

## The Use of GIS for Identifying Optimum Landfill Sites in Osogbo, Southwestern, Nigeria

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**Abstract:** The amount of waste disposed off globally has significantly increased due to increase in population and change in consumer habits. Million tons of organic waste are disposed of globally through incineration, land applications, landfill, and other methods. Selecting appropriate places for waste landfills is a challenging task for planners, especially in states with dense populations such as Osogbo due to land scarcity, land prices, and increased solid waste generation. Therefore, this study aimed to identify the optimal suitable areas for the solid waste landfill for proper waste management in the study area. In this work, a multi-criteria decision-making approach combining GIS and the Fuzzy Logic technique for landfill suitability site evaluation was used. Six factors are involved in the selection process namely soil, drainage, land use/land cover, built-up areas, road network, and slope. Using the weighted overlay analysis tool in the GIS environment, the results of the MCDM assigned to each criterion show that five potential sites in this study were suitable for the construction of a potential landfill, of which two are located in the most suitable zone and three are located in the unsuitable zone. It was concluded that the results presented on the final aggregation maps demonstrate the significance of selecting the appropriate criteria weights for the environmental and economic set of standards.

**Keywords:** Fuzzy logic multi-criteria decision making, GIS, Landfill, Suitable location, Waste disposal

### I. Introduction

The most important aspect of urban planning is locating an ideal place for the disposal of municipal solid waste [1]. However, the sites of landfills and the methods of disposal might result in major environmental issues or climate change [2]. The main environmental issues that need to be addressed are the effects of landfills on ground and surface water, air, soil, odour emission, and issues with the transportation of solid waste [3]. Lots of issues in the sector of waste management have arisen as a result of landfills [4].

To avoid risks to the public's health or damaging effects on the environment, solid waste management must be effective and efficient. Solid waste generation has increased as a result of rapid industrialization and rising world population. It is more difficult to manage the waste that a city produces now [5]. In addition, Tahir *et al.* [5], emphasized once more that, notwithstanding actions and procedures for trash reduction, reuse, and recycling, it will always be necessary to transport the remaining garbage to a landfill.

In the modern solid waste management system, landfilling garbage has become a crucial component [6]. Furthermore, EPA [6] stated further that, there are several types of landfills: open dumping, controlled tipping, sanitary landfills with bounds and daily covers, sanitary

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landfills with leachate recirculation, and sanitary landfills with leachate treatment. In the hierarchy of waste management, landfilling comes in last place. Due to its convenience compared to other ways, it is the most commonly used throughout the world [7].

Solid waste disposal facilities are one of the issues the community has to deal with. There are no scientifically certified sites, even though the majority of the solid wastes are transported in push carts from the source to the temporary transfer stations. The study area lacks conventional transfer stations. All medical facilities and businesses have their own methods for getting rid of the trash, while some choose to dump it in a nearby body of water [8].

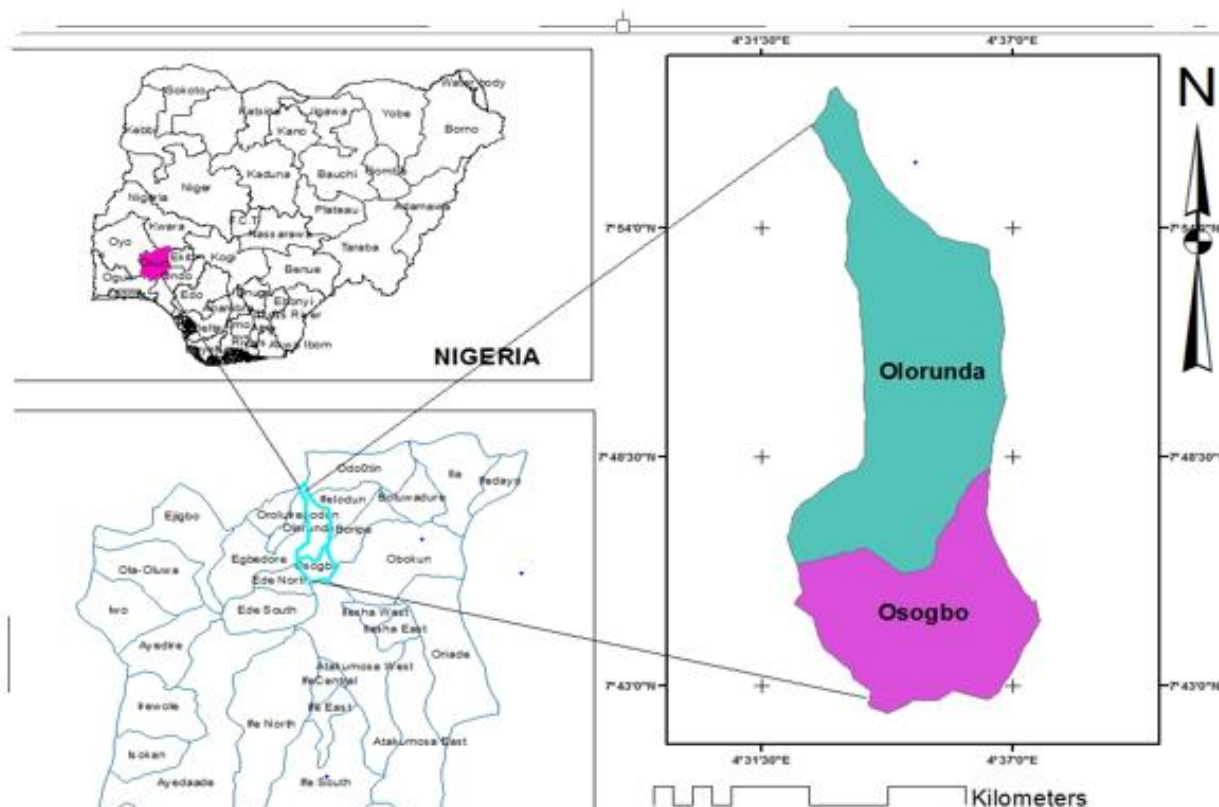
The dumping locations are poorly designed, involve open field disposal which are adjacent

to rural villages, and are not placed at the proper distance from the study area. This study focuses on using GIS and FMCDM with the integration of dynamic data to provide suitable sites for the construction of a sanitary landfill in the study area, thereby offering a long-term solution to solid waste management.

## II. Materials and Methods

### A. Study area

Osogbo is the capital city of Osun State, It is mapped between latitudes  $7^{\circ}45'02.59''\text{N}$ , and  $7^{\circ}59'02.59''\text{N}$  and between longitudes  $4^{\circ}31'16.13''\text{E}$  and  $4^{\circ}42'15.49''\text{E}$ , which had 131,761 residents as of the 2006 census with an average elevation of about 320m above mean sea level, covering an area of 148km<sup>2</sup> as presented in Figure 1 [9].



**Figure 1: Map of Study Area**

## B. Method

Secondary data were used in the study. The secondary data for the study were acquired from reports, books, journals, and governmental institutions. The data were selected based on the criteria that must be satisfied to determine the most suitable location for a landfill according to the United State of America Environment Protection Agency (EPA) landfill manual 2006. The methodology utilizes GIS to evaluate the entire region based on certain evaluation criteria (multi-criteria decision-making) for the analysis of landfill site suitability. Siting a sanitary landfill requires a substantial evaluation process in order to identify the best available disposal location, that is, a location which meets the requirements of government regulations and minimizes economic, environmental, health, and social cost [10]. The characteristics of data used were summarized in Table 1.

The standardization procedure was specified as a relative ranking of fuzzy set membership.

As a result, the function can have any value within a continuous range, from acceptable to unsuitable (i.e., one to zero), and any shades in between. As a result, the function can be asserted with some degree of ambiguity. As an outcome, the fuzzy maps created for each criterion have membership values between 0 and 1, where 0 represents the locations that are least suited for landfill siting and 1 represents those that are most favorable (Table 2). The regions that are exceptionally suitable for dump sites are represented by the locations that have fuzzy membership values greater than 0.9.

## III. Results and Discussion

Based on the findings and availability of data from this study, five (5) possible landfills sites were selected in accordance with the requirements from national and environmental impact assessment. The final map created through the use of Fuzzy Logic technique for landfill suitability site evaluation **site** overlaid the standardized maps of various criteria. In the illustrations, the colours red and green,

**Table 1: Characteristics of Data Acquired**

DATA	SOURCE	RESOLUTION	RELEVANCE
SRTM DEM	<a href="https://dwtkns.com/rstm30m">https://dwtkns.com/rstm30m</a>	30m	To extract slope and drainage
Landsat 8	GLCF	30m	To extract the land use map and distance to a residential area in the study area.
Soil map	Centre for world food	1:1,300,000	To extract the soil types and geology of the study area
Administrative map	OSGOF	1:130,000	To extract the boundary of the LGA's that made up the study area.
Topographic map	Nigerian Geological service	1:50,000	To delineate the river system in the study area
Geological map	Applied Geology Department, FUTA		To extract the geological features in Osogbo

**Table 2: Fuzzy Memberships and their Linguistic Terms**

Linguistic terms for landfill site selection	Fuzzy membership
Unsuitable	0 - 0.1
Very low suitable	0.1 - 0.3
low suitable	0.3 - 0.6
Highly suitable	0.6 - 0.8
Very high suitable	0.9 - 1.0

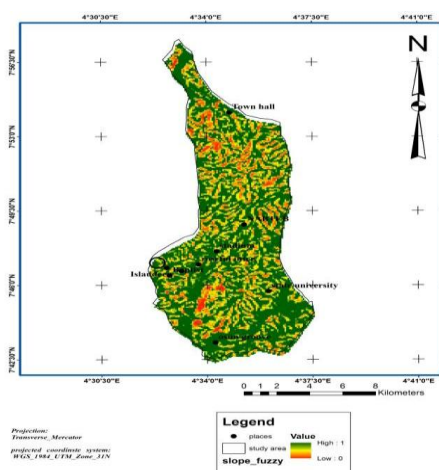
respectively, stand in for the membership values of 0 and 1. More than half of the study area (55.97%) was determined to be unsuitable for landfilling, while the remaining portions had varying degrees of very low, high, and very high appropriateness: 20.12%, 10.5%, 24.7%, and 15.8%, respectively. All five potentially viable landfilling regions were located to the north and north-east of the city under investigation.

### A. Slope map

From the findings, 95.7% of the entire research area under the slope class of 0 - 8° falls under this classification. The dumping of solid wastes is best done on terrain with a slope of less than 10% as reported by Sener & Karagu [11] - [12]. The majority of the land in this area is appropriate for the solid waste disposal site based only on this. While slope classes between 8 - 20% and 20% above, respectively made up of 2.48% and 1.82% of the study area. Figure 2 depicts the research area's slope map, and Table 3 displays the slope's degree and suitability value.

### B. Proximity to road network

The result from the finding shows the Euclidean distance in meters and the suitability values assigned on a scale of 0 to 1 metre are shown in Table 4.

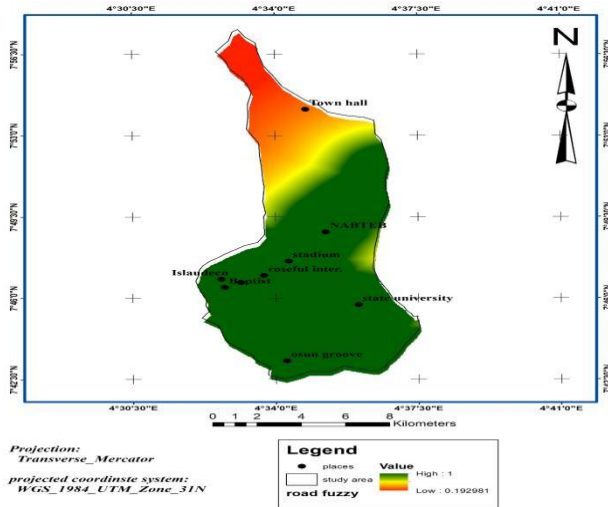
**Figure 2: Slope of the Study Area****Table 3: Slope and their Suitability Value**

Slope in degrees (%)	Suitability value
0 - 3	0.9 – 1
3 - 5	0.6 - 0.8
5 - 10	0.3 - 0.6
10 - 20	0.1 - 0.3
Above 20	0 - 0.1

Figure 3 displays the reclassified Euclidean distance according to this criterion.

### C. Soil Map

Based on the percentage of clay, the sandy clay loam that covered the remaining 5.5% of the



research area was rated as suitable between 0.6 and 0.8. 94.5% of the research area was composed of clay (light) soil, which is considered to be a low-risk location for landfill site selection. As a result, it was given the suitability value of 1, which is the most suitable. Figure 4 depicts a rasterized soil map of the research region, and Table 5 lists the area covered, the amount of clay, and the suitability value assigned for the two types of soil found in the study area.

Figure 3: Road Fuzzy Membership Map.

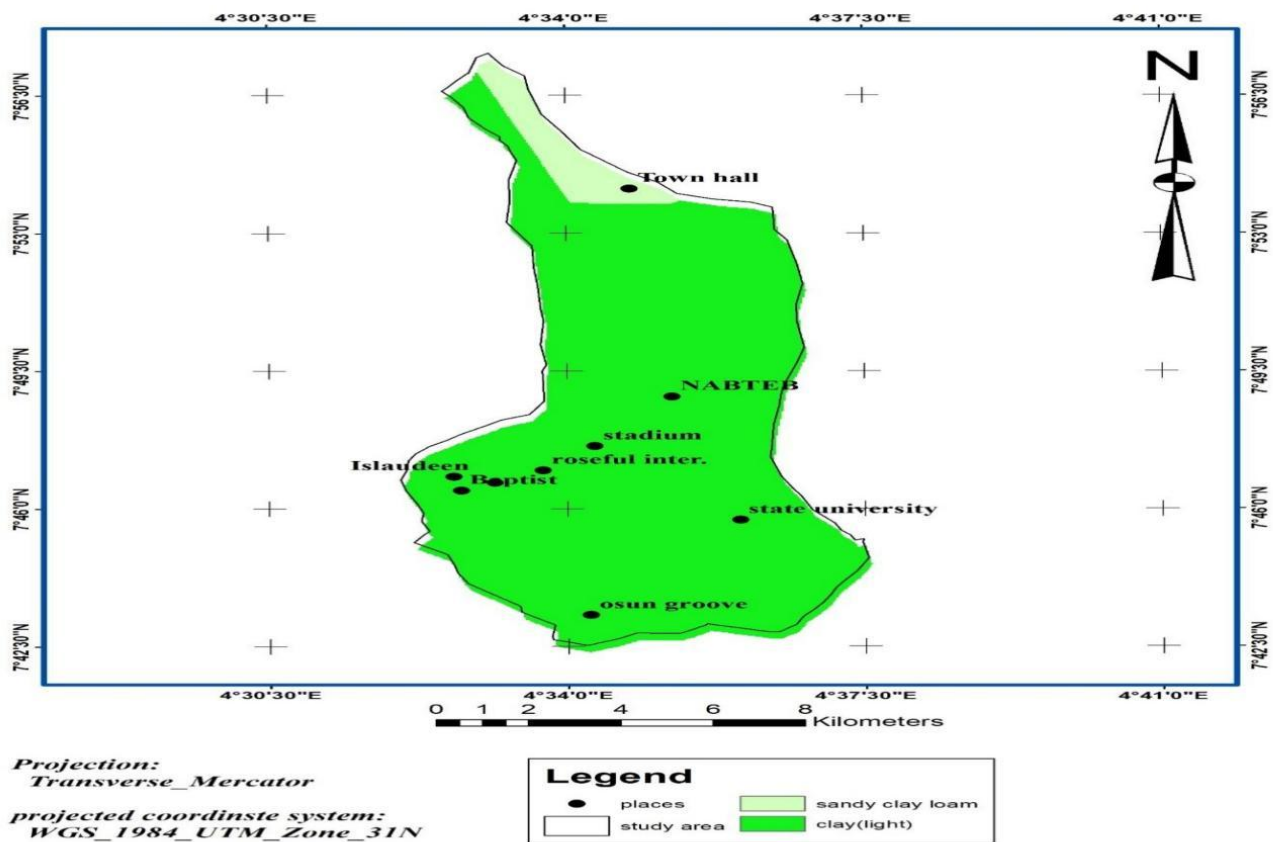


Figure 4: Rasterize Soil Map of the Study Area

Soil Type	Suitability	Area (Hectares)	Percentage of clay
Clay(light)	1	14063.093	94.5%
Sandy clay loam	0.6-08	737.700	5.5%

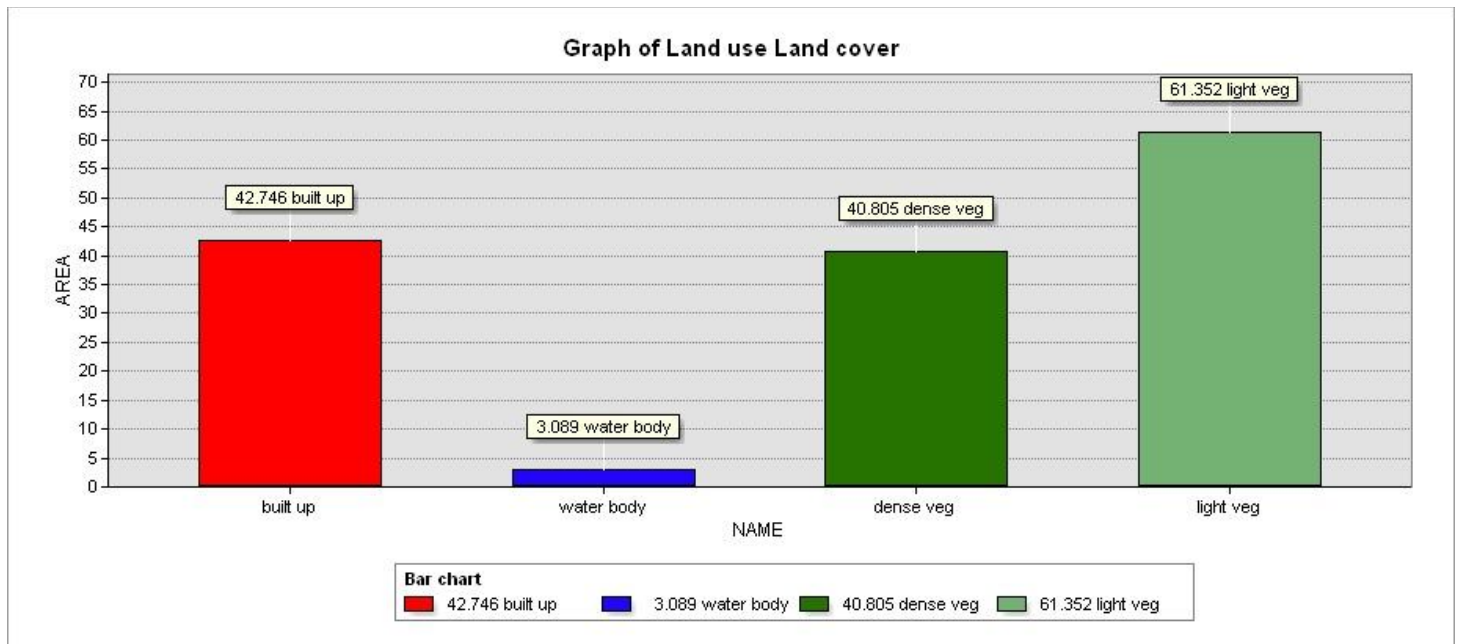
**D. Land use/land cover**

At the end of the process, four land use/land cover types were identified and classed in order to assign various appropriateness values. According to Table 6 and the map in Figure 5 and 6, light vegetation had the maximum appropriateness rating of 1, while a water body and a residential area received the lowest rating of 0.

Based on the analysis, it was discovered that light vegetation, with a total area of 61.3521 km<sup>2</sup>, is the most suitable area, while water bodies, with a total area of 3.0888 km<sup>2</sup>, are among the least suitable areas, making up 30.97% of the total area.

**Table 6: Area and Suitability Value by Land Use/Land Cover**

S/N	Land use/land cover type	Area cover in km <sup>2</sup>	Suitability value
1	Built up area	42.746	0
2	Dense vegetation	40.805	0.6 - 0.8
3	Light vegetation	61.352	1
4	Waterbody	3.089	0



**Figure 5. Bar Chart for Land Use/Land Cover**



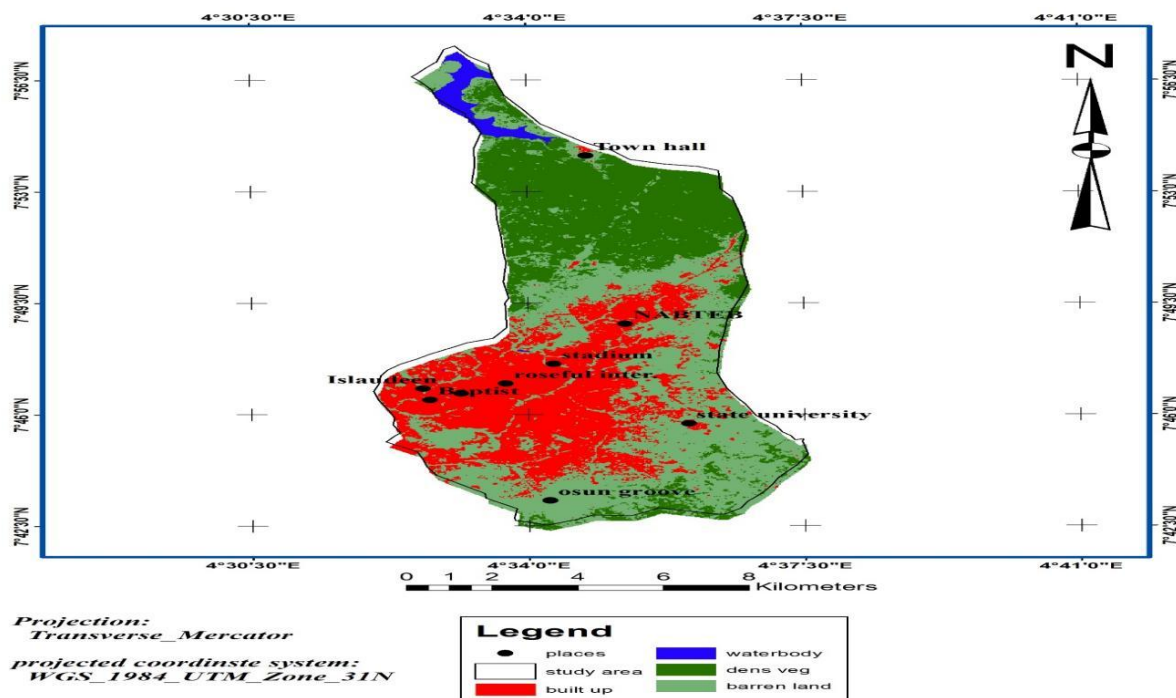


Figure 6: Land Use/Land Cover Maps

#### E. Built-up Area Map/ Residential area

According to the EPA landfill requirements, a dump site should be located at least 300 meters away from urban residential or commercial zones, as shown in Figure 7 [13]. Therefore, as indicated in Table 7, which represents a full non-membership area for the location of the landfill site, the first 300 meters from the residential area were given the appropriateness of 0, and the furthest distances (3000 – 3500 meters) were given the suitability of 1.

#### F. Distance to drainage

The fuzzy function membership has a 500 m buffer zone that represents full non-membership, or places that are not suited for landfill placement. Sites farther away from 800 m have the maximum appropriateness since another zone is set at that distance. Figure 8 depicts the drainage course's Euclidean Distance map after it has been classed. On

#### G. Overlaying and Identification of Suitable

##### Sites

The weighted overlay Geo-processing tool in ArcGIS 10.3 was used to carry out the overlay analysis. The pie chart of the suitability zones and the outcomes of the overlay analysis are shown in the Figures 9 - 12 below. According to the analysis, 60.5% of the area falls into the unsuitable zone, 20.8% into the low-suitable zone, 9.2% into the suitable zone, 8% into the extremely suitable zone, and 1.5% into the very high appropriate zone. There are five (5) prospective landfill building sites listed, two of which are in the most suitable zone. The area covered and the percentage by each suitability zone are shown in Table 9 below, along with a suitability map of the area, the locations of planned dump sites, and the locations of both current and prospective landfills

Table 7: Euclidean Distance from Built-up Area

Distance from Built-up Area	Suitability value assigned
0 – 300	0 - 0.1
300 – 1000	0.1 - 0.3
1000 – 2000	0.3 - 0.6
2000 – 3000	0.6 - 0.9
3000 – 3500	0.9 – 1

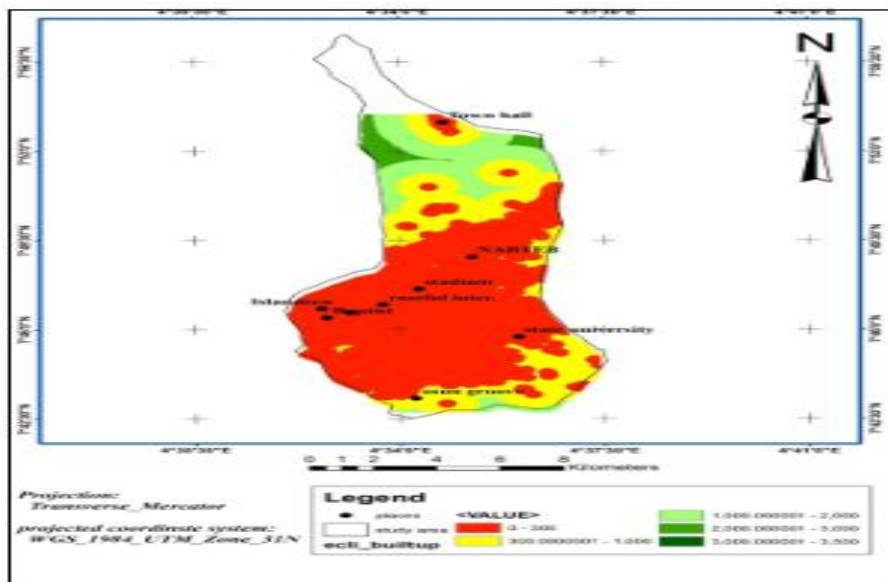


Figure 7: Euclidean Distance from Built up Area Map

Table 8: Euclidean Distance to Drainage

Distance to drainage (m)	Suitability value
0 - 500	0 - 0.3
500 - 800	0.3 - 0.6
800 - 1000	0.6 - 0.9
1000 - 1300	0.9 – 1



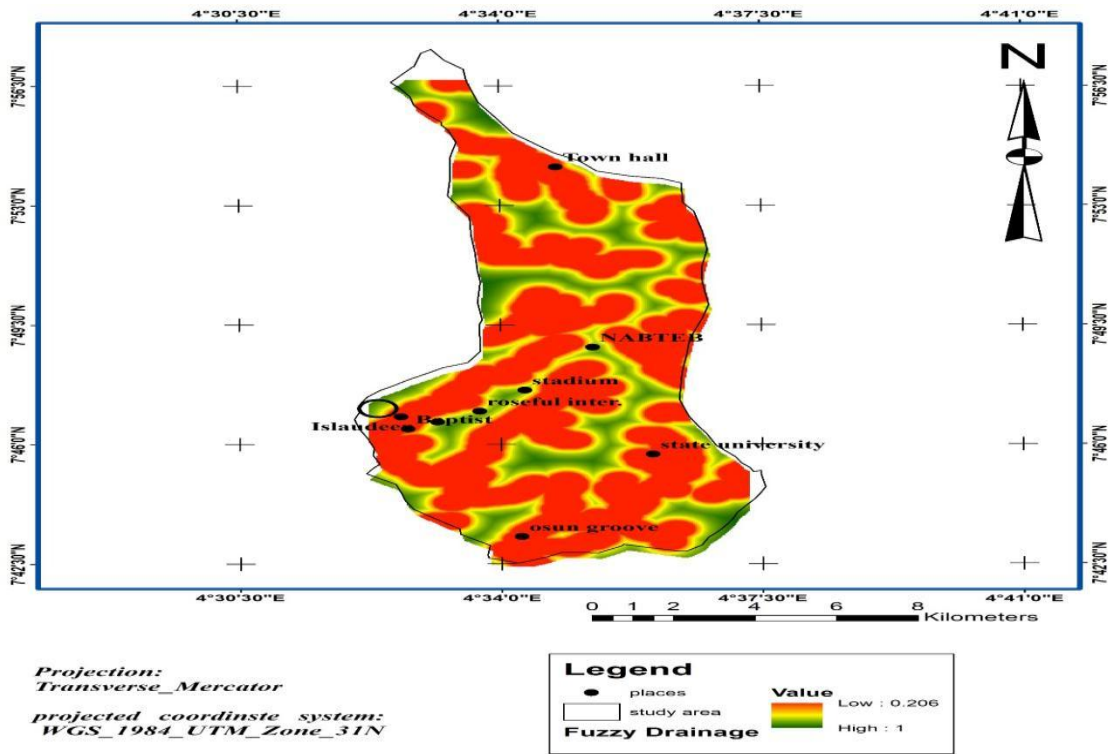


Figure 8. Reclassified Euclidean Distance to Drainage

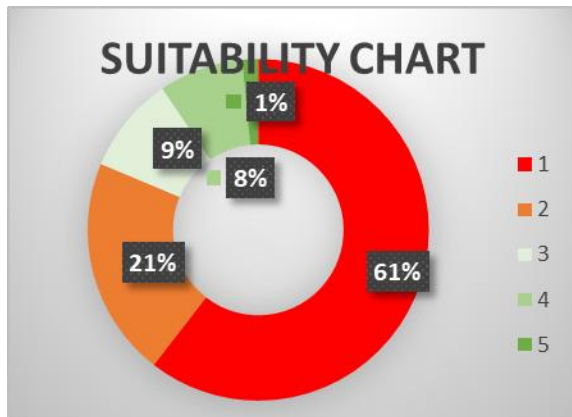


Figure 9: Suitability of the Landfill

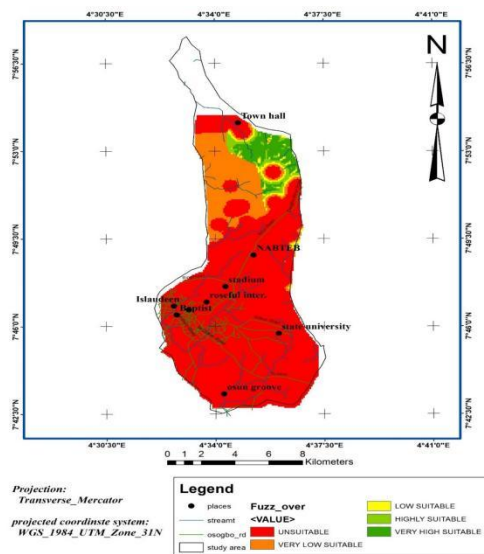


Figure 10: Suitability Map

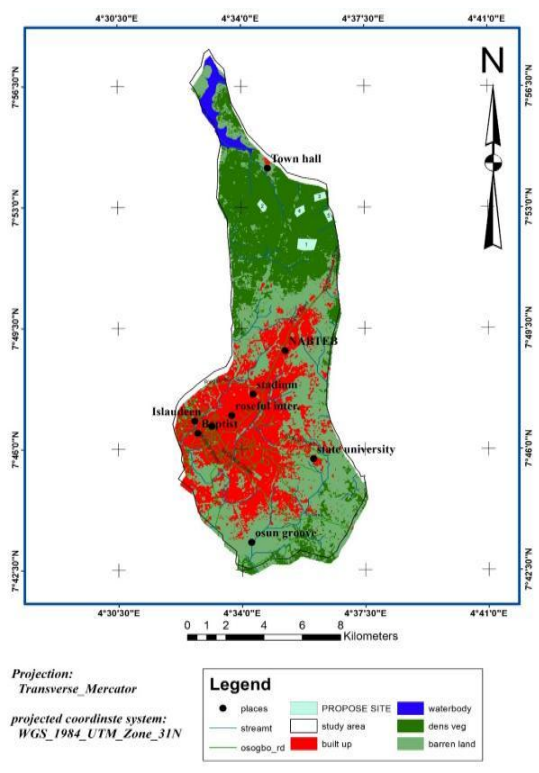


Figure 11: Location of Proposed Landfill

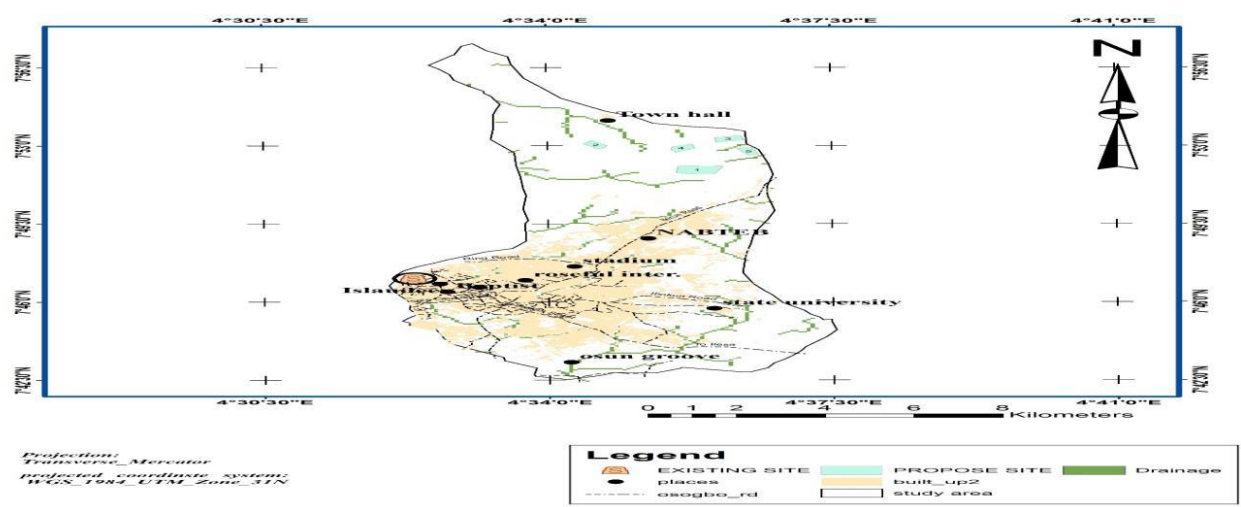


Figure 12: Location of Existing and Proposed Landfill Sites

**Table 9: Area and Percentage of Each Suitability Zone**

Suitability Rate	Area in km <sup>2</sup>	Percentage (%)
Unsuitable	89.525	61
Low suitable	30.882	21
Suitable	13.615	9
Highly suitable	11.839	8
Very high suitable	2.220	1

**H. Evaluation of different alternative to all criteria**

The results from the analysis revealed the best suitable dump sites from a list of five waste locations within the study area. The weights were determined by utilizing triangular fuzzy numbers to express the preference ratings for the alternatives and weights for several factors. The various decision-making criteria are given weights in order to produce the fuzzy suitable index. The fuzzy suitable index is obtained and shown in Table 10 using the aggregation algorithms.

**Table 10: Evaluation of Different Alternative to all Criteria with Fuzzy Index**

Criteria	Site 1			Site 2			Site 3			Site 4			Site 5		
Built up	0	0.0	0.1	0.3	0.45	0.6	0.6	0.7	0.9	0.3	0.4	0.6	0.6	0.7	0.8
Slope	0.1	0.2	0.3	0.1	0.2	0.1	0.2	0.3	0.3	0.1	0.2	0.3	0.1	0.2	0.3
LULC	0.6	0.7	0.8	0.6	0.7	0.8	0.6	0.7	0.8	0.6	0.7	0.8	0.6	0.7	0.8
Road	0.6	0.7	0.8	0	0.05	0.1	0.3	0.4	0.5	0.3	0.4	0.5	0.5	0.55	0.6
Soil	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9
Drainage	0.3	0.5	0.6	0.3	0.45	0.6	0.1	0.2	0.3	0.3	0.5	0.6	0	0.05	0.1
Geology	0.7	0.8	0.9	0.6	0.7	0.8	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9
Fuzzy index	0.4	0.5	0.6	0.4	0.51	0.7	0.4	0.6	0.7	0.4	0.5	0.7	0.5	0.54	0.63

According to the fuzzy appropriate index table, sites 3 and 5 have the most potential among the landfill sites, making them the most suitable of the five suggested sanitary landfill sites. Based on the findings from this research, it was observed that, the approved or legalized site that was approved by Osun state government as a waste disposal (landfill) site located in Trade fair, Ido Osun was determined to be in an unsuitable zone based on the existing solid waste disposal site that was studied from this research.

**IV. Conclusion**

In order to aid in the decision-making process, this study provides a strategy for the initial selection of the best landfill site choices. The study shows that GIS and fuzzy set theory, a technique for multi-criteria decision analysis, are practical decision-support tools that can help decision-makers select the optimum refuse site. Environmental factors such as slope, land use, land cover, distance to drainage, soil, built-up area, and proximity to road are taken into account by the method. According to the results analysed, 60.5% of the area is classified as

restricted or inappropriate, 20.8% as low suitability, 9.2% as moderate suitability, 8% as high appropriateness, and 1.5% as very high suitability. To assist planners in choosing prospective future landfill sites, a record of sites assessed on a suitability index and supplemented with recommendations on on-site management procedures should be established. Finally, it would be required to examine the environmental risks in order to completely preserve the ecosystem, its resources, and its inhabitants.

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