# Geospatial Assessment of Suitable Landfill Sites Location in Owerri

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author TSA designed the study, wrote the first draft and handled the literature researches. Author KOEU managed the analysis of the study and made corrections to the first manuscript. Both authors read and approved the final manuscript.*

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| **Original Research Article** |

## ABSTRACT

This study was done with the aim to map the present waste disposal sites in the city, to prepare a landfill suitability map of the area, to recommend the best and the most suitable locations to site the dump sites/ landfills based on a multi criteria decision making technique and GIS.

It was carried out in the city of Owerri, capital of Imo state, South Eastern part of Nigeria, from May to August 2016.

Data used in this research work were the coordinates taken at the existing landfill sites (Table 1), a Landsat 8 Satellite Imagery and a Shuttle Radar Topographic Mapper (SRTM). Arc GIS v 10.2 and Erdas Imagine 2014 were used to analyze the data. Selected criteria were mapped using the GIS technique and spatial analytic tools, then different constraint map layers were overlaid to obtain a potential suitability map.

The results showed ten proposed landfill sites at Awaka, Obinze, Amone, Okuku, Irete, Amaeze, Ihiagwa and Imeabam, with the site at Imeabam, being the most suitable.

A more efficient waste disposal system can be developed if GIS is used more in decision making as was illustrated in this research work.

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# 1. INTRODUCTION

## 1.1 Background of Study

Dumpsites and landfills are very key components in the entire system of waste management. In many developing countries, techniques such as waste reduction, recycling and reuse are widely used to manage solid waste, however there is always residual matter left [1]. The necessity to get rid of these residuals results in using the cheapest waste management option which is landfilling and since this approach is economical, it is likely to be the dominant method for waste disposal for a foreseeable future [2]. This makes landfills indubitable in the entire success of a good waste management system.

In Nigeria, the selection of suitable landfill sites that combine social, economic and environmental factors for locating waste dump sites has been recognized as a major problem in planning and construction. Common problems that exist with the selection of landfill sites are the availability of land for solid waste disposal, environmental degradation [3] and so many others. Also the cost involved in doing detailed analysis and queries for conventional methods, such as ground surveys, may be too prohibitive to embark on and has thus discouraged government from doing so due to limited funds. All these challenges and more, with the indispensable necessity of landfills, have encouraged the wrong practice of siting them at unsuitable locations.

## 1.2 Definition of Problem/Proposed Solution

The impacts of an improperly sited landfill are undesirable and can have adverse effects on human, plant and animal health. It poses as a huge hazard to the quality of land, water bodies and general ecosystem as they can be negatively impacted. Impacts range from the pollution of water bodies, outbreak of epidemics, death of aquatic life, contamination of soil, noise pollution from machinery, odours from sites etc. Hence, the need for the introduction of technological applications in the making of these decisions has been widely recognized, though rarely applied.

In landfill siting, Geographical Information Systems (GIS) can be used as a tool to aid the decision-making process. It can process large amounts of data in a short time and also help in storing the links between environmental issues and the elements and potential impact of the proposed [4]. The ability of GIS to perform spatial queries, weigh different criteria and perform overlay and buffer operations makes it particularly able to handle the problem of improperly located landfills.

## 1.3 Literature Review

In Damataru, capital of Yobe state [5], attempted to determine most suitable sites for landfills via a combination of GIS technology and Multi-Criteria Decision Making Method (MCDM) also known as the Analytical Network Process (ANP). In this study, criteria considered were based on established guidelines, and that of Yobe state environmental protection agency (YOSEPA), and modified according to available datasets for landfill siting. The selection of waste disposal site was carried out through some screening process. A GIS-based constraint mapping was employed to eliminate the environmentally unsuitable site and to narrow down the number of sites for further considerations. Based on the analysis, fourteen sites were identified to fulfill the required criteria; however, only seven met the land availability criteria of twenty hectares and above.

Suitable sites for waste dump sites have been selected in Owo L.G.A of Ondo State in Nigeria [6]. Enhanced Landsat ETM+ images of 2002 2007 and 2012 were acquired for the land use / land cover map of the area. GIS analysis and operations which included Multi – Criteria Evaluation and overlay operations were performed for the selection of most suitable sites for landfills. Bearing in mind variables such as land-use/ land-cover type, distance to surface waters, proximity to urban areas; distance to transport route, geology and soil type of the study area, weighted factor maps have been combined with overlaid constraint maps to produce suitable sites for landfills.

GIS has been used to identify suitable landfill sites in Akure, Ondo State, Nigeria [7]. Criteria for site selection included natural physical characteristics, socio-economic, ecological and land use factors. Different tools and techniques were developed for solid waste disposal site selection in Developing Countries. Landsat Enhanced Thematic Mapper plus (ETM$^+$) 2002

and Shuttle Radar Topographic Mission (SRTM) 2011 were used to map the most suitable site for waste disposal in Akure. The result indicated that the most suitable sites in the study area were located at 750 m to surface water and 300 m to major and minor roads, which ensured that economic costs of implementation are mutual. The selected areas have slopes less than 12%, with infrastructural advantage and minimizing environmental impacts. The study proposed four acceptable landfill sites for solid waste disposal in the city.

## 1.4 Scope of Research

The scope of this study is restricted to identifying suitable landfill sites in Owerri and trying to find whether and how GIS can be a useful tool in producing a site suitability map by collecting data through RS creating the suitability map through GIS.

## 1.5 Justification of Research

The impacts of an improperly sited landfill site are undesirable and can have adverse effects on human, plant and animal health. Owerri, as a thriving state capital of the Heartland of the Nation, is at risk of having her land, water bodies and general ecosystem negatively impacted by the commensurate effects of siting landfills wrongly which can range to pollution of water bodies, leading to eutrophication; outbreak of epidemics; death of aquatic life; contamination of soil, noise pollution from machinery; odours from sites [8] etc. Hence, this research work is viable and justified because it attempts to answer the

question of siting landfills, which in turn can mitigate the health, economic and physical problems that improper siting has caused.

## 2. MATERIALS AND METHODS

### 2.1 Materials

All the data used for this research include primary and secondary data.

The primary data used in the research work are the X, Y, Z data of the present landfill sites: They are the coordinates (latitude and longitude) and elevation of the present landfill sites in Owerri. The coordinates were gotten by making use of a Navas Garmin 60 GPS and the Table 1 summarizes them.

Secondary data used for this research work include:

1. A Landsat 8 (2016) Satellite Imagery: A Landsat 8 Imagery, containing the study area was obtained from the National Space Research and Development Agency (NARSDA).
2. A SRTM map of Nigeria: The SRTM, i.e. the Shuttle Radar Topographic Mapper, which illustrates the elevation of the earth's terrain, was obtained from NARSDA.
3. Cadastral map of the study area: A cadastral map of the study area was also obtained from NARSDA.

The Table 2 summarizes the data sources for primary and secondary data types.

**Table 1. Data gotten from field work**

| Location | Latitudes | Longitudes | Altitudes (m) | Status |
|----------|-----------|------------|---------------|--------|
| Avu | 5° 26' 36.59" N | 6° 59' 10.80" E | 84 | Not active |
| Aladinma | 5° 29' 50.96" N | 7° 2' 53.41" E | 85 | Not active |
| Aba Road | 5° 28' 10.86" N | 7° 2' 15.27" E | 99 | Not active |
| Old Nekede Road | 5° 27' 52.66" N | 7° 1' 46.43" E | 83 | Active |

*Source: Authors' Field Work*

**Table 2. Name of data, type of data and source**

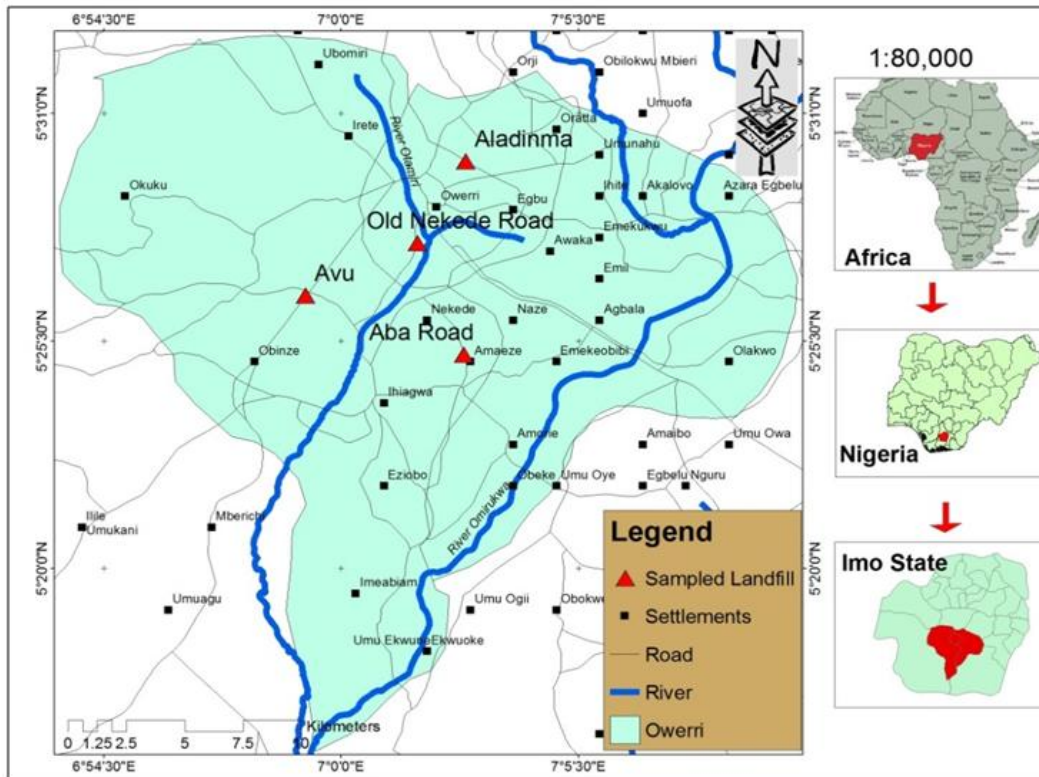| S/N | Data | Type | Source |
|-----|------|------|--------|
| 1 | Data from Landfill Sites | Primary | Field Work |
| 2 | Landsat 8 satellite imagery | Secondary | NARSDA |
| 3 | SRTM map | Secondary | NARSDA |
| 4 | Cadastral map | Secondary | NARSDA |

**Fig. 1. Map of Owerri metropolis, showing the locations of the existing landfill sites**

## 2.2 Hardware and Software Requirements

The hardware that was used for the execution of this research work were:

1. A Laptop; ZINOX, 2.80 GHz, 300GB hard drive and 4G RAM
2. A3 Printer

The soft wares that were needed for the execution of this research work were:

1. ArcGIS v 10.2
2. ERDAS Imagine 2014
3. Microsoft Word, for the processing and editing and displaying of the textual information.
4. Microsoft Picture Manager Software, for the enhancement and the presentation of pictures.
5. Microsoft Excel Software, for the compilation and computation of field work data.

## 2.3 Methods

To carry out the analysis, a composite suitability analysis was employed.

The satellite imagery was clipped to the study area, using the Data Management Tool in the ArcGIS 10.2 software and was imported into the Imagine 2014 software. In the Erdas Imagine environment, the land use land cover map was created using Supervised Classification. The classes that were used for this map include built up, water bodies, bare surface, forest vegetation, and farmland.

The SRTM map was imported into the ArcGIS environment and was clipped to the study area. An elevation map was then created from the SRTM map. From the cadastral map, the layers for the water bodies and major and minor roads were obtained.

Buffering operations were then made using the following selection criteria: proximity to roads, with a buffering of 500 m; proximity to water bodies, with a buffering of 2 km, with each criterion being assigned different weights according to their importance.

An overlay operation was performed, in the ArcGIS environment, between the slope map and the land use land cover map to produce a

constraint map. This constraint map showed the areas that were absolutely unsuitable for the location of landfill sites and areas that could be suitable, barring other selection criteria.

Finally, an overlay of all buffered maps was performed on the constraint map that pointed out the different areas suitable for locating landfills.

## 3. RESULTS AND DISCUSSION

### 3.1 Suitability of Land Use Land Cover

The land use/ land cover of the town was analyzed from the Landsat 8 (2016) image. The land-use/land cover constraint map (Fig. 2).

Classes that were represented were the built-up areas, cultivated areas, natural vegetation, and water bodies. Built up-areas include churches, market, hospitals, mosques, parks, residential areas etc. The Land Use Land Cover map that was produced is displayed below. These areas should have a buffer of about 3, 000 m to avoid the occurrences of noise pollution, social and ecological disturbances and the outbreak of diseases. In the present study, about 29.8% (Fig. 2) from the total area were located at distance of 3000 m from environmentally sensitive area. This was the most suitable area for solid waste dumping site. Classification was done using the maximum likelihood classifier ability of the ERDAS Imagine 2014 software. The result of the classification is displayed below:
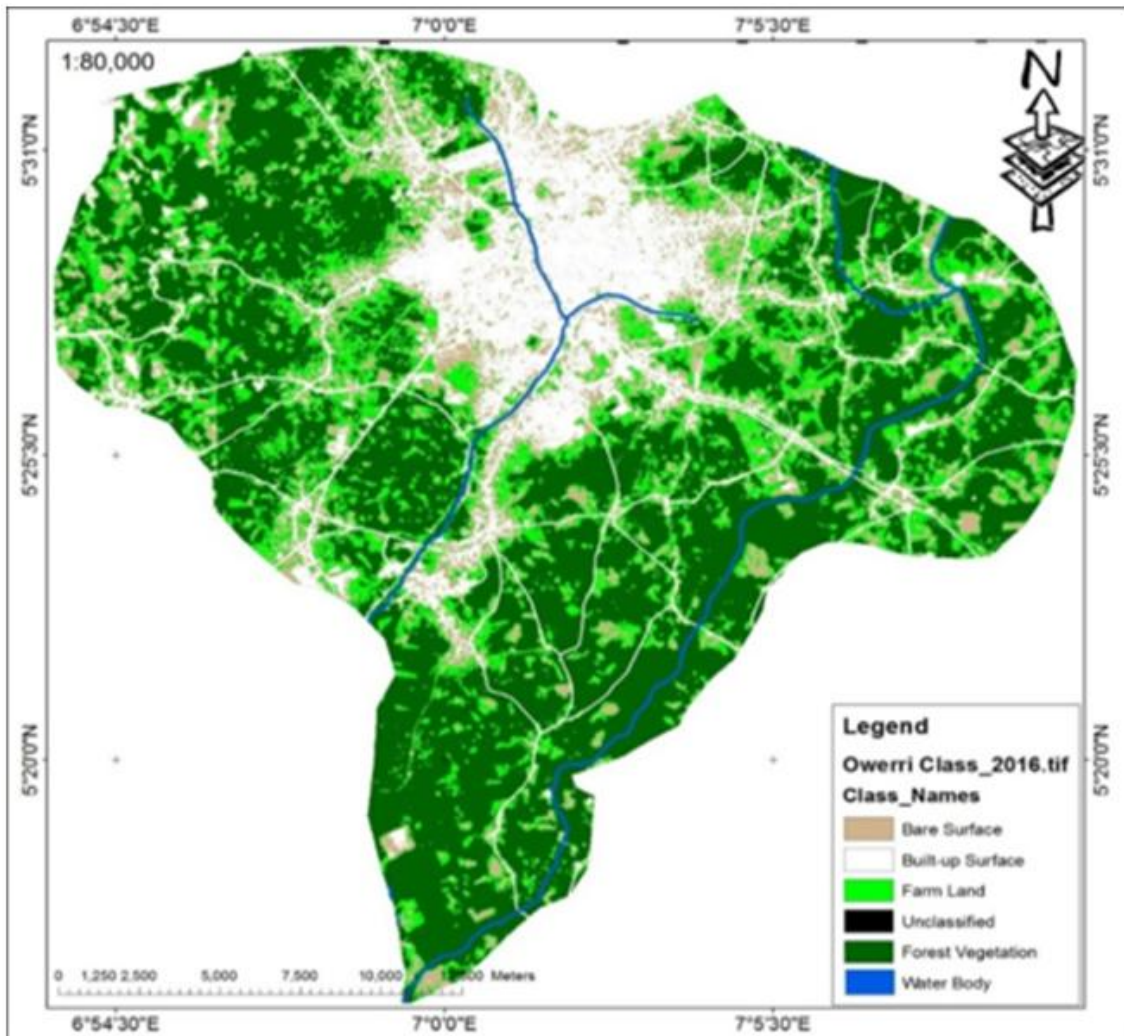


**Fig. 2. Land use/ land cover map of the study area**

**Table 3. Information from land use/ land cover map**

| Class names | Count | Area (M$^2$) | Area (Ha) | Area (%) |
|---|---|---|---|---|
| Unclassified | 0 | 0 | 0.00 | 0.00 |
| Water Body | 12100 | 10033925 | 1003.39 | 0.99 |
| Forest Vegetation | 403762 | 334819638.5 | 33481.96 | 33.02 |
| Farm Plantation | 144185 | 119565411.3 | 11956.54 | 11.79 |
| Built-up Surface | 606540 | 502973295 | 50297.33 | 49.61 |
| Bare Surface | 56043 | 46473657.75 | 4647.37 | 4.58 |
| Total | 1222630 | 1013865928 | 101386.59 | 100.00 |

From the map above, it was deduced that the water bodies covered 1003.39 Ha (0.99%), the built-up areas covered 50297.33 Ha (49.61%), the forest vegetation occupied 33481.96 Ha (33.02%), the farm plantation occupied11956.54 Ha (11.79%) and bare surface covered 4647.37 Ha (4.58%) of the total area of Owerri Municipal, which was found to be 101386.59 Ha or 1013865.928 Km$^2$.

The Table 3 summarizes the findings from the land use/ land cover map.

## 3.2 Suitability of Slope

The slope of the terrain has an effect on the suitability of a site for a landfill with the lower slopes being more suitable and higher slopes being less suitable. It is of popular opinion that a slope between 4% - 10% is highly suitable for solid waste dumping (5). Areas with high slopes have the potential of contributing to surface and groundwater pollution and are hence not a good site for dumping waste.

The elevation map of the study area was generated from the SRTM map and is displayed Fig. 3.

From careful observation, it is clear that a majority of the study area falls under the slope class of 0-10%, which covers 90.7% of the total study area. Whereas 4.2, 2.3 and 2.8% of the study area was covered by slope classes 10-15, 15-20 and 20% respectively.

This shows that the effect of slope as a significant criterion for selecting landfill sites in Owerri is negligible as the town is more or less flat in its topography.

## 3.3 Suitable Distance from Settlements

Churches, market, hospitals mosques, parks and residential areas etc. are all part of built up areas

and it is important that landfills are located away from these areas. There should at least be a buffer of 3000 m. Babalola and Busu (2010) show that the area located at the distance greater than 3000 m from environmentally sensitive area were selected as highly suitable for solid waste dumping site, however in this study, a distance of 2000 m was preferred.

In the present study, about 29.8% (Fig. 4) from the total area were located at distance of 2000 m form environmentally sensitive area. This was the most suitable area for solid waste dumping site, barring other selection criteria.

The constraint map is produced is displayed in Fig. 4.

## 3.4 Proximity to Major and Minor Roads

As the general concept, the landfills shall not be located within 100 m of any major highways, city streets or other transportation routes. Landfill site must be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. The study preferred a buffer of 2000 m distance from main roads by referring to different sources. It was reclassified as unsuitable road within 500 m, low suitable between distances from 500 to 1000 m. The distance starting from 100 up to 500 was considered as moderate suitable and highly suitable is distance between 500-1000 m, with the mean buffer being a distance of 500 m. The result indicated that 31.3% from the total buffered distance is highly suitable for solid waste dumping site with the class of value 4 for this study. The land that is unsuitable for solid waste dumping site by referring to distance from road is 30.9% of the total area (Table 1 and Fig. 5).

## 3.5 Proximity to Water Bodies

In the study area, there is Otamiri River and River Orammiriokwa which both begin at the northern end of the study area and flow towards the southern side of the area.
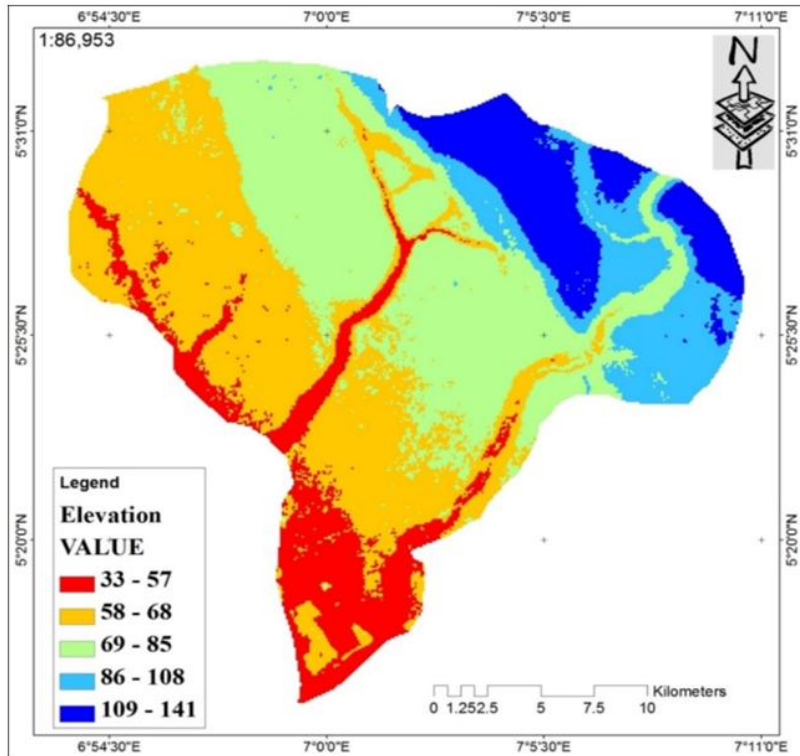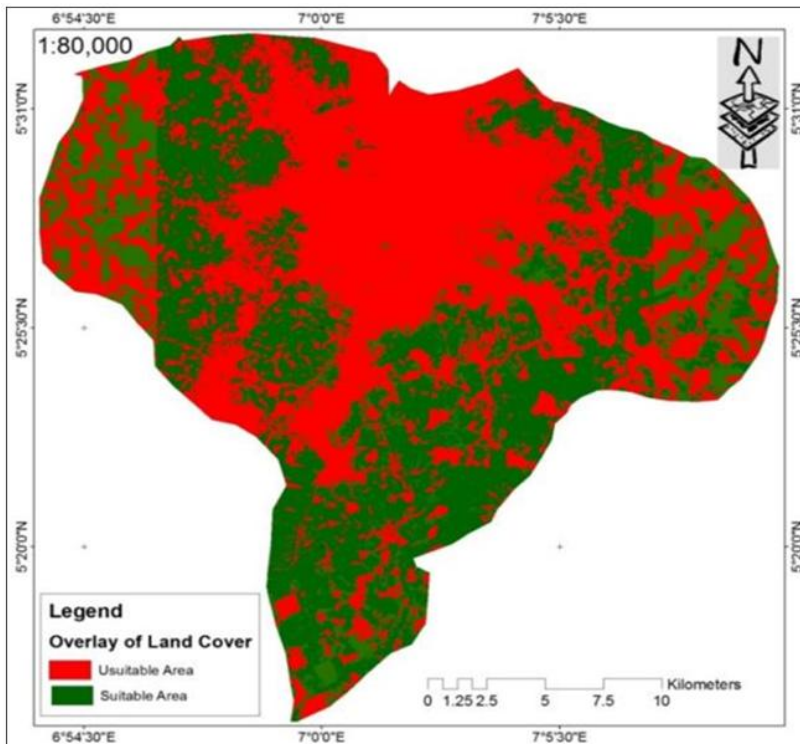
**Fig. 3. Elevation map of the study area**



**Fig. 4. Constraint map, showing suitable and unsuitable areas**
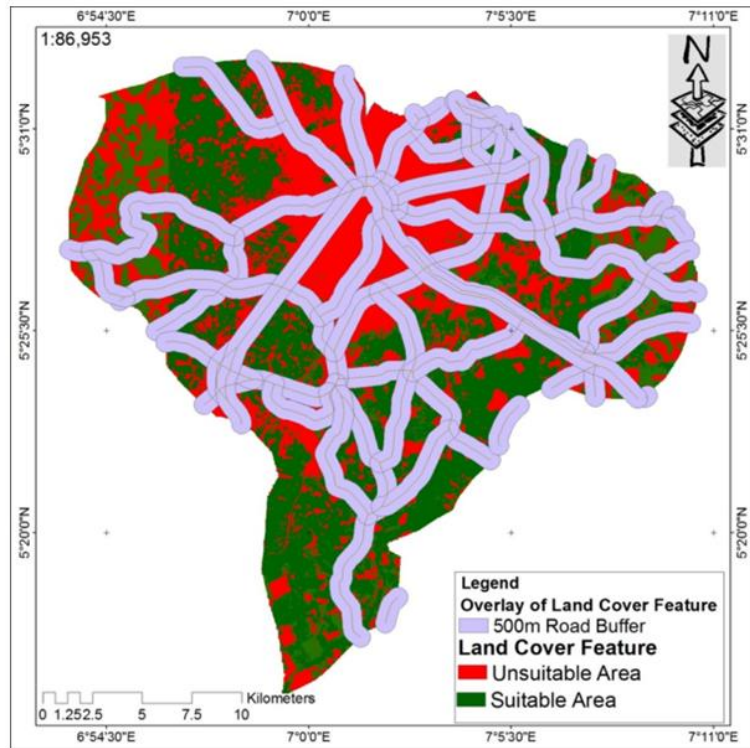
**Fig. 5. 500 m buffer of roads overlaid on constraint map**
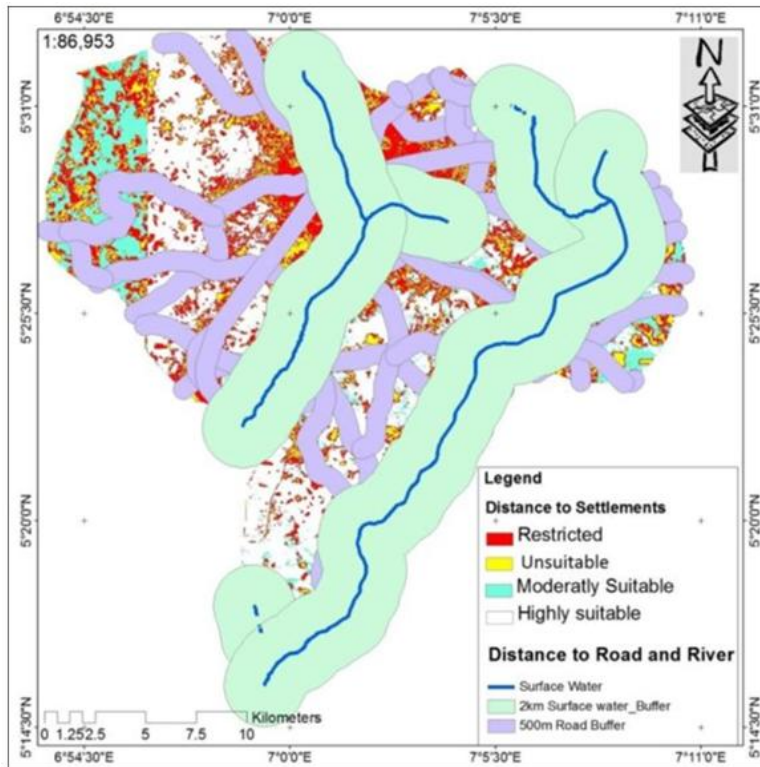


**Fig. 6. 2 km buffer of water bodies overlaid on buffered road**

To maintain the environmental health of these water sources, at least a 2000 m (2 km) buffered distance was ringed through straight line calculation [8]. This relatively large buffer was necessary to mitigate the risk of contamination and pollution from landfills into water bodies to the barest minimum. The result of the buffered water bodies is shown in Fig. 6.

## 3.6 Final Suitability Map

Based on the above procedures, a final suitability map was produced. The landfill suitability map (Fig. 7) has four colors (classes): brown, yellow, cyan and black. The proposed area for Landfill site is marked by black color shaded with ten digit numerical number to help visualize their area extent. Out of the total area of the study site, about 12.8% (12956.5 ha) fall under this category. The cyan color represents moderate suitable area and it covers an area of 16.5% (16740.98 ha). The area which is shaded by yellow color represents the unsuitable class and the remaining 70.7% (62253.87 ha) is under restricted class. By using the stated criteria, the suitable areas for Landfill site fall on the eastern

and southern west direction from the town (Fig. 7).

From the landfill suitability map (Fig. 7), it can be inferred that the proposed landfill sites are located at around Awaka, Obinze, Amone, Okuku, Irete, Amaeze, Ihiagwa and Imeabam with index numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 respectively. Irete has multiple proposed landfill sites (5, 6 and 7) while the proposed site at Imeabam (index number 10) is the most suitable due to its land mass, distance from residential and built up area and proximity to the road network.

Also from the map (Fig. 7), it is observed that six proposed sites (i.e. 2, 4, 5, 6, 7 and 10) are located at Owerri West L. G. A. That accounts for 60% of the total proposed sites. The remaining four (i.e. 1, 3, 8 and 9) where located at Owerri North L.G.A which accounts for the remaining 40%. Owerri Municipal, the third local government area in Owerri Metropolis, has no proposed landfill site in its entire area extent and ironically, all the existing landfills, both active and non-active, have all been located in this L. G. A.
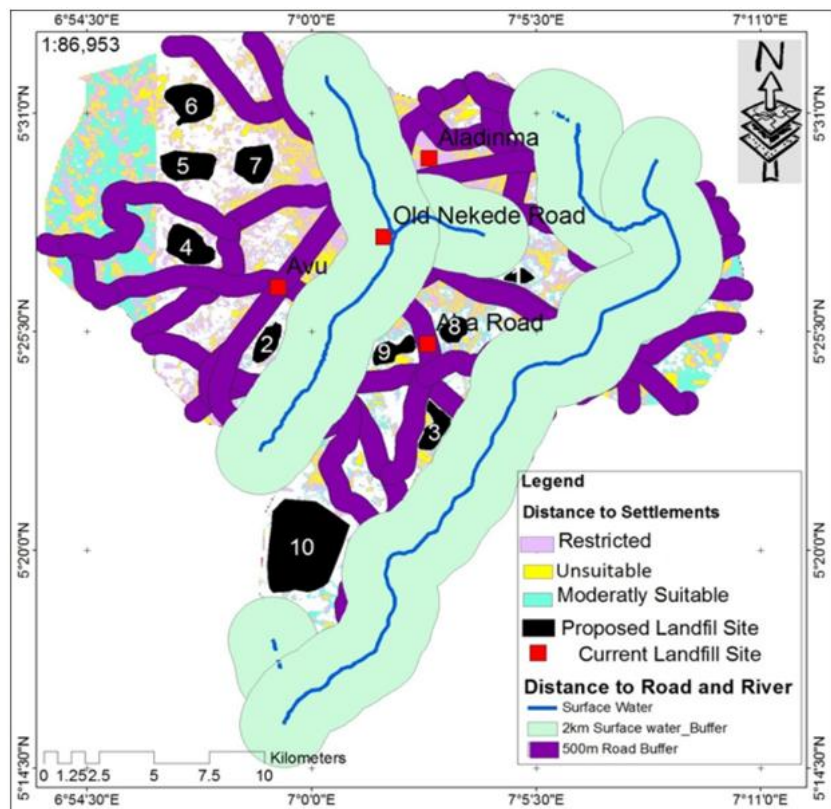


**Fig. 7. Final suitability map**

## 4. CONCLUSION

GIS as a decision support tool for landfill siting has been proven to be useful in finding suitable locations for landfill siting purposes in Owerri Metropolis, as it was the major tool employed in locating them by creating maps according to the set criteria. A landfill siting process requires evaluating many criteria and processing much spatial information. Using GIS for locating landfill sites is an economical and practical way for the evaluation of and production of maps in a short time when there is a need for fast evaluation.

This study has addressed the issue of improper siting of landfills in Owerri and in the course of the research work, it was found out that there was a case of improper location of landfills in Owerri Metropolis. In addition, ten proposed landfill sites have been identified which are located at Awaka, Obinze, Amone, Okuku, Irete, Amaeze, Ihiagwa and Imeabam, seven proposed landfill sites were located at Owerri West L. G. A. at Irete, Obinze, Ihiagwa and Imeabam, with three sites located at Irete, three proposed landfill sites were located at Owerri North L.G.A, i.e. Awaka, Amone and Okuku, no proposed landfill site was located at Owerri Municipal L.G.A, and the site at Imeabam is the most suitable among the proposed landfill sites.

The increase in commercial, residential and infrastructural development due to the population growth and urban expansion in Owerri is directly affecting the amount of waste generation in the area. This study is therefore considered very imperative because it will serve as a catalyst for further improvement on waste dump siting and management in Owerri Metropolis.

Evidence abound that residential areas of many cities in developing nations are plagued with diverse environmental challenges due to the abuse of landfill siting [5]. Hence, this work, and others like it, is viable and indeed timely.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Amakihe E. Geographic Information System (GIS) as a decision support tool for selecting potential landfill sites. Under-graduate Project Work, Novia University of Applied Sciences, Raseborg; 2011.
2. Nwambuonwo OJ, Mughele E. Using geographic information system to select suitable landfill sites for megacities (Case study of Lagos, Nigeria). Computing, Information Systems & Development Informatics. 2012;3(4):48-57.
3. Bartelme N. Geographic information systems. Springer Handbook of Geographic Information; 2010. ISBN: 978-3-540-72678-4
4. Ayo B, Ibrahim B. Selection of landfill sites for solid waste treatment in Damaturu town-using GIS techniques. Department of Remote Sensing Faculty of Geo-information Science and Engineering, Universiti Teknologi Malaysia, Malaysia. Journal of Environmental Protection. 2010;2:1-10.
5. Oyinloye MA. Using GIS and remote sensing in urban waste disposal and management: A focus on Owo L.G.A, Ondo State, Nigeria. European International Journal of Science and Technology. 2014;106-118. ISSN: 2304-9693
6. Oyinloye MA, Fasakin JO. Application of Geographical Information System (GIS) for siting and management of solid waste disposal in Akure, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 2011;4(2):06-17. ISSN: 2319-2399
7. Babalola A, Busu I. Selection of landfill sites for solid waste treatment in Damaturu town-using GIS techniques. Journal of Environmental Protection. 2011;2:1-10.
8. Tirusew AE, Amare SM. Solid waste dumping site suitability analysis using Geographic Information System (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia. African Journal of Environmental Science and Technology. 2013;7(11):976-989.