Tropical Built Environment Journal. Volume 11, No. 1, 53-73, 2025 www.tbejournal.com
ISSN: 1118-1790

LAND SUITABILITY ANALYSIS FOR MUNICIPAL SOLID WASTE DUMPSITES USING GIS TECHNIQUE IN AWKA SOUTH L.G.A, ANAMBRA STATE

[1]Aso, Chukwuemeka J., [2]Okoye, C. O., and [1]Onuoha, D. C.
[1]Department of Environmental Management, Faculty of Environmental Sciences, Nnamdi Azikiwe University, Awka.
[2]Department of Urban and Regional Planning, Faculty of Environmental Sciences, Nnamdi Azikiwe University, Awka.
Corresponding Author's Email: cj.aso@unizik.edu.ng ; Phone: +2347032338113

ABSTRACT

Identifying suitable location for waste dump sites is an essential requirement in developing countries of the world for the effective management of waste resources and leading to optimal utilization and sustainable environment. This study is aimed at analyzing suitable sites for waste disposal in Awka, Anambra state using GIS technique with a view to curbing waste management problems resulting from unplanned and unharnessed dump sites. The data that was used for the study includes coordinates of existing dumpsites, satellites imagery, digital elevation models (DEM), road data, water bodies and administrative map of the study area. ERDAS imaging software was used for the image classification, ArcGIS 10.8 software was used to generate and integrate the thematic maps which constitute the criteria for subsequent suitability analysis whereas analytic Hierarchy process (AHP) is used to generate weights for various criteria. The site suitability map for waste dumpsites is developed using multi-criteria evaluation (MCE) to assign weights to different criteria which was developed. Findings revealed that land cover/use, slope, elevation, soil, geology, proximity to roads, settlements, and water bodies are key determinants of landfill suitability. Open spaces, flatter slopes, higher elevations, stable geology, and well-drained soils were identified as highly suitable, while proximity to water bodies and urban centers reduced suitability. The suitability map classified the study area into zones of low, moderate, and high suitability, highlighting that only a small portion of Awka South falls within the high suitability zone. The study concludes that GIS-based modeling is a reliable approach for sustainable landfill siting and recommends prioritizing development in high suitability zones while reassessing existing landfill locations.

Keywords: *Waste, Dump Site, Waste Disposal* and *GIS*

1.0 INTRODUCTION

1.1 Background to the Study

One of the major environmental problems in the world today is the generation of solid waste. A number of factors such as: population increase, rapid economic growth, upsurge in peoples' standard of living, urbanization and proliferation of industrial activities have escalated solid waste production. Solid waste is useless and sometimes hazardous material with low liquid content. It include municipal garbage, industrial and commercial waste, sewage sludge, wastes resulting from agricultural and

animal husbandry operations and other connected activities, demolition wastes and mining residues (Unep, 2020). According to Abdel-Shafy and Mansour (2018), Solid waste management issue is the biggest challenge to the authorities of both small and large cities' in developing countries. This is mainly due to the increasing generation of such solid waste and the burden posed on the municipal budget. In addition to the high costs, the solid waste management is associated with lack of understanding over different factors that affect the entire handling system. According to Ashish, Shweta and Anurag (2014), Solid waste is the useless, unwanted and discarded material resulting from day to day activities in the community. WHO (2021) also stated that Solid waste refers to any type of garbage, trash, refuse or discarded material. It can be categorized according to where the waste is generated, for example; municipal solid waste, health care waste and e-waste. WHO, further stated that over 2 billion tons of municipal solid wastes are produced annually.

Municipal solid waste (MSW) is defined as waste collected by the municipality or disposed of at the municipal waste disposal site and includes residential, industrial, institutional, commercial, municipal, construction and demolition waste (Hoornweg *et al.,* 2015). Municipal solid waste is collected and deposited in sanitary dumpsite (Landfill). A dumpsite is a piece of land where waste materials are dumped. According to Daniel, Ekeleme ,Onuigbo , Ikpeazu and Obiekezie (2021). Dumpsite is a piece of land where waste materials are disposed of. It accommodates household, industrial and commercial wastes. Various harmful substances (organics; alkenes, aromatics, hydrocarbon, acids, esters, alcohols, hydroxyl benzenes, heavy metals and many more) may also be present in it. Dumpsites have been the most organized common methods of waste disposal and have remained so in many places in the world. In developing countries like the Federal Republic of Nigeria, the prevailing practice of municipal solid waste disposal is to dispose of the solid waste in dumpsites. Even though this is the right thing to do, some people still dispose waste inappropriately.

Irrational disposal of solid waste attract birds, rodents and fleas to the community and create unsanitary conditions like stagnation in drainage canals, littering of refuse on the major roads, foul odour in the environment. In order to avoid irrational disposal of solid waste at inappropriate locations, it is important to map out designated dumpsites within the locality where solid waste will be appropriately disposed. These dumpsites should be situated far away from residential quarters for easy control and management.

Solid waste management refers to the complete process of collecting, treating and disposing of solid wastes. Ashish *et al.,* (2013) defined Solid waste management as the discipline associated with the control of generation, storage, collection, transfer, processing and disposal of solid waste. Solid waste management is a global environmental issue which presents a very significance problem in today's world. Solid waste management is a multi-dimensional issue that incorporates political, institutional, social, environmental and economic aspects (McAllister, 2015). According to Fides *et al*., (2014), the fundamental target of solid waste management (SWM) is to protect the health

of the population, promote environmental quality, develop sustainability and provide support to economic productivity through conversion of waste into resource. Additionally, solid waste management is geared towards providing sufficient protection to the environment and the general public from the risky effects of waste (Yahaya *et al.,* 2011). The removal or discarding of solid waste is a very significant aspect of waste management scheme; this involves a lot of attention in other to avert environmental pollution and health complications. The global trend of waste management problems is a product of unsustainable methods of waste disposal, which is as a result of inadequate planning and implementation (Abbas *et al.,* 2011).

Exponential increase in population in Awka and the resulting urbanization has brought the need to develop environmentally sustainable and efficient solid waste management systems. Dumpsite constitutes one of the primary methods of municipal solid waste disposal. Appropriate selection of dumpsite is important in order to minimize environmental damage as well as to prevent negative impact to the public health, thereby improving the overall sustainability associated with the life cycle of the dumpsite (Yue Wang, Juan Li, Da An, Beidou Xi, Jun Tang, Yang Wang, Yang Yang, 2018) The current dumpsites in Awka are unplanned and sited haphazardly. It is located near the artery road, resident area, industrial layout and water surface. This might cause serious health and environment hazards. Moreover, it is rapidly filling up. The researcher wishes to avert these hazards by adopting the use of GIS in finding suitable dumpsite for solid waste disposal in the study area and to evaluate the most suitable alternative location for the proposed dumpsite. There is therefore a need for the evaluation of the existing dumpsite while taking into cognizance the World Bank standard for dumpsite siting, as a criteria for establishing new sites in the study area.

1.2 Aim of the Study

The aim of this study is to determine suitable sites for municipal waste dumpsite in Awka, Anambra State using GIS technique with a view to curbing waste management problems resulting from unplanned dumpsites.

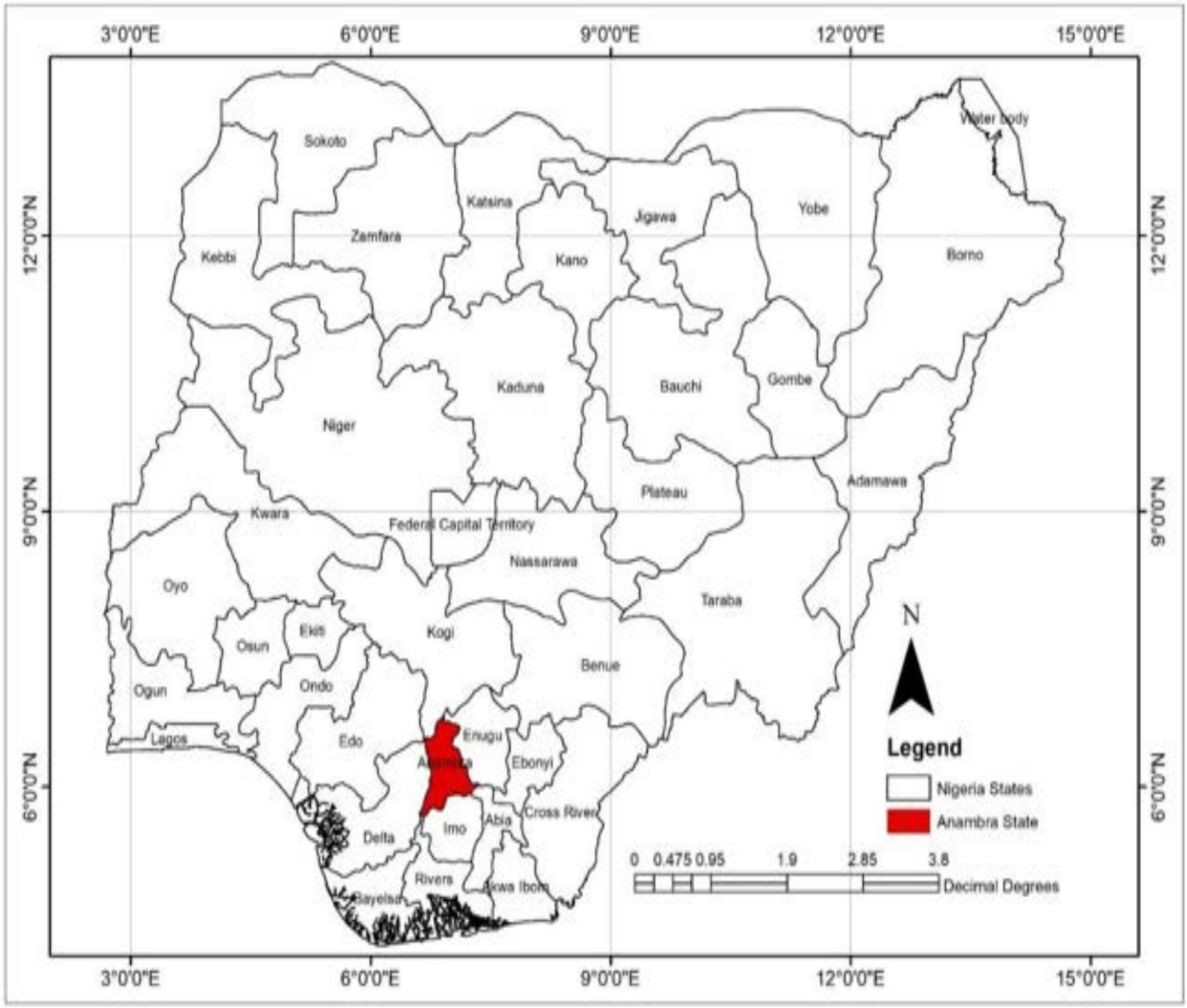
2.0 STUDY AREA

2.1 Climate

Awka South is a Local Government Area (LGA) in Anambra State, Nigeria. It is home to Awka, the capital city of Anambra State, making it a key administrative, political, and commercial center. The LGA is strategically positioned along major transportation routes, including the Enugu-Onitsha Expressway, which facilitates movement to and from neighboring states. Awka South shares boundaries with Awka North, Njikoka, and Orumba North LGAs, making it a central hub within Anambra State. It is located between latitude 6°06′00”1N and 6°15′00” N of the Equator and longitude 7°0′00”1E and 7°09′00” E of the Greenwich Meridian (see figures 2.1, 2.2 and 2.3).

.

Fig. 2.1: Nigeria Showing Anambra State.



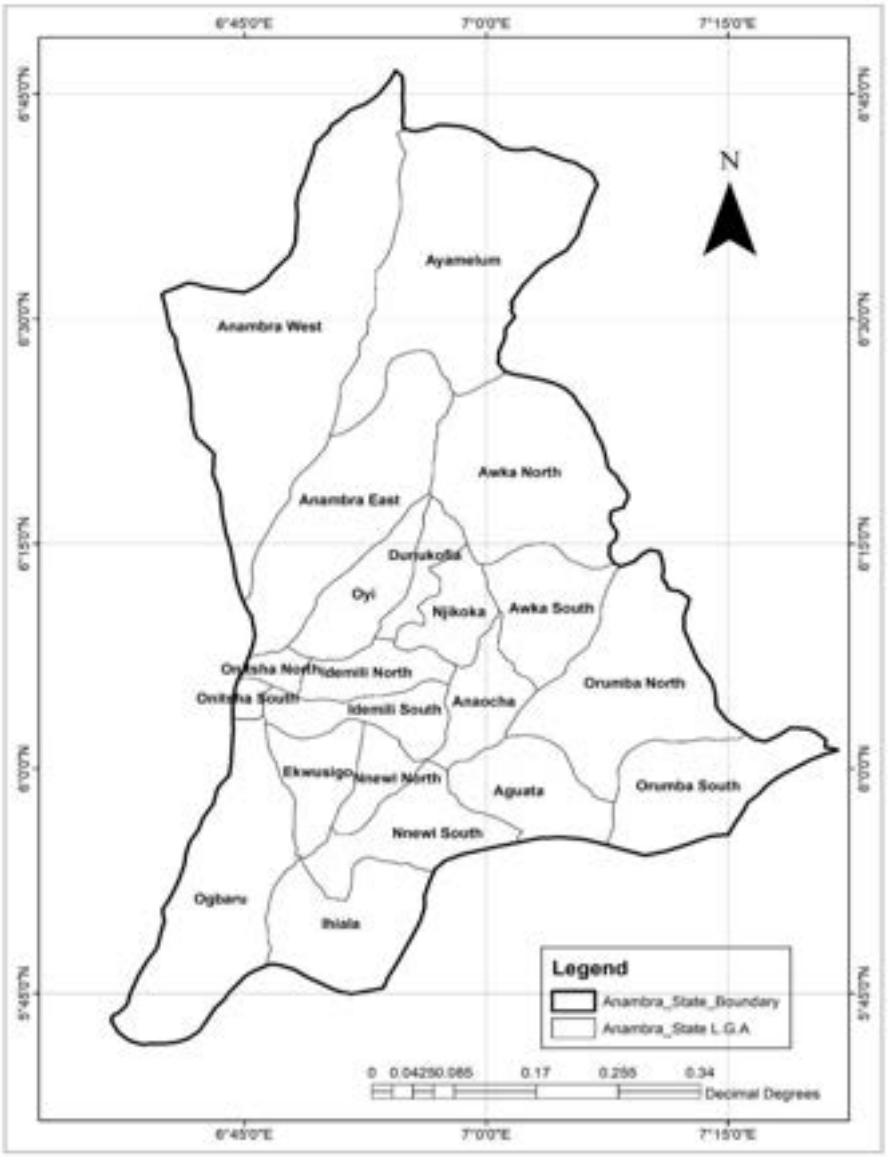


Figure 2.2: Map of Anambra State

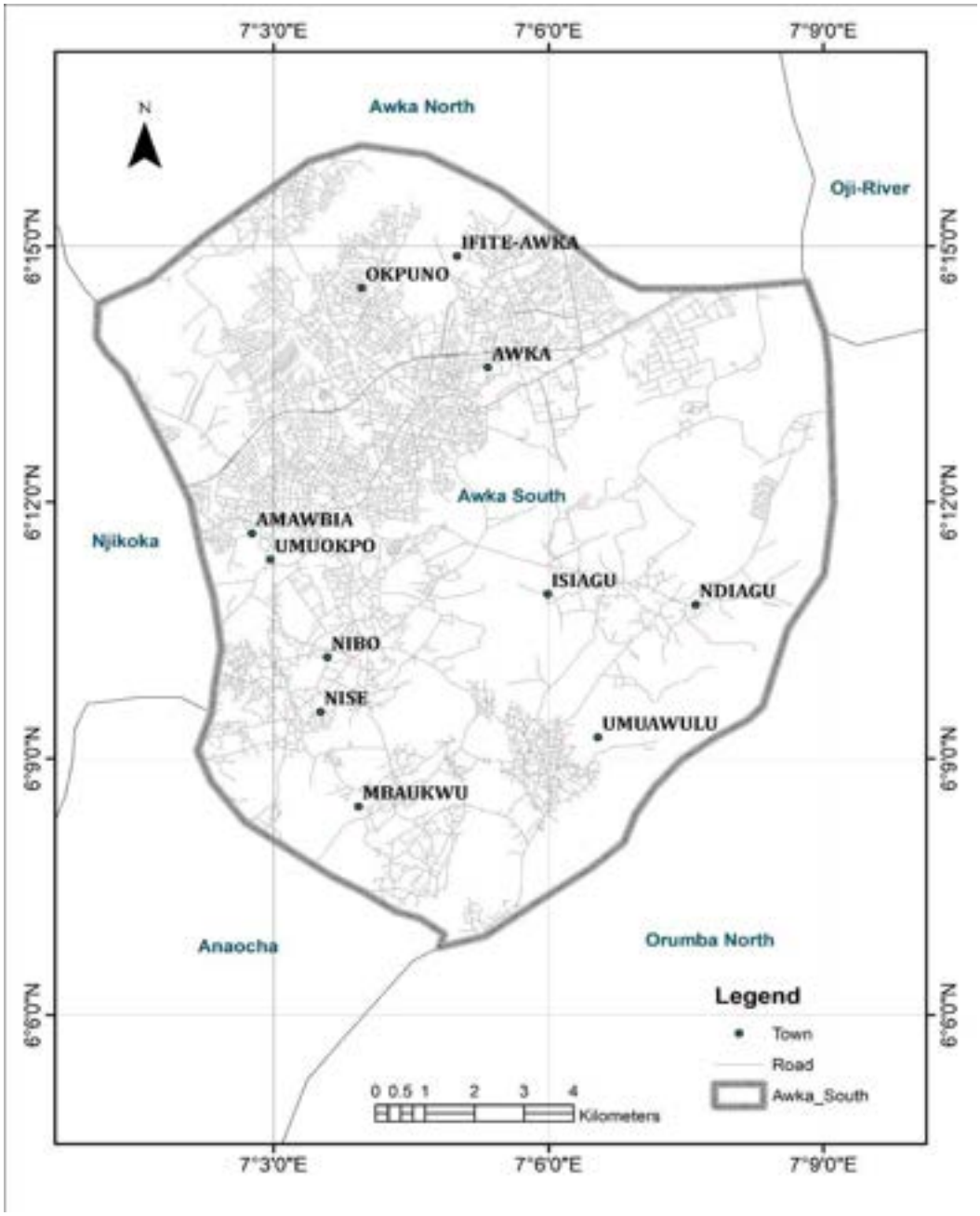


Figure 2.3: Map of Awka South

2.2 Climate

Awka South experiences a tropical rainforest climate, with two major seasons: the rainy season (April to October) and the dry season (November to March) (Emmanuel, Ojinnaka and Baywood, 2015). The area receives an annual rainfall of approximately 1,500mm to 2,000mm, with the peak of the rains occurring between July and September. The climate is generally warm and humid, with temperatures ranging from 25°C to 35°C throughout the year (Emmanuel, Ojinnaka and Baywood,

2015). The harmattan season, which occurs between December and February, brings dry and dusty winds from the Sahara Desert, leading to lower temperatures and reduced humidity. High humidity levels, especially during the rainy season, contribute to lush vegetation growth and support agricultural activities in some parts of the LGA.

2.3 Topography

The topography of Awka South is characterized by a mix of rolling hills, low-lying plains, and gentle undulations. It lies within the Awka-Orlu Uplands, which feature moderately elevated terrain that aids in natural drainage. The elevation varies across different parts of the LGA, with some areas having slightly elevated landforms, while others are more level. The hilly nature of some parts helps prevent flooding, although certain low-lying areas may experience water accumulation during heavy rains. The landscape is suitable for urban expansion, agriculture, and infrastructural development. However, some sections, particularly those with sandy formations, are prone to erosion, necessitating erosion control measures such as afforestation and proper drainage systems (Ejikeme, Igbokwe and Emengini (2015).

2.4 Soil

The soil in Awka South is predominantly lateritic, characterized by a reddish-brown color due to its high iron and aluminum content. This type of soil is relatively fertile but can become compacted over time, making it less suitable for extensive farming without proper soil management techniques. While the soil is ideal for construction due to its stability, it may require amendments such as organic fertilizers or compost to enhance its agricultural productivity.

2.5 Geology

The geological composition of Awka South is mainly sedimentary, consisting of formations such as the Nanka Sands and Imo Shale. The Nanka Sands, which are dominant in parts of the LGA, are known for their loose and sandy texture, making them highly susceptible to erosion. The Imo Shale, found in some sections, consists of clayey and fine-grained sedimentary rocks that contribute to groundwater retention.

3.0 MATERIALS AND METHODS

The flowchart for the methodology that was adopted in this study is shown in figure 3.1.

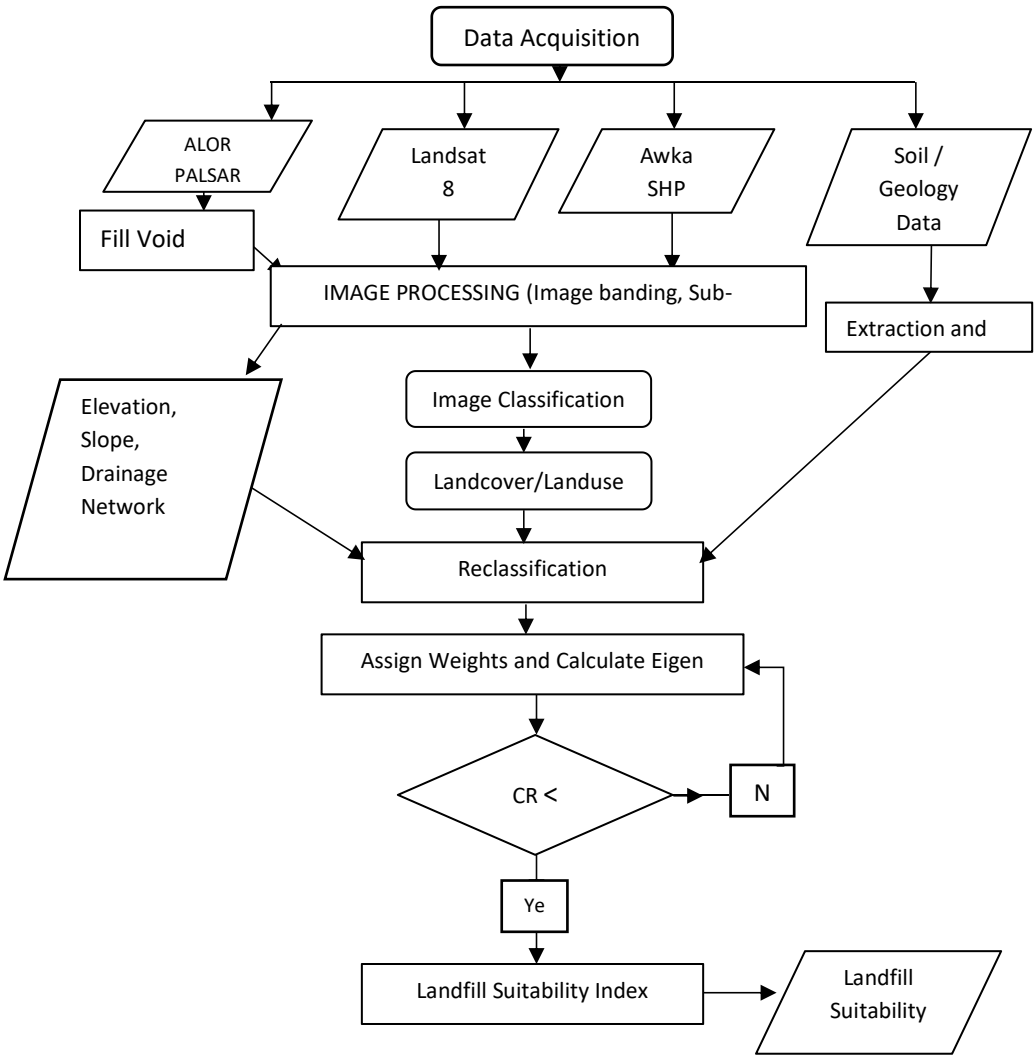


Figure 3.1: Flowchart of methodology

This study employs a spatial analysis approach, integrating remote sensing and Geographic Information Systems (GIS) to evaluate landfill suitability. The research design involves data acquisition, pre-processing, classification, and analysis, ensuring a systematic methodology for assessing environmental and infrastructural factors affecting landfill site selection.

Image classification

Supervised classification was performed using ArcGIS Pro's Image Classification Toolbar. Training samples were created, evaluated, and refined through histogram, scatterplot, and statistical tools. A signature file was generated, and classification was executed using the Maximum Likelihood Classification (MLC) algorithm to categorize land cover types accurately. The detailed steps followed for the image classification workflow are illustrated in the chart shown in figure 3.2.

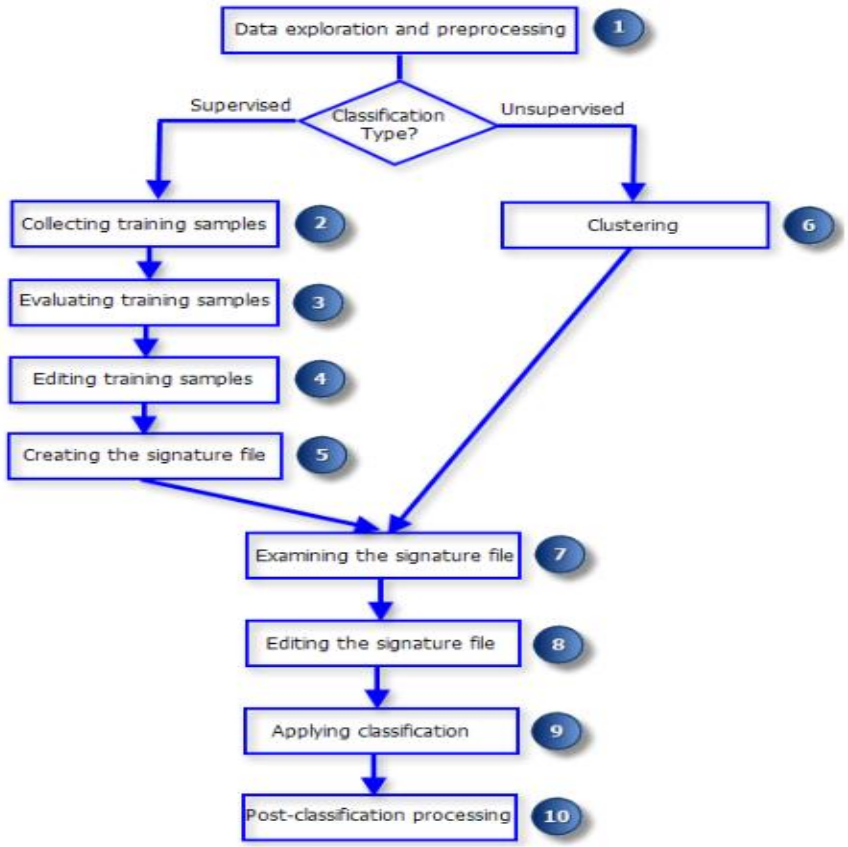


Figure 3: Image classification workflow

Digital Elevation Model (DEM) Processing

Alos Palsar DEM was processed to correct data inconsistencies due to errors in elevation records. Sink filling was conducted using the spatial analyst tool in ArcGIS Pro to eliminate artificial depressions and ensure reliable topographical representation. After the DEM sinks has been filled, it was used to extract the slope information that was used for landfill suitability analysis.

Landfill Suitability Analysis

Landfill suitability Analysis was modelled using AHP. The AHP, introduced by Saaty (1980), is an effective tool for dealing with complex decision-making, and may aid the decision maker to set priorities and make best decisions. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results. The AHP helps to capture both subjective and objective aspects of a decision. Again, both benefits and risks can be weighed, assigning a number value to each criterion (benefit or risk factor under consideration), with more important benefits receiving a higher number on the scale to determine which projects have the highest overall value, or the most valued benefits and least risks.

According to Saaty (1980), the AHP is an appropriate approach for the determination of relative importance of each factor with each other factor, as it accounts for weighted

decision criteria which are useful for complex decisions involving multivariate selection criteria. The approach uses a ratio matrix known as the Eigenvector method to compare one criterion with another. Additionally, it uses a numerical scale with values ranging from 1 to 9, where 1 means that the two factors are equally important and 9 means that the one factor is absolutely more important than the other as shown in Table 1 If a factor is less important than another then this is indicated by reciprocals of the 1 to 9 values (1/1 to 1/9)

Table 1 Relative Importance in Pairwise Comparison

Judgment value	**Description**
1	Equal importance
3	Moderately importance
5	Strongly Importance
7	Very strongly important
9	Extremely important

Source: (Saaty, 1980)

Comparing the Factors

The Judgment value of each factor in relation to other factors was obtained to a higher degree of consistency from the judgment of experts in various field of concern. These judgments of experts were obtained through literatures where the experts provided the relative importance of the factors under consideration based on Saaty (1980) judgment value as shown in Table 1 above. Table 2 shows the coding of factors that were considered where F1 to F7 represent the factors.

Table 2: Coding of Factors

F1	Land Cover/ Land Use
F2	Slope
F3	Geology
F4	Soil
F5	Proximity to Settlements
F6	Water Bodies
F7	Road Network
F8	Electric Transmission Line

The AHP is considered to be a sufficient mathematical method for analyzing complex decisional problems. It determines the weights by comparing the relative importance of the criteria in a pairwise

manner through a pairwise comparison matrix. The pairwise comparison matrix was formed by inputting the judgment value between factors as the matrix elements by following the basic rules as established by Saaty.

4.0 RESULTS AND DISCUSSION

4.1 Identification and selection of Evaluation criteria

Selection of the criteria and factors for landfill suitability analysis using AHP was achieved based on their theoretical relevance as documented in (Ali *et al.,* 2020).
The following criteria (factors/constraints) (table 3) were used.
Table 3: Criteria (Factors/Constraints)

S/N	Criterion	Factor/ Constraint	Requirement	Reason for Selection	Original Data Structure	Resolution
1	Land Cover/ Land Use	Factor	Barren/Open spaces	Barren/open spaces are prime areas for landfill sites	Raster	30m
2	Slope	Factor	<10Degrees	Flat or gentle slopes are preferred for landfill siting because they are less prone to erosion and are easier to construct	Euclidean Raster	30m
3	Elevation	Factor	Between 100m – 164m	Areas at higher elevations are more suitable because they are less prone to flooding.	Euclidean Raster	30m
4	Geology	Factor	Between 140m – 378m (Flat, Undulating and Rolling terrains)	Areas with stable rock formations are preferred because they provide a stable foundation for the landfill.	Vector	-
5	Soil	Factor	Between 3 – 13 degrees	Areas with soils that have a low permeability and are thick enough to contain the waste are preferred	Vector	-
6	Proximity to Urban Areas	Factor	500m Away from Urban Areas	Landfills should be located away from urban areas to minimize the risk of contamination and health hazards.	Raster	30m
7	Water Bodies	Factor	500m Away from Water Bodies	Landfills should not be located in areas that are close to rivers, lakes, or other water bodies to prevent contamination of the water.	Vector	-
8	Road Network		Less than 500m away from road networks	Landfills should be located near a well-developed road network to ensure efficient transportation of waste and minimize traffic disruption.	Vector	-

Based on the criteria selected (table 3), the data used for achieving the aim of the research were assembled. Land cover/landuse was extracted from image classification performed on the Landsat 8 image, slope and elevation and stream network were extracted from the SRTM downloaded from www.earthexplorer.usgs.gov, soil and geology data and soil data were also acquired from https://www.pubs.usgs.gov and www.fao.org respectively. The road proximity and urban proximity areas were derived from Awka road network and Awka urban areas using Euclidean distance algorithm.

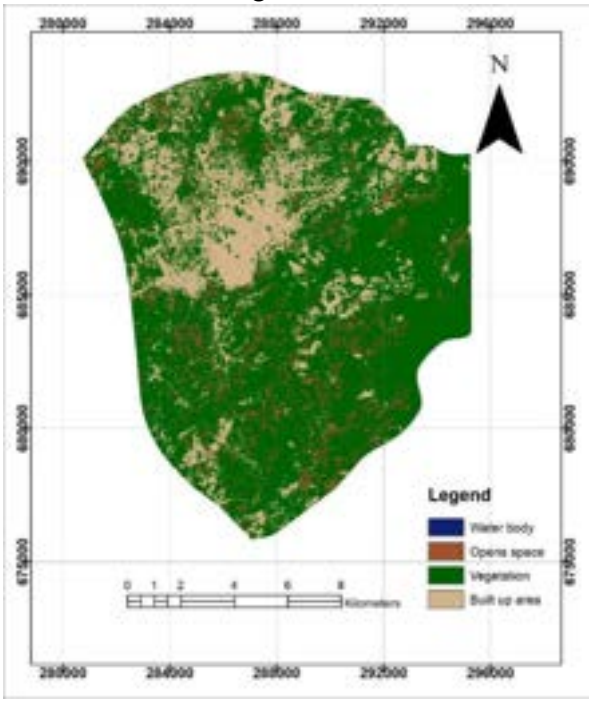


Figure 4: Landcover/landuse data

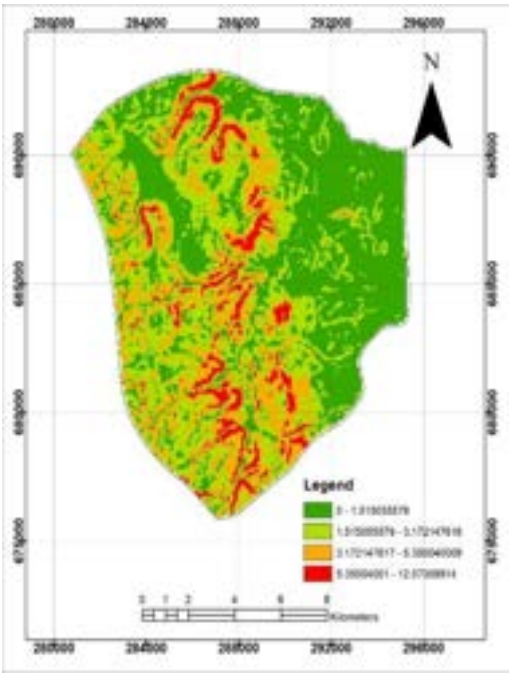


Figure 5: slope data

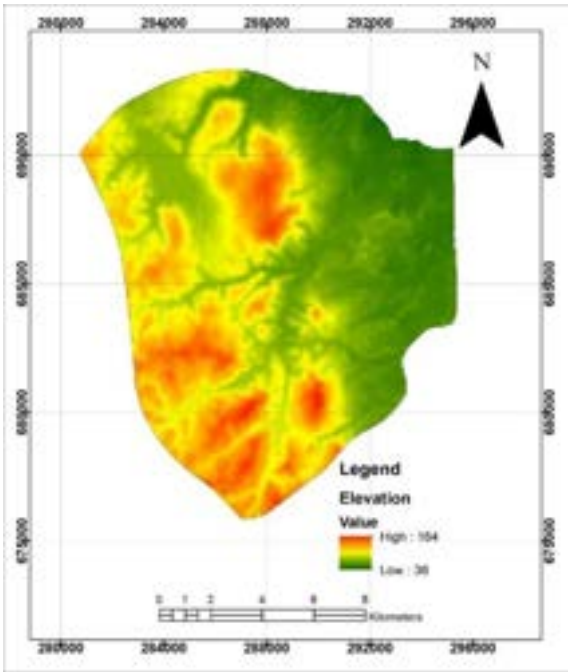


Figure 6: Elevation Data

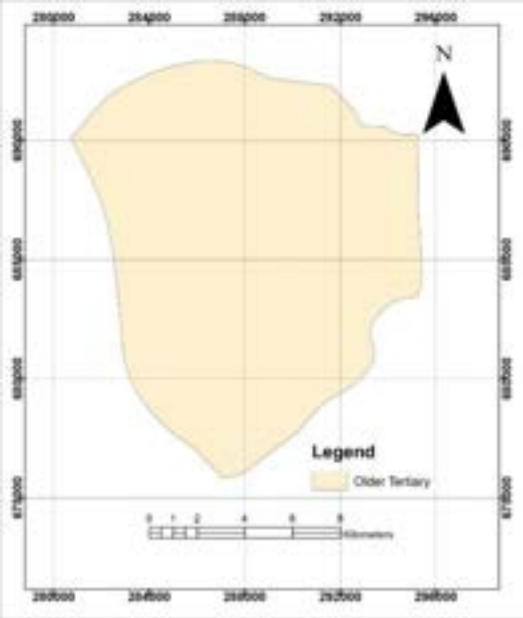


Figure 7 Geology Data

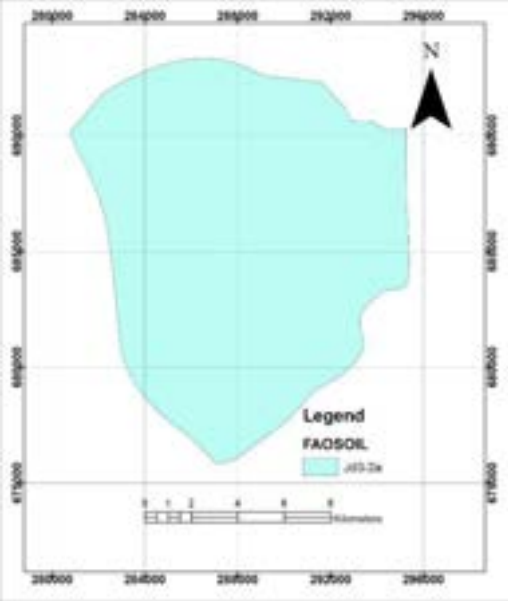


Figure 8: Soil Data

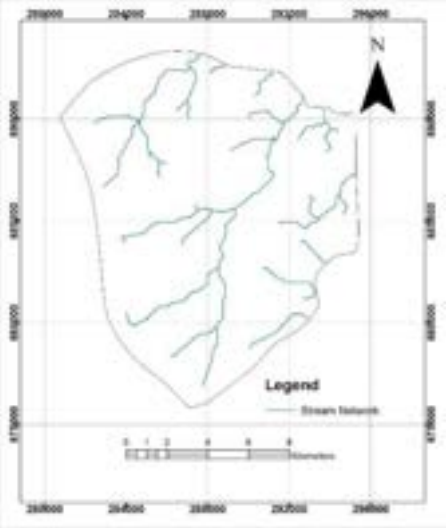


Figure 9: Stream Network Data

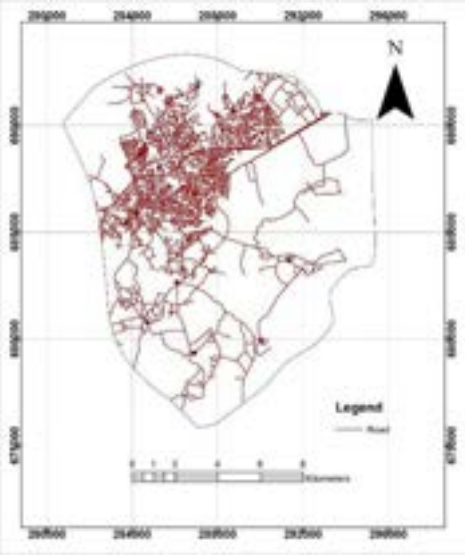


Figure 10: Road Network Data

The land cover/land use classification for Awka South, shown in Figure 4, was divided into four distinct categories: water bodies (represented by blue), open spaces (brown), vegetation (green), and built-up areas (beige). These categories provide valuable insight into the current land usage and concentration of specific land types across the region. Water bodies are primarily found in low-lying areas, open spaces are common in rural and peri-urban regions, vegetation is present in natural areas and parklands, and built-up areas are mostly concentrated around the urbanized parts of Awka. This classification is crucial for determining

whether certain areas are suitable for landfill siting without disturbing valuable ecosystems or existing infrastructures.

The slope data for Awka South, depicted in Figure 5, shows that the region has a slope range between 0° and 12.07°. These variations in slope are important for assessing the suitability of different areas for landfill siting. Flatter areas tend to be more favorable for landfill construction due to easier development and reduced environmental impact, while areas with steeper slopes may face challenges such as erosion risk or difficulties in waste compaction and landfill operations. Understanding these slope variations helps identify the most stable and economically viable locations for landfills.

The elevation data for Awka South, shown in Figure 6, indicates that the highest point in the area is 164 meters, while the lowest is 36 meters. This range in elevation is significant because it affects water drainage, construction stability, and the potential for groundwater contamination. Higher elevations can serve as natural barriers against waste migration, whereas lower areas may be more susceptible to flooding or water accumulation, which needs to be considered when selecting landfill sites to minimize environmental risks.

The entire Awka South LGA sits on older tertiary geology, as shown in Figure 7, which suggests that the region has stable rock formations that have been in place for millions of years. This geological stability could be beneficial for landfill siting, as the underlying rock may offer a reliable foundation. However, the permeability of these rock formations needs to be assessed to ensure that there is no risk of groundwater contamination from the landfill.

The soil data for the region, as illustrated in Figure 8, shows that Awka South predominantly has the JD3-2A soil type. This type of soil has specific drainage properties and texture that are important in determining whether an area is suitable for landfill siting. Soils that are highly permeable may not be ideal for landfill construction as they could allow contaminants to leach into the environment, posing a risk to local water sources and ecosystems.

Figures 9 and 10 depict the stream and road networks in Awka South. The stream network is crucial for understanding the natural water flow and identifying areas that are vulnerable to contamination from landfills. It is essential to avoid siting landfills near streams or rivers to prevent leachate from entering the water system. In contrast, the road network plays an important role in facilitating the transportation of waste materials to landfill sites. Areas with well-established road infrastructure are more suitable for landfill operations, as they allow for more efficient waste collection and transportation.

The study provides a comprehensive framework for identifying suitable landfill sites in Awka South by integrating these factors—land cover/land use, slope, elevation, geology, soil type, and infrastructure such as streams and roads This integration ensures that the selected sites meet both environmental and logistical requirements, including minimizing environmental impact, ensuring efficient waste transportation, and considering the proximity to populated areas. This approach contributes to sustainable landfill siting that aligns with broader urban planning goals and minimizes adverse effects on the local community and environment.

4.2 Reclassification and Standardization of Criteria

Reclassification and standardization of criteria is the first step when implementing AHP and weighted linear combination model. Each of the cells has a value for each input criteria. At this stage it will be practically impossible to combine the criteria, hence the need for reclassification of each of the individual datasets. Different number systems cannot be directly combined effectively (ESRI, 2014). For instance, combining a cell value in which slope is 2˚ with a cell value in which distance to is 10m is almost impossible because of disparity in units. However,

standardizing them to a common measurement system that represents a relative weighting scale permits analysis to be completed freely between the datasets and show the suitability level for each of the standardized criteria. To combine datasets, there is a need to standardize or transform all the individual datasets into a common measurement scale.

For this research, all the datasets were reclassified into three classes: (1) for low Suitability areas (2) moderate suitability areas and (3) High suitability areas. The initially derived datasets values categorized into ranges were floating and continuous in nature and there was a need for them to be reclassified so that each range of value can be assigned one discrete integer value such as 1, 2, 3 according to the measurement scale. This is because the inputs of the weighted overlay must contain discrete integer values. The reclassified and standardized criteria are shown in figure 11 - 17.

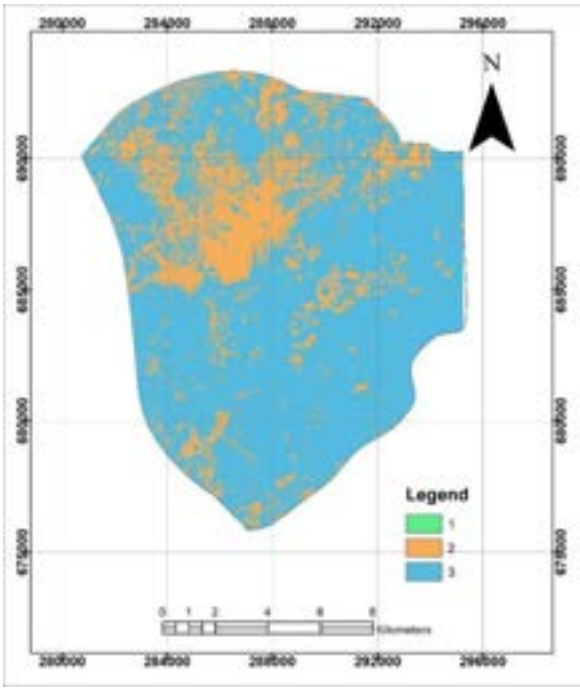


Figure 11: Landcover/landuse Reclassification

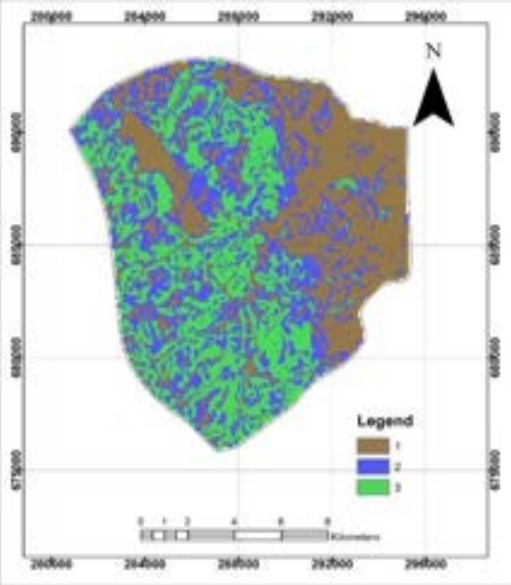


Figure 12: Slope Reclassification

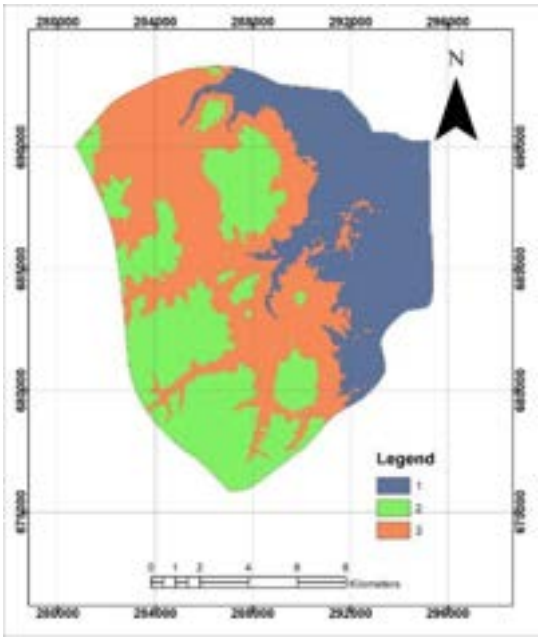


Figure 13 Elevation Reclassification

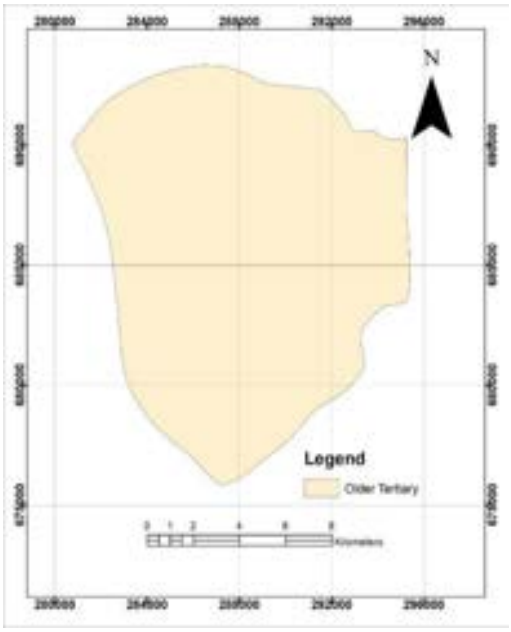


Figure 14: Geology Reclassification

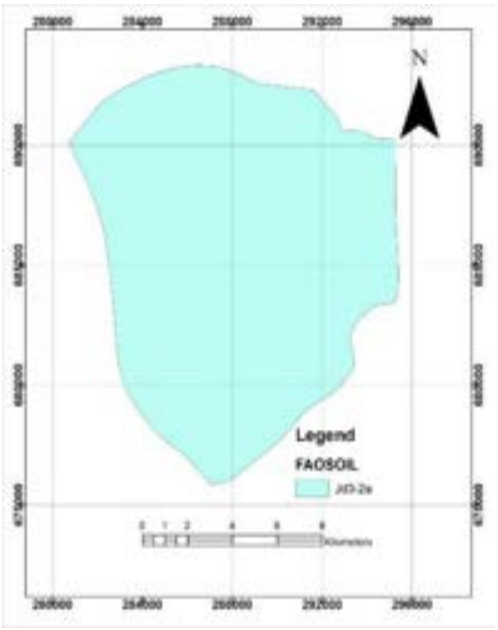


Figure 15: Soil Reclassification

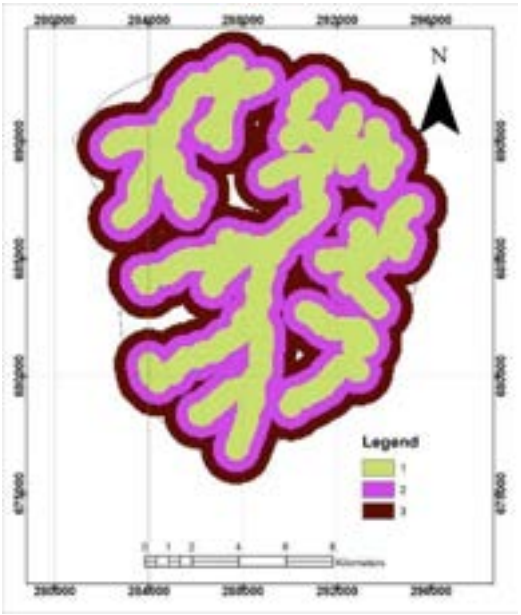


Figure 16: Stream Network Reclassification

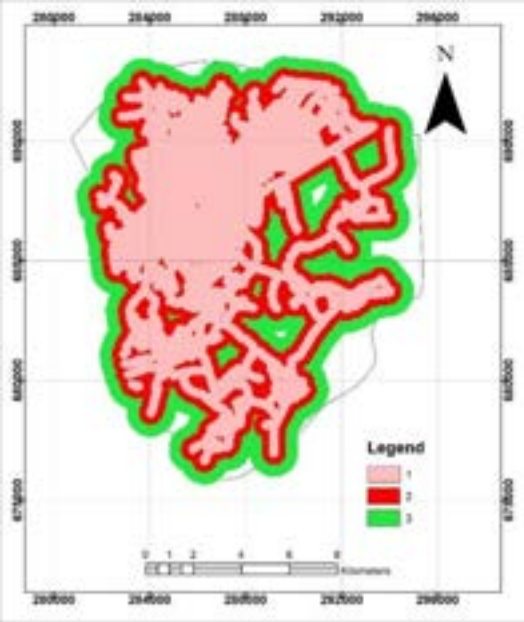


Figure 17: Road Network Reclassification

To effectively combine the various factors influencing landfill suitability, the data was reclassified into three suitability categories: low, moderate, and high suitability areas. This classification process allowed for standardization of all datasets, ensuring that they could be integrated to identify optimal sites for landfill development.

The land cover/landuse data (Figure 11) was reclassified into three types: water body (classified as low suitability or 1), open space (high suitability or 3), vegetation (high suitability or 3), and built-up areas (moderate suitability or 2). This reclassification reflects the fact that water bodies are least suitable for landfill siting due to potential contamination risks, while open spaces and vegetated areas are more suitable for landfill development due to lower environmental impact. Built-up areas, while generally unsuitable, may still have moderate suitability depending on their specific characteristics, such as proximity to infrastructure or population density.

Similarly, the slope data (Figure 12) was divided into three suitability categories based on the steepness of the terrain. Areas with slopes ranging from 0° to 3.17° were classified as high suitability (3), as flatter terrain is easier to develop and less prone to erosion or instability. Areas with slopes between 3.17° and 5.35° were classified as moderate suitability (2), while steeper areas, with slopes from 5.30° to 12.07°, were classified as low suitability (1), as these regions are more prone to environmental challenges such as runoff and erosion, which could complicate landfill management.

The elevation data (Figure 13) was also reclassified into three categories, reflecting the importance of elevation in landfill siting. Areas with an elevation range between 36m and 50m were classified as low suitability (1), as they are more prone to flooding or water accumulation. Areas with elevations between 50m and 80m were categorized as moderate suitability (2), while the highest areas, ranging from 80m to 164m, were classified as high suitability (3). Higher elevations provide natural barriers and are less likely to experience issues with flooding or waterlogging, making them more suitable for landfill siting.

The geology and soil data (Figures 14 and 15) were both reclassified as high suitability (3), as the entire Awka South LGA is situated on older tertiary geology, which is generally stable and reliable for construction. Similarly, the soil type in the region, which is primarily JD3-2A, was classified as high suitability (3) because it is a soil type that is conducive to supporting landfill operations.

For the stream network data (Figure 16), a Euclidean distance buffer was applied to ensure that landfills are sited away from water sources, which is critical for preventing contamination of local water supplies. Areas within 1km of water sources were classified as low suitability (1), areas between 1 and 2km were classified as moderate suitability (2), and areas farther than 2km from water sources were classified as high suitability (3). This classification ensures that landfills are located at safe distances from streams and rivers to minimize the risk of leachate runoff into water bodies.

Similarly, proximity to road networks (figure 17) is an important factor for landfill siting, as access to transportation is necessary for waste collection and management. A Euclidean distance buffer was applied to the road network data, with areas within 1km of a road network classified as high suitability (3), areas between 1 and 1.5km as moderate suitability (2), and areas between 1.5 and 2km as low suitability (1). This classification ensures that the landfill sites are easily accessible for waste transportation, reducing operational costs and improving efficiency.

By reclassifying each of these factors—land cover/land use, slope, elevation, geology, soil type, distance from water bodies, and proximity to road networks—the study standardized the data into three suitability categories. This reclassification was essential for combining all the datasets in a way that allowed for the identification of the most suitable areas for landfill siting in Awka South. The integrated factors provide a comprehensive and balanced assessment of the potential landfill sites, ensuring that environmental, economic, and logistical considerations are all taken into account.

4.3 Analytical Hierarchy Process and Determination of Criteria weight

Analytical hierarchy process is an effective tool for dealing with complex decision-making, and may aid the decision maker to set priorities and make best decisions by reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results. AHP helps to capture both subjective and objective aspects of a decision. Again, both benefits and risks can be weighed, assigning a number value to each criterion (benefit or risk factor under consideration), with more important benefits receiving a higher number on the scale to determine which projects have the highest overall value, or the most valued benefits and least risks.

AHP approach uses a ratio matrix known as the Eigenvector method to compare one criterion with another. Additionally, it uses a numerical scale with values ranging from 1 to 9, where 1 means that the two factors are equally important and 9 means that the one factor is absolutely more important than the other as shown in Table 4 If a factor is less important than another then this is indicated by reciprocals of the 1 to 9 values (1/1 to 1/9)

Table 4: Relative Importance in Pairwise Comparison

Judgment value	**Description**
1	Equal importance
3	Moderately importance
5	Strongly Importance
7	Very strongly importance
9	Extremely importance

Source: (Saaty, 1980)

4.4 Pairwise Comparison Matrix Formation

Pairwise comparison matrix was formed by inputting the judgment value between factors as the matrix elements by following the basic rules as established by Saaty. Table 5 was formulated using pairwise comparison matrix.

Table 5 Pair-wise comparison matrix of the study

	Land Cover/ Land Use	Slope	Elevation	Geology	Soil	Proximity to Settlements	Water Bodies	Road Network
Land Cover/ Land Use	1	2	2	2	3	3	3	4
Slope	0.5	1	2	2	2	2	3	3
Elevation	0.5	0.5	1	2	2	2	2	3
Geology	0.5	0.5	0.5	1	2	2	2	3
Soil	0.5	0.5	0.5	0.5	1	2	2	2
Proximity to Urban Areas	0.3	0.5	0.5	0.5	0.5	1	2	2
Water Bodies	0.3	0.3	0.5	0.5	0.5	0.5	1	2
Road Network	0.3	0.3	0.3	0.3	0.5	0.5	1	1
Total	3.9	5.7	7.3	8.8	11.5	13	16	20

4.5 Landfill Suitability

The landfill suitability was determined by obtaining the summation of the product of the weight of each criterion with its standard suitability score according to Equation 1.

$LS = \Sigma w_i x_i$ ... (1)

Where;

LS = Landfill Suitability

w_i= the relative importance (weight) of each criterion

and x_i = the standardized score of each criterion *i*.

Hence the landfill suitability with the constraints was derived from equation

$LS = (\sum_{i=1}^{n} wi \times xi) \times \prod cj$ … (2)

With c_j=Boolean value of limited criterion In order to make the map easily understandable, a reclassification was performed to reclassify the result to index levels/categories—low, moderate and high. The natural breaks reclassification method in ESRI's ArcGIS Pro was used for this purpose. The natural breaks (jenks) classification algorithm finds data break points between classes depending on the natural patterns in which the data are clustered. Class break points are set where there are relatively huge jumps in the data values. Hence a model was developed using the formula and weighted linear combination to determine the landfill suitability. The formular used is: LS is = (F1*0.25) + (F2*0.18) + (F3*0.15) + (F4*0.13) + (F5*0.10) + (F6*0.08) + (F7*0.06) + (F8*0.05)

Note: F1, F2, F3, F4, F5, F6, F7 and F8 are thematic layers representing the constraints, see table 4.7 and figure 4.15 for the graphic model used.

5.0 CONCLUSION / RECOMMENDATION

5.1 Conclusion

GIS-based analysis is an essential tool for identifying suitable locations for landfill

establishment to promote sustainable waste management practices. Incorporating GIS-based analysis in waste management planning can ensure sustainable and environmentally responsible waste disposal practices. By considering the suitability of a location for landfill establishment, decision-makers can minimize the negative impacts of waste disposal on the environment and local communities while promoting sustainable waste management practices.

5.2 Recommendation

Based on the results of the GIS-based landfill suitability analysis for sustainable waste disposal in Awka urban area, the following recommendations can be drawn:

1. Prioritize the development of potential landfill sites in the high suitability zone, which covers only a small percentage of the study area, to maximize the use of suitable land and minimize any negative impacts on the environment and public health.
2. Select locations strategically when choosing landfill sites, consider not only the suitability but also the surrounding environment. Ensure that sites are not located in sensitive areas such as wetlands, flood-prone regions, or areas with high groundwater vulnerability. This will help to minimize potential environmental risks and negative community impacts. Implement sustainable waste management practices that prioritize waste reduction, reuse, and recycling, to minimize the amount of waste that needs to be disposed of in landfills and to conserve limited suitable land resources.
3. Emphasize the importance of source reduction measures, such as minimizing packaging and encouraging the use of reusable products. These practices can significantly reduce the volume of waste generated, lessening the burden on landfills.
4. Existing landfills should be assessed in light of the suitability analysis. Consider relocating or implementing mitigation measures for landfills that fall outside high suitability zones, particularly if they are situated in gully-eroded areas or other unsuitable locations.
5. Lastly, the results obtained from this study should be used for informed decision making on waste disposal and management in the study area.

REFERENCES

Abbas, I. I., Nai'ya, R and Arigbede, Y. A. (2011). Case Study Use Of Remote Sensing And Gis In Effective And Efficient Solid Waste Management Planning (A Case Study Of Samaru, Zaria, Nigeria). *Research Journal of Earth and Planetary Studies*, 1(2) 046 – 052.

Abdel-Shafy, H.I. and Mansour, M.S.M. (2018) Solid Waste Issue: Sources, Composition, Disposal, Recycling, and Valorization. Egyptian Journal of Petroleum, 27, 1275-1290. https://doi.org/10.1016/j.ejpe.2018.07.003

Ashish R Mishra, Shweta A Mishra, and Anurag V, Tiwari. (2014). *Solid Waste Management Case Study,* Yavatmal, India. 2(1), 2323-9637

Daniel, Ayoola & Ekeleme, Ike & Onuigbo, Chinemerem & Ikpeazu, Victor & Obiekezie, Smart. (2021). Review on effect of dumpsite leachate to the environmental and public health implication. GSC Advanced Research

and Reviews. 7. 051-060. 10.30574/gscarr.2021.7.2.0097.

Emmanuel, U.A, Ojinnaka, O.C, and Baywood, C.N, (2015): Flood Hazard Analysis and Damage Assessment of 2012 Flooding Anambra State Using GIS and Remote Sensing. *American Journal of GIS. 4(1)*

Ejikeme, J.O., Igbokwe, J.I., and Emengini, E.J., (2015) modelling the impact of flooding using geographic information system and remote sensing, *International Journal of Technical Research and Applications.* **e**-ISSN: 2320-8163, *3(4). 67-72*

Fides, K. K., E. and Waithaka, H. (2014). Determination of Suitable Landfill Site Using Geospatial Techniques and Multi-Criteria Decision Analysis: A Case Study of Nakuru Town, Kenya. *International Journal of Science and Research (IJSR)* 3(11), 500-505. ISSN: 2319-7064.

Hoornweg D., Bhada-Tata P., and Kennedy C. (2015). Peak waste: When is it likely to occur? *J IndEcol* 19(1):117–28. doi: 10.1111/jiec.12165

Mohsin, Mohd & Ali, Sk Ajim & Shamim, Syed Kausar & Ahmad, Ateeque. (2021). A GIS-based Novel Approach for Sustainable Sanitary Landfill Site Selection Using Integrated Fuzzy AHP and Machine Learning Algorithms. 10.21203/rs.3.rs-641684/v1.

Saaty T. L. (1980). *The analytic hierarchy process*, New York. (McGraw-Hill, New York. USA).

World Health Organization (2021).Compendium of WHO and other UN guidance on health and environment. https://www.who.int/tools/compendium-on-health-and-environment/solid-waste

Yahaya T., Okpuzor J. and Oladele E.O. (2011). Investigation of Toxicity of Detergents. *Journal of Environmental Science and Technology*, 4: 638-645.