Siting of Urban Solid Waste Processing Plant in Abuja, Nigeria.

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Abstract:

GIS and remote sensing technologies have advanced quickly in recent years, and they are now widely employed in every aspect of life. The Federal Capital Territory (FCT) is one of the fastest-growing cities in Nigeria. This has over time consequently led to an increase in urbanization trend with a surging increase in population. This has weighed considerable pressure on the limited social infrastructures in the country in serving the populace, requires a proper waste management system. Thus, the goal of this research is to use GIS-based multi-criteria analysis (weighted overlay approach) in determining the best suitable areas for siting a waste processing plant. The weights for each factor were applied using the Analytic Hierarchy Process (AHP) to get the best result and identify the most suitable site. Various datasets (criteria) were integrated into the study which was standardized according to a review of past literature and experts in the field. These criteria are Rivers, dumpsites, road network, farmlands, built up, electricity substation, and slope. All these criteria maps were prepared in the GIS environment after which the relative importance of each criterion was evaluated and then employed weighted overlay analysis to generate the suitability map. The results of the potential suitability map were prepared through multi-criteria analysis in the ArcGIS environment and categorized into very low, low, moderate, high, and very high waste processing sites, and unsuitable sites of the study area were determined. The best sites are those that possess the optimal quality and characteristics for sustainable municipal solid waste processing plants. Abaji is the best location for a waste processing plant since it has a high level of appropriateness. It is underdeveloped, thus there are no built-up areas or traffic congestion.

Keywords — Waste-To-Energy, GIS, AHP, Kaduna, Nigeria.

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I. INTRODUCTION

The term municipal solid waste (MSW) is "generally referred to as diverse collection of wastes produced in metropolitan areas" (Abdel-Shafy, and Mansour, 2018)., and the type of these wastes differs by region. Despite this, non-liquid, non-gaseous, and undesired materials generated from household, commercial, and industrial sources are referred to as solid waste.

The management of municipal solid waste entails a number of tasks which includes: collection, transportation, treatment, and disposal. According to Allende (2009), waste generated by human is on the increase daily, and is of major concern to the society. This coupled with the increase rate in population and per capital income in the urban areas is a major contributor to the rather increase, which impacts negatively on the environment and health of the populace across the globe.

Sustainable development Goal 6 aims at ensuring availability and sustainable management of water and sanitation for all (UNOOSA, 2021). Improving water quality by reducing pollution, eliminating dumping, and avoiding the release of dangerous chemicals and materials, halving the share of untreated wastewater, and significantly increasing recycling and safe reuse globally is one strategy to reach this goal.

The poor management of waste is closely associated with problems like disease transmission, stink, atmospheric and water pollution, aesthetic alteration, and economic losses. In most developing and under developing countries, population rise has raised concerns about municipal solid waste management issues (Bartone, 2000). World Health Organization ranked improper solid waste management as the second most important problem (after water quality) causing health concerns. Only around a third of city dwellers have access to "adequate and regular rubbish removal" (Senkoro 2003). As a result of rising population and urbanization, annual garbage creation is estimated to rise by 70% from 2016 levels to 3.40 billion tonnes in 2050, according to World Bank 2019 projections. With an increase in population, more waste is generated and the need for proper waste disposal and processing. Urban solid waste management processes are still poorly inadequate in Nigeria, attributive to poor documentation of waste generation, inefficient collection systems, and disposal of municipal wastes with toxic and hazardous waste, indiscriminate disposal or dumping of wastes, and inefficient utilization of disposal site space (Ayuba and Manaf, 2013). Urbanization in Abuja metropolitan areas, due to the spontaneous population increase has posed difficulties for the state and local environmental protection agencies in providing effective and efficient municipal solid waste management (Olanrewaju and Ilemobade, 2009). Urban growth affects land use, and when not controlled causes the emergence of illegal structures and slums, which is characteristic of some areas within the metropolis. This has ultimately affected the city plan, thereby affecting services such as; waste collection, which has eventually lead to illegal dumping (Ayuba, 2013). Thus, with the rapid rate of waste generated and cost implications of its disposal, it is of necessity to consider sustainable, effective and socially supported modes of recycling, reprocessing, and modifying of such solid wastes through the siting of integrated systems, one of which is the waste processing plant. A waste processing plant is a facility licensed by the National Environmental Trash Management Act 59 of 2008 to store, recover, treat, reprocess, recycle, or sort waste for storage, recovery, treatment, reprocessing, recycling, or sorting.

Study Area

The study area Abuja is the capital of Nigeria and it is situated in the center of the nation. It has a landmass of 8,000km2 with a population of 1, 406,239. The Federal Capital Territory falls within latitude 7º25'N and 9º20' North of the Equator and longitude 5°45' and 7º39' (Kadafa, 2017). Abuja is bounded on the north by Kaduna state, by Niger State on the west, by Nasarawa on the East, and by Kogi on the South-West. Abuja is located in the Guinea savannah vegetation area and has two distinct seasons (dry and wet). Abuja is divided into two geological zones, each with comparable structural and lithological properties. The Precambrian basement complex and sedimentary rocks, which both have a significant impact on the morphological properties of the local soil, are found in these areas (Ola, 2001 and Aderoju, *et al.*, 2018).

MATERIALS AND METHOD

Several studies have been carried out on site suitability analysis of solid waste disposal sites using GIS analysis to find the most suitable locations. There are large numbers of published studies indicating the important roles GIS and Remote Sensing can add to the effective siting of solid waste processing plants.

Aderoju *et al.*, (2018), aimed at identifying suitable sites for Municipal Solid Waste (MSW) disposal in Abuja, Municipal Area Council, and

Bwari area council of Abuja which meets global specifications and standards. He integrated geospatial datasets such as Landsat-7 ETM+, Nigeria Sat-X, and ASTER-GDEM, base map, soil and geology maps, and multi-criteria evaluation. This was used to evaluate the relative importance of each criterion and then employed weighted overlay analysis to generate the suitability map. The analysis found six prospective sanitary landfill sites; however, only four of the six sites were examined due to their land area size and lack of intersection with the Abuja land-use plan. Furthermore, the findings revealed that none of the existing MSW disposal sites satisfied the global requirements in question.

Di, (2015) in his study, GIS software and GIS-based multi-criteria analysis (MCA), a decision-making model was built for optimal site selection for a sewage treatment plant. This study used two types of data: a digital elevation model and a satellite image. Several factor maps and constraint maps were created for the final analysis, as the analytic hierarchy process was used to apply the weights for each factor. This was aimed to get the best result and find the optimal site, an MCA model has been made to be an example for future similar studies, and an optimal site was selected. Although the study's objectives were met, there were several limitations in various aspects of the investigation. SRTM pictures with a spatial resolution of 30m, Landsat 8 OLI imagery, Google Earth imagery, and ground control point (GCP) data gathered by ground point survey were the main data sources for this investigation (GPS). The maps were created using geographic information system (GIS) overlay and suitability analysis, remote sensing techniques, and multi-criteria analysis approaches.

Kaoje *et al.,* (2016) focused on waste management at its final destination or dumping grounds in Birnin Kebbi, with the goal of selecting the most acceptable site for municipal solid waste disposal. Geographic Information System and Remote Sensing Technology To perform an effective site appropriateness analysis of the research region, a multi-criteria evaluation method was used. The Landsat 8 OLI was used to gather the data needed for this study. The site suitability criteria considered for this study were evaluated using buffer distance analysis and overlay operation. The result achieved in this study generated maps that show better sites for urban solid waste disposal/landfill in Birnin Kebbi. Berisa, and Birhanu, (2015) focused on the selection of a suitable site for the disposal of municipal solid waste generated from Jigjiga Municipality using GIS techniques due to the indiscriminate dumping of waste in inappropriate sites. To determine the most suitable landfill site in the study area, the current study combined environmental and socioeconomic variables such as closeness to road networks, distances from dwellings and key built-up areas; surface water (river), boreholes, and reservoirs. Out of five possible dump sites, the most acceptable site was identified as having a fair size (24 ha), being located at the optimal distance from households (4.8 km) and being accessible to main roads (1 km).

Adegbite *et al.,* (2020) considered criterions such as dumpsites, transport networks, power transmission lines, power substations, settlements, rivers, slope, markets, institutions, and industries for the selection of the waste to an energy power plant in Ibadan. The datasets were sourced from world-pop and shuttle radar topographic mission (SRTM) for the raster layers, 14and Ibadan Master Plan, and Grid 3 for the vector data. Depending on which layer was evaluated, the data was processed as euclidean distance and categorization into two or three layers. Before the analytic hierarchy procedure for the weighted overlay analysis, reclassification into suitable or unsuitable, as well as most appropriate, less suitable, and unsuitable, was done.The multi-criteria decision analysis was done in order to select a suitable site for waste to energy plant in Ibadan. Two sites A and B are proposed as the most suitable site to establish the waste-to-energy plant to be in Akinyele and Ido Local Government Areas in Ibadan City, Oyo State of Nigeria.

According to study by Ebistu, and Minale, (2013), that focused on identifying prospective regions for environmentally friendly solid waste dumping sites in Bahir Dar. The main data used for this study were spot images with a spatial resolution of 5 m; digital elevation model (DEM) with 30 m spatial resolution, and a ground control point (GCP) collected by ground point survey (GPS) and a topographical map of the study area. The maps were created using geographic information system (GIS) overlay and suitability analysis, remote sensing techniques, and multi-criteria analysis approaches. The final suitability map was created by overlaying analyses on an Arc map and categorizing the research area into high, moderate, less suitable, and unsuitable sectors. According to the findings, 65 percent of the research region is unsuitable for solid waste disposal, 1.3 percent is slightly more suitable, 21.8 percent is fairly suitable, and 11.9 percent is most suitable.

From literatures review, there has not been appreciable work conducted as regards to siting a urban solid waste processing plant within the Federal Capital City and its environs. Thus, this is of significant importance to the sustainable and economic development of the Nation's capital.

Materials

The river, road network, electricity substations, built-up, and farmlands were acquired from the GRID3 Portal and imported into the ArcMap interface. Prior to further analysis to be carried out, the shapefiles of each factor were projected to have the same spatial reference system. Afterward, the euclidean distance was carried out on each of the criteria. The Euclidean distances generated of each criterion were further reclassified into the assigned classes of preference. Past literature reveals that waste Processing plants should be located close to a power source like electricity substations so that connections can be easily made. Also, it should be sited close to waste dump sites to reduce the cost of transporting wastes. To reduce the construction and maintenance costs of the waste processing plant, the distance between the suggested plant and road networks should be as minimal as possible.

Before the integration of the data sets, individual class weights and map scores were assessed using Satty's (1980) Analytic Hierarchy Process (AHP); in this method, the relative importance of each individual class within the same map was compared to each other by pair-wise and important matrices were prepared for assigning weight to each class. The AHP was used to classify the zones into high influence, moderate influence, and low influence. The zones classification was done based on the waste dumpsites in Abuja, river, road network, farmlands built-up, slope, electricity substations. The results of the potential suitability map were prepared through multi-criteria analysis (weighted overlay analysis) on Arcmap categorized into very low, low, moderate, high, and very high waste processing sites and unsuitable sites of the study area were determined.

Table 1 Weighted percent influence.

RASTER LAYER	INFLUENCE%
Electricity sub- station	20
Dumpsite	18
Road Network	17
Farmland	15
Built-up	10
Slope	10
River	10
Sum of influence	100

II. RESULT AND DISCUSSION

Dumpsites

As shown in figure 1, the dumpsites layer was divided into three categories unsuitable, less suitable and most suitable. Solid waste transportation accounts for a large portion of a waste processing plant's operating costs, which could affect the plant's economic viabilit. When it comes to a solid waste processing plant, lowering transportation costs means choosing locations that are close to potential solid waste sources. As demonstrated in table 1, the dumpsite's influence was assigned 18 %.

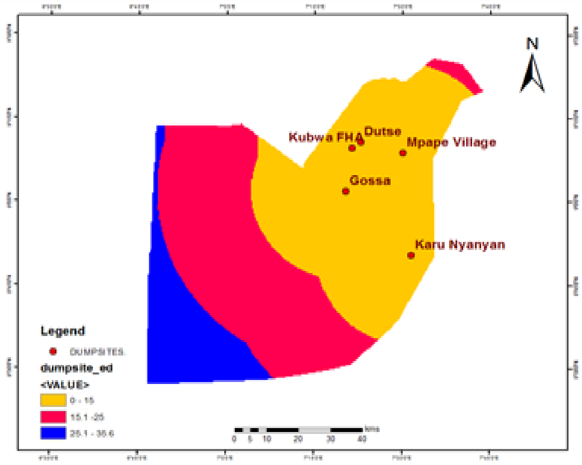

Fig. 1 Euclidean distance of dumpsites

Electricity substations

Electricity substations are economically important since waste processing requires electricity, and they have the capacity to raise or lower manufacturing costs. As a result, it should be considered while deciding where the finest waste processing plants should be built. It's vital to locate the processing plant near substations in order to reduce manufacturing costs. In comparison to places further away from the substations, areas closer to them are deemed to be more suited. The dumpsite was given a 20 percent influence rating.

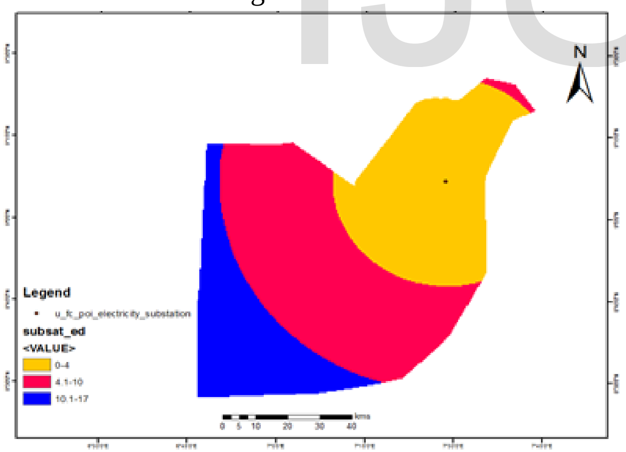

Fig. 2 Euclidean distance of Electricity substations

Road network

Access to the road network is crucial when locating a waste processing plant. It is crucial since it reduces transportation costs while also improving accessibility. A solid waste processing plant should be near major roadways as well as potential solid waste sources such as landfills and/or transfer facilities. It must be close to roadways so that final waste processing goods can be conveniently accessed. A 20 percent influence grade was given to the dumpsite table 1.

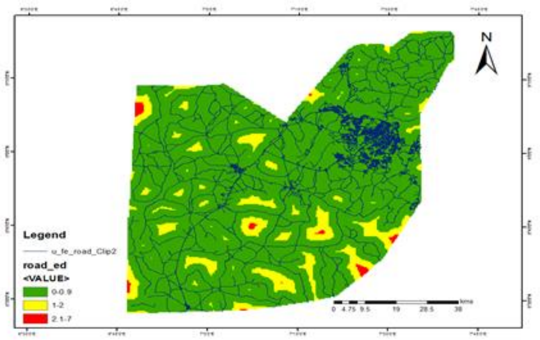

Fig. 3 Euclidean distance of road network

The Final Suitability Map

All the criterion layers table 1 were integrated at this point in order to find a suitable location for a waste processing plant in the study area. Overlay analysis was performed to identify the most suitable site for waste processing plant using weighted overlay tool in ArcGIS environment. The built up, rivers, road network, electricity substations, farmlands, dumpsites, and slope were all reclassified and aggregated at the end of these operations. The identified suitable areas were divided into five main classes (Table 2).

Table 2: Waste Processing Plant Suitability Index

Suitability Level	Area(hectares)	Percentage %
Very Low	69256.41	9.13
Low	184138.83	24.27
Moderate	165692.84	21.84
High	165749.28	21.85
Very High	173759.55	22.91

Five suitability classes with varied degrees of suitability were developed based on the results of the waste processing plant suitability criterion. A weight value was assigned to each factor ranging from 1 (very low) to 5 (very high). Each criterion was assigned a value based on its suitability for determining the location of a waste processing plant.

Finally, the waste processing plant suitability analysis finds that around 173759 hectares of the study area has very high suitability level, accounting for about 23% of the total study area. The fairly appropriate region accounts for 21% of the total area or 165692.84 hectares. Also, total of 69256 hectares (9 %) of the study area is unsuitable (Figure 5). In the study area, the most suitable site for a waste processing plant is in Abaji local government area which is in the city's western section.

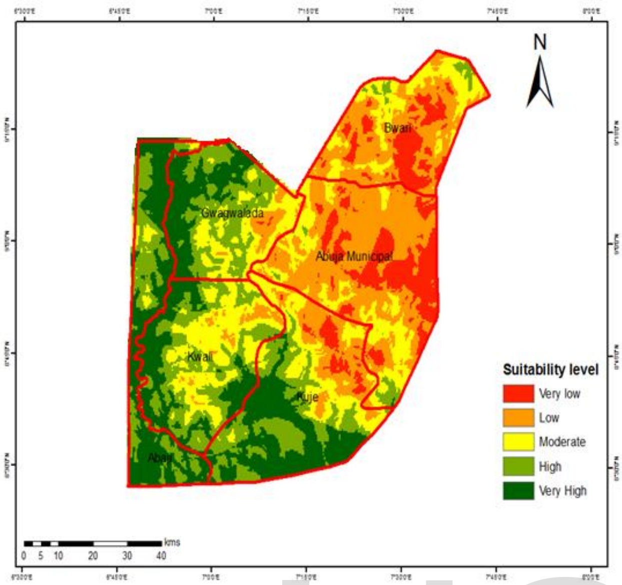

Fig 4: Final suitability map of a waste processing plant

III. CONCLUSION AND RECOMMENDATION

Majority of areas within Bwari and Abuja municipal are not suitable sites for locating a waste processing plant. This is because these regions are characterized by low and extremely low suitability levels for siting a waste processing plant, respectively according to the analysis conducted. In addition, there is a high concentration of built-up and high level of economic activities, thus siting of such plant further away is preferable. The moderately suitable sites are Kuje, Kwali and Gwagwalada because they show moderate and high suitability levels and they are not as congested with roads and built up due to little, massive development presently. Abaji is the most suitable site for siting of waste processing plant because it shows very high suitability level. It is underdeveloped, hence not congested with built up and roads.

RECOMMENDATION

This work recommends that the FCT takes a bold step in citing more than one processing plant in most suited areas for optimal functionality. Thus, this technical innovation will provide job opportunities for the always-ready-to-work unemployed citizens in Nigeria. In addition, the siting of a waste processing plant will help further to reduce the environmental pollution menace caused by large tonnage of waste generated daily which will make human settlements become more safe, resilient and sustainable.

REFERENCES

[1] 1) Adegbite, A. A., Usman, R., Ekwe, D.O., Idris, H.O. and Akinfenwa J.O. (2020). Siting a Waste to Energy Power Plant in Ibadan, Oyo State, Nigeria. International Journal of Scientific & Engineering Research Volume 11, Issue 2, February-2020 590.

[2] 2) Aderoju, O. M., Dias, G. A., & Gonçalves, A. J. (2020). A GIS-based analysis for sanitary landfill sites in Abuja, Nigeria. Environment, Development and Sustainability, 22(1), 551-574.

[3] 3) Allende, R. (2013). Waste history in the Gambia. URL/Accessed on 20 January 2013. Thesis (MSC). University f the Gambia. .

[4] 4) Ayuba,K. A. and Manaf, L. A. (2013). Current Status of Municipal Solid Waste Management Practise in FCT Abuja. Research Journal of Environmental and Earth Sciences, 5(6), 295-304.

[5] 5) Bartone, C. (2000). Strategies for Improving Municipal Solid Waste Management . Workshop, 18-22.

[6] 6) Berisa, G., & Birhanu, Y. (2015). Municipal solid waste disposal site selection of Jigjiga town using GIS and remote sensing techniques, Ethiopia. International Journal of Scientific and Research Publications, 5(4).

[7] 7) DI, Z. (2015). Using GIS-based Multi-criteria Analysis for Optimal Site Selection fora Sewage Treatment Plant.

[8] 8) Ebistu, T. A., & Minale, A. S. (2013). 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, 7(11), 976-989.

[9] 9) Kadafa, A. (2017). Solid waste management practice of residents in Abuja municipalities (Nigeria). IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), 11(2), 87-106.

[10] 10) Kaoje, I. U., Dankani, I. M., & Ishiaku, I. (2016). Site suitability analysis for municipal solid waste disposal in Birnin Kebbi, Nigeria. IOSR Journal of Humanities and Social Science (IOSR-JHSS), 21(7), 01-10.

[11] 11) Ola, B. (2001). The Federal Capital Territory of Nigeria; A geography of its development. Ibadan: Ibadan University Press Publishing House; University of Ibadan

[12] 12) Olanrewaju, O. O., & Ilemobade, A. A. (2009). Waste to wealth: A case study of the Ondo State integrated wastes recycling and treatment project, Nigeria. European Journal of Social Sciences, 8(1), 7-16.

[13] 13) Saaty, T. (1990). How to make a decision: The Analytic Hierarchy Process. Eur. J. Oper. Res. 48, 9–26.

[14] 14) Senkoro, H. (2003, March). Solid waste management in Africa: a WHO/AFRO perspective. In Dar es Salaam at the CWG Workshop.

[15] 15) UNOOSA (2021) Sustainable Development Goal 6: Clean Water and Sanitation. (2021). Retrieved, from https://www.unoosa.org/oosa/en/ourwork/space4sdgs/sdg6.html

16) World Bank (2019) Solid Waste Management, (2019) . Retrieved, from https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management