

Locating Suitable Solid Waste Dumping Sites using Remote Sensing and GIS Techniques in Aba Municipal, South-Eastern Nigeria

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ABSTRACT

In most cities of Nigeria, indiscriminate solid waste dumping sites have taken over roadways, clogging drainage systems and slowing traffic flow. Conditions arising from indiscriminate waste disposal can lead to contamination of the environment and outbreaks of diseases. The main objective of this study was to examine the existing and predict potential suitable areas for solid waste dumping in Aba municipal in South-eastern Nigeria. The data used for this study were Landsat image; elevation map, ground control point of existing solid waste dumping sites, and topographical sheets of the study area. The maps were prepared by overlay and multi-criteria thresholds of roads, settlement, slope and distance to stream, We found that that 65% of the solid waste dumping area located close to roads and clustered in densely populated areas around the city center The final predictive suitability map for locating solid waste dumpsites indicated that, 11.35sqkm (19.41%) is not suitable, 26.47sqkm (45.25%) is less suitable, 16.17sqkm (27.65%) is moderately suitable and 4.5sqkm (7.69%) is highly suitable for Solid waste disposal. The potential most suitable areas for solid waste dumping sites fall about 5000m west of Ariaria market and 10,000m south east of Umu Mba in Aba Municipal.

INTRODUCTION

The Basel Convention defines waste as substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law (Basel, 2019). Solid waste is any nonflowing substance that is relatively undesirable or unuseful as a result of human and natural activities. Some of these solid waste products include automobiles, electrical appliances, and other inorganic materials which are not destroyed but are discarded when they are no longer in use. Cities in general absorb a great deal of materials which are transformed into useful purposes while a lot will always be left as waste. As a result of increased urbanization and industrialization, most of these cities have a higher concentration

of waste than their systems can absorb (Grimm et al., 2008; Wang et al., 2019). The goal of solid waste management is to guarantee that waste is collected and disposed of in a way that is safe for humans, animals, and ecosystems. Waste management in industrialized countries has evolved into material flow management, which entails careful processing of raw materials, reduced greenhouse gas emissions, and environmental protection.

In developing countries like Nigeria, individuals and businesses dispose of the majority of municipal solid waste at designated dumping points (Abila & Kantola, 2013; Ogwueleka, 2009). Most of the time, these spots are left unattended. These waste products are collected once or twice a week by government-appointed workers and deposited in landfills, where they are burnt or buried (Ogwueleka, 2009). A detailed examination of the streets of Aba municipal exposes how solid waste collection points have taken over the majority of the roads, clogged drainage systems, and slowed traffic flow unsanitary conditions can result from improper municipal solid waste disposal, which can lead to environmental contamination and vector-borne disease outbreaks.

Due to low recycling and reuse options in developing countries, the proportion of municipal solid waste (MSW) that ends up in landfills is expected to be higher (Aboyade, 2004). This means that, despite the fact that dumpsites are the least favoured alternative for long-term municipal solid waste (MSW) management, they will continue to exist for a long time. There is ample evidence that residential areas in many cities in developing countries face a variety of environmental difficulties arising from solid waste disposal in landfills (Leton & Omotosho, 2004; Wafi et al., 2019).

Available data from the Abia State Environmental Protection Agency on the amount of solid waste generated in Aba between 2017 and 2020 reveals that the waste volume varies depending on their sources. The data also reveals a strong link between municipal activities and the amount of solid waste generated. For example, between 2017 and 2019, there was an increasing trend in the general volume of waste generated (Table 1), but by 2020, there was a 45 percent drop, which could be due to the government's total lock-down of economic activities during the peak of the Covid 19 pandemic.

Table 1. Solid Waste Generated in Aba between 2017 and 2020

Origin of Waste\ Year	2017	2018	2019	2020
Mining	11112	10112	14338	9233
Industry	800413	1434221	1723944	767 233
Agricultural\ Forest	100423	153 221	400313	334, 443
Construction and Demolition	200348	300123	398226	145 334
Household, commercial and Government Bodies	1322133	1441372	1568385	876221
Waste Water Treatment	25330	25312	78,331	20113
Total(Tonnes)	2,459,759	3,211,140	4,183,537	905,567

Allocating a solid waste dumping location is a tough task that requires the consideration of proximity to human settlement and other infrastructural factor (Khan & Samadder, 2014; Yukalang et al., 2018). The use of remote sensing and GIS techniques to detect proximity-based variables such as distance to roads and settlements impacts the appropriateness of solid waste dumpsites is required for the generating spatial models needed for site design. Geographic Information Systems (GIS) have been used in conjunction with multicriteria criteria thresholds to produce maps of the most suitable sites for solid waste collection (Bilgilioglu et al., 2021; Marceta et al., 2021; Wang et al., 2019). One such threshold is documented in the Environment Protection Agency Landfill Manual (Vallero & Blight, 2019). The EPA guideline establishes a minimal standard for locating municipal solid waste sites.

Solid waste heaps continue to grow in Nigerian cities on a regular basis, and the sites have become breeding grounds for flies and other vectors, posing health risks, blocking traffic, and degrading the environment. Aba Urban has unquestionably experienced population expansion, resulting in increases in residential, commercial, industrial, and other activities. These operations, together with settlement, will undoubtedly have an impact on solid waste generation and disposal. The purpose of this research is to assess the suitability of solid waste dumping sites in Aba, Abia State, Nigeria. The objectives include: to report on the location of existing collection points, determine their acceptability, and propose suitable sites for waste dumping in Aba municipal.

MATERIALS AND METHODS

The study area

Aba is the largest commercial city in South-Eastern Nigeria and is located between latitudes $5^{\circ} 2' 30''$ N to $5^{\circ} 8' 00''$ N and longitudes $7^{\circ} 20' 00''$ E to $7^{\circ} 26' 00''$ E (Figure 1).

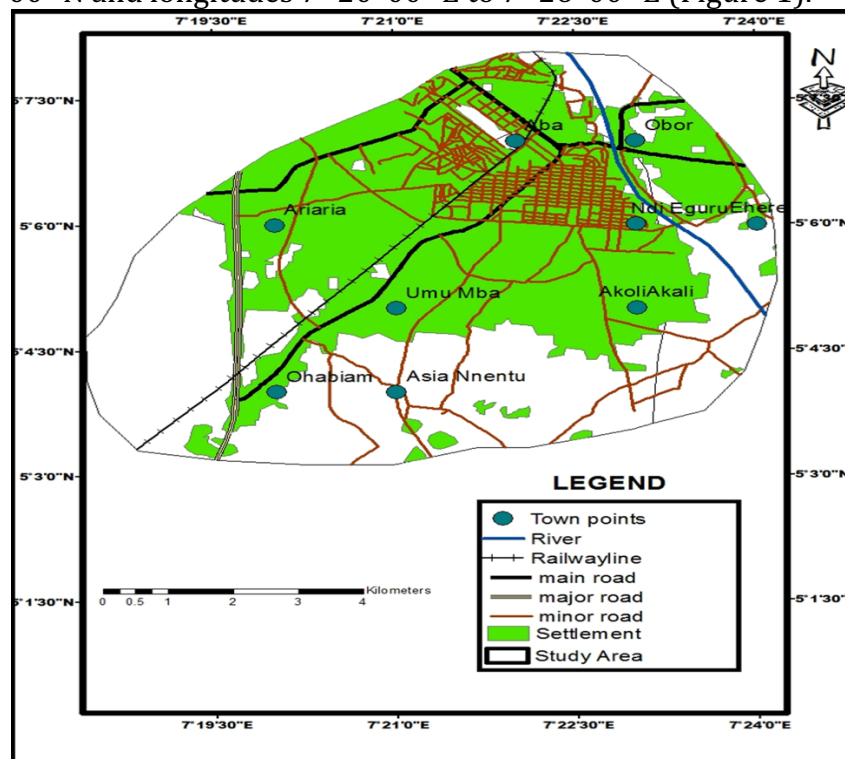


Figure 1. The Study Area

Rainfall is relatively constant throughout the year, with an annual total of 2000mm-2300mm with an average daily temperature of 28°C in the dry season and 24°C in the wet. The vegetation in this area belongs to the rainforest zone. The trees in this area are exceptionally tall, reaching a height of roughly 30 meters. These trees are evergreen and have intertwined branches that form canopies. The municipal soil is largely sandy and loamy, as is typical of the coastal areas. The Geology of Aba is primarily made up of coastal plain sand with relatively flat topography.

Data

Field surveys and observation were used to gather the primary data. These datasets included surveying and collecting coordinates of existing waste collection sites, as well as ground trothing remotely sensed data. Informal interviews, field trips, and firsthand inspections of dumpsites were all part of the data collection process. Data on elevation and coordinate points of existing solid waste collection points were collected using the Global Positioning System (GPS). Landsat TM satellite image, covering the study area (188/056) for February, 2016 sourced from the United States Geological Survey (USGS).

Feature layers such as highways and water bodies were digitized using ArcGIS online, while soil and geology (1:50,000) were digitized from 1972 maps from the Abia State Ministry of Environment. Elevation matrices were created using data from the Shuttle Rader Topography Mission (SRTM) Digital Elevation Model (DEM) collected in February 2000. Table 2 shows the specifics of the data gathered.

Table 2. Nature and sources of data used

Data	Source	Time	Resolution	Application
Landsat 8	USGS	2018	30M	To extract the Land-use types.
SRTM (Shuttle Rader Topography Mission)	USGS EROS Archive		1 arc-second	To extract the slope
Administrative Map	Open street map	2020		To extract the road network
GPS coordinates	Field work	2020		For the geometric data of the existing solid waste collection sites
Geology Map	Abia State Ministry of Environment	1975	1:50,000	To digitize and extract the geological map of Aba Municipal
Soil Map	Abia State Ministry of Environment	1975	1:50,000	To digitize and extract the soil map of Aba Municipal

Image processing and classification

Four ground control points at WGS 1984 and UTM zone 32 were used to register the Landsat TM image. The following parameters were used in the registration process: The effect of several atmospheric conditions (pressure, air temperature, humidity, aerosols, and solar zenith angle.) was corrected using an absolute atmospheric correction model implemented in Arc Map on the Landsat-8 imagery. A subset covering Aba was extracted from the full scene of the imagery.

Image classification procedure was undertaken to categorize all pixels into land cover classes using supervised classified method. Following the classification, 80 samples were chosen at random to test the classification accuracy using the Kappa matrix. Overall, 75.75 percent of the predictions were correct.

Method of Data Analysis

The datasets collected from the study area were evaluated to determine the suitability of the existing waste dumpsite and to suggest alternative locations. GIS, multi-criteria based land use/land cover, road network; slope, water bodies, and settlement were used to find the most acceptable solid waste disposal sites in the study area. These records were chosen for waste collection point suitability based on the EPA landfill manual of 2006 (Table 3). Weighted overlay sum techniques were utilized to evaluate the appropriateness of the selected criteria. Each of the input data is given a weight influence based on its importance, and the results are then multiplied by each of the constraints one by one.

Table3: Factor criteria table derived from EPA landfill manual

Criteria	Unsuitable	Less suitable	Moderately suitable	Highly suitable
Distance to water body	0-160m	160m-480m	480m-960m	>960m
Slope	15° -20°	10° -15°	5°-10°	0°-5°
Distance to road	100m	200m -500m	500m-1500m	>1500m
Distance to Residential	0 -250m	250m-450m	450m-550m	550m-700m

For each layer, Euclidean distance output raster was generated to show the measured distance from the road network, residential area, and water body to the waste collection points. Next, the slope map and Euclidean distances for each layer were reclassified and ranked from 1 (least suitable) to 10. Moreover, the values of classes between levels were assigned numeric values inside each map layer through reclassification to build a single ranked map of probable solid waste collecting areas. Because having all metrics on the same numeric scale provides them equal weight in choosing the most appropriate locations, all data map layers were reclassified into new numeric values or scored as '4 to 1' to indicate the distinctions across suitability zones. These tasks were performed in Arc GIS.

RESULTS AND DISCUSSION

Assessment of the Existing Waste Collection Points

Figure 2 depicts the existing solid waste collection points. An examination of the overlay reveals that 65 percent of the Waste Collection points are along roadways and grouped in heavily populated regions surrounding Aba municipal's city core. During the rainy season, the nuisances are at their worst, as the area becomes overrun with flies and insects.

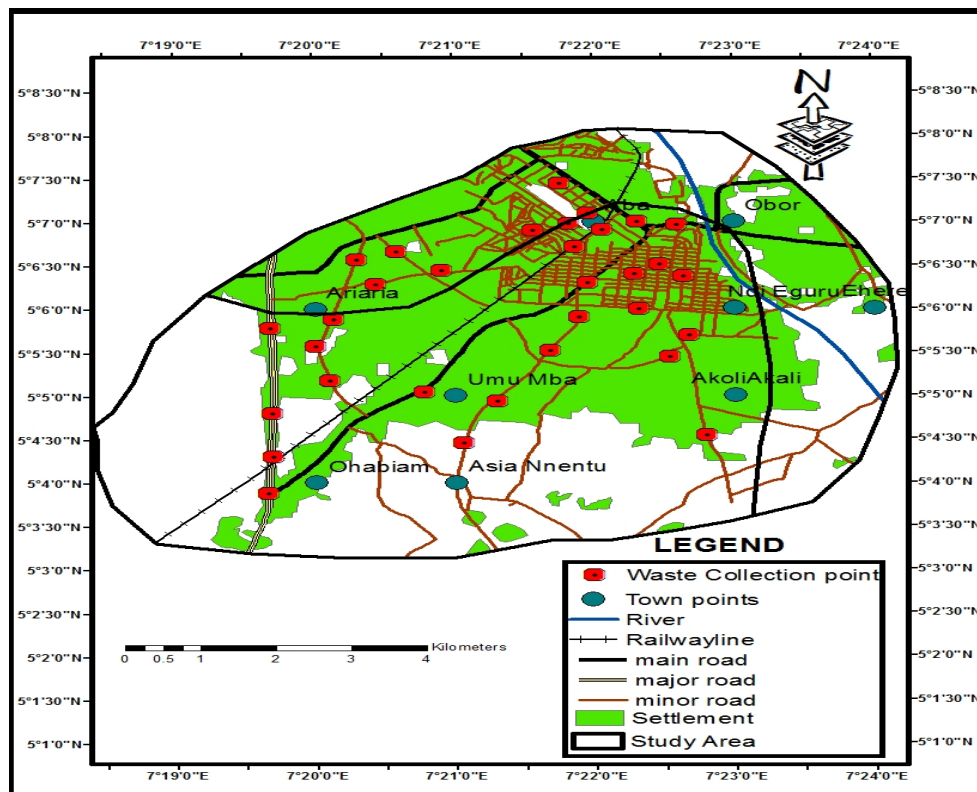


Figure 2: Results of the Waste Collected Points Generated During Fieldwork

Suitability Results of solid waste collection site in Aba Municipal

Land use/land cover

Aba is depicted as a typical urban area on the land cover map (Figure 3) obtained from the categorization of the Landsat image. This is indicated by 64 percent of settlements/built-up area, 21% of vegetation, and 15% of agricultural land. Following a review of the literature, it was determined that selecting an area that was occupied by bare and grassy fields for solid waste disposal was the best option. The research area's bare land is mostly surrounded by built-up. Worse, the agricultural land is located in close proximity to highly inhabited areas.

As a result, highly vegetated land cover types appear to be the best choice for solid waste disposal and collection in Aba. As a result, given the nature of Aba's land use, there should be no garbage collection sites within the municipality; instead, solid waste should be dropped and processed at densely vegetated land cover types simultaneously

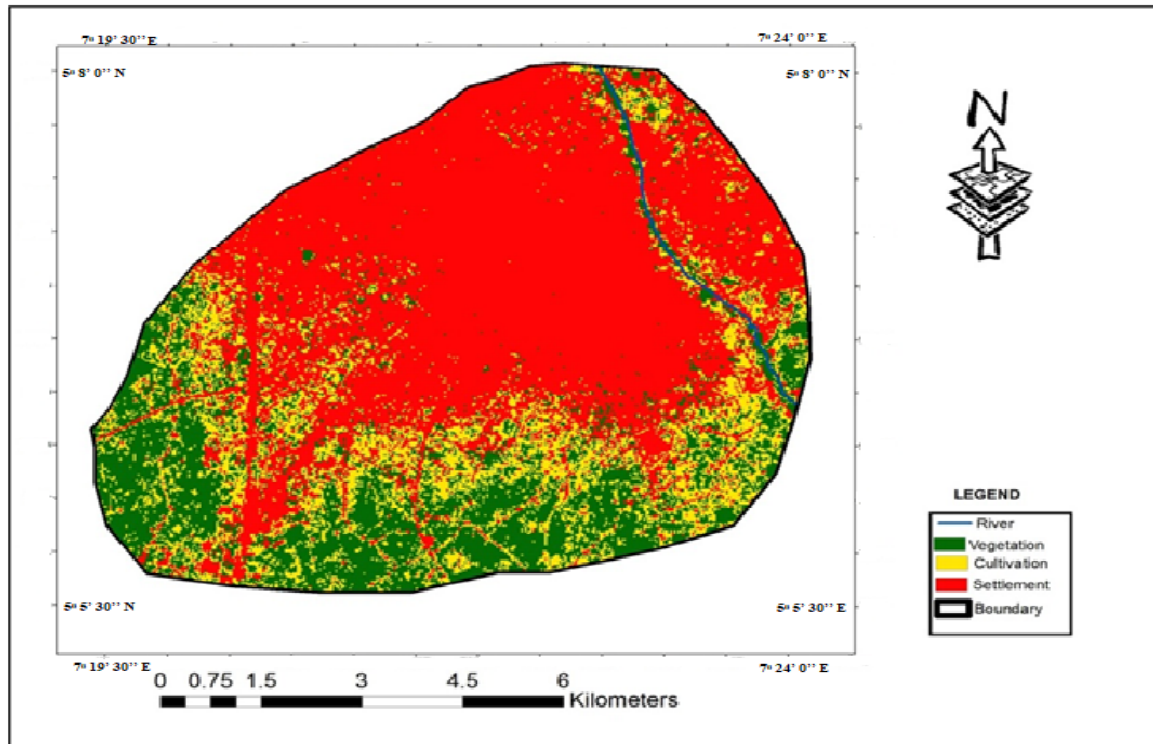


Figure 3: Land Cover Map of The study Area

Roads

As a general concept, the waste collection area shall not be located within 100 m of any major highway, city streets, or other transportation routes. Solid waste dumping sites must be located at a suitable distance from the roads network to facilitate transportation and consequently to reduce relative costs. The study preferred a buffer above 2000 m distance from main roads by referring to the EPA manual. The reclassified result (Figure 4) further indicated that only 2.6 km² representing less than 5% of the total area, is suitably located. Other results showed that 39.23km² (greater than 70%) is unsuitable for waste collection.

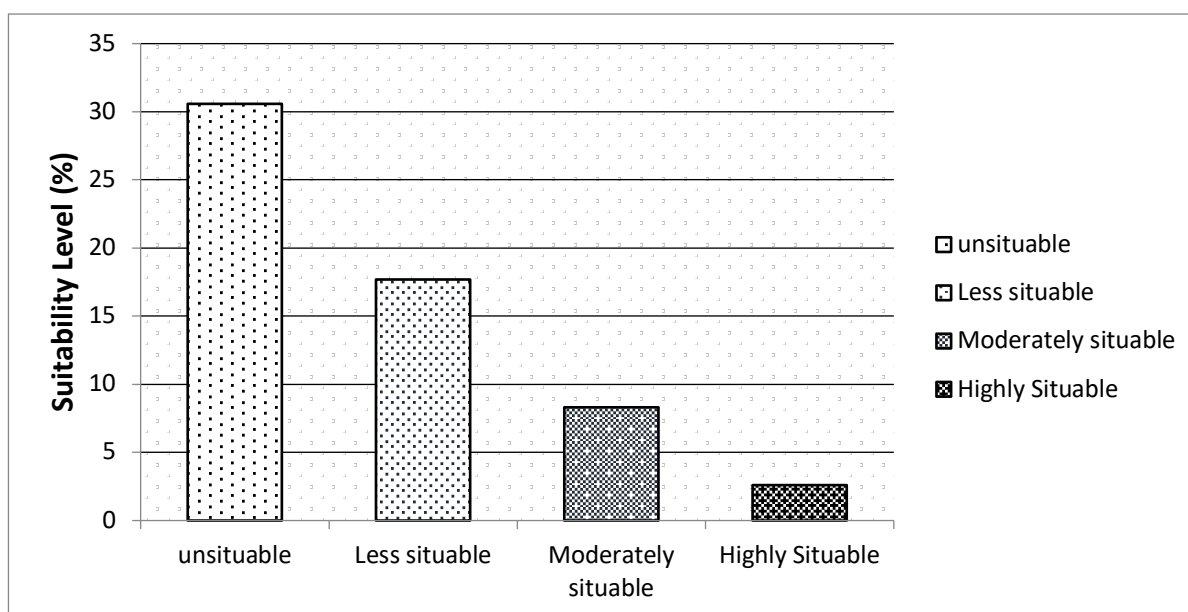


Figure 4. Roads Suitability Levels for Solid Waste Collection in Aba Municipal

Slope

Slope provides a good drainage system needed to prevent leaching of waste water and other soluble from dumpsite into underground and surface water. Lower slopes are highly suitable than the land with higher slopes for waste disposal and collection. Different research shows that areas with high slopes will have high risk of pollution and potentially not a good site for dumping. The slope suitability class indicates that 5km² about 75% of the study area is highly suitable for waste collection. About 2.3km² of the area is moderately suitable while the remainder is not suitable. Hence, topography is not a constraint of waste collection in the study area.

Settlement and streams

Like other criteria, settlement areas were classified according to their suitability. The study considered the reclassified distances from the settlement as unsuitable from 0 to 2500m, less suitable between 2500m and 4500m, suitable from 4500m to 5500m, and most suitable from 5500 to 7000m for the urban area. These classes showed that of the area coverage, 39.23 km² (unsuitable), 10.82km² (less suitable), 7.09km², (moderately suitable) and only 3.89km² (suitable). The Euclidean distance of 2000m. was applied as the most suitable distance from stream. From the result of the analysis, the most suitable distance from stream has area coverage of 9.55km²(14.78%) which implies that the farther the distance, the more suitable it becomes.

Overlaying and identifying suitable sites

The site selection for a solid waste disposal dumping site involves the comparison of different options based on environmental, social, and economic impact. Hence, based on experience and likely impact on the surrounding environment, different weights were assigned to all parameters. The larger the weight, the more important is the criterion for the overall utility. The weights were developed by multiplying each raster by their given weight and summing them together. The final suitability map for locating solid waste dumpsites is seen in Figure 5.

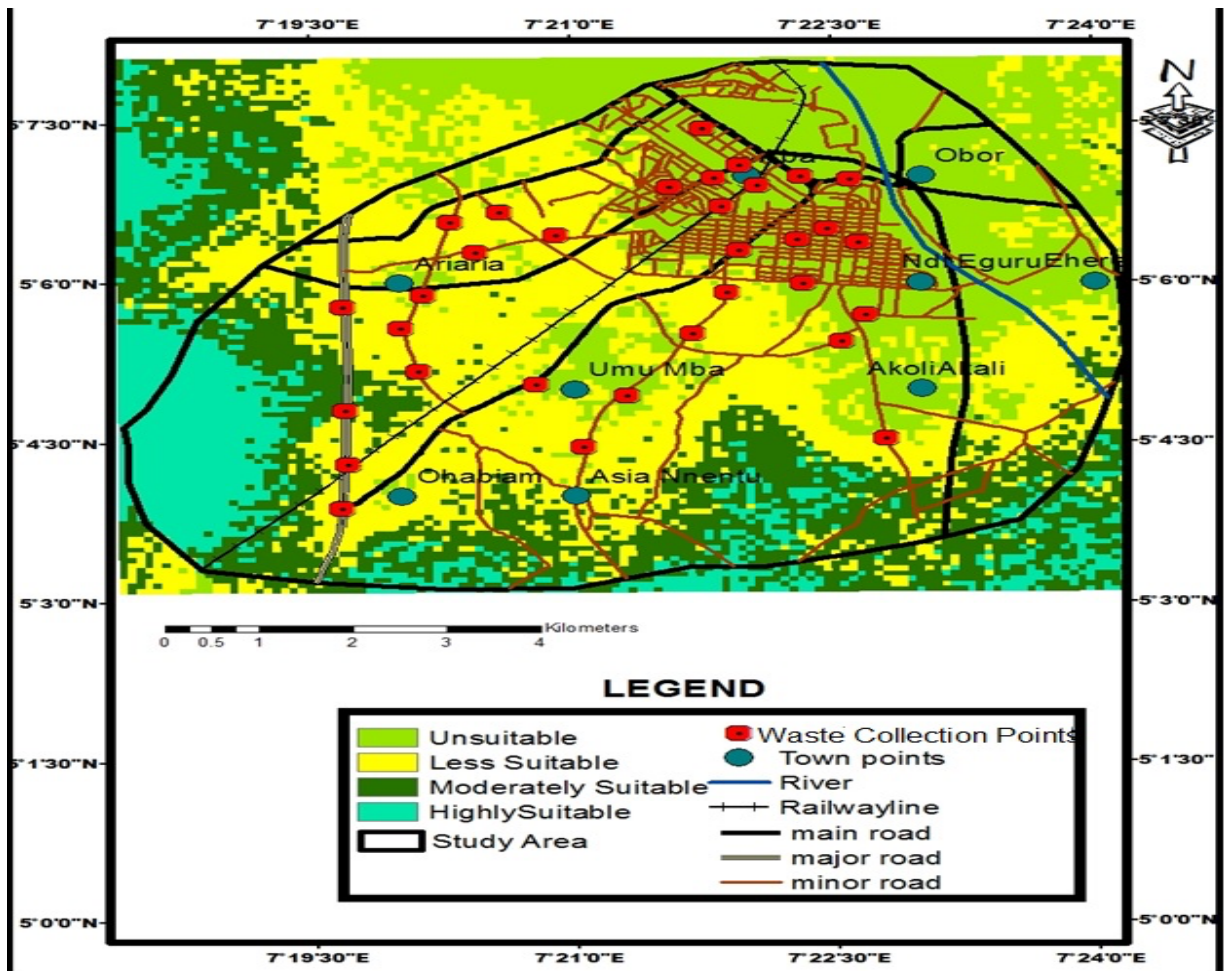


Figure 5. Modeled Suitability Levels for Aba

The result shows that an area of 11.35sqkm (19.41%) is not suitable, 26.47sqkm (45.25%) is less suitable, 16.17sqkm (27.65%) is moderately suitable and 4.5sqkm (7.69%) is highly suitable for solid waste disposal Figure 6.

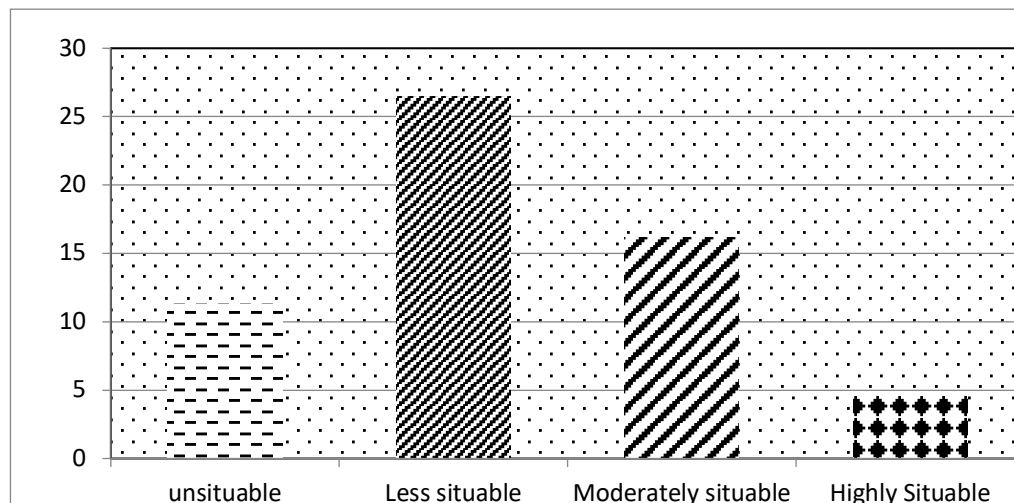


Figure 6: Predicted Suitability Levels in Area

Discussion

The current study is an essential step toward filling a major gap in waste disposal site detection and improving the cost-effectiveness and efficiency of waste management initiatives in Aba municipal. GIS and Remote Sensing are appropriate for site selection studies because of their ability to manage enormous volumes of geographical data from multiple sources (Bilgilioglu et al., 2021) and they have been widely used in the recent past for site selection studies (Khudhair et al., 2020). To enable transportation and hence lower relative costs, solid waste dumping sites should be positioned at a reasonable distance from roadways. As a result of the unanticipated of the urban sprawl of Aba, the distance between waste disposal and residential areas is getting narrow.

The hydrological condition of the environment impacts the rate at which materials are dispersed; more specifically, the hydraulic qualities of the water bodies determine the rate at which toxins from solid waste are distributed (Manfredi et al., 2010; Nai et al., 2021). The proximity of a solid waste dump site to water bodies is an important environmental consideration in site selection, as it protects other land uses from runoff and discharge. As a result, solid waste disposal sites should be located away from bodies of water.

CONCLUSION

The generation of solid waste has expanded extensively amid the ongoing past because of the rising worldwide population and rapid urbanization and its improper disposal and poor management (Mussa & Suryabhagavan, 2021). In this study, we used land use, slope, water sources, settlement, and roads as the determining factors for locating the solid waste collection sites. The results have shown that four sites in Aba were selected as the most suitable. The findings of this study have shown the ability of GIS and remote sensing as a veritable tool for analyzing waste collection points using laid-down criteria. Overall, the suitability of garbage collecting sites in Aba is influenced majorly by proximity to human settlements and roads. The aim and objectives of this study have been achieved through the acquisition of the necessary datasets and implementation of spatial analysis. The strength of this work lies in its simplicity, flexibility, and user friendliness.

The increase in commercial, residential, and infrastructural development due to the population growth and urban expansion Aba is directly affecting the amount of waste generation in the area. This study is considered very imperative because it will serve as a catalyst in the area for further improvement on waste dump siting and management. Therefore adequate management and control of the use of the existing one need to be improved upon so as not to create the same state of condition exhibited by the existing collection sites in the study area.

Virtually the waste collection points in Aba Urban are mostly unsuitable. Therefore, there should be an overall restricting and reassignment of the existing waste collection points. Concerning the municipalities, adequate spatial planning is nonexistent for locating dumpsites. Thus, through integrated management, a system can be designed to foster environmental sustainability.

It is recommended that Aba's municipal waste management authority have our suitability model at their fingertips so that it can be used as a guide for dumpsite approval.

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References

- Abila, B., & Kantola, J. (2013). Municipal solid waste management problems in Nigeria: Evolving knowledge management solution. *Proceedings of World Academy of Science, Engineering and Technology*, 78, 292.
- Aboyade, A. (2004). The potential for climate change mitigation in the Nigerian solid waste disposal sector: A case study from Lagos. *An Unpublished MSc Dissertation, Department of Environmental Strategy, Lund University*.
- Basel. (2019). *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (2019) (187 signatory countries as of February 2019)*. basel.int. : <http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx>
- Bilgilioglu, S. S., Gezgin, C., Orhan, O., & Karakus, P. (2021). A GIS-based multi-criteria decision-making method for the selection of potential municipal solid waste disposal sites in Mersin, Turkey. *Environmental Science and Pollution Research*, 1–17.
- Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science*, 319(5864), 756–760.
- Khan, D., & Samadder, S. R. (2014). Municipal solid waste management using Geographical Information System aided methods: A mini review. *Waste Management & Research*, 32(11), 1049–1062.
- Khudhair, M. A., Sayl, K. N., & Darama, Y. (2020). Locating site selection for rainwater harvesting structure using remote sensing and GIS. *IOP Conference Series: Materials Science and Engineering*, 881(1), 012170.
- Leton, T. G., & Omotosho, O. (2004). Landfill operations in the Niger delta region of Nigeria. *Engineering Geology*, 73(1–2), 171–177.
- Manfredi, E. C., Flury, B., Viviano, G., Thakuri, S., Khanal, S. N., Jha, P. K., Maskey, R. K., Kayastha, R. B., Kafle, K. R., & Bhochhibhoya, S. (2010). Solid waste and water quality management models for Sagarmatha National Park and Buffer Zone, Nepal. *Mountain Research and Development*, 30(2), 127–142.
- Marceta, U., Vujic, B., Srdjevic, Z., Mihajlovic, V., & Radosav, D. (2021). Multi-Criteria Decision-Making Model to Support Landfill Prioritization: Methane Risk Assessment. *Polish Journal of Environmental Studies*, 30(2), 1297–1306.
- Mussa, A., & Suryabhadgavan, K. V. (2021). Solid waste dumping site selection using GIS-based multi-criteria spatial modeling: A case study in Logia town, Afar region, Ethiopia. *Geology, Ecology, and Landscapes*, 5(3), 186–198.
- Nai, C., Tang, M., Liu, Y., Xu, Y., Dong, L., Liu, J., & Huang, Q. (2021). Potentially contamination and health risk to shallow groundwater caused by closed industrial solid waste landfills: Site reclamation evaluation strategies. *Journal of Cleaner Production*, 286, 125402.
- Ogwueleka, T. (2009). Municipal solid waste characteristics and management in Nigeria. *Journal of Environmental Health Science & Engineering*, 6(3), 173–180.
- Vallero, D. A., & Blight, G. (2019). The Municipal Landfill. *Waste*, 235–258.
- Wafi, T., Othman, A. B., & Besbes, M. (2019). Qualitative and quantitative characterization of municipal solid waste and the unexploited potential of green energy in Tunisia. *Bioresources and Bioprocessing*, 6(1), 1–16.
- Wang, Z., Liang, L., Sun, Z., & Wang, X. (2019). Spatiotemporal differentiation and the factors influencing urbanization and ecological environment synergistic effects within the Beijing-Tianjin-Hebei urban agglomeration. *Journal of Environmental Management*, 243, 227–239.

Yukalang, N., Clarke, B., & Ross, K. (2018). Solid waste management solutions for a rapidly urbanizing area in Thailand: Recommendations based on stakeholder input. *International Journal of Environmental Research and Public Health*, 15(7), 1302.