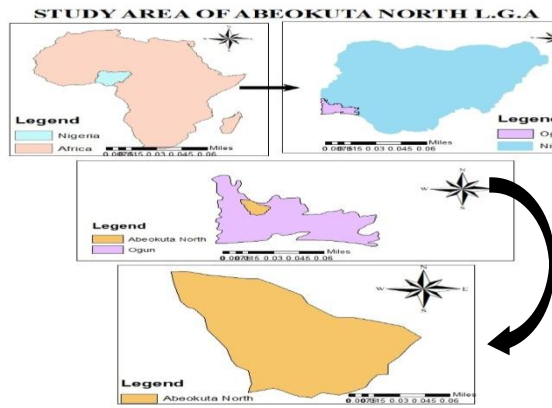

Figure 1.0: Description of the study area

Source: Authors, 2022.

2.3 Methods

The adopted approach involved the identification of factors used to determine potential landfill site such as the geomorphology of the study area, proximity to water sources, land use, land value, topographic surface, soil properties, economic distance cost from population centers, distance from population centers and proximity to recreation areas among others.

In addition to the base maps above, slope classification, slope direction and altitude, distance from main roads, transmission lines, and maps of water bodies were provided. The land use map was obtained from sentinel 2 land cover datasets of 2022. The existing land use in the study area are built up areas, water bodies, crops, roads and shrub lands. The total study area is 808km^2.

2.3.1 Establishment of restriction factors

Literary evidences show that different researchers have used varying criteria for site selection purposes. This is because different criteria applies to different region and all facilities. The adopted method in this work provides a selection of environmentally friendly disposal sites, thus supplying reasonable, convenient and administratively transparent solutions to the waste landfill problems.

Due to data constraints; river system, land use, human settlements, road networks and slope of the area were modeled (Figure 1.1a & 1.1b) and used as guides to select suitable landfill. Areas of cultural and historical importance such as church yards, Muslim prayer grounds, and graveyards etc. are exempted from landfill siting. . Criteria were specified in accordance to the legislation in force to assume that landfill sites would be located on flat areas using elevation map (Figure 1.3 aspect map) and outside the buffer zones of the rivers, roads, farmlands and residential areas. These criteria are:

Table 1: Showing the criteria way for selecting landfill

Criterion	Buffer zone(m)	Adopted Buffer Distance(m)
Built up Area	500 - 2000	1000
Water bodies	100 - 1000	500
Crops	100 - 500	250
Major roads	100 -500	500
Minor roads	100 - 500	250
Slope	2%–10%	Relatively Flat
Railroads	200 -500	250
Shrubs	200 - 500	200

The following are the importance ranking of the various factors considered for suitability analysis in the study area.

Table 2: Showing the levels of importance adopted for the selection factors

Relative importance	Definition	Description
1	Equal important	Two factors contributing uniformly to the predefined goal.
2	Less Moderate important	Experience and judgment are less moderate in favor of one as compared to another.
3	Moderately important	Experience and judgment are negligibly in favor of one as compared to another.
4	Very less strong important	Experience and judgment are less important in favor of one as compared to another.
5	Less strong important	Experience and judgment are less strong in favor of one as compared to another.
6	Strong important	Experience and judgment are strongly in favor of one as compared to another.
7	Very strong important	Experience and judgment are very strongly in favor of one as compared to another.
8	Extremely important	The sign favoring one as compared to the other parameter is of the maximum possible validity

2.3.2 Multi-Criteria Decision Analysis on the factors

Analytical Hierarchical Process (AHP) method was adopted for carrying out multi-criteria decision making based on the complexity of the data inputs. These are methods for organizing and analyzing complex decisions, using mathematics and psychology based on expert judgments.

Table 3: Showing the Criteria Comparison Matrix (C)

	Ranking or Criteria Comparison Matrix (C)							
CRITERIA	A	B	C	D	E	F	G	H
BUILT UP AREA	**1.00**	7.00	5.00	4.00	3.00	2.00	2.00	1.00
WATER BODIES	0.14	**1.00**	2.00	2.00	2.00	2.00	4.00	5.00
CROPS	0.20	0.50	**1.00**	3.00	2.00	3.00	4.00	3.00
MAJOR ROADS	0.25	0.50	0.33	**1.00**	3.00	3.00	5.00	2.00
MINOR ROADS	0.33	0.50	0.50	0.33	**1.00**	2.00	3.00	3.00
RAILROADS	0.50	0.50	0.33	0.33	0.50	**1.00**	3.00	2.00
SLOPE	0.50	0.25	0.25	0.20	0.33	0.33	**1.00**	5.00
SHRUBS	1.00	0.20	0.33	0.50	0.33	0.50	0.20	**1.00**
SUM	**3.93**	**10.45**	**9.75**	**11.37**	**12.17**	**13.83**	**22.20**	**22.00**

Source: Authors, 2022.

Table 4: Showing the Normalized Criteria Comparison Matrix

	Normalized Criteria comparison Matrix (C)									
Criteria	A	B	C	D	E	F	G	H	Average	*Weight*
BUILT UP AREA	0.25	0.67	0.51	0.35	0.25	0.14	0.09	0.05	0.29	28.95
WATER BODIES	0.04	0.10	0.21	0.18	0.16	0.14	0.18	0.23	0.15	15.37
CROPS	0.05	0.05	0.10	0.26	0.16	0.22	0.18	0.14	0.15	14.54
MAJOR ROADS	0.06	0.05	0.03	0.09	0.25	0.22	0.23	0.09	0.13	12.67
MINOR ROADS	0.08	0.05	0.05	0.03	0.08	0.14	0.14	0.14	0.09	8.90
RAILROADS	0.13	0.05	0.03	0.03	0.04	0.07	0.14	0.09	0.07	7.23
SLOPE	0.13	0.02	**0.03**	0.02	0.03	0.02	0.05	0.23	0.06	6.48
SHRUBS	0.25	0.02	0.03	0.04	0.03	0.04	0.01	0.05	0.06	5.88
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.00

Source: Authors, 2022.

2.3.3 Landfill Selection modeling

In this study; river system, water bodies, crop and shrub areas, human settlements, road networks and elevation factors are considered and their corresponding constraint map are created. A model of approach for these study is created. These factors are transferred into information system separately by using ArcGIS software. GIS-based analyses were conducted using ArcGIS Spatial Analyst which provides a platform for working with gridded data sets. This was used to produce suitability maps highlighting "suitable" geographic areas derived from weighted and combined map layers based on established criteria.

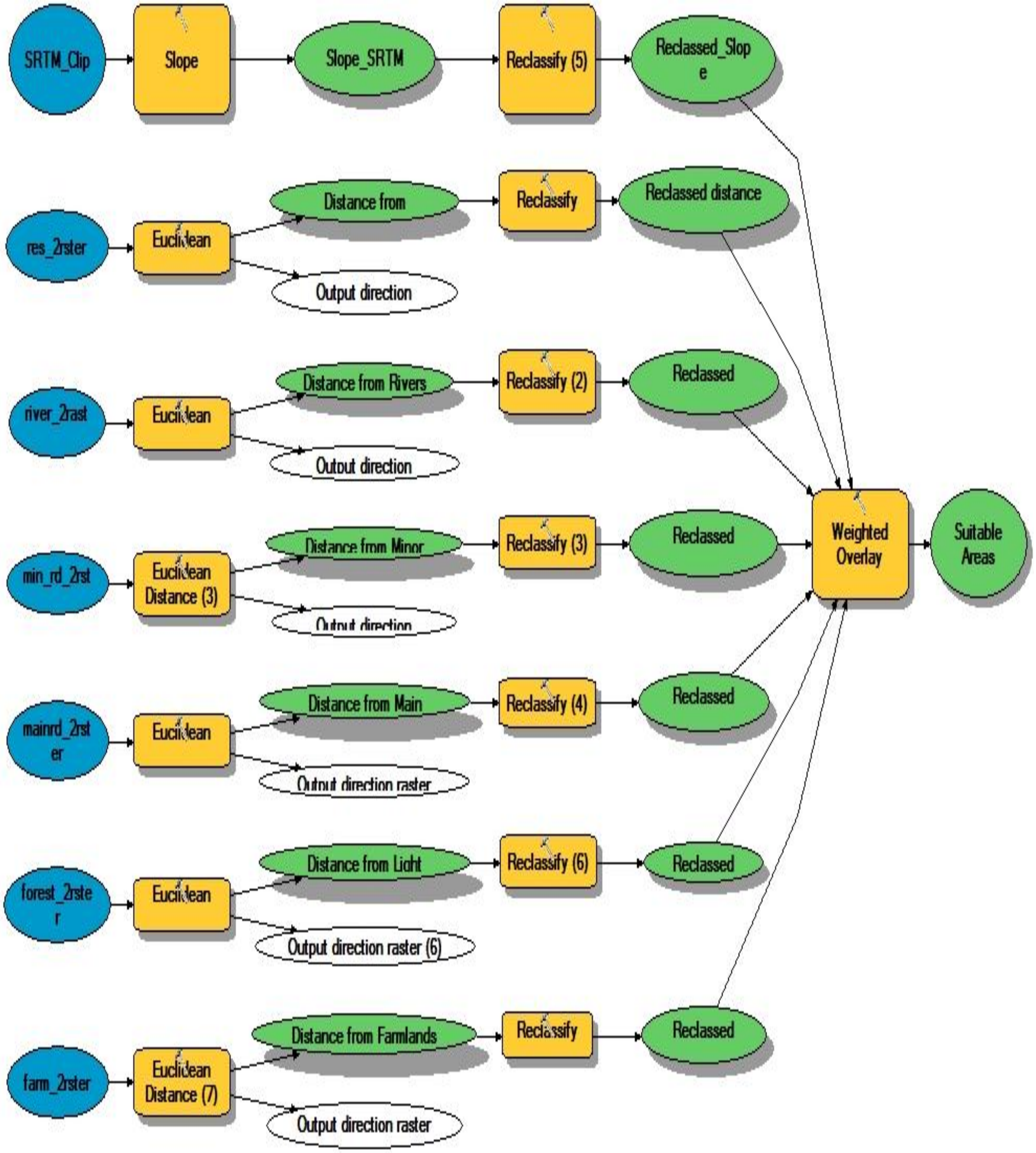

Figure 1.1a: Designed model for the study
Source: Authors, 2022.

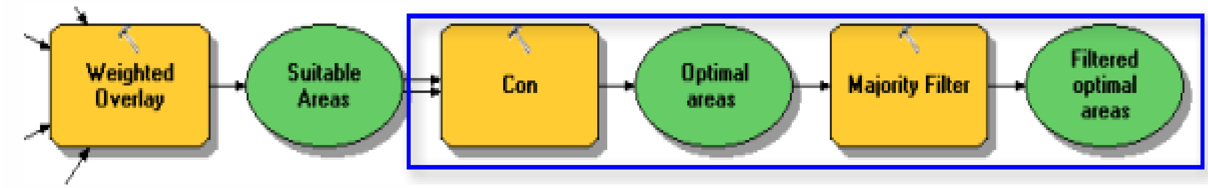

Figure 1.1b: Work Model followed in GIS to achieve results
Source: Authors, 2022.

2.3.4 Selecting best site

All the locations in the Filtered optimal areas layer are suitable. The last step in this exercise is to locate the best site out of the alternatives. The roads within the study area is displayed in the roads layer. By examining the Filtered optimal areas layer with the roads layer, it was observed that there are some suitable areas for the landfill site that are not close to roads within the LGA. These areas were first excluded by locating suitable sites that are intersected by roads and then best site is located based on area.

2.3.5 Validation of Results

A number of candidate sites have been revealed. In order to check the suitable areas derived from the analysis, field check is carried out to ascertain the accuracy and suitability of the selected site. The locations of the candidate sites are also given in Figure 1.4

3.0 RESULTS AND DISCUSSION

A key factor in decreasing the potential for contamination is the geomorphic characteristics or subsurface geology of the area which is characterized by low hydraulic conductivity, low effective porosity, and high retention (absorption, adsorption) of hazardous solutes.

In this study, all input data required for the analyses are generated from land use, vector maps, and topographical maps. These maps are used to derive 12 input data layers such as wetlands, slope, elevation, Highway, township and village roads, railway, natural gas pipeline, electricity, urban centers and villages.

Buffer zones and restrictive factors were eliminated using the Euclidean Distance tool in the Spatial Analyst extension of ArcGIS 10.6. The final map, depicting suitable landfill siting areas, was obtained by summing up the constraint map and the factor map overlays through reclassification and weighting. Different layers relating to these criteria were used to compare maps and located areas which conform to the criteria. It was emphasized that these were the criteria used to solve the siting problem in the study area.

Different layers such as water course, road networks, residences, and farmlands were overlaid. Two Boolean operations were performed using the topographic data. One was the area with heights relatively flat or near flat, and the others which are sloppy. The final landfill sites also felt within the topography of a flat terrain.

Runoff from rains must be planned for by developing drainage channels within the site careful study of the slope map. Sloping areas within the landfill will cause larger volumes and higher peak runoff flows from the site than would occur naturally. The runoff would be directed into channels that are capable of carrying most storms without overflowing or flooding adjacent areas.

The study has found that the increase in the amount of garbage production in no doubt positively correlated with the increase in human population and in turn increases the pressures on sitting new landfills. During this study, the utilization of GIS as a tool in sitting the new landfill was employed and conclusions were drawn as to the effectiveness of its use.

The results of the GIS-based study showed that although highly suitable areas were limited, a site was still able to be chosen under the predefined parameters. The site is not located on, or near, any environmental interest areas and is located a significant distance away from streams, urban areas, which minimizes social conflict and environmental impacts. The highly suitable landfill area is located in an area within 210km^2 of the study area from the city centre (Figure 1.4 and table 5). Since the site is located in a highly suitable area, environmental, social, and economic concerns have been met.

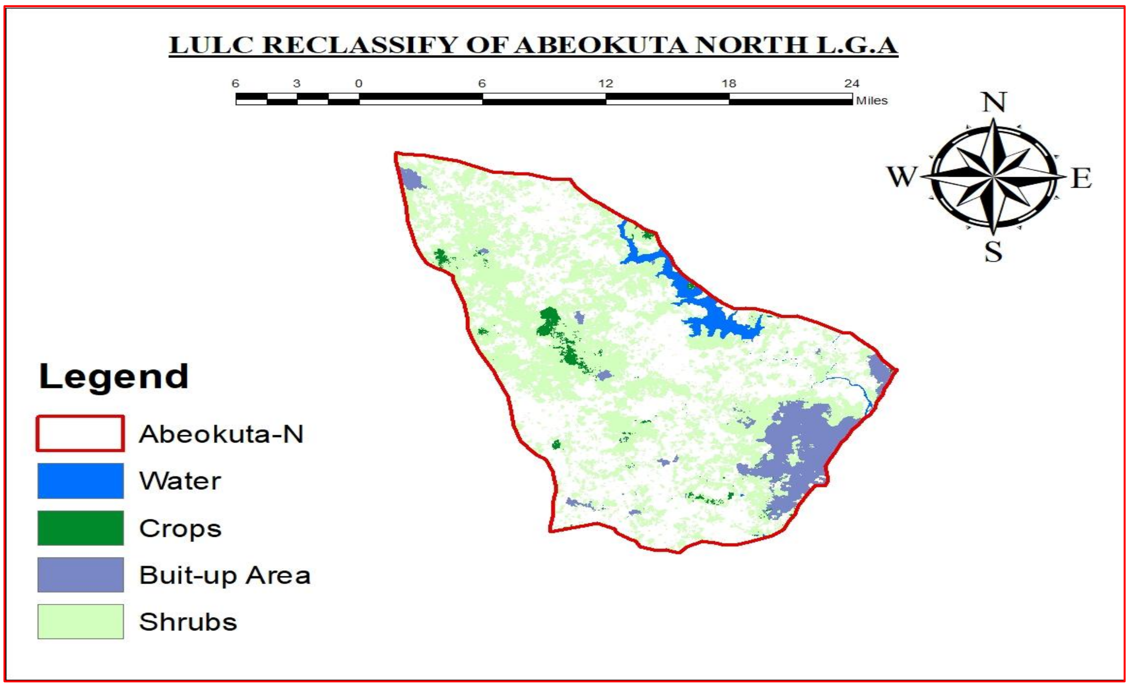

Figure 1.2: Land use map of the study area

Source: Authors, 2022.

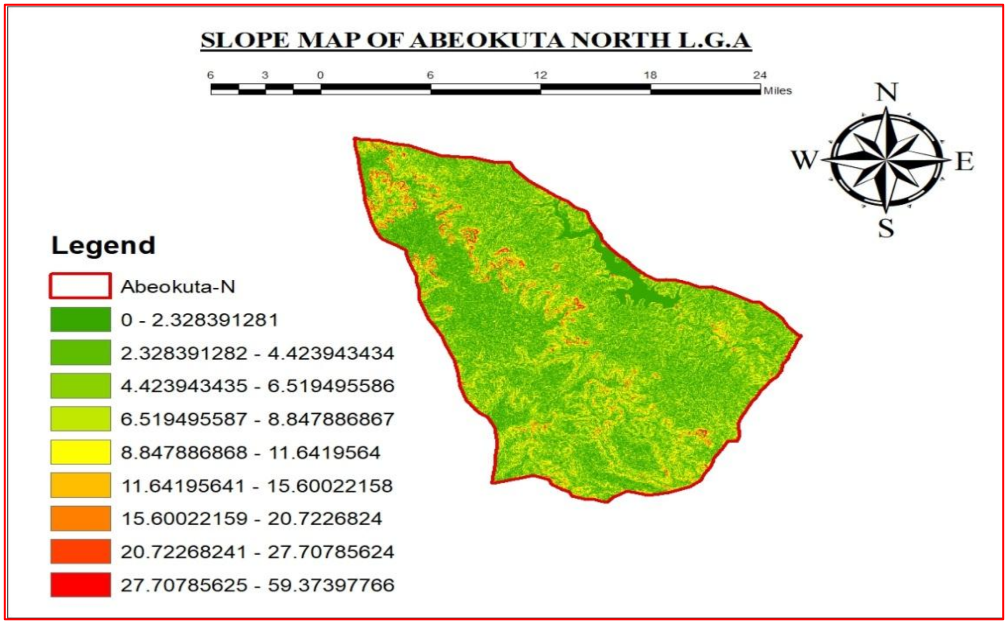

Figure 1.3: Slope Map of the study area
Source: Authors, 2022.

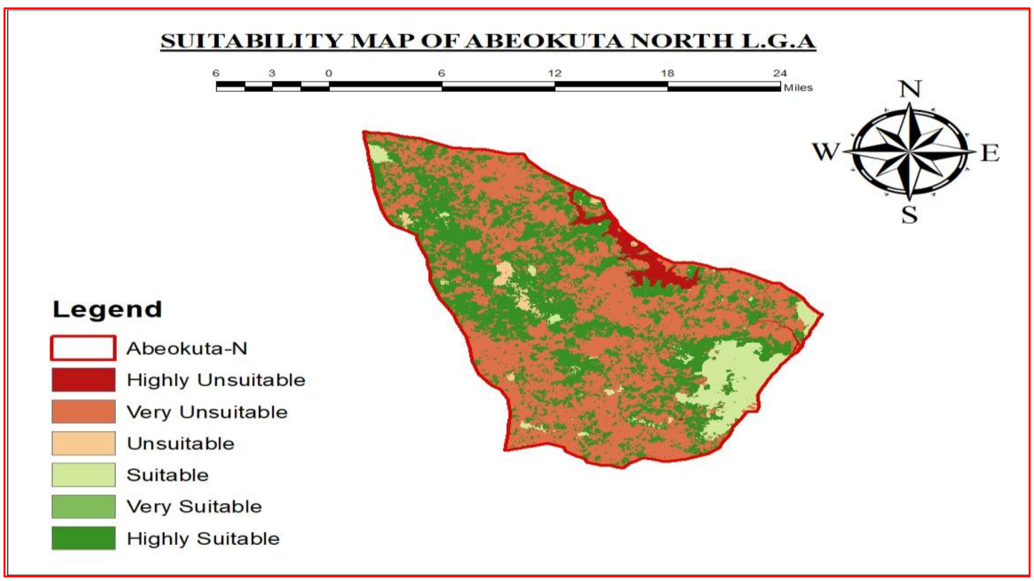

Figure 1.4: Best sites for Landfill in the study area
Source: Author 2022

Table 5: Showing Suitability Coverage Area

SUITABILITY	AREA(km2)	% COVERAGE	COMMUNITIES
Highly unsuitable	64.64	8	Water bodies
Very unsuitable	290.88	36	Atapa Ikoyi, Ogoye, Ijale Orile, Ijale Papa
Unsuitable	56.56	7	Aiyetoro,Imala,Olohunda
Suitable	161.6	20	Idi emi,Abeokuta south
Very suitable	24.24	3	Idiya, Adimo,Igbo Aje
Highly suitable	210.08	26	Gbopa ehin, Igbasa, Owode
TOTAL	**808**	**100**	

3.1 Limitations

There were still limitations surrounding the analysis despite the factors that were included in the model.

Some layers that were not available such as depth to water table and data on the existing water wells are not available. The incorporation of more layers into the GIS-based model is a sine-qua-non for future research because they would increase the relevancy of the final output suitability with the consideration of more factors.

4.0 CONCLUSION AND RECOMMENDATION

The study has found that the increase in the amount of waste generation is positively correlated with the increase in population and in turn increases the pressures on siting new landfills. During this study, the utilization of GIS as a tool in siting the new landfill was employed and conclusions were drawn as to the effectiveness of its use. Analysis showed that there are 5 suitable location areas in the study area which are found in the East, North east and south eastern regions of the area. The criteria used in this study are not fixed factors since they can vary from area to area and these criteria can be changed accordingly in the analysis process. Conclusively, it was found that the suggested landfill site is suitable and does not affect any existing land use in the study area.

The application of a GIS tools that enables organized and systematic analyses of spatial data, presentation of results in the form of aesthetically pleasing and output maps has been employed in this present study. This tools has made it easy to find a suitable landfill site by incorporating the evaluation of multiple criteria. This present study is therefore proposed for use in neighboring towns like Idiroko, Aiyetoro and Sango among others

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