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Research Paper

Site Suitability Mapping For Dumpsites in Aba and Umuahia, Abia State, Nigeria

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ABSTRACT

Waste management is a formidable task in numerous developing nations and their urban areas. Deficiency in waste management system and diminishing amount of available land suitable for waste disposal, have further compounded the problem. This study aimed to determine suitable sites for dumpsites in Aba and Umuahia, Abia State, Nigeria. Sites selection were made by spatial analysis using ArcGIS 10.8, Google Earth Pro, AHP calculator and ERDAS IMAGINE 2014.Suitable site are areas that passed all criteria for solid waste disposal adopted for this research, based on assigned weight for distance to road (m), slope (%), land-use/land-cover and soil type. The most suitable area for solid waste dumping site in the study site in Aba, constitute about 26.97%; 10.84% is moderately suitable; 10.59% less suitable class and 51.60% unsuitable. The most suitable area for solid waste dumping site in Umuahia is about 31.81; moderately suitable area covers an area of 1.24%; less suitable covers 60.53% representing and 6.42% of the area is unsuitable. It is recommended that dumpsites be sited following their suitability as detailed in this study.

Keywords: *Solid waste, dumpsites, suitability, spatial analysis*

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I. INTRODUCTION

The rapid growth of urban, agricultural and industrial activities due to population explosion has led to the generation of huge amounts of solid and liquid waste that pollute the environment and destroy natural resources [1]. Municipalities have their own policies, individual approaches and methods to manage the solid wastes. They consider wastelands outside the urban area as the best suitable for the solid waste disposal. Such improper site selection will create morphological changes that lead to environmental hazards in the urban and its surrounding areas.

Solid waste disposal is of enormous concern in developing countries across the world, as poverty, population growth, and high urbanization rates combine with poor funding has led to poor waste management [2]. Identifying Municipal Solid Waste (MSW) disposal sites and appropriately managing them is a challenging task to many developing countries like Nigeria. Open dumping system which is currently practiced in most area in Nigeria, causes environmental degradation and public health problems, as a result from non-adherence to the various criteria for suitable site selection [3].

Waste management in Aba and Umuahia, two cities within Abia State, has been grappling with a series of challenges that span from the initial collection of waste to its ultimate disposal. In most cities in Abia State, waste management practices are very rudimentary with trash just being collected and transported to pits outside the city. One significant issue plaguing these cities is the prevalent practice of open dumping, which has had adverse consequences for both the environment and the local communities. This problem can be traced back to the failure to adhere to established criteria for the selection of suitable waste disposal sites [4].

A range of factors, both environmental and socio-economic, need to be considered when selecting a suitable dumpsite. These factors include the landscape's slope, its proximity to roads, soil quality, land usage, as well as its relation to human settlements, the livelihoods of the local populace, and the methods employed for waste disposal. Assessing all these elements can be a laborious, time-consuming, and costly process. Choosing a suitable location for a landfill in an urban setting is a crucial aspect of urban planning, and where a scientifically sound approach is used to choose the location, such as using geospatial techniques, the environmental impact could be predicted and thus it is less likely to face opposition [5,6]. Several developing nations have not yet embraced this approach primarily because it demands a high level of technical proficiency in crafting, operating, and overseeing procedures that guarantee adherence to environmental rules [7].

Geographic Information Systems (GIS) technology empowers users with a suite of tools and functionalities for collecting, storing, retrieving, manipulating, and analyzing data. These capabilities are instrumental in generating valuable information that can facilitate informed decision-making in the context of environmental concerns [4].

Use of geospatial techniques in selection of suitable dumpsite have seen minimal application in emerging nations like Nigeria, and in Abia State in particular [4]. This research stems from the evident challenges posed by deficiency in waste management system in Abia State, which promotes haphazard waste dumping at unauthorized spots, and an inadequate number of disposal facilities. According to existing reports, surface and groundwater near existing dumpsites in Aba and Umuahia are polluted and residents near such sites, not leaving waste pickers, have been linked with ailments associated with noxious gases and infectious agents from existing dumpsites, which are not well sited within these cities [8-10].

This study aimed to carryout site suitability mapping for dumpsites in Aba and Umuahia, Abia State, Nigeria, using geospatial technique.

II. MATERIALS AND METHODS

2.1 Study Area

The two focal points of this research investigation, Aba and Umuahia, represent the largest urban centers within Abia State. Umuahia stands as the administrative nucleus of Abia State, whereas Aba takes the helm as the primary hub for commerce and industry. Situated a mere 43 miles from Port Harcourt in Rivers State, renowned as Nigeria's epicenter for the oil industry, these cities hold pivotal geographic and economic significance within the region. This dichotomy of functions between the two cities adds a multifaceted layer to the region's overall identity and significance.

The climate in both cities experiences significant variations in relative humidity and temperature between the dry and rainy seasons. The region also grapples with abundant rainfall, resulting in seasonal flooding exacerbated by poor drainage infrastructure and construction practices. Understanding these climatic dynamics and challenges is essential for planning and managing the environment in Aba.

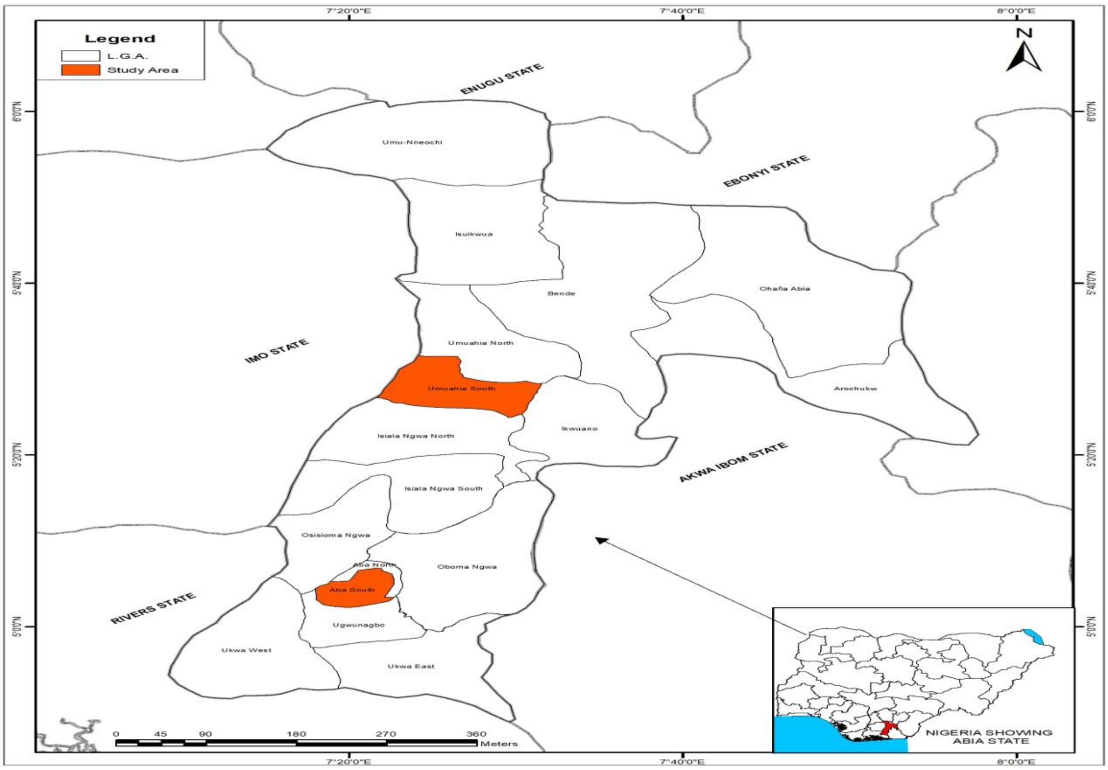

Figure 1: Abia State showing the location of the study area (Aba and Umuahia)

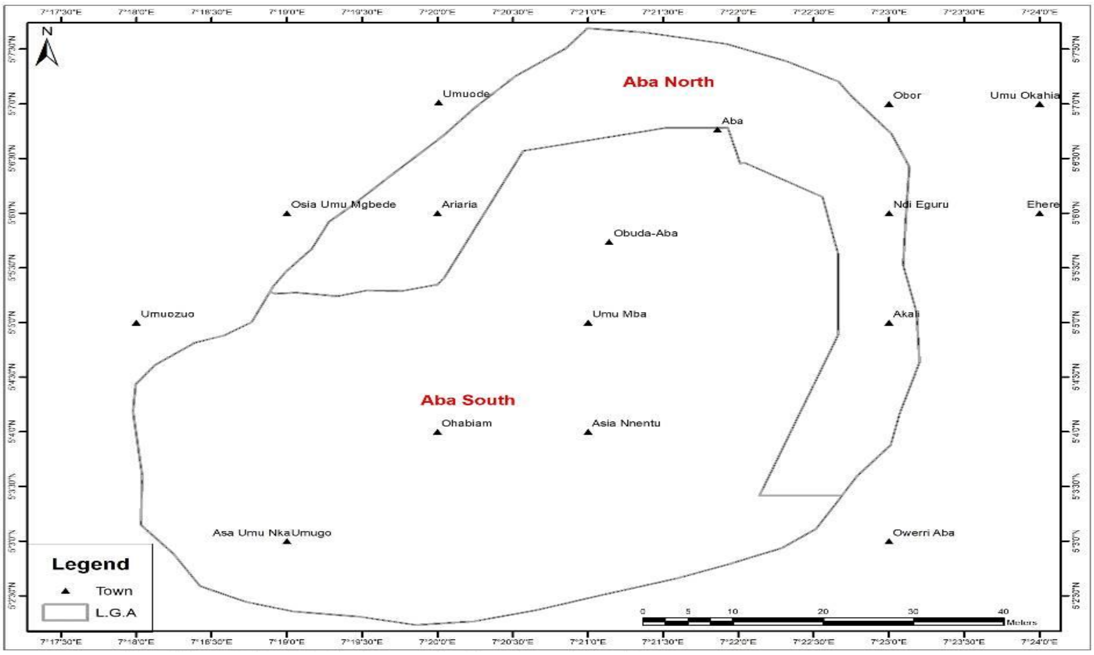

Figure 2: Location map of the study area: Aba North and South

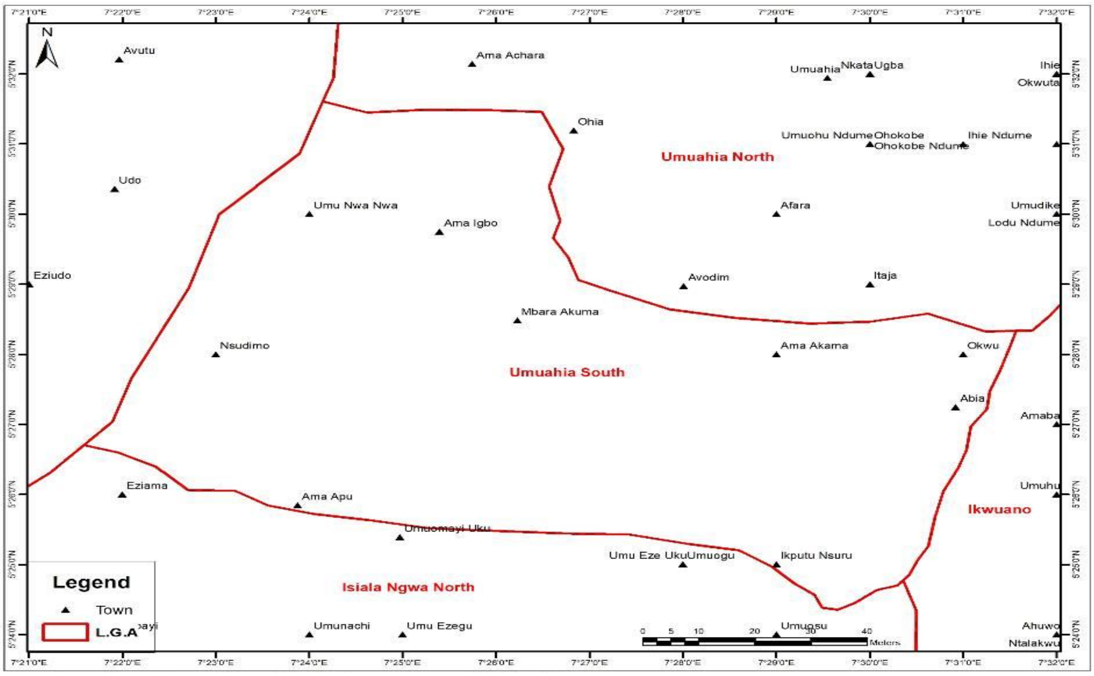

Figure 3: Location map of the study area: Umuahia South

2.2 Data Types and Sources

This study employed a combination of primary and secondary data sources to ensure a comprehensive and robust research framework. Primary data were gathered through field surveys and direct observations, while secondary data were sourced from a variety of external references, including the internet, reports, books, journals, governmental institutions, and various other pertinent documents.

Data for the mapping were gathered from the sources listed in Table 1. ArcGIS 10.8, Google Earth Pro, AHP calculator (developed by Klaus Goepel) and ERDAS IMAGINE 2014 were the major software used for the spatial analysis.

Table 1: Sources of Data and Spatial Data Characteristics

S/N	Data Type	Resolution (Scale)	Path and Row	Year	Area of Interest (km^2)	Source
1.	Landsat 8+ ETM	30m x 30m	188/056	2023	Aba and Umuahia	USGS
2	ASTER DEM	30m x 30m	188/056	2023	Aba and Umuahia	USGS
3.	GIS database/topo map of Abia State	1.50, 000	-	2023	Aba and Umuahia	Abia State Ministry of Lands and Survey
4	Soil Data	30m x 30m	188/056	2023	Aba and Umuahia	FAO/UNESCO

2.3 Method of Data Analysis

2.3.1 Criteria Selection and Assign Weight

Based on a detailed literature review, five conditioning factors were selected representing the criteria for selecting a waste dumpsite and they include: distance to road (m), slope (%), soil type (m), land-use and distance from river (m) as shown in Table 2.

Table 2: Criteria Classification

Parameter	Suitability class				Assigned Weight
	Unsuitable	Less suitable	Moderate suitable	High suitable	
Distance to Road (m)	0-50	51-100	101-200	>200	0.20
Slope (%)	>20	15-20	10-15	<10	0.15
Land-use/land-cover	built-up	Water body	farmland/bare surface	Thick forest	0.20
soil type	sandy	sandy loam	clay loamy	clay soil	0.25

Distance from river (m)	0-500	1,000	1,500	2,000	0.20

2.3.2 Suitability of Soil Type

Soils with very high or less infiltration are unsuitable for waste disposal because it may cause water or air contamination, while soil with moderate infiltration factor (such as Sandy clay loam) is suitable for siting dump site.

2.3.3 Suitability of slope

Drawing upon the valuable findings of Sener et al. (2011), the research establishes the threshold of a 10% slope as a robust guideline for identifying suitable sites for waste disposal. This criterion is integrated into the slope map assessment, forming an essential component of the decision-making process for selecting appropriate locations for waste dumping.

2.3.4 Suitability of land use/land cover

The land cover and utilization represent the combined natural and human-made features that become susceptible to various risks when situated near landfill sites. Reviewing existing literature, it was recommended to designate areas dominated by open terrain and grassy landscapes as suitable locations for the disposal of solid waste.

2.3.5 Suitable distance from main roads to solid waste dumping site

In adherence to the overarching principle, it is imperative that landfills are situated at a minimum distance of 50-100 meters from prominent highways, urban streets, or other transportation corridor.

2.3.6 Suitable distance from river to solid waste dumping site

In the study area, rivers and streams have been safeguarded by establishing a protective buffer zone extending 300 meters from their banks.

2.4 Final Suitability Map

Final suitability map forthe study area was developed using the spatial multi criteria decision making, aimed at combining various criteria and alternatives using Multi Criteria Decision Rules. In order to create a suitability raster for the location of dump sites in the study area, the Weighted Linear Combination (WLC) technique was used to arrive at single suitability index S from multi attributes.

III. RESULTS

3.1 Suitability Map for Waste Dump Site in Aba

3.1.1 Slope Maps

From the study area slope map (Figure 4) below, the slope map indicates high and low and reclassified (Figure 5) into four classes; N, S1 to S3, unsuitable, highly suitable, moderately suitable and less suitable. Hence, the study area is said to be more low than high according to the Figure 4.From the reclassified slope map below (Figure 5), colors were used to indicate the level of suitability. Blue represents S1 which means highly suitable, green represents S2 which means moderately suitable, yellow represents S3 which means less suitable and red represents N which means unsuitable.

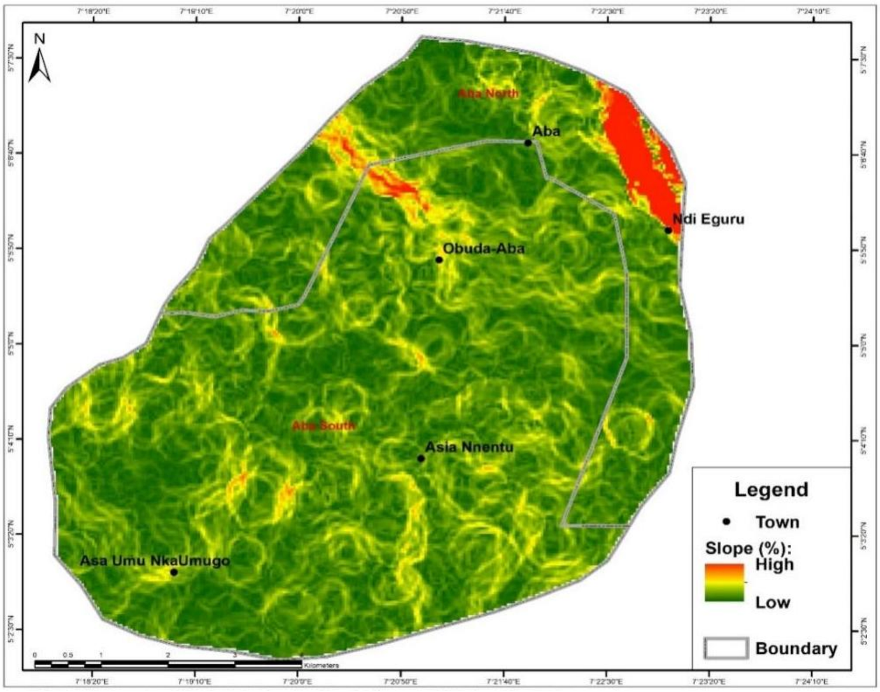

Figure 4: Slope Map for Locating Waste Susceptibility in Aba

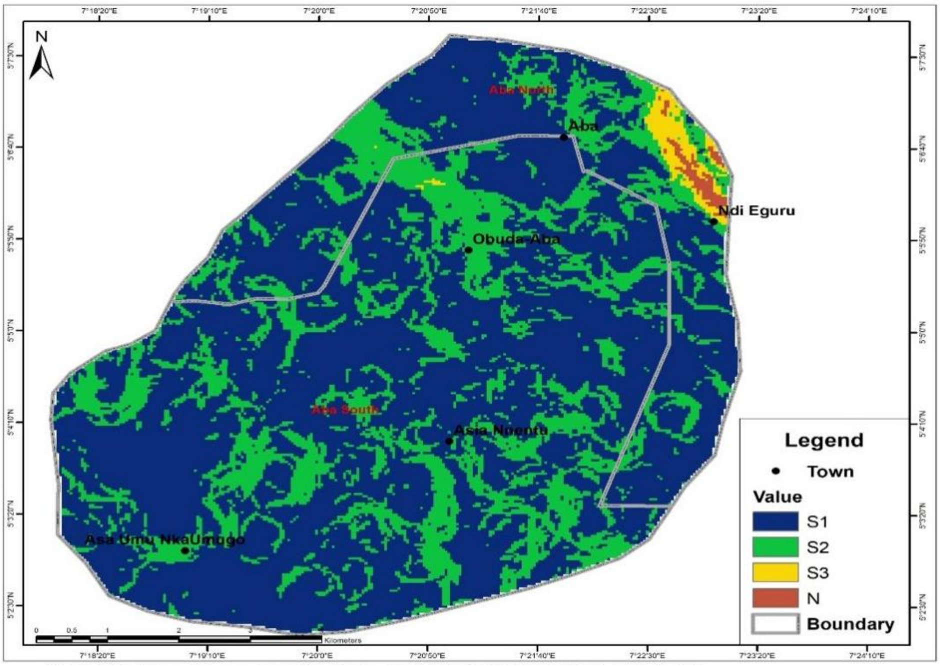

Figure 5: Reclassified Slope Map for Locating Waste Susceptibility in Aba

3.1.2 Road Proximity Map

In Figure 6, the study area road use colors and numbers to describe the suitability of road distance in selecting a dumpsite and reclassified into four classes (Figure 7). Brown represents N which means unsuitable, blue represents S3 which means less suitable, green represents S2 which means moderately suitable and yellow represents S1 which means highly suitable.

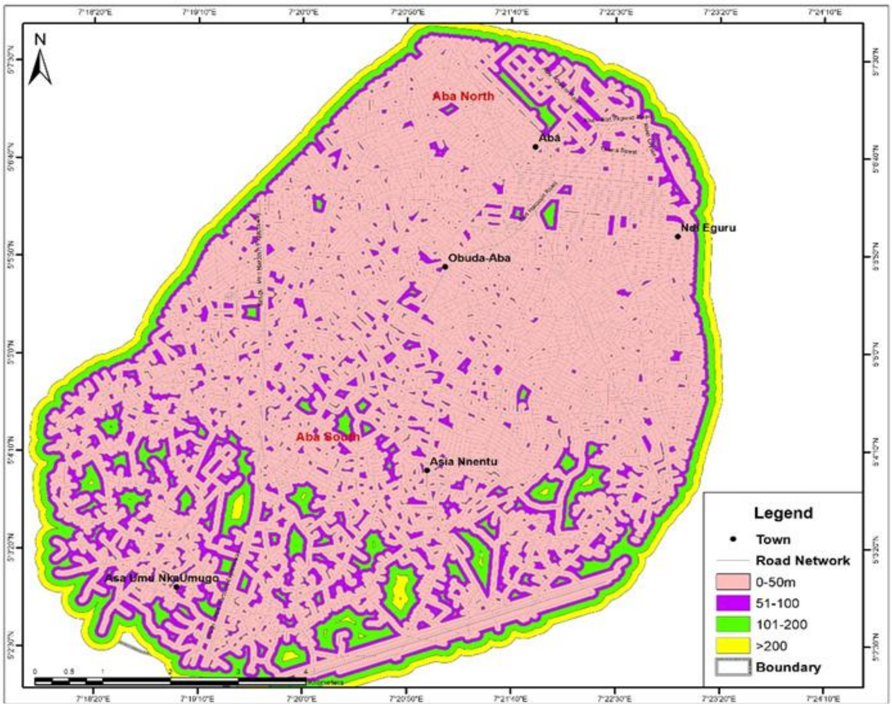

Figure 6: Road ProximityMap for Locating Waste Dump Site in Aba

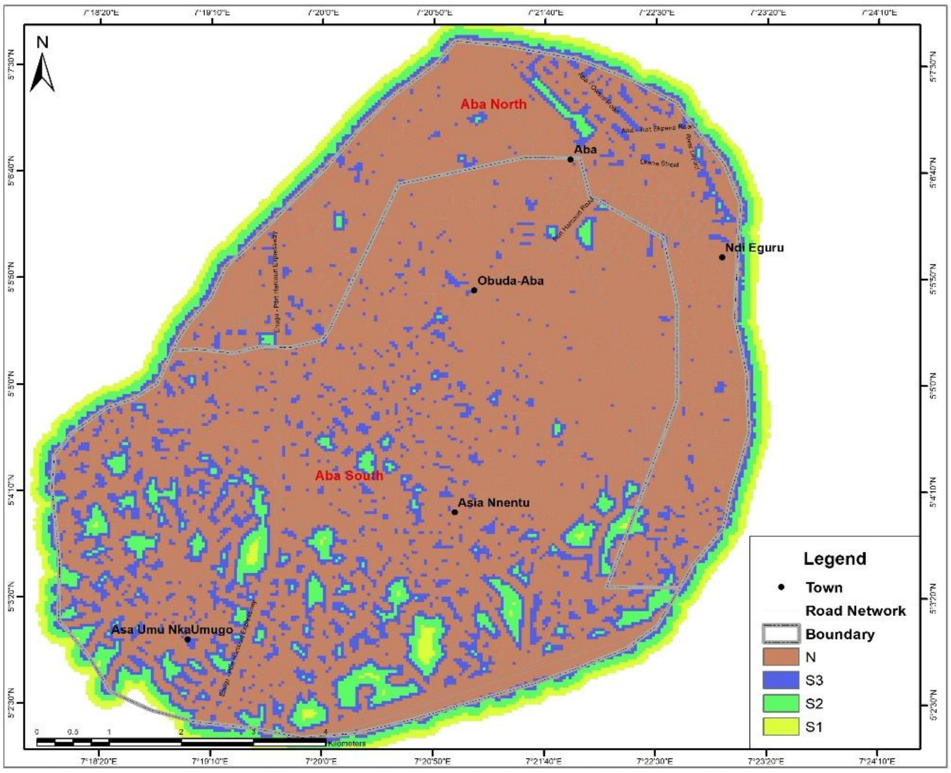

Figure 7: Reclassified Road Proximity Map for Locating Waste Dump Site in Aba

3.1.3 Soil Map

Figs 8 and 9, show the soil map of the study area and the reclassified soil map respectively. In the reclassified soil map, S2 indicates moderately suitable. This soil map study shows that all the communities in Aba South are moderately suitable for waste dump siting using soil as a criterion.

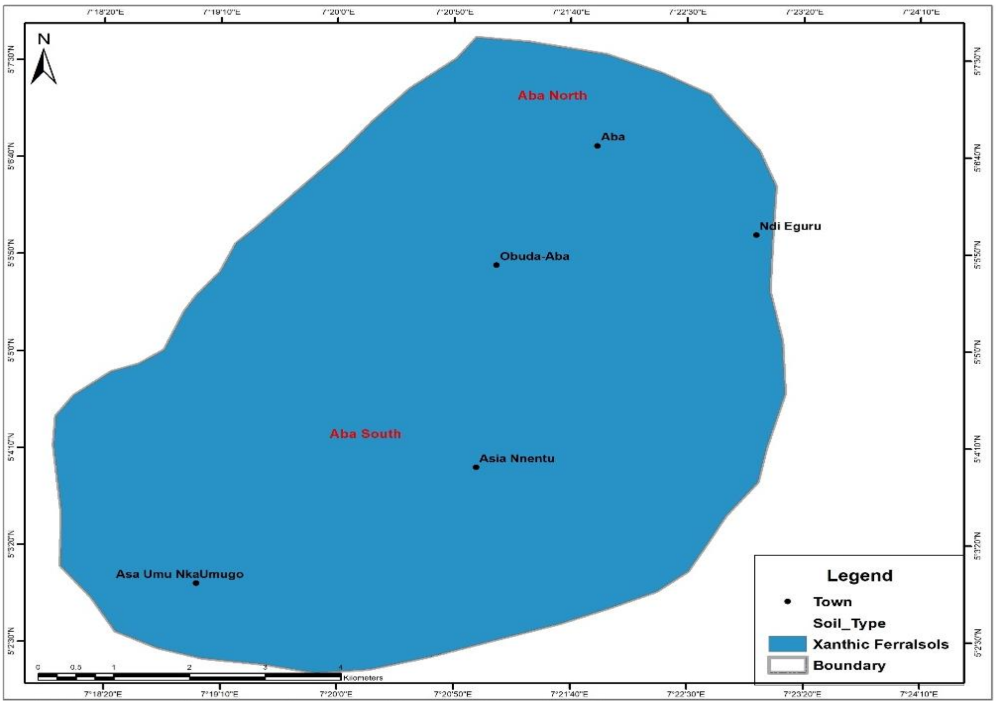

Figure 8: Soil Map for Locating Waste dump site in Aba

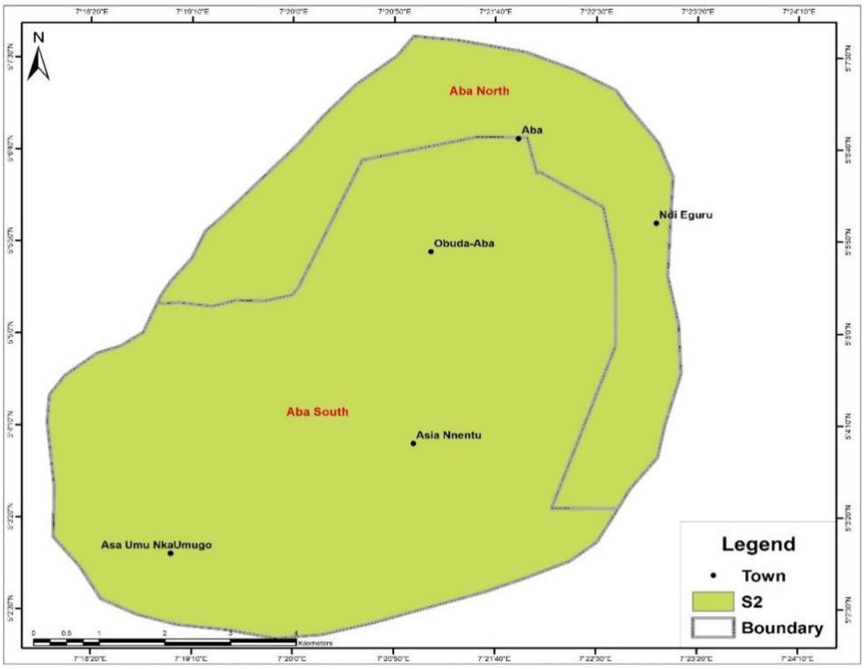

Figure 9: Reclassified Soil Map for Locating Waste Dump Site in Aba

3.1.4 Land-Use and Land-Cover Map

In the map (Figure 10), the orange color represents the built-up areas, while light green and dark green represents both light vegetation and thick vegetation respectively.

From the reclassified land use map, suitability analyses shows that S1 indicates highly suitable, S2 indicates moderately suitable, while N indicates unsuitable.

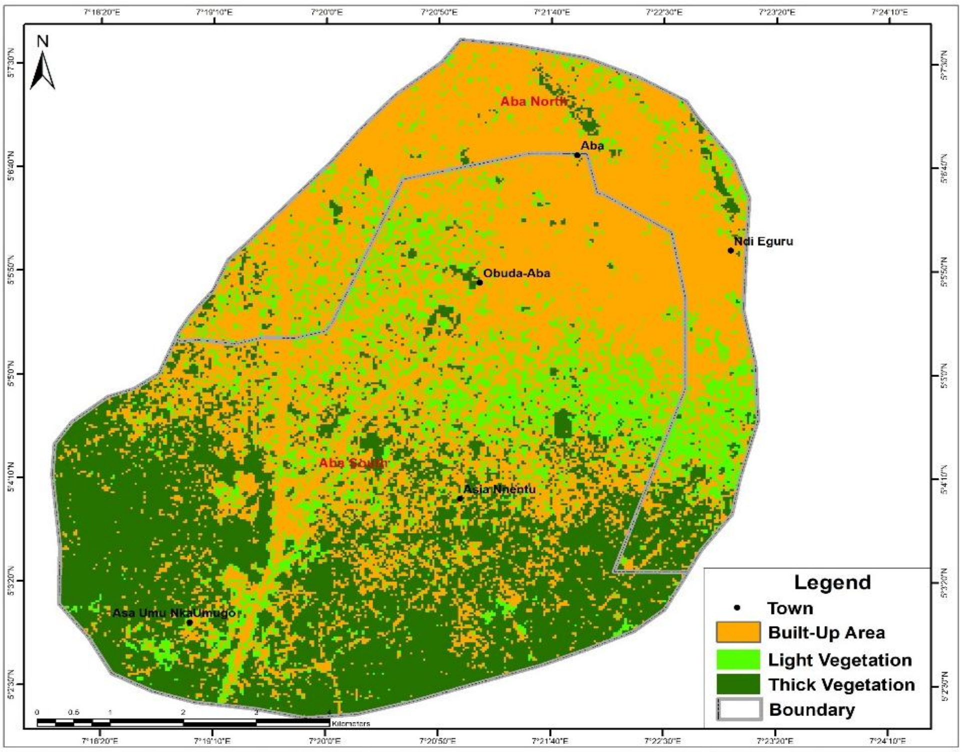

Figure 10: Land-Use and Land-Cover Map for Locating Waste Dump Site in Aba

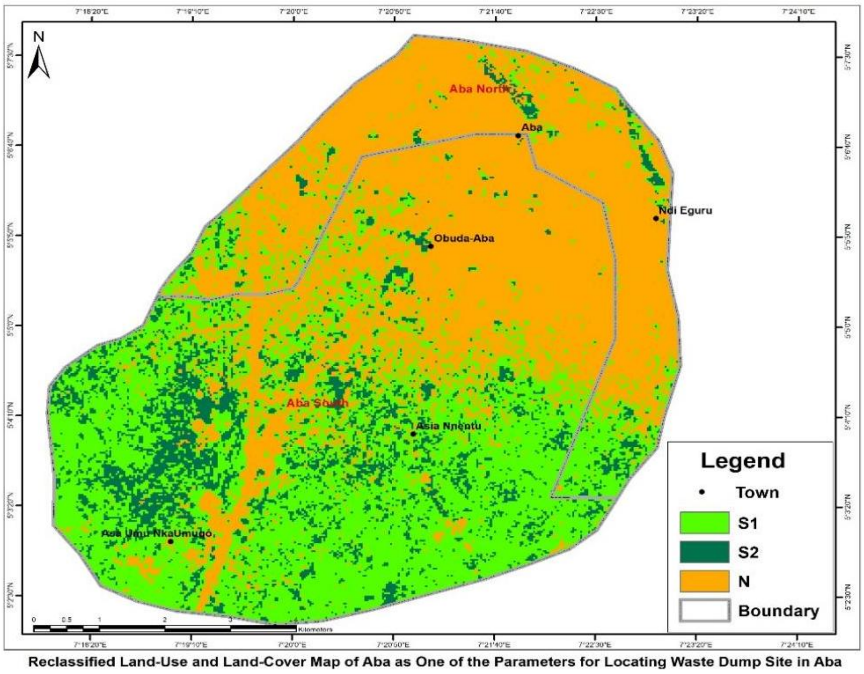

Figure 11: Reclassified Land-Use and Land-Cover Map for Locating Waste Dump Site in Aba

3.1.5 River Map

In the map (Figure 12), the blue colour represents 0.5km from dump sites, while red indicates 1km from dump sites, green indicates 2km distance away and purple represents 2.5km away from suitable dump sites.

From the reclassified river proximity map, suitability analyses shows that S1 indicates highly suitable (sky blue colour), S2 indicates moderately suitable (blue colour), S3 indicates less suitable (green colour), while N indicates unsuitable (brown colour).

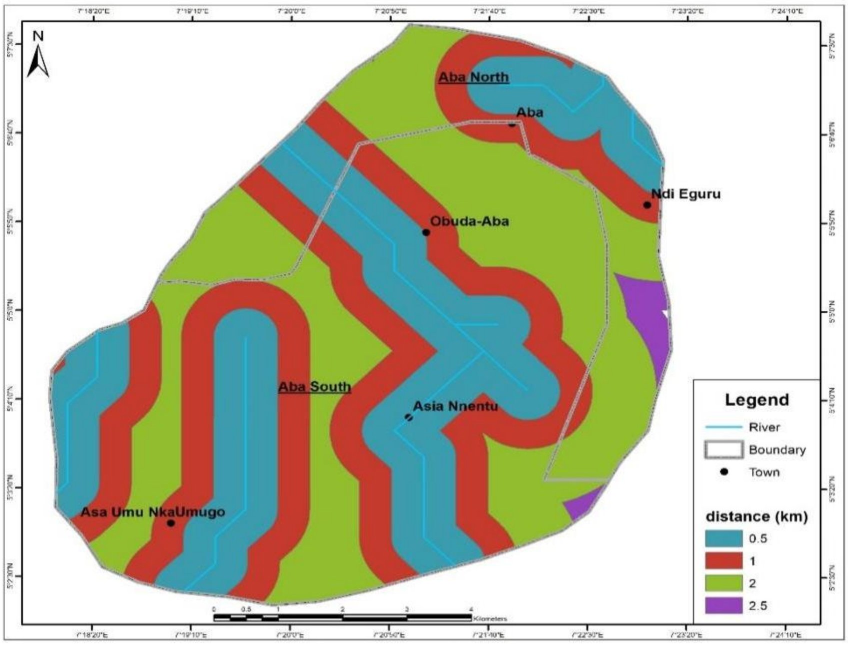

Figure 12: River Map for Locating Waste Dump Site in Aba

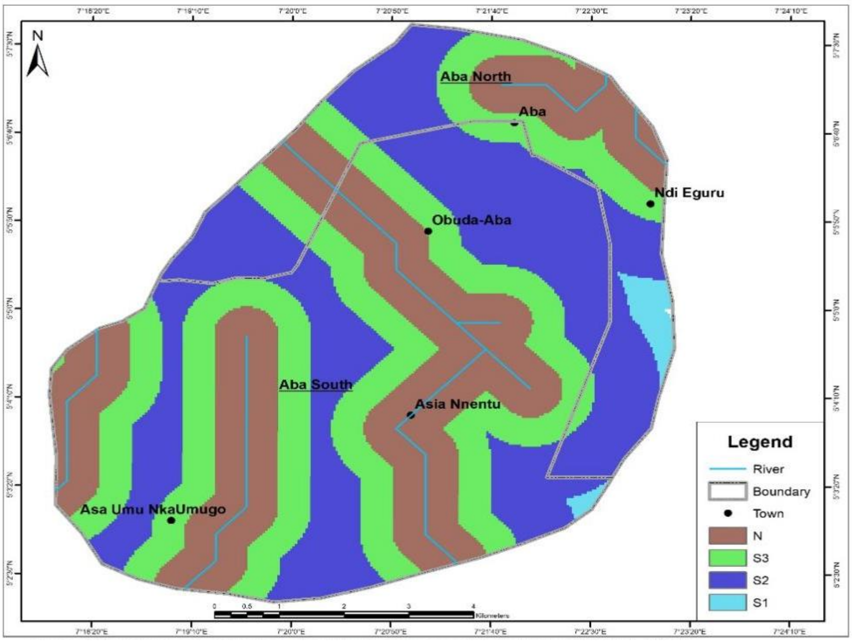

Figure 13: Reclassified River Map for Locating Waste Dump Site in Aba

3.1.6 Final suitability Map

Figure 14 shows the suitability map for Aba and the summary of the output is illustrated in Table 3. Figure 4 has four colors (classes): red, yellow, green, and ash. The most suitable area for solid waste dumping site is marked by red color shaded (S1). Out of the total area of the study site, about 26.97% fall under this category. The yellow color represents moderate suitable area (S2) and it covers an area of 10.84%. The area which is shaded by green color covers 10.59% representing less suitable class (S3) and the remaining 51.60% under unsuitability class (N) (Table 3). Suitable site are areas that pass all criteria for solid waste disposal adopted for this research among which the most suitable sites were identified.

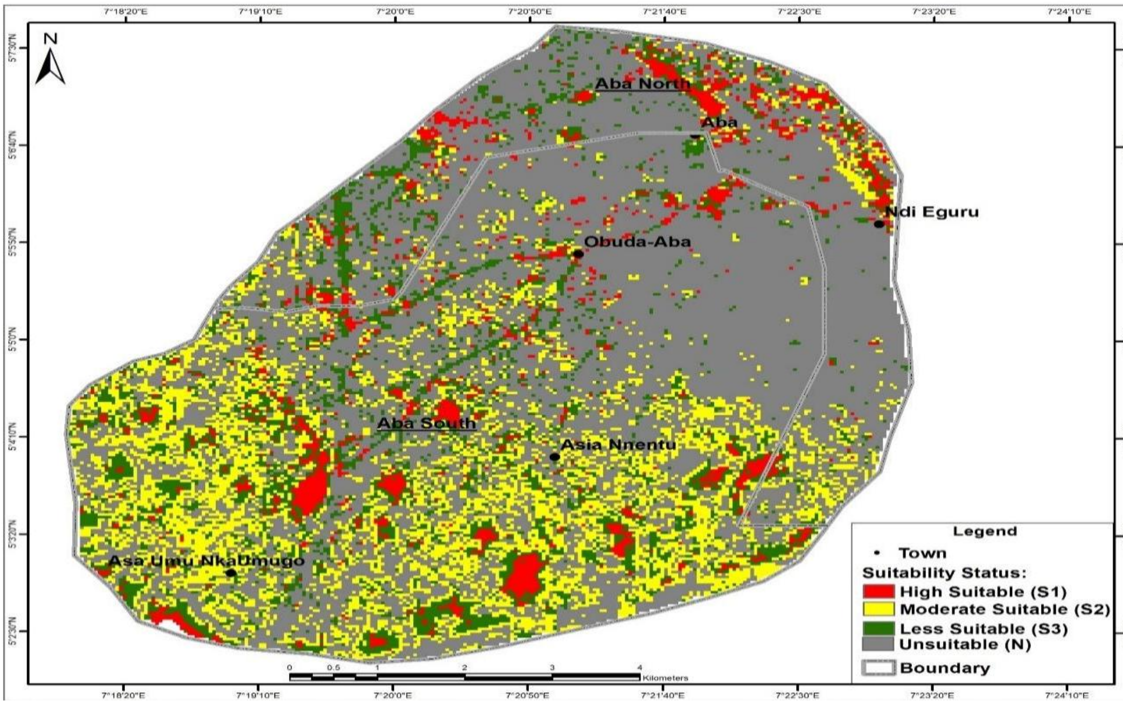

Figure 14: Final Suitability Index Map forAba

3.2 Map for Waste Suitability Site in Umuahia

3.2.1 Slope map

Figure 15 shows the slope map for Umuahia South. The slope map indicates high and low and reclassified (Figure 16) into four classes; N, S1 to S3, unsuitable, highly suitable, moderately suitable and less suitable.

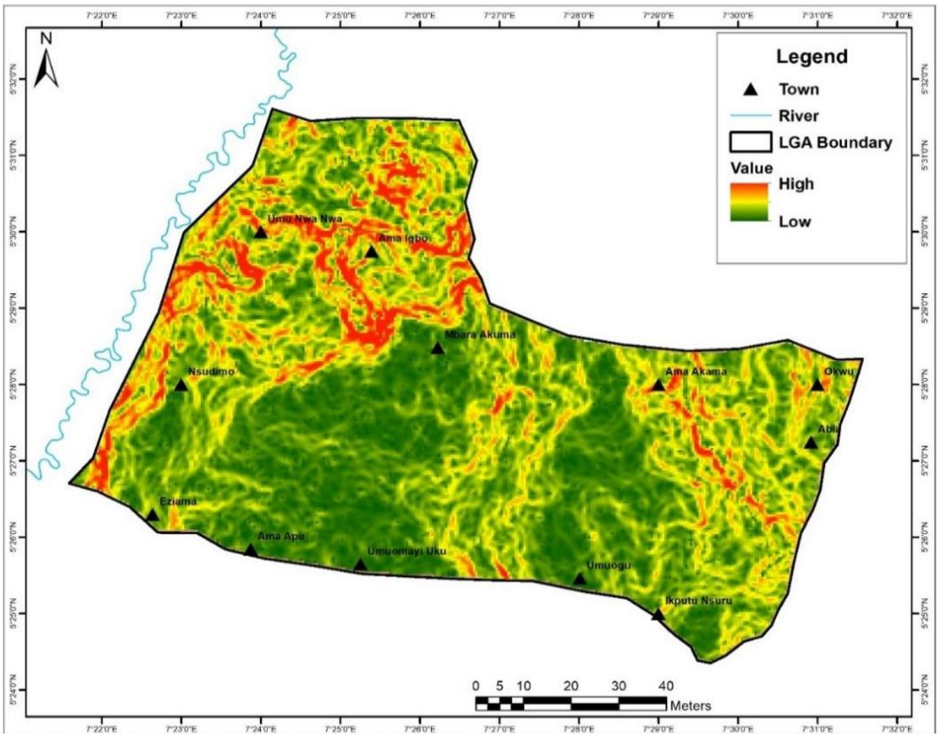

Figure 15: Slope Map for Locating Waste Dump Site in Umuahia

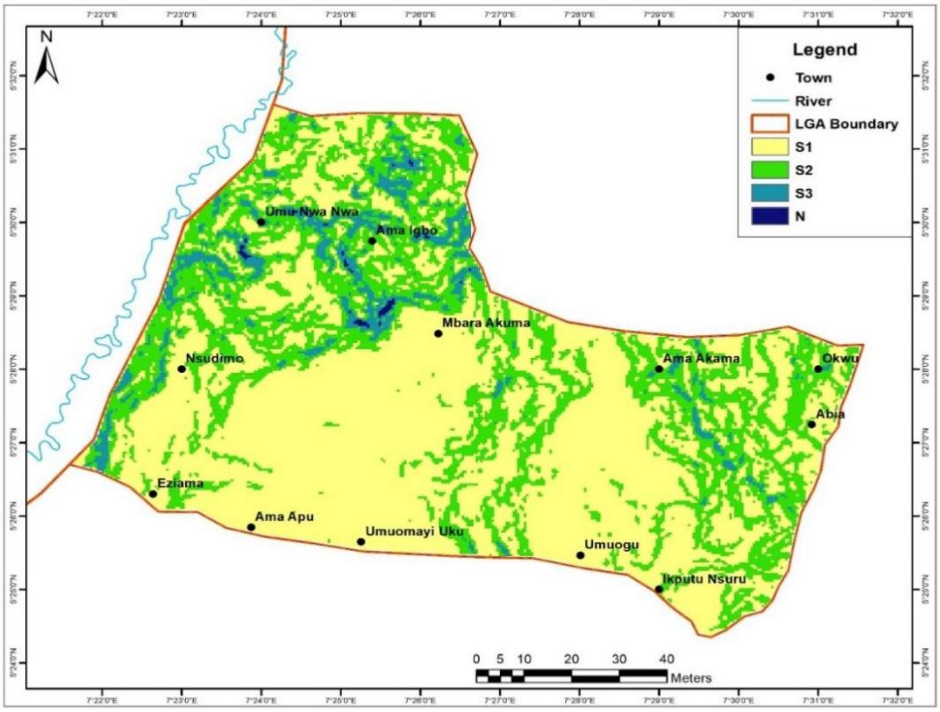

Figure 16: Reclassified Slope Map for Locating Waste Dump Site in Umuahia

3.2.2 Road Proximity Map

Figure 17 shows the road proximity map for the study area and Figure 18 shows the reclassified into four classes. The road proximity study here shows that almost all the communities in Umuahia South are highly suitable for dump site facility using road distance as a criterion.

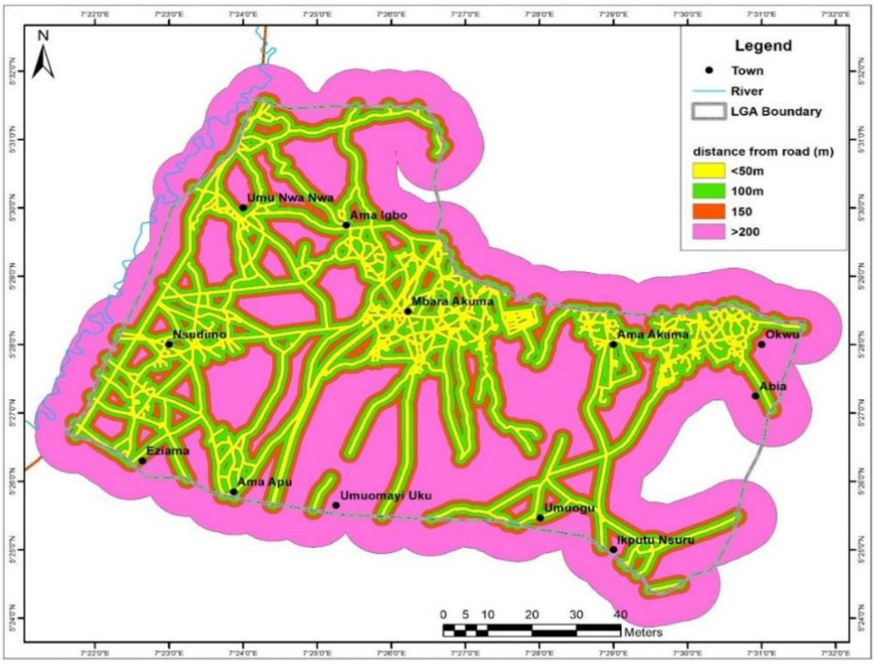

Figure 17: Road Proximity Map for Locating Dump Sites in Umuahia

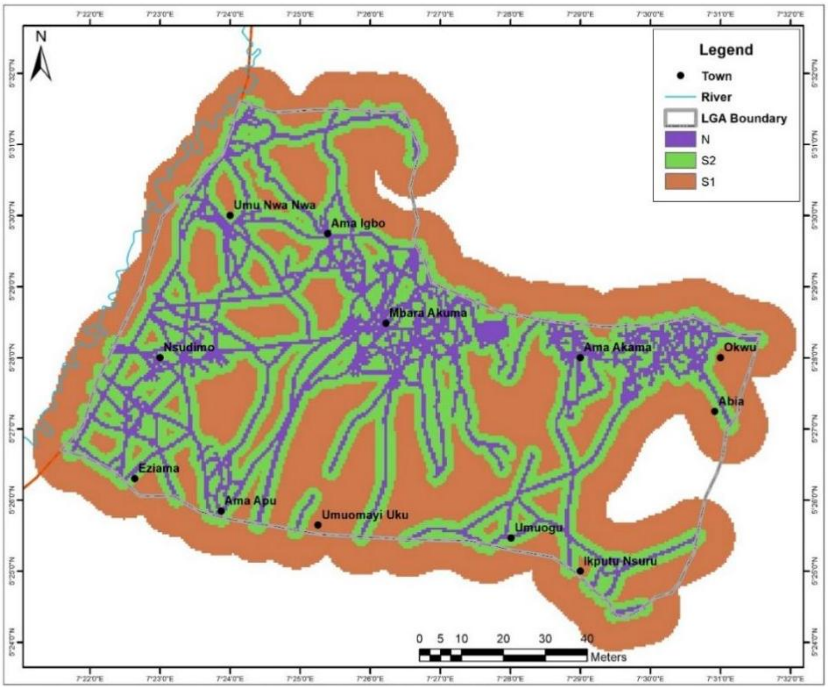

Figure 18: Reclassified Road Proximity Map for Locating Dump Sites in

3.2.3 Land-Use and Land-Cover

Figure 19 shows the land use and land cover map and Figure 20 shows the reclassified land-use and land-cover map. From the reclassified land use map, suitability analyses shows that S1 indicates highly suitable, S2 indicates moderately suitable, while N indicates unsuitable.

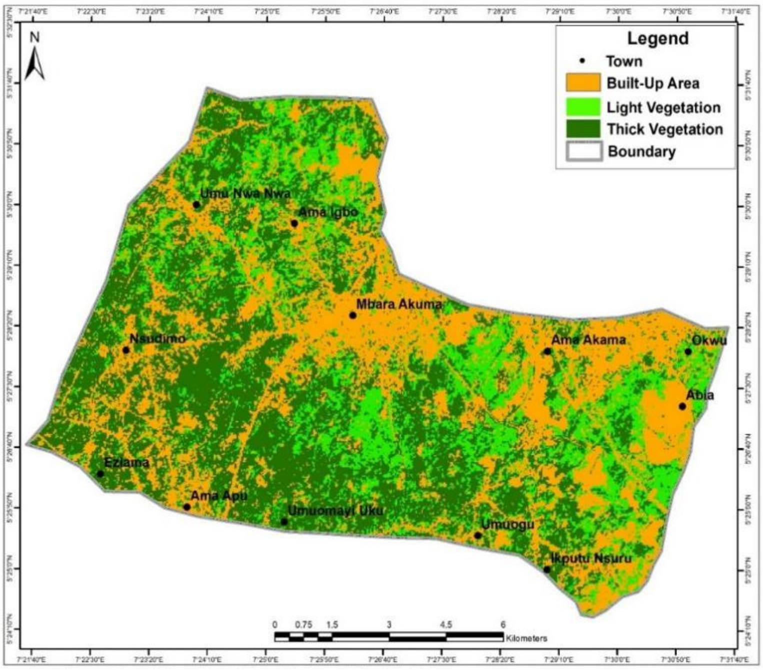

Figure 19: Land-Use and Land-Cover Map for Locating Dump Sites in Umuahia

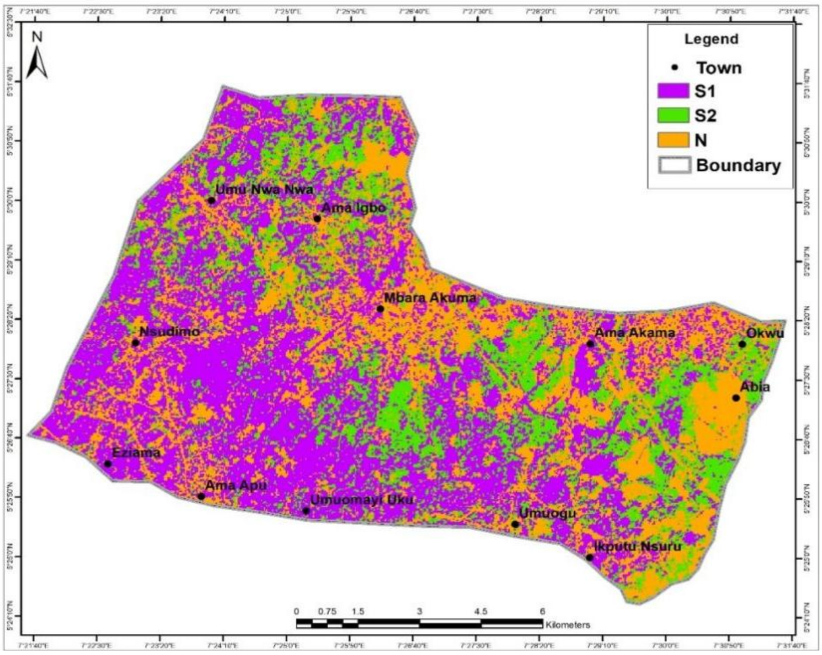

Figure 20: Reclassified Land-Use and Land-Cover Map for Locating Dump Sites in Umuahia

3.2.4 Soil Map

Figures 21 and 22, show the soil map of the study area and the reclassified soil map respectively. This soil map study shows that all the communities in Aba South are moderately suitable for waste dump siting using soil as a criterion.

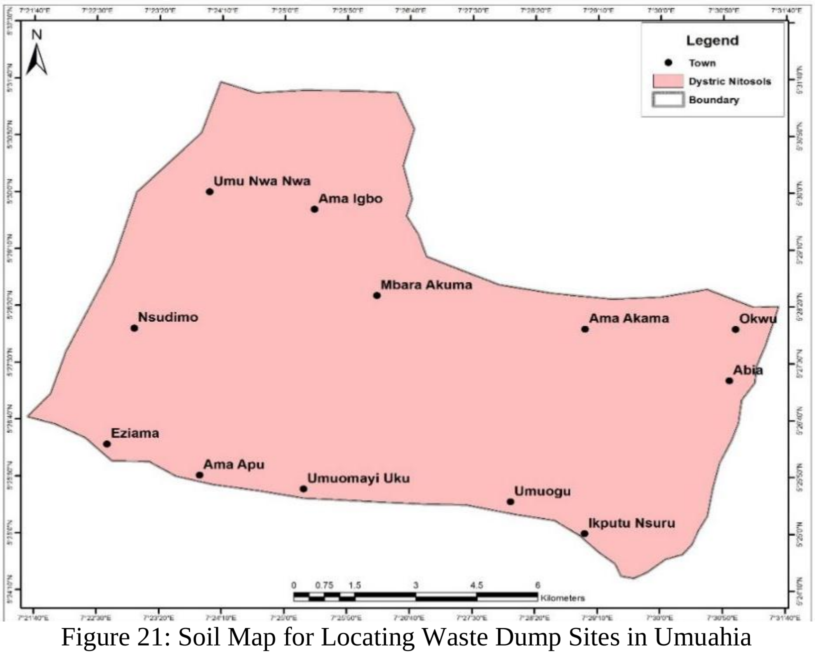

Figure 21: Soil Map for Locating Waste Dump Sites in Umuahia

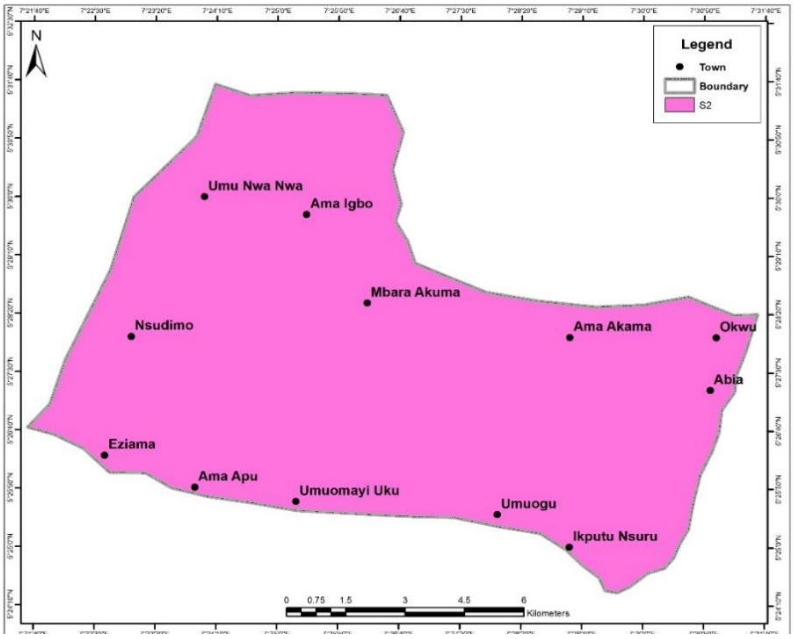

Figure 22: Reclassified Soil Map for Locating Waste Dump Sites in Umua

3.2.5 Final Suitability Map

The final suitability map for Umuahia South is shown in Figure 5. The most suitable area for solid waste dumping site is marked by orange color shaded (S1). Out of the total area of the study site, about 31.81% fall under this category. The purple color represents moderately suitable area (S2) and it covers an area of 1.24%. The area which is shaded by green color covers 60.53% representing less suitable class (S3) and the remaining 6.42% under unsuitability class (N) (Table 3). Suitable site are areas that pass all criteria for solid waste disposal adopted for this research among which the most suitable sites were identified.

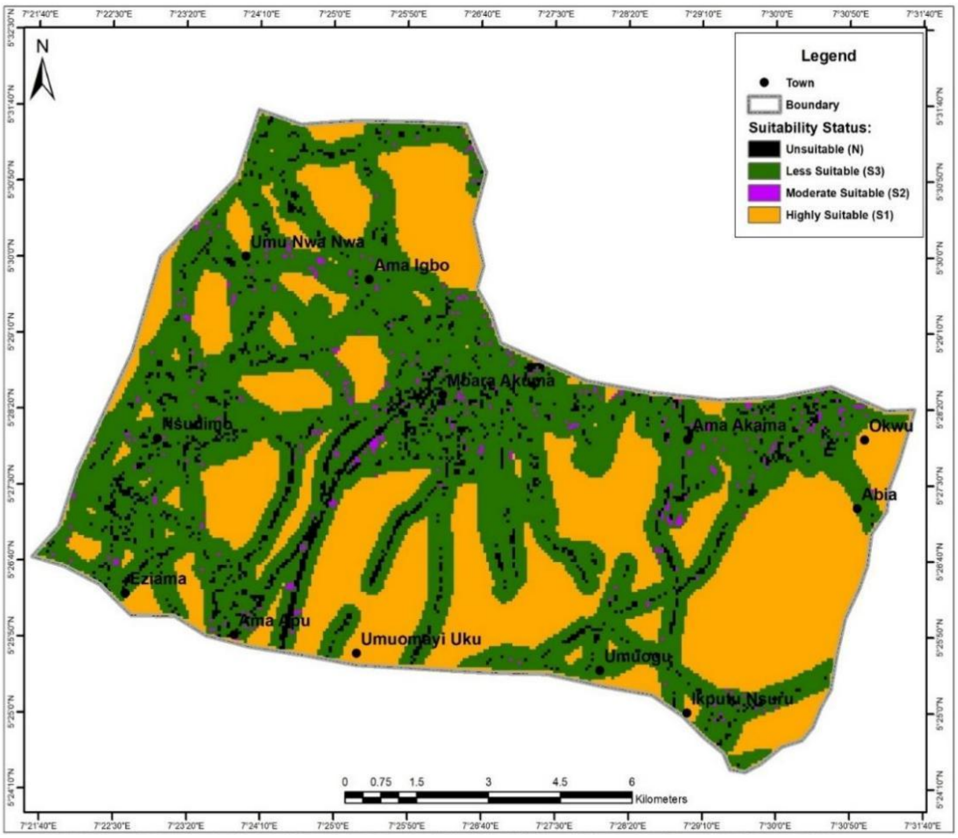

Figure 5: Final Suitability Index Map for Umuahia South

Table 3: Percentage of Suitability Classes

City	Level of suitability	Value	Percentage
Aba	N	Unsuitable	51.60
	S3	Less Suitable	10.59
	S2	Moderately Suitable	10.84
	S1	Highly Suitable	26.97
Umuahia South	N	Unsuitable	6.42
	S3	Less Suitable	60.53
	S2	Moderately Suitable	1.24
	S1	Highly Suitable	31.81

IV. DISCUSSION

Solid waste management in Nigeria is marred by so many challenges, among which is unavailability of adequate National Waste Management Plan and planning that does not take into consideration the local conditions of the area before setting up a dumpsite [3]. Choosing a suitable location for a landfill in an urban setting is a crucial aspect of urban planning due to its significant implications for both the environment and human well-being. In the present study, various elements were assessed to identify appropriate locations for solid waste disposal in Aba and Umuahia, to reduce any adverse effects on the environment.

The analysis of slope inclination reveals that nearly all the communities in Aba South exhibit a high to moderate suitability for the establishment of dump site facilities, as determined by slope as a key criterion. The incline of the land significantly influences a landfill's suitability, with gentle slopes considered more favorable and steeper ones less so. Generally, a consensus holds that a slope ranging from 4% to 10% is deemed highly appropriate for depositing solid waste [11]. Regions characterized by steep inclines possess a heightened susceptibility to both surface and groundwater contamination, rendering them unsuitable for waste disposal. Adequate slope is imperative for establishing an efficient drainage system, thereby preventing the seepage of wastewater and soluble substances from landfills into subterranean and surface water bodies. This investigation prioritizes areas with lower gradients as more viable for waste deposition, aligning with previous studies indicating that high-slope terrains pose a greater risk of pollution and are, consequently, ill-suited for waste disposal [4,12].

The findings in this study revealed that nearly all the communities within the Aba South region are markedly inappropriate for the establishment of waste disposal sites, particularly when road proximity is considered as a determining factor. Conversely, the results derived from the map for the Umuahia South area indicate that virtually all the communities are highly suitable for the placement of waste disposal sites, specifically when evaluating their proximity to roads. This suggests that Umuahia South offers more favorable conditions for the establishment of such sites in terms of road accessibility, in contrast to Aba South, where the majority of communities are unsuitable for this purpose. Land is a limited resource, and its prices are rising, making it a daunting task for municipal authorities to select a dumping site. To optimize transportation efficiency and, as a result, lower associated expenses, it is imperative to place the solid waste disposal site at an appropriate distance from the road infrastructure. This strategic placement ensures that waste can be transported with ease, ultimately leading to cost savings. According to Aderoju [13] a widely accepted principle prescribes that waste disposal sites should not be situated within 100 meters of significant highways, urban roads, or transportation routes.

The study identified only one soil type, referred to as ferralsols, within the research area, which stands out due to its high clay content, comprising approximately 45%. This clay-rich soil covers nearly 100% of the entire Aba South Local Government Area, making it a particularly desirable choice for this region. On the other hand, Umuahia South showcases the nitosols soil type. According to Food and Agriculture Organization [14], ferralsols, often known as red and yellow weathered soils, display their distinctive hues due to the buildup of metal oxides, especially iron and aluminum. These soils possess remarkably poor fertility, primarily stemming from meager nutrient stores and the strong retention of phosphorus by oxide minerals. Consequently, their potential for agricultural purposes is severely constrained. However, these characteristics make them a preferable choice for the selection of landfill sites. Certain soil characteristics play a vital role in enhancing the safety and economic viability of establishing and operating a landfill [4,15]. Additionally, when considering soil permeability, effective porosity, and workability, it becomes evident that specific features are of paramount importance.

In the region of Aba South, as depicted in the land use map, it is apparent that the built-up areas surpass the extent of light and thick vegetation. This finding implies that Aba South predominantly features built-up zones that are unsuitable for waste disposal, leaving only a limited amount of land suitable for this purpose. This scarcity of suitable sites can be attributed to the presence of the bustling Ariaria market and the substantial degree of urbanization in the area.

On the other hand, when examining Umuahia South using the land use map, it becomes evident that this region boasts a significantly higher proportion of vegetation compared to Aba South. This abundance of vegetation renders Umuahia South highly conducive to the establishment of waste disposal sites. This stark contrast in land use patterns between Aba South and Umuahia South underscores the influence of urban development and land characteristics in determining the suitability of areas for waste disposal.

The location of landfill or disposal sites must be carefully chosen to ensure they do not pose a threat to or cause pollution of nearby water surfaces. Siting of non-sanitary landfills in built-up areas increases the chance of groundwater. The proximity of landfill or disposal sites to surface water bodies can have dire consequences, resulting in adverse effects on water quality, water quantity, and the loss, disruption, or modification of aquatic habitats [15]. Therefore, it is of utmost importance to strategically plan and manage waste disposal to safeguard our invaluable surface water resources and the ecosystems they support.

By means of the MCDA, the findings, particularly in the context of Aba South, were quite revealing. According to the data presented in Table 3, it became evident that only a mere 26.97% of the entire Aba South region was found to be highly suitable for establishing a waste dump site. In stark contrast, over half of the area, precisely 51.6%, was unequivocally unsuitable for such a project. This stark contrast can be attributed to the substantial portion of the region that is densely populated and interwoven with road networks. These factors were identified as the primary obstacles to the establishment of a waste dump site in the area. For Umuahia South, the results indicate that 31.8% of this region is exceptionally well-suited for the siting of a dump site. These particular areas are characterized by their lack of dense urban development, unobstructed access to roads, and favorable slope conditions. In contrast, a mere 6.42% of the total land area is deemed unsuitable for such a purpose, while a substantial 60.53% falls into the category of being less suitable, thereby discouraging the consideration of these regions for the establishment of a waste dump site.

In the specific context of evaluating site selection criteria, the application of ArcGIS Multi-Criteria Decision Analysis (MCDA) played a pivotal role. This choice was made because MCDA methodology offers a structured approach to deconstruct complex decision problems into manageable components, allowing for a more in-depth examination of each aspect independently. By breaking down the decision-making process into comprehensible and distinct parts, MCDA enables a systematic assessment of the relative importance of various parameters. Subsequently, it seamlessly integrates these assessed components in a coherent and logical manner, culminating in a well-informed decision that takes into account the multifaceted aspects of the site selection process within the realm of environmental considerations [12,13,16].

V. CONCLUSION

These findings underscore the critical importance of site suitability assessments based on factors such as road connectivity, urban development, and slope conditions, which play a pivotal role in determining the feasibility of siting waste disposal facilities.

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