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A GIS-based suitability analysis for siting a waste-to-energy power plant in Kaduna, Nigeria

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Abstract

The success of any waste management system requires accurate and up-to-date data on quantity, and composition of waste. Waste generation data from households are needed to address issues relating to municipal solid wastes such as management methods, performance improvement, policy, regional and local planning, administration, cost accounting, design and operation of landfill facilities, and environmental quality. This study carried out a suitability analysis for siting a waste-to-energy power plant in Kaduna using GIS and remote sensing techniques with the specific objectives of identifying existing waste dumpsite in the study area, identifying other factors needed for waste-to-energy plant in the area, and identifying the most suitability site of waste-to-energy in Kaduna. The slop map of the study area was created using the Shuttle Radar Topographic Mission (SRTM). In the ArcGIS environment, Euclidean distance analysis was performed on institutions, rivers, dumpsites, roads, markets, transmission lines, and electricity substations. The waste-to-energy power plant suitability map was created using a multi-criteria technique by overlaying the datasets. The waste-to-energy-power-plant suitability map was made by combining the criteria. Dogon Dawa, Sabon Birinin Jaji, Ganga, Buruku, chikun, Dokwa, ikara, and Kuban are the best sites. The results of the site suitability assessment further revealed that the Makafia local government, located in the city's northern outskirts, was the most suitable area for locating the waste-to-energy power plant, covering 73686 hectares, or 26% of the total area. In addition, the map lays the groundwork for decision-makers to locate a waste-to-energy generating plant.

This study shows how decision-making about solid waste management may benefit from the use of geospatial technology. Additionally, it is advised that before approving the placement of a waste-to-energy power plant, decision-makers in the study region refer to it as a reference.

Keywords: Waste Generation and Composition; Municipal Solid Waste; Waste-To-Energy; GIS; Multicriteria Analysis; SRTM

1. Introduction

Any undesired material that needs to be discarded is considered waste [1]. However, garbage is officially classified as a resource in the incorrect location. Waste is anything that we no longer need and want to get rid of. Unusable residues in raw materials, leftovers, rejections, and trash from industrial activities, used or scrap packaging materials, and even the saleable product all contribute to solid waste. Waste collection, disposal, and dumpsite management are critical issues, particularly when rapid urbanization is present [2]. According to the study, between a third and half of the solid waste produced in most Nigerian cities is not collected, resulting in illegal dumping on streets, open spaces, and waste

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land these buttresses [3]. According to the report, indiscriminate waste disposal along the Kaduna Metropolis is the primary factor influencing residents' yearly vulnerability to floods. The Kaduna State Government established the Kaduna Environmental Protection Agency (KEPA) and the Kaduna State Urban Development Authority to supervise city planning and development (KASUDA) but they are bedeviled by sharp practices, professional inadequacy and technical inefficiency by all standards. Furthermore, waste management has been identified as a challenge in many countries around the world, especially in developing countries, and a link has been found between rapid urbanization, population explosion, industrial development, and the rate of waste generation in such cities. Waste management has become a major problem in most Nigeria cities. In recent years, there has been a phenomenal increase in the volume of wastes generated daily in the country. This is due to the huge volume of waste generated in the cities on a daily basis, which calls for proper handling in order to protect the environment and the population. emphasized that waste is inseparable from life because as long as man is alive, he stores up, uses, and disposes off materials and the complexity of waste which modern civilization produced is directly related to the living standard, socio-economic and cultural attributes of that particular environment. World Bank projected municipal waste generation emerging economies must respond to the challenges of will rise worldwide from 1.3 billion tons annually in urbanization and energy demand [4]. In recent improvement of people living standards, the quantity of consumption against limited solid waste management2012 to 2.2 billion tons annually by the year 2025 times, WTE has gradually been regarded as a way out to the [5]. Along with population problems derived from growing waste quantities in explosion, rapid urbanization, economic development and expanding cities as well as fast increasing energy.

The primary difficulty in managing solid waste in affluent countries has switched from ensuring minimal harm to public health and the environment to determining how discarded materials should be managed so that future generations do not lose out on their value [6]. Published studies illustrating the essential roles GIS and Remote Sensing may play in the optimum location of solid waste management and energy-generating facilities have sparked a lot of attention. Residential (household waste), industrial, institutional, street sweeping, construction, sanitation, and business solid waste are the different types of municipal waste [7]. Furthermore, municipal solid trash refers to solid garbage generated by households, streets and public areas, stores, offices, and hospitals, which are typically the responsibility of municipal or other governmental bodies. Commercial solid trash is usually no longer considered municipal. However, because this garbage eventually becomes part of the municipal garbage stream, it must be considered when managing solid trash. [8], conducts an in-depth examination of a municipal solid waste incineration power facility in Alexandria, Egypt, utilizing GIS-based multi-criteria analysis. To create the optimum spatial option, the work analyzed five factors: Lowest operation price, Nearness to the electrical, and each criterion was assigned to each criterion using mathematical or weighted overlay methods [9].

Municipal Solid Waste (MSW) has been on the increase capabilities mostly in developing nations are aggravating rapidly and its composition has become more varied (World the Problems as well as its socioeconomic and [10]. It is anticipated to expand rapidly in the future; with environmental consequences [11]. It is worthy thus, waste disposal and management pose serious to mention that a well-organized municipal solid waste challenges to cities around the world. In developing countries, municipal waste threatens both the environmental and social qualities [12]. These recent projections have attracted more attention to the challenges waste disposal and waste management pose as an integral topic to be considered by present and future policymakers to attain the sustainability of cities. [13] reported that MSW is regarded as a major environmental problem that affects urban sustainability in many developing countries. [14] saw the economic gains municipal waste can provide to the city of Kaduna and encourage various stakeholders to adopt biogas from MSW for energy generation in Nigeria. Waste-to-energy (WTE) continues to remain the best solution because of its ability to convert heat energy to electrical energy thereby producing sustainable energy for many cities [15]. Among the sustainable means of waste management and energy generation being adopted around the world, Waste-To-Energy remains a best practice to properly manage waste and reduce the depletion of natural resources, and other environmental challenges associated to waste generation [16]. Nigeria has an installed electricity generation capacity of 7000 MW, but capacity utilization currently ranges between management system is concerned not only with efficient collection of generated municipal solid site and was commissioned on August 2018 to generate 50MW of electricity thereby providing electric energy for form the multi-criteria analysis, sometimes referred to as 20% of the Addis Ababa's residents. The Ethiopian government provided $96 million for the construction of the first major WtE plant in Africa [17].

1.1. Waste to Energy in Africa

The Koshe dumpsite in Addis Ababa, like every other dumpsite in Africa, has created major environmental threats to communities living on the fringes of Ethiopia's capital. However, the Reppie Waste-to-Energy facility began building its WTE plant on the Koshe power line in September 2014, avoiding issues with delicate land use and Vacant Land and a Composite index. It was suggested that these characteristics be quantified to mimic the suitability values of various regulatory criteria directing the optimal placement for a solid waste-to-energy facility. [18] found that the strength of each layer is proportional to its importance in performing weighted overlay analysis. Their findings were plotted on maps, with the ideal site for a nuclear power plant being located at Ulu Dong, with an area of roughly 10064 acres. Many researchers who are attempting to make the best decisions possible based on a variety of elements that may influence the outcome of a geographical decision use a mixture of Geographic information systems (GIS) and other systems and technologies.

1.2. Overview of Waste to Energy (WtS)

Around 2500 WTE plants are in operation around the world, with a total disposal capacity of 300 million tons per year. In addition, between 2011 and 2015, 280 thermal plants with a capacity of about 75 million tons per year were built. Again, there are several waste-to-energy conversion techniques, with direct solid waste combustion being one of the most common. Since the 1970s [19], innovative thermo-chemical techniques such as pyrolysis, gasification, and plasma arc gasification have been developed and tested to choose waste streams on a minimal scale in a particularly desirable environment. chamber with temperatures and pressures used to control the parameters. Moreover, every generation makes use of various kind of requirements for the input operating in particularly designed system configurations in special modes to generate extensive variable products on different particular scales towards the WTE facilities. China has developed new CFB technology incineration method to burn waste to produce energy which is better than the old incineration method. There are currently 28 CFB power plants in China and their research for suitable waste to power plant energy is ongoing. Not only the WTE is beneficial for the environment but also economically beneficial for the countries. In 2013, the global WTE market was estimated at US$25.32 billion, up 5.5 percent from the previous year. WTE technologies that use thermal energy conversion are the most popular, accounting for 88.2% of total market revenue in 2013 [20].

[21], proposed a GIS multi-criteria site selection method for power plants. The function of AHP and GIS in choosing the best location for a nuclear power plant is detailed in the paper, along with site selection criteria and outcomes. The Raub District in Pahang was chosen as a research location because its geography met the majority of the criteria. Low population density, residential area, river access, geography, land use, power infrastructure, and land ownership were among the seven characteristics considered in the analysis. In addition, the following stages were completed: represent the criterion in GIS layers, conduct GIS analysis to obtain numerous proposed sites, and classify the criteria based on their weight value. A GIS-based site suitability analysis for developing a solar power park in Namakkal District, Tamil Nadu was presented by [22]. The major parameters that were evaluated in identifying a suitable location were topography, distance to infrastructure, and area for organizing a park. The efficiency of the incoming solar energy for tapping was determined. Power consumption by industry in the analysis, peak demand and cost considerations were taken into account. Two interconnected steps were used in this research. To begin, the research area's land use/land cover map was created using remote sensing and LANDSAT 8 satellite data. Second, the aspect angles map and slope map for the research area were created using a Digital Elevation Model (DEM). This research reveals a potential site for a Solar Power Park.

GIS (geographic information systems) are strong tools for geographical analysis that allow you to capture, store, query, analyze, display, and produce geographic data. As a result, they have a significant impact on the spatial decision-making process. The capabilities of GIS in location analysis have dramatically improved as a result of recent developments in the field of decision making. These advances are examined using attribute data analysis, particularly processes for GIS Multi-Criteria and Multi-Objective location analysis. The expression of uncertainty in establishing the relationship between evidence and the decision to be made; procedures for the aggregation of evidence in the presence of varying degrees of trade-off between criteria; and procedures for conflict resolution and conflict avoidance in cases of multiple objective decision problems [23].

Other systems and approaches, such as decision support systems (DSS) and the approach for multi-criteria decision-making, are used in conjunction with geographic information systems (MCDM). As a result, combining GIS with other approaches allows Combining these technologies to create a synergistic impact that improves the efficiency and quality of spatial analysis for industrial site selection [24], [25] and how to simulate the majority of the MCDM methodology [26].

The geographical location is crucial in determining which MSW management technique is appropriate for the local area. Potential threats to human health, agriculture, construction materials, forests, and ecosystems, in particular, should be considered [27]. The right technology for the job can lower the cost of pollution control, garbage collection, and transportation while simultaneously minimizing the impact on the environment and residents. Mauritius Strategy for Implementation (MSI) may not be built in the city center, where the real estate cost is too high to be recovered by revenue, in addition to following environmental law and economic requirements [28]. MSI should be located in a rural or suburban location to limit the impact on humans and the environment, such as air pollution and noise. The location of an anaerobic fermentation plant, on the other hand, is far more flexible than that of an incineration facility. This is due to the relatively small amount of land required and the resulting lower direct societal repercussions. It can be used by multiple towns, implemented in a single town, or simply put in a single home. Odor emissions have now been well controlled, allowing for the establishment of an AF plant for single-family household use, lowering waste collection and transportation costs.

There is potentially large number of actors in the waste management process. For a program to be successful, it must include political bodies, waste generators, trash haulers, funding agencies, regulatory agencies, building contractors, plant operators, energy and material purchasers, landfill site owners, and residents. Each group has the potential for delaying or derailing the project [29]. As the program progresses, a plan for informing the public about its progress should be devised and implemented. Before public bodies vote on program spending, more effort should be done to build public support. The public must regard the program as something to be proud of, as a symbol of the community's progressiveness and commitment to environmental protection. Collaboration was identified by [30] as a catalyst for raising household awareness about recycling and waste, improving waste handling and disposal operations, including characterization and segregation, strengthening law enforcement, utilizing scavengers as a legitimate agent of MSWM, recommending inclusive policy initiatives, creating integrated, sustainable MSWM plans, and reducing waste Expenses are reduced by sharing the costs of facilities and equipment among agencies.

National policy on MSW laws must be consistent. Cross-jurisdictional and inter-agency coordination should be encouraged, and economic mechanisms to improve waste management should be made easier to employ [31] Various regions, however, have different national laws and local rules. Different MSW definitions, for example, are used in EU countries. Plus, there's more. For different MSW management strategies, different laws are in place. Most European governments have increased landfilling taxes and are trying to limit MSW disposal to no more than 5% of the collected material [32] This regulation will ensure that MSI's solid waste is properly processed rather than being buried in the ground. Governments also encourage the sale of electricity. The most common public issue about MSW incineration is the large number of flue gases released, which may contribute to global warming and harm human health. MSI's solid waste will be properly processed rather than buried as a result of this law. Electricity sales are also encouraged by governments. The massive number of flue gases emitted, which may contribute to global warming and endanger human health, is the most prominent public concern about MSW incineration. Biogas from AF facilities can be sold at a premium in the Netherlands and other EU countries [32]. As a result, legislation should play a critical role in influencing decision-making as part of the macro monitoring framework.

In Nigeria, the power supply scenario is defined by limited generation and inefficient transmission and distribution. Nigeria's current electricity generation capacity is insufficient to meet the demands of a country with over 180 million inhabitants [33]. Insufficient generation and inefficient transmission and distribution scribe the power supply scenario in Nigeria. Nigeria's existing power generation capacity is insufficient to meet the demands of a country with a population of more than 180 million people [33].

Some of the materials municipal solid waste, such as plastics and metals, can cause major environmental and health problems if not properly treated, such as river contamination, heavy metal pollution, and so on. Inadequate waste management and immature treatment technologies, especially across wide areas of developing countries, may aggravate the situation. Waste managers and decision-makers in developing and emerging countries have to respond to these new challenges, and in recent times waste-to-energy (WTE) has been increasingly viewed as a solution to the problems derived from rising waste quantities in expanding cities as well as rapidly growing energy demands.

Today, Geospatial Technology plays a major role in solid waste management. Advancements in remote sensing and GIS techniques have made waste disposal site selection more accurate and convincing [34]. The various factors such as socioeconomic, environmental, and land use should be considered along with the people’s well-being for developing a waste disposal

This study aims to carry out a suitability analysis for siting a waste-to-energy power plant in Kaduna using GIS and remote sensing techniques with the specific objectives of identifying existing waste dumpsite in the study area, identifying other factors needed for waste to energy plant in the study area, and to identify the most suitability site of waste to energy in Kaduna.

1.3. Study Area

Kaduna State was created on May 27^{th,} 1967. It lies within the sub-humid agro-ecological zone of north-central Nigeria, the state shares boundary with the following states; Zamfara, Katsina, and Kano, in the North, Bauchi, Plateau in the Eastern part of the country, while Nassarawa and Federal Capital Territory (F.C.T) in the South and Niger State in the West. The State is between longitudes 7^0 and 9^0 East of the Greenwich Meridian and also between latitudes 9^0 and 11^0 north of the equator. The State occupies an area of approximately 48,473.2 square kilometers. Kaduna metropolis is the capital city of the State. The Metropolis is located between latitude 10^0 28^I and 10^0 37^I North and longitude 07^0 19^I and 07^0 31^I East occupies an area of about 260km^2; the distance between the eastern and western limits of the city is approximately 13.7km [35]. It is made up of two main local government areas, the Kaduna North and the Kaduna South, other adjoining local government areas that make up the entire metropolis are Igabi and Chikun.

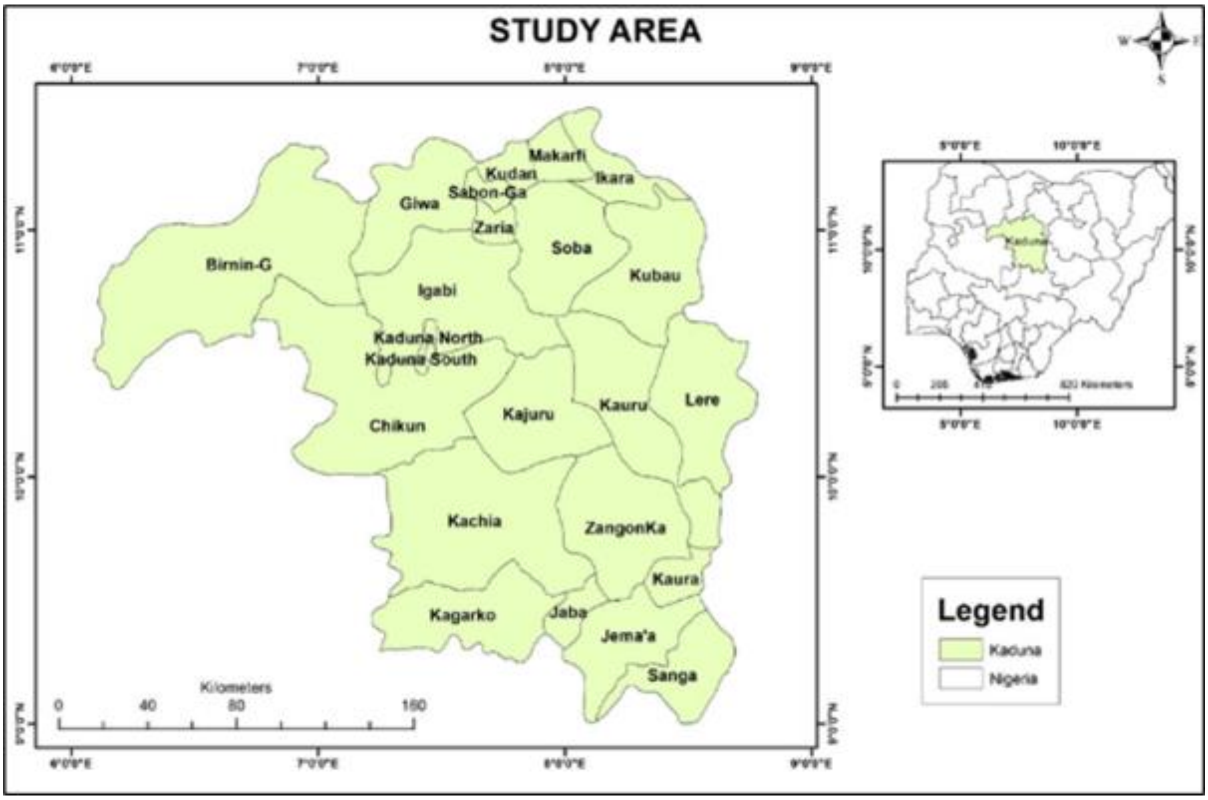

Figure 1 Study Area Map

2. Materials and method

2.1. Introduction

This study utilized both spatial and non-spatial data and the problem of gathering the data in an exact format and at a high resolution made the data collection process tough. This study employed a variety of datasets to conduct the analysis for locating a waste-to-energy power facility.

All of the datasets utilized, as well as their format and resolution, are listed in the table below. In order to describe the waste-to-energy power plant site suitability analysis, the table highlights the many types of geospatial data used and their sources in the data processing steps. Various datasets from various sources are included in the table.

2.2. Description of the data

The Kaduna Metropolis provided the majority of the data for this study. WGS 1984 Zone 31N contained the coordinate system of the river, railway, high-speed rail connection, railway network, power substations, power lines, waste dump sites, settlement, and slope. The linear and angular units were measured in meters and degrees, respectively. The Kaduna Metropolis' availability determined the study area's boundaries. Using the Environment tab in the Geoprocessing toolbar, all of the data was resampled to fit the resolution of the SRTM data

2.3. Data Processing and Analysis

The following are the primary steps used during data processing and analysis:

The ArcGIS program was used to digitize the river, road, institution, railway network, transmission lines, and power substations in the Kaduna Metropolis. The shapefiles of each feature were created by scanning and georeferencing the map in the ArcMap environment. The spatial analyst toolbar was then used to perform Euclidean distance on the vector layers. Also, when converting a shapefile to a raster, Euclidean distance is applied.

The waste-to-energy power plant should be located adjacent to the electricity grid via power lines so that connections may be made quickly. It should also be located near waste dumps to save money on waste transportation. To reduce waste to energy power plant construction and maintenance expenses, the distance between the proposed waste to energy power plant location and transportation networks should be as short as possible.

2.4. SRTM data was used to create this data.

The data from the Shuttle Radar Topographic Mission (SRTM) was downloaded and imported into ArcMap from the SRTM 90m Digital Elevation Database (DEM) website. This was done to build the study area's slope map using the slope tool in the ArcGIS environment's arc toolbox. The slope was studied to develop a slope suitability map, which will place the site in a terrain range suitable for a waste-to-energy generating plant.

2.5. Settlement density data

The research area was cropped out of a Nigerian settlement density map taken from the World Pop website.

Table 1 Population of Some L.G.A by Gender in Kaduna Metropolis

L.G.A	Female	Male	Total population
Kaduna North	171431	186263	357694
Kaduna South	191904	210486	402390
Igabi	210960	219269	430229
Chikun	181376	186874	368250
Total	*755671*	*802892*	*1558563*

2.6. Data Analysis Techniques

Individual class weights and map scores were assessed before data integration using [36] Analytic Hierarchy Process (AHP); in this method, the relative importance of each class within the same map was compared pair-wise, and important matrices were prepared for assigning weight to each class. The AHP was utilized to divide the zones into three categories: high, moderate, and low. The garbage dumpsites in Kaduna, the river, the settlement, the rail, the transmission lines, the slope, the railway, the road, and the power substations were all used to classify the zones.

2.7. Reclassification

This entails reclassifying each layer into one of three groups: extremely acceptable, suitable, or unsuitable. A value, a range of values, or a list of values are reassigned to a new output value by the reclassification tool [37].

2.8. Weighted overlay

This stage assigns a numerical weighting factor to each thematic layer based on its relative importance to all other levels; this is known as weighted overlay [38] The classification data was then overlaid to create a suitability map that identified places that would be ideal for a waste-to-energy power plant to be built. To effectively perform the weighted overlay, the raster dataset must be an integer, and then the weighted overlay tool to integrate all reclassified vector and raster layers to portray the final result for the most suited sites. The approach for determining the most suitable sites for the waste-to-energy power plant is depicted in the diagram below.

Table 2 Weighted Overlay Pairwise Comparison Table

Raster Layer	% Influence	Field Value	Scale Value
Slope	9	1	1
		2	2
		3	3
Institution	9	1	1
		2	2
		3	3
Industry	9	1	1
		2	2
		3	3
Rail	9	1	1
		2	2
		3	3
Waste dumpsites	10	1	1
		2	2
		3	9
Market	9	1	1
		2	2
		3	3
Settlement	9	1	Restricted
		2	2
River	9	1	Restricted
		2	2
Transmission line	9	1	1
		2	2
		3	5
Road	9	1	1
		2	2
		3	3
Sub stations	9	1	1
		2	2
		3	5
Sum of influence	100		

Table 3 Dataset and Sources Utilized in this Investigation

S/N	Data	Source/Link	File format	Resolution	Date
1	Settlement	https://www.worldpop.org/geodata/summary?id=17208	Raster	30m	2019
2	Elevation	http://srtm.csi.cgiar.org/	Raster	90m	2018
3	Road network	Grids3	Vector		2017
4	Power lines	Grids3	Vector		2017
5	Market	Grids3	Vector		2017
6	River	Grids3	Vector		2017
7	Waste dump sites	GPS Point			

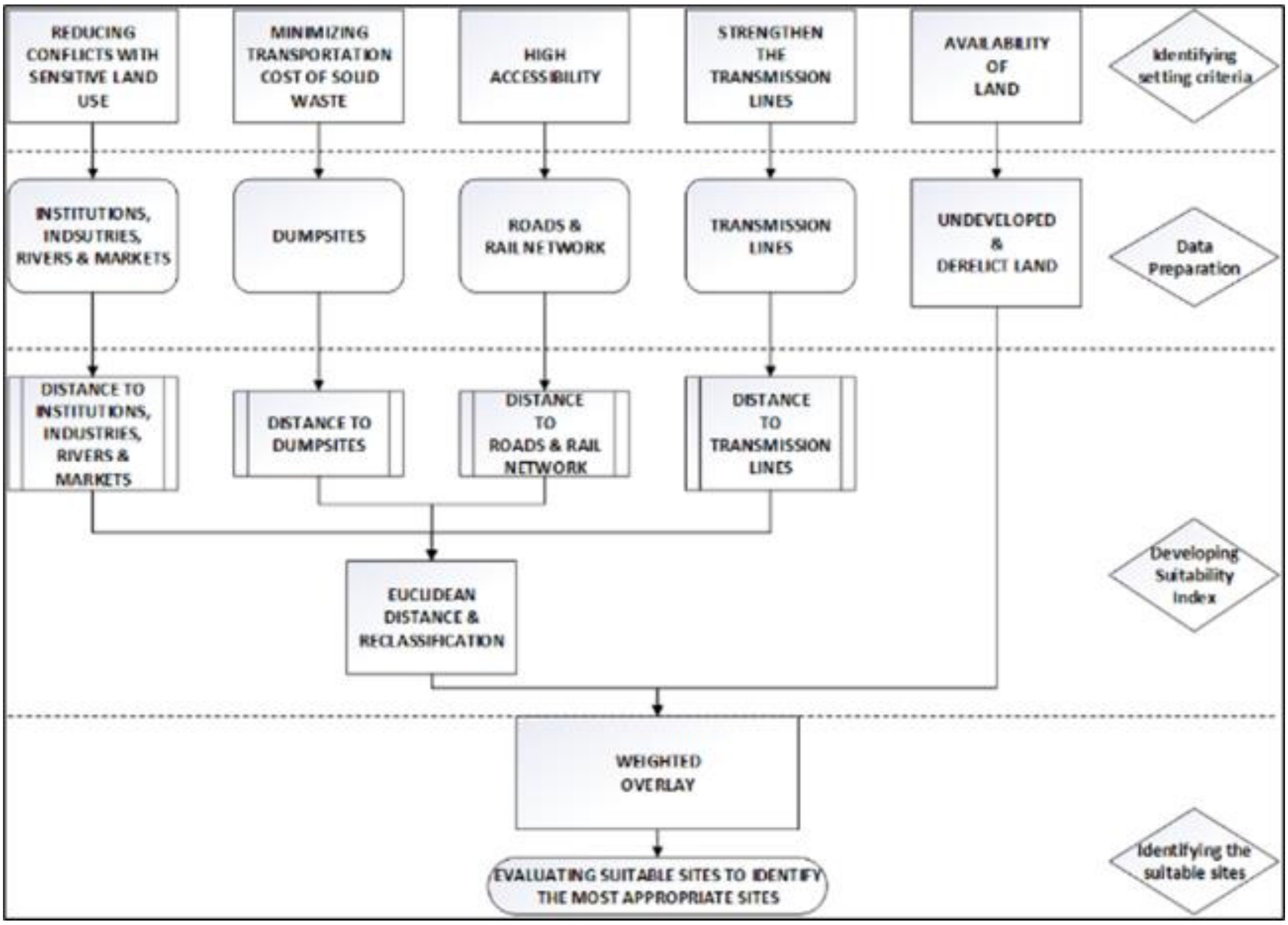

Figure 2 Methodology Workflow

3. Results and Discussion

3.1. Important GIS Analysis Criteria

To discover eligible regions, all of the criteria for locating a waste-to-energy power plant were prepared using remote sensing and GIS techniques. The appropriateness analysis takes into account the following layers: settlements, dumps, highways, railways, industries, rivers, markets, substations, transmission lines, and slope According to the importance of the fields, each criterion was given a weight and a rank. Using ArcGIS' Spatial Analyst tool, the relative ranking of each criterion was given an AHP. Figure 2 summarizes several steps involved in spatial analysis.

3.2. Layers of Vector (Criteria's)

To begin, ArcGIS was used to digitize the roadways, railway network, river, transmission lines, and substations in the Kaduna metropolis. Thereafter, Euclidean distance analysis was performed as shown in Figure 3, 4, 5, 6, and 7 to create distances to the several criteria identified as mentioned earlier. The Euclidean distance raster output contains the measured distance from every cell to the nearest source.

3.3. Reclassification of all the Criteria

3.3.1. Slope

The rate of change in elevation of a surface place is referred to as slope. It describes how land shapes rise and fall, as well as the slope percentage. The moderate degree of slope is far more appropriate in this study than the larger degree of slope. In ArcGIS 10.4.1, the slope dataset was created using the Shuttle Radar Topography Mission (SRTM) elevation with a resolution of 90m. The usage of slope in this study is to take into account places with a moderate slope. The slope raster was divided into three groups: unsuitable, suitably suitable, and highly suitably suitable. Figure 8 shows the result of the reclassified slope map.

Table 4 Pairwise comparison table for Slope

Raster Layer	% Influence	Field Value	Level of Suitability	Scale Value
Slope	16	1	Unsuitable	3
		2	Less suitable	2
		3	Most suitable	1

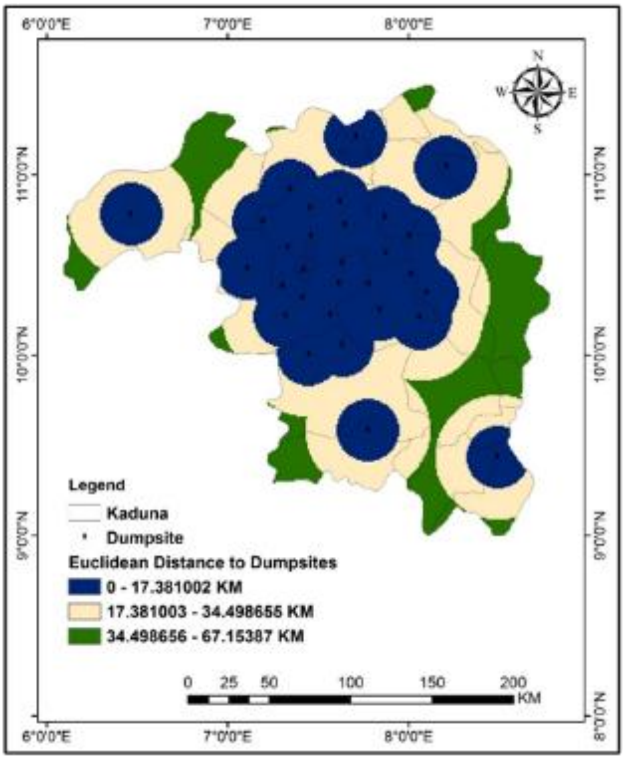

Figure 3 Euclidean distance of Dumpsites

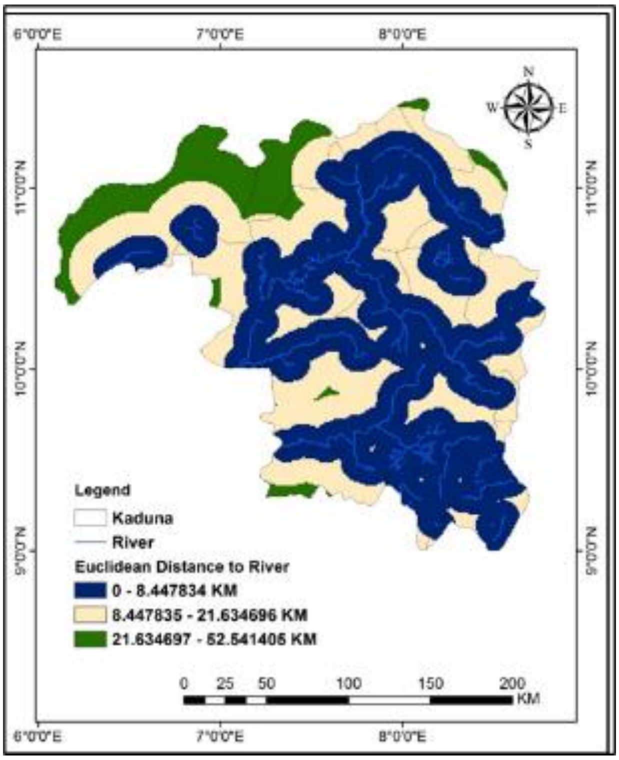

Figure 4 Euclidean distance of River

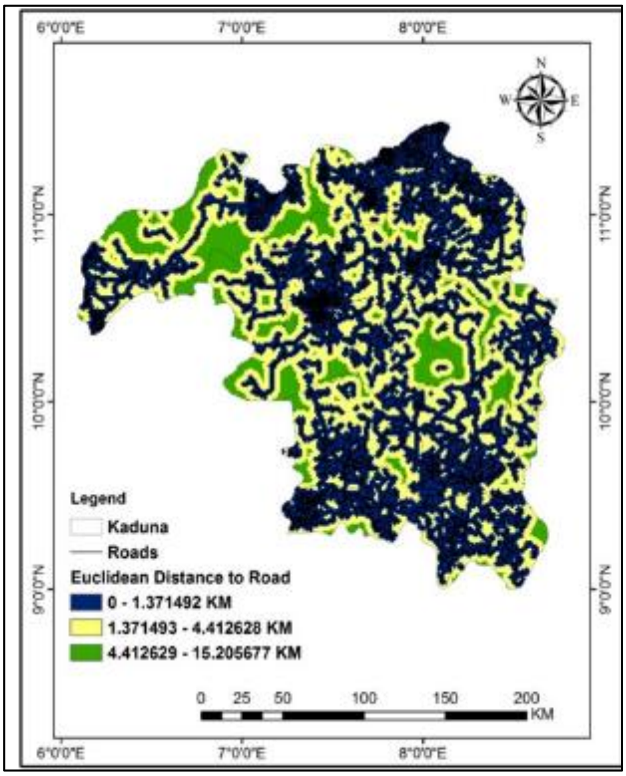

Figure 5 Euclidean distance of Road

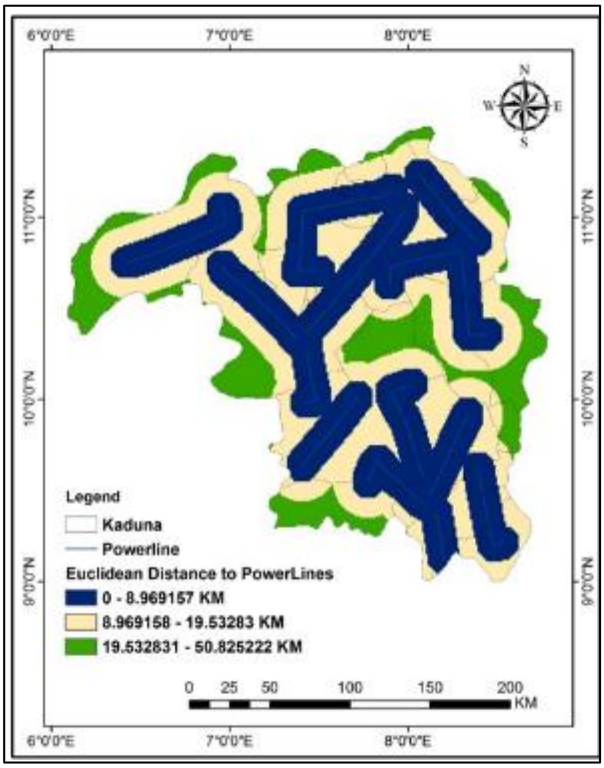

Figure 6 Euclidean distance of Power Lines

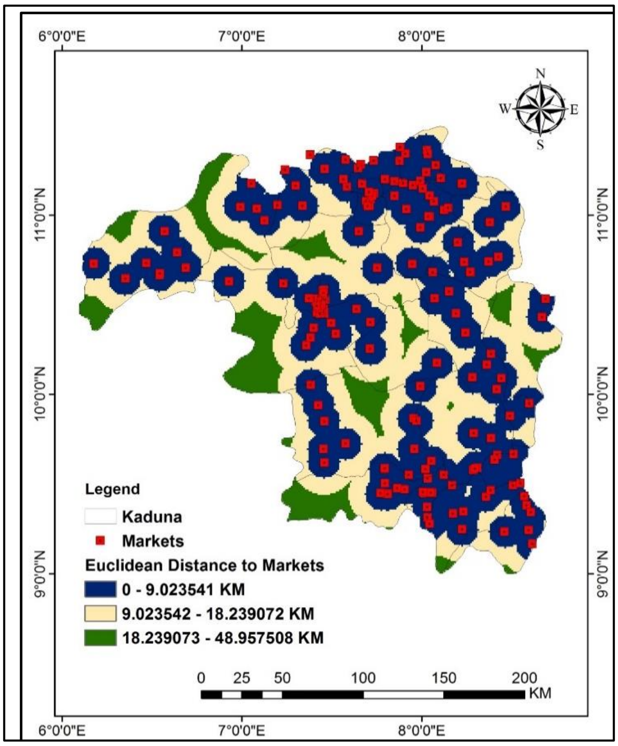

Figure 7 Euclidean distance of Markets

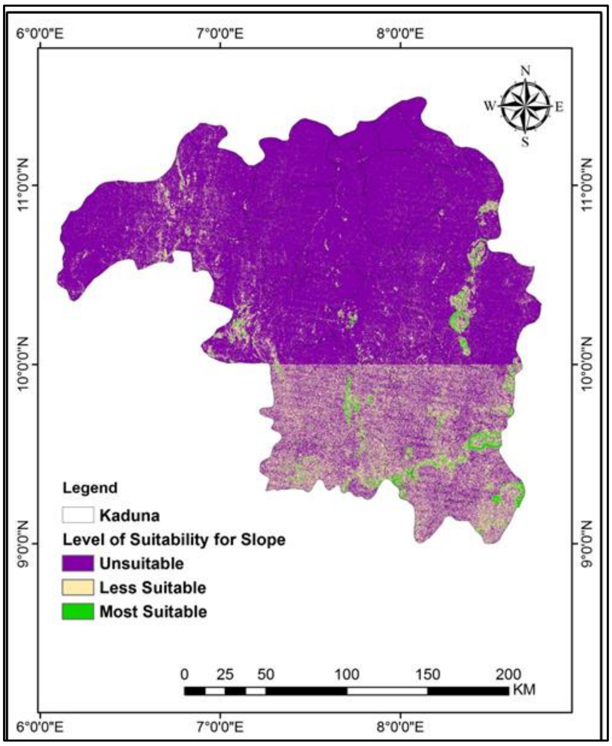

Figure 8 Reclassified slope Map of the study area

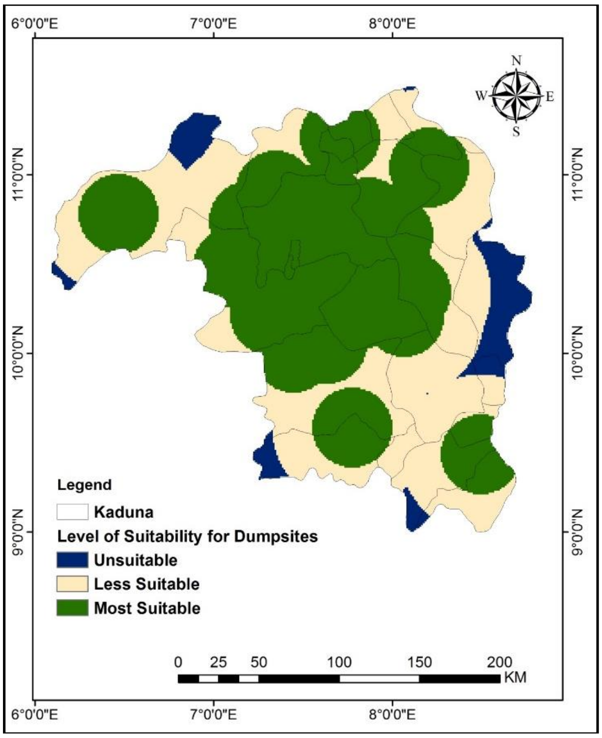

Figure 9 Reclassified Dumpsite Map of the study area

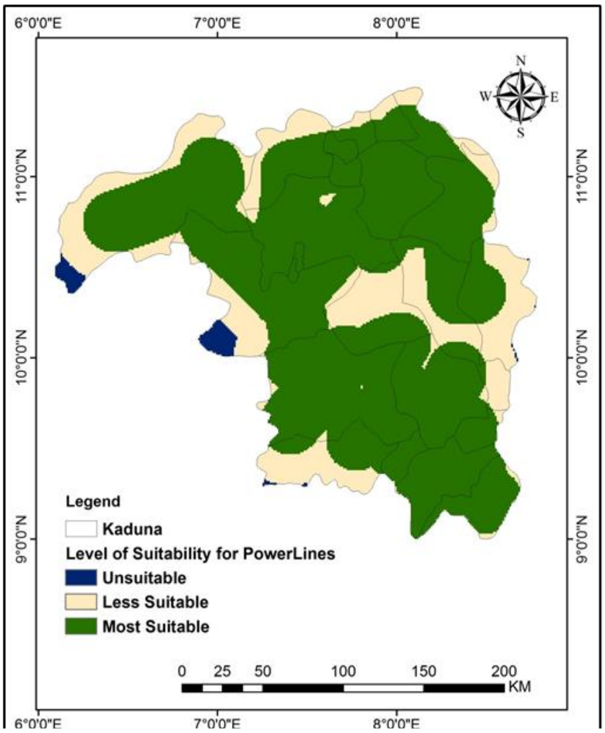

Figure 10 Reclassified power lines Map of the study area

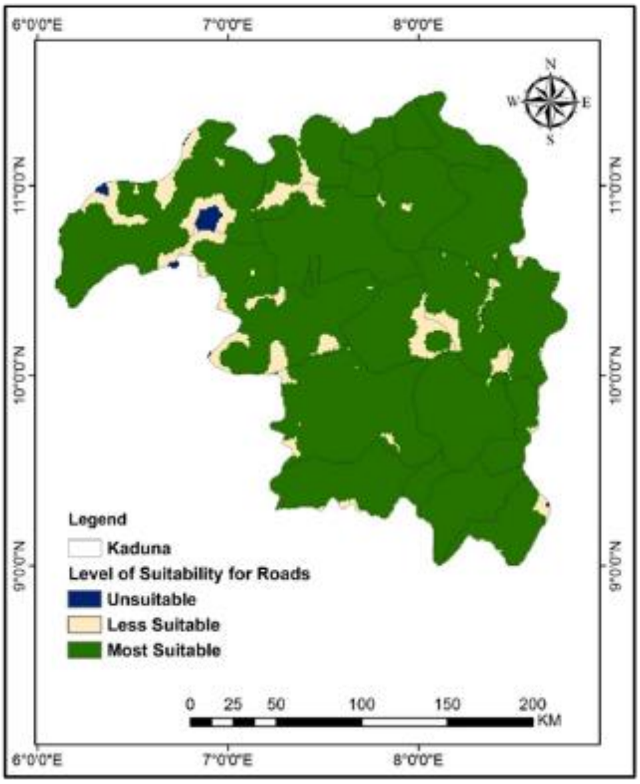

Figure 11 Reclassified roads Map of the study area

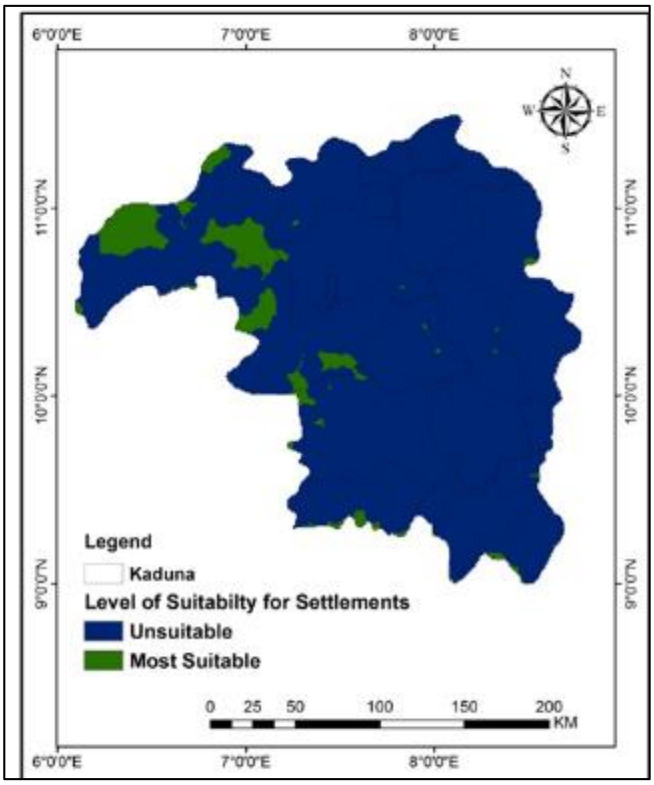

Figure 12 Reclassified Settlements Map of the study area

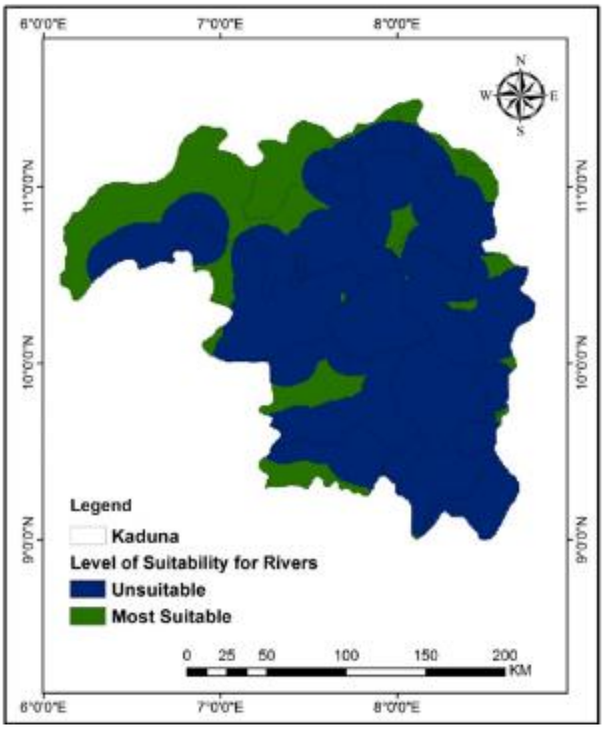

Figure 13 Reclassified Rivers Map of the study area

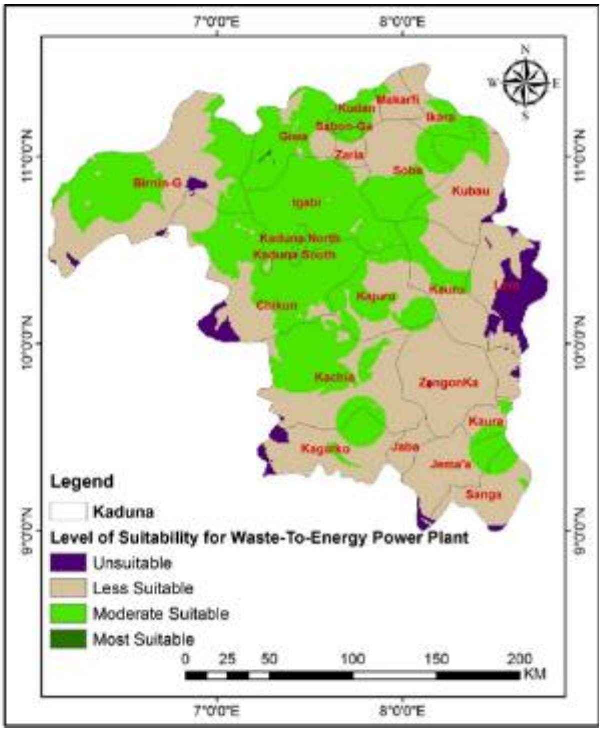

Figure 14 Waste to energy power plant suitability Map of the study area

3.3.2. Settlement and Rivers

In the case of a solid waste incineration power plant, some annoying elements such as odor, noise, and emissions are unavoidable. This means that certain sites should be situated away from sensitive land uses such as residential neighborhoods, educational and health facilities, and so on. As a result, the greater the distance between the power plant site and sensitive land uses, the better the chances of avoiding and/or mitigating the negative effects of these bothersome elements. As a result, areas near rivers and densely populated areas were restricted to avoid being too close to the power plant. In the research area, settlements encompass 49960.954611 hectares, whereas other regions such as vegetation and bare land cover 276053.22122 hectares as represented in Figure 12.

3.3.3. Integration of Criteria Maps and Preparation of Final Suitability Map

All of the criterion layers are integrated at this point to find a viable location for a waste-to-energy generating plant in the research region. Overlay analysis was performed on the waste-to-energy power plant using ArcGIS 10.4.1's weighted overlay tool. The towns, rivers, railway networks, roads, transmission lines, substations, markets, institutions, dumpsites, and slopes were all reclassified raster datasets that were aggregated at the end of these operations. The Weighted Overlay tool combines all raster layers according to their weights. To depict the data as clearly as possible, the final raster was classed manually as seen in Figures 9,10, 11, 13, 14, and 15. Table 4 shows how the selected appropriate regions were grouped into four primary classes that range from one to three.

3.4. The Final Suitability Map

According to the results of the waste-to-energy power plant suitability criteria, four suitability classes were identified with varying degrees of suitability. For each factor, a weight value was given from 1 (Unsuitable) to 3 (Most Suitable). Each parameter was given a value based on its suitability for waste-to-energy power plant site selection. The weighted value of each factor was added and the average value of them was taken to determine the suitability of land for waste-to-energy power plant establishment. The result of the waste-to-energy power plant suitability analysis further reveals that approximately 83686 Hectares of the study area is most suitable and this is represented by 26 % of the study area. The area moderately suitable is 18 % represented by 58794 Hectares. Also, approximately 45% of the study area is unsuitable and is represented by 14241 Hectares. The most suitable areas are Sabon-buruku Jaji, Ganga, Buruku, Chikun, Dokwa, Ikara, Kuban, Birinin-gwari, Kaura, and Sabon-gari as represented in Figure 15.

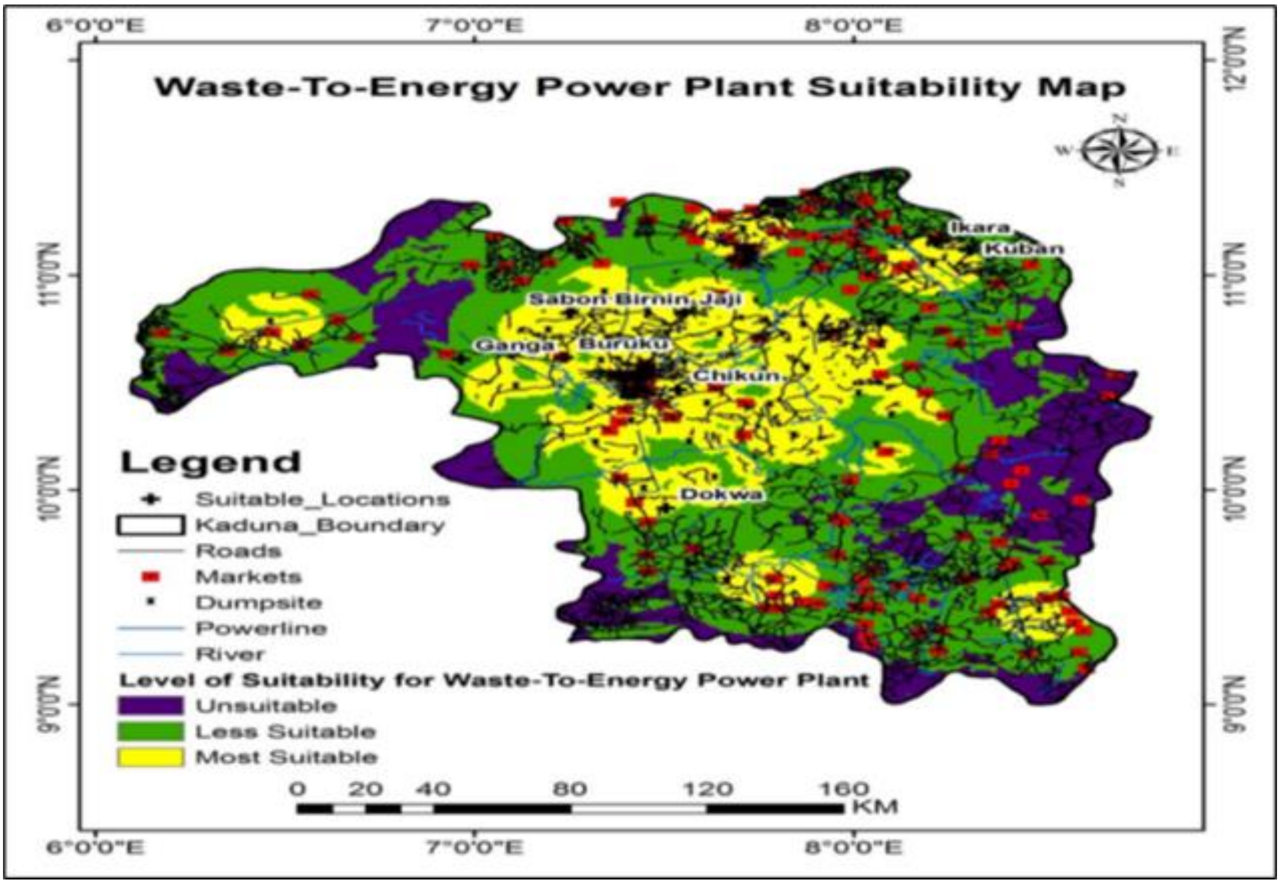

Figure 15 Waste-To-Energy Power Plan Suitability Map

Figure 16 Woman Displaying Asusu at Panteka

Figure 17 Man Sorting Waste at Dumpsite

Figure 18 Transporting Waste with a Wheelbarrow and Push Cart

3.5. Recycling Centre; Panteka Market

Panteka market, an informal solid waste recycling market in the heart of Kaduna metropolis was discovered to be a center for local fabrications and general trash recycling. It is equally a hub of garbage business in the metropolis. In the Panteka market, which is predominantly dominated by men, many sorts of recycling were taking place. Despite their tiny number in the Panteka waste recycling sector, women were found to play an important role. Many types of recycling were taking place in the Panteka market, which is dominated by men. Women were discovered to play a crucial part in the Panteka waste recycling business, despite their small number. Women's activity in recycling or recovery microenterprises is more likely to be associated with certain materials, such as textiles and plastics, tins, which are largely domestic waste, and less likely to be associated with metals, building materials, and things requiring strength, technical knowledge, or capital investment, according to the findings. Figures 16, 17, and 18 show a representation of some pictographs from some dumpsites.

4. Conclusion

The study's particular goals were to determine the viability of waste-to-energy power generation, identify the elements that influence waste-to-energy power plant site selection, and locate the best waste-to-energy power plant site(s) in the study area. Analytical Hierarchy Process (AHP), a multi-criteria decision-making process, was employed. The factors were given weights based on how important they are in identifying the best location for a waste-to-energy generating plant. Due to the large amounts of trash generated daily, the first objective's outcome indicates that waste-to-energy power generation is a possibility in Kaduna.

The use of municipal solid waste in the generation of power in Kaduna may contribute to the city's sustainability by reducing the amount of solid waste that has to be disposed of, hence extending the landfill's lifespan. In addition, the supply of electrical energy would be increased as a result of this. However, increasing the effectiveness of the municipal solid waste management system might help the power plant become more viable by maintaining a consistent flow of solid trash.

The criteria were represented in GIS layers, and the GIS analysis was run to obtain several potential sites. The criteria were then classified based on their weight values. The site suitability map will be useful in determining the suitability site for a waste-to-energy power plant. The results of the site suitability assessment revealed that the Makafia local government, located in the city's northern outskirts, was the most suitable area for locating the waste-to-energy power plant, covering 73686 hectares, or 26% of the total area. In addition, the map lays the groundwork for decision-makers to locate a waste-to-energy generating plant.

Recommendations

Following the identification of the most ideal sites for waste-to-energy power plants in the research area, it is advised that decision-makers in Kaduna and Nigeria as a whole have a working knowledge of the places where waste-to-energy power plants can be built in Kaduna. Since this study has taken into account all of the criteria for ideal locations of waste-to-energy power plants in its analysis, the government should make an effort to build one to help prevent waste from being dumped indiscriminately and to help solve the problem of power distribution.

Compliance with ethical standards

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No conflict of interest is to be disclosed

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