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Multicriteria Geographic Information System (GIS) Analysis for Solid Waste Management in Enugu Metropolis Enugu State, Nigeria

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Abstract:
Waste management has been one of the pressing issues in the world especially in growing countries which Nigeria is one. Waste management is so important that it cannot be overlooked, because people must be generating wastes and if not properly handled, pollutes the environment, spreads diseases and reduces the aesthetic nature of the environment. The aim of the research was to perform a multi-criteria GIS analysis for solid waste management in Enugu metropolis. The aim was achieved through: establishment of criteria for suitable landfill sites, classification and assignment of relative weights to the selected criteria, assessment of the existing landfill site and then the production of suitability map showing possible locations for siting landfill sites for proper solid waste management.Multi-criteria Decision Analysis (MCDA) and Geographic Information System (GIS) were used for the identification of suitable landfill site. GIS was used in integrating various layers of information to produce a suitability map for solid waste landfill site location. Multi-criteria Decision Analysis especially Analytical Hierarchy Process (AHP) was used to identify the significant role of each criteria in the analysis. Six (6) criteria were considered and were used as input map layers, and they include slope, elevation, land use, road network, river distribution and soil texture. Each criterion was ranked according to their level of importance using pairwise comparison method. Weighted overlay tool in ArcGIS was used to produce final suitability map with four (4) levels of suitability. Out of the total area 22, 915.800 m^2 (approximately 23,000 hectares), 25.53% is seen to be of low suitability, 55.55% is of medium suitability, 11.20% is high in suitability while just 7.20% was of extreme suitability. From the results generated, six (6) potential sites were selected for location of landfill site in Enugu metropolis. It is recommended that the proposed landfill sites should be open further for geotechnical and hydrological investigations before taking off.

Keywords: Waste Management, Geographic Information System, Analytical Hierarchy Process, Remote Sensing,.

I. INTRODUCTION

Solid waste can also be referred to wastes from households, municipal services, construction debris and agricultural activities. This also includes non-hazardous, non-liquid wastes from institutions and industries (Republic Act 9003, 2001). According to the World Bank (2001), waste generation is greatly influenced by a country's development. Waste can be categorized based on material, such as plastic, paper, glass, metal, and organic waste. Categorization may also be based on hazard potential, including radioactive, flammable, infectious, toxic, or non-toxic. Categories may also pertain to the origin of waste, such as industrial, domestic, commercial, institutional or construction and demolition. In most developing countries, the problems associated with solid waste management are more acute than in the developed countries (Zerbock, 2003). Lack of financial resources and infrastructure to deal with solid waste creates a vicious cycle; lack of resources leads to low quality of service provision which leads to fewer people willing to pay for services, which in turn further erodes the resource base and so on (Kuniyal, Jain, and Shannigrahim. 1998; Zerbock, 2003). The problem is further complicated by the rapid growth in population and urbanization, which has influenced an increase in the volume of waste being generated and also on waste retrieval/disposal services in municipal areas. However, more often than not, an increase in population is not matched with an equal increase in service and revenue for the local municipalities for waste management (Zerbock, 2003). Generally, the more economically prosperous a country is, the more waste it generates per capita but the factor that seem to bridge the gap between waste generation and it's resultant effect is the method or efficiency of waste management strategy adopted by such country. A typical example could be seen when comparing the waste situation in developed countries like; Britain, United States of America, Canada where there exist much economic activities that generate more waste but with a corresponding well organized waste management system compared to the situation in developing countries like; Nigeria, Ghana and Cameroun with their steady increase in population and a corresponding increase in their rate of waste generation from industrial and human activities but without an efficient waste management system. It is realized that the waste situation in developed countries are much better than that of the developing countries irrespective of the volume of waste they generate due to the waste management strategy they practice or employ. Furthermore, the increase of waste generation in the different regions of a country is indicative of its degree of urbanization. Regardless of the origin, content or hazard potential, solid waste must be managed systematically to ensure environmental best practices. As solid waste management is a critical aspect of environmental hygiene, it needs to be incorporated into environmental planning. In Nigeria, especially in major urban centres, solid waste management is a critical problem. In fact, Nigerian Government has taken different steps in the past to combat the problem without success. You don't need to look far before you see mountain of refuse in most of urban centres. Annually, 25 million metric tonnes of solid wastes are generated in Nigeria (Ogwueleka, 2009). Earlier on, the step taken was based on waste disposal on some designated landfills (that were not sanitary because they were not constructed with underlain (LDPE) to prevent leachate problem). This system i.e. one-fits-all does not work again because of increase in population and urbanization that effect the land use pattern. Then, when and where the municipal government cannot cope with waste collection and disposal successfully, people resolve into waste dumping into storm water, during the rainfall, open dumping and stream dumping. Based on observation, waste management problem in most of Nigerian communities is multidimensional in nature. It is associated with lack of community participation in solid waste management. Most of the policies that concerns this issue are made without considering the community people who are the waste generators. For instance, in a study conducted at Orita-Aperin communities in the year 2004, it was found out that attitudes and belief of community people affected their waste management practices. Furthermore, Taiwo stated that in Nigerian context, waste disposal is normally seen by the municipal government as a venture without any financial gain. That is the issues of environmental protection and healthful living is not very important to some health planners. In addition to this, the question of whose responsibility it is to take care of waste generated in a community has not been clearly answered. Unless in some civilized areas, many people do not realize that they are liable to the disposal of wastes generated by them as they dump them by the road side for government workers to pick up. The Enugu state waste management agency (ESWAMA) was established to develop and implement policies on the management of solid and liquid waste that would promote the health and well-being of the people.The state sanitation law compels residents to cooperate with ESWAMA in efforts to keep the environment clean. They required cleaning up their environment bagging waste and disposing them at nearby designated dump sites. However, the Government of Enugu adopted different method of solid waste disposal. The incineration machine were used as recently solid waste conversion vehicles are used and yet solid waste still constitute a major health hazard in Enugu metropolis. It is believed that the refuge disposal vehicles are not enough to cover the designated areas within the Enugu metropolis of Abakpa- Nike; Trans-Ekulu, Ogbete market, New market, Obiagu, Achara layout Some people who were recently arraigned in the Environmental court for waste disposal related offences claimed to lack knowledge of where and how to properly dispose their waste. In recent times, Solid waste management problem has become a major concern in an industrialized developing country, like Nigeria and in Enugu in particular, considering the high growth-rate of population and industrialization in the city. It is in this regards that this study seeks to investigate, examine and carry out multi-criteria GIS analyses on the waste management strategy being employed by the waste management agency (ESWAMA) in the study area (Enugu metropolis) to actually ascertain the state of waste management (collection and disposal) in the area to help the government and planners take adequate steps and decisions towards ensuring an improved standard of living and the health safety within the study area. The rate of development in Enugu metropolis has shown that more solid wastes are generated as days goes by. Majority of the industries are located in the area, also the major ministries of the state are located in Enugu metropolis. The centralization of the major development facilities in the heart of the state has contributed immensely to the clustering of higher percentage of the population in this area which in turn affects the generation and management of solid waste. Ojiako, Emengini and Iwuchukwu (2014) maintained that human population increase brought about by urbanization brings about the maximum utilization of natural resources. The clustering leads to overpopulation and also leads to improper erection of buildings and other facilities against the original (master) plans of the state. Most of the places mapped out for refuse dump and even recreational activities originally, had been de-zoned to residential areas. The inadequacy of refuse dump sites and inaccessibility to the few existing ones has created room for indiscriminate waste disposal. Many researches had been carried out with respect to finding lasting solution to waste management in Nigeria which Enugu is not an exception. Iyida, (2015), wrote on the implication of Administration on Solid Waste Management in Enugu Metropolis. In his finding, it was concluded that irregular waste collection of wastes affects urban development in Enugu Metropolis. He suggested that Government should enforce strictly the environmental related bye-laws, generate more funds for solid waste management. Presently, the state has started a program on sweeping the roads by a group of youths called “Enugu Clean Team”. Some youths were employed to sweep the roads on a daily basis, asides Sundays with a considerable monthly pay. They concentrate mainly on the cleanliness of the major roads with little or nothing done about other roads scattered within the Metropolis. They bag the wastes collected from the sweeping and dump them in the waste bins provided by Enugu state waste management Authority (ESWAMA) pending when the vehicles will convey them to available dump sites. Much has not been done about those suggestions as there are still indiscriminate waste disposal and burning of wastes around the metropolis. Amalu and Anim, (2014), did an appraisal on solid waste management practices in Enugu. They discovered from the respondents of their questionnaires that majority of the residents are uneducated and hence, had little or no idea of the effects of indiscriminate disposal and burning of wastes. The problems that led to the aforementioned researches are still in existence today. There are still indiscriminate dumping of refuse in drainages even close to the waste bins which is due to ignorance on the part of the people.Also,duetothe fact that Enugu State Waste Management Authority (ESWAMA) field workers do not dispose of some of the waste bins as at when due. Even though they are trying in the aspect of sweeping the road and sometimes carting away of the waste’s bins to the dumpsites, they make use of open dump sites which are prone to diseases and also reduce the aesthetic nature of the environment. Sometimes, the refuse are dumped along flowing water because of the distance of the open dump from the waste generation points. They participate more in creating awareness over the task force drive to arrest individuals who have not paid the ESWAMA levy not minding what the people do with the waste. Unfortunately, it is difficult for the Enugu State Waste Management Authority to meet up with the increasing demand for refuse dump baskets and the disposal of the few in existence especially in areas like: Timber shade in Mary Land Estate, Kenyetta market, Ogbete main market, some areas of Abakpa.There are also irregular disposal of the wastes deposited to the roadside waste bins placed by

ESWAMA and also open dumps; that leads to people burning the wastes even inside the bins. Most people are even afraid of disposing their wastes in the bins provided by ESWAMA as unauthorized scavengers have free access to those wastes without interruption.

The above problems motivated this study of multi-criteria GIS analyses of the existing management of solid wastes procedure so as to provide lasting solution for the management that will meet up with both Governmental and environmental standards. This research will base on the assessment of the existing waste management method which is open dump and the determination of suitable sites for location of landfills.

II. MATERIALS AND METHODS

2.1.Study Area

Enugu State is in the South East geo-political Zone of Nigeria. The name Enugu was derived from two Igbo words Enu-Ugwu meaning hilltop denoting that the city has a hilly geography. It shares border with the following states: Abia and Imo to the south; Ebonyi to the East, Benue to the North-East, Kogi to the North-West and Anambra State to the West. The Enugu metropolis which is the study area is made up of 3 Local Government Areas namely Enugu-East L.G.A, Enugu-North L.G.A and Enugu-South L.G.A. It is located between Latitude 6^0 22'N and 6^0 38'N and Longitude 7^0 26'E and 7^0 38'E. see figure 1.1. Enugu urban area as a whole has a population of 722,664. The area is dominated by the Igbo speaking tribe of Nigeria. The official languages used are Igbo and English.

The Igbo people are widely known to be resourceful, enterprising and hardworking. Cultural features common in the area includes some festivals that are shared in common like the New Yam festival and the Masquerade festivals. Enugu urban area is highly industrialized.In the area Precambrian basement rock is overlaid with sediments bearing coals from the cretaceous and tertiary age. The city itself at the extreme may reach an elevation of 1,000 meters (3,300ft).

The highland is underlain by sandstones, while the lowland is underlain by shale. The study area is located in the tropical rain forest zone with a derived savannah. It has a tropical savannah climate; the climate is humid and this humidity is at its highest between the month of March and November.

The rainy and dry seasons are the only weather periods that recurs in the area. Other weather condition that affects the area includes Harmattan a dusty trade wind. The average annual rainfall in the area is about 2,000 millimetres (79in) which arrives intermittently and becomes heavy during the rainy season.

The mean temperature in the hottest month of February is 87.16 degrees Fahrenheit (30.64 degrees Centigrade) while the lowest temperature occurs in the month of November reaching 60.54 degrees Fahrenheit (15.86 degrees Centigrade). The lowest rainfall of about 0.16 Cubic Centimeters (0.0098cu in) is normal in February while the highest is about 35.7 Cubic Centimeters (2.18 Cu In) in July (Nigeria Meteorological Agency, Enugu State).

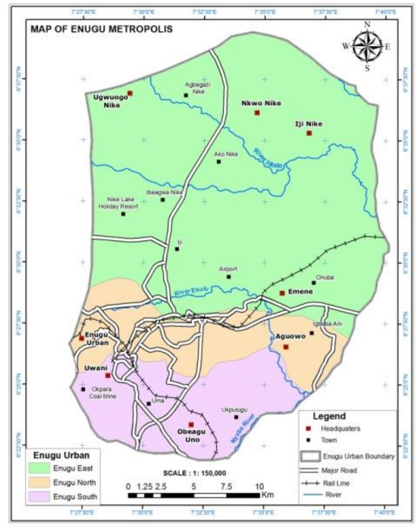

Figure 1.1: Map of Enugu Metropolis (Source: Office of the Surveyor General, Enugu State)

2.2.Data and Methods

2.2.1 Criteria and Factors for Landfill Site Selection

Geographic Information System (GIS) is a very important tool in the display and analysis of data to support the process of environmental decision making. To meet a specific objective, several criteria need to be evaluated and this method is referred to as multi-criteria evaluation (Carver, 1991). When selecting suitable sites for the location of landfill sites, many criteria are put into consideration. The more the criteria and factors considered, the better the result but sometimes the difficulty in the acquisition of some data limits the work to selection of most suitable factors. Below are the criteria used in this research and their importance in site selection.

a. Slope

Slope is an important factor when siting a dumpsite since higher slopes would increase runoff of pollutants from the dumpsite, and thereby contaminate areas further away from the dumpsite (Lin and Kao, 1999). Slope can be expressed in two different ways. One is slope in degrees which indicates the angle between ground surface and horizontal plane. The other is percentage slope which indicates the percentage ratio of elevation change on horizontal distance change. The former (slope in degrees) was used in this research. Low slope is required to minimize erosion and water runoff (Jibril *et al*, 2017).

b. Elevation

Elevation is an important parameter in the identification of landfill site. It was generated from SRTM data of the study area in ArcMap 10.5. The elevation of the study area ranges from 88 meters to 553 meters above mean sea level. Areas with elevation range between 200m to 250m are considered suitable while areas below and above it are suitable. Considering that, areas with elevation range between 193m and 243m were considered suitable in this research. Also, flat surfaces are more suitable for landfill site than areas that are on a steep slope.

c. Land Use / Land Cover Mapping

Land use land cover refers to the type of material present on the land space, what people do land surface and the pattern of the change. The knowledge of the land use / land cover of an area is one of the important criteria to be considered in siting landfill. Land use / land cover of the study area was mapped LANDSAT 8. Image classification was done to categorize the image to different classes through supervised classification. General land use of the area were identified namely: built-up area, farm land, forest, bare land and river. Solid waste disposal sites should not be placed too close to built-up areas to avoid the spread of diseases and pollution around human habitation. Landuse types such as farm land, forest and bareland are considered suitable for land fill siting.

d. Distance from road

Landfill location must be close to roads network for accessibility and ease of transportation. For this study, a distance of 500m was considered suitable because suitable in line with Jibril*et al* 2017.

e. Distance from rivers

In order to reduce vulnerability to ground and surface water pollution from contamination, landfills should not be located near streams and rivers.

f. Soil Type

Soil with medium, relatively low, and very low permeability are considered fairly suitable and optimal to site a landfill (Jibril *et al*, 2017). Specifically, the solid waste disposal site should be constructed on clay-rich soils.

2.2.2 Data Acquisition

The Quick bird image and the administrative map of Enugu state used for this research were gotten from the Ministry of Land and Survey, Enugu state. The Landsat 8 image was sourced from the United States Geological Survey's (USGS) site. It was from the Quick bird image that digitizing of roads, rivers and other features were done while the Landsat image was used for land use/land cover classification. The primary data which include: coordinates of existing landfill sites, landfill sites with their attributes were gotten through field work by the researcher. Table 2.1 below shows the factors that were considered in the selection of landfill sites, their sources and requirement for suitability.

Table.2.1. Criteria Considered and Their Sources

Criteria	Data Source	Requirement for suitability	Original Data Structure	Resolution /Feature Type
Slope	Aster DEM (Earthexplorer.usgs.gov)	Should have slope of 1º- 15º	Raster	30m
Elevation	Aster DEM (Earthexplorer.usgs.gov)	Should have an elevation of less than 250m	Raster	30m
Land Use/Land Cover	Landsat 8 OLI (Earthexplorer.usgs.gov)	Must be forest and farmland	Raster	30m
Distance to Road	Digitized from Street Map of Enugu	Must not be located closer than 500m to major roads	Vector	Line
Distance to Water Bodies	Digitized from Topographic map of Enugu	Must not be located less than 250m from water bodies	Raster	30m
Soil Texture	Extracted from Soil Map of Nigeria (sourced from European Digital Archive of Soil Maps)	Should be a combination of silt and clay	vector	Point

2.2.3 Processing Techniques

These include the techniques involved in achieving the objectives of the research. These include the following:

a. Map scanning

The result of scanning an existing document or map, is a raster image, recording a value of dark or light for each grid cell or pixel of the scan. Scanning captures map features, texts, and symbols as individual cells, or pixels, and produce an automated raster map. Scanning results to the conversion of images into array of pixels, thereby producing images in the raster format. A raster file is an image in a series of dots called pixels or picture element that are arranged in rows and columns. The administrative map was scanned for subsequent processing in GIS environment. The scanned map was saved in a format that is readable in Arcmap environment, JPEG.

b. Georeferencing

The administrative map of the state was georeferenced in ArcGIS 10.5 using the coordinates of control points from a handheld GPS, points of grid intersection were chosen for purpose of georeferencing.

c. Digitizing

Digitizing in GIS is the process of converting geographic data either from a hardcopy or a scanned image into vector data by tracing the features. During the digitizing process, features from the traced map or image were captured as coordinates in point, line, or polygon format. There are several types of digitizing methods. Manual digitizing involves tracing geographic features from an external digitizing tablet using a puck (a type of mouse specialized for tracing and capturing geographic features from the tablet). Heads up digitizing (also referred to as on-screen digitizing) is the method of tracing geographic features from another dataset (usually an aerial, satellite image, or scanned image of a map) directly on the computer screen. Automated digitizing involves using image processing software that contains pattern recognition technology to generated vectors. For this research, heads on digitizing was used to trace the features of interest.

d. Image pre-processing

Pre-processing of Landsat imagery consists of those operations that prepare data for subsequent analysis that attempts to correct or compensate for systematic errors. The imagery was geometrically correct. The digital image had little impurities and so required corrections such as radiometric and atmospheric correction. Radiometric correction was done to correct errors in the digital numbers of images. The process improves the interpretability and quality of remote sensed data. The energy that sensors onboard aircrafts or satellites record can differ from the actual energy emitted or reflected from a surface on the ground. This is due to sun's azimuth and elevation and atmospheric conditions that can influence the observed energy. Therefore, in order to obtain the real ground irradiance or reflectance errors must be corrected. The value recorded for a given pixel includes not only the reflected or emitted radiation from the surface, but also the radiation scattered and emitted by the atmosphere. In most cases we are interested in the actual surface values. To achieve these values radiometric correction was applied. Atmospheric correction: is the process of removing the effects of the atmosphere to produce surface reflectance values. Atmospheric correction can significantly improve the interpretability and use of an image. Ideally, this process requires knowledge of the atmospheric conditions at the time the image was acquired.

e. Image classification

Image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised. In this research, supervised classification was used. In supervised classification, the image processing software is guided by the user to specify the land cover classes of interest. The user defines "training sites" – areas in the map that are known to be representative of a particular land use – for each land cover type of interest. The software determines the spectral signature of the pixels within each training area, and uses this information to define the mean and variance of the classes in relation to all of the input bands or layers. Landsat 8 Operational Land Image Thermal Infrared Sensor (OLI TIS) of 2019 was acquired for land use/land cover map of Enugu metropolis. The OLI image was used to determine the available area that can be used as potential sites for siting disposal point/landfill. Land sat 8 OLI Panchromatic images of band 7 (blue), band 4 (green), and band 5 (red) etc. were combined into colour composite using LAYER STACK tool of ERDAS IMAGINE 9.2. Four classes of landuse/landcover were determined through visual interpretation, the chosen comprised of bareland, farms, forest, and river. Five sample sets of spectral signatures were defined for each class to represent the class of landuse/landcover. The maximum likelihood parameter was defined as the criteria for supervised classification. The supervised classes were given 25 output spectral classes of landuse. The supervised classification was recoded into five classes for final land use/ landcover map. The land use types of the study area are: built-up areas, river, farm lands, bare lands, forest etc.

f. Analytical Hierarchical Process (AHP) – Pair-wise Comparisons

All evaluation criteria are not equally important in influencing the selection of potential sites. The AHP method is used to assign appropriate weights to the criteria reflecting their relative importance. This method has the ability to deal with qualitative/subjective data. The AHP used in the research is based on pair-wise comparisons, which are used to determine the relative importance of each criterion, e.g., slope, proximity to road, proximity water bodies, soil type proximity to residential area, etc. The first step of this method is to structure the decision problem in a hierarchy. The goal of the decision is on the top level of the hierarchy; the next level consists of the criteria relevant to the decision problem; at the third level are the alternatives (e.g., sites) to be evaluated. The second step is the comparison of criteria in order to rank the alternatives. By comparing a pair of criteria at a time using a verbal scale, decision makers can quantify their opinions about the criteria magnitude. It uses a fundamental nine point's scale measurement to express individual preferences or judgments (table 2.2) creating a reciprocal ratio matrix. Specifically, the weights are determined by normalizing the eigenvector associated with the maximum eigen value of the reciprocal ratio matrix.

Table .2.2. The Fundamental Scale of Pair-Wise Comparisons in AHP.

Intensity of Importance	Definition
1	equal importance
2	weak or slight
3	moderate importance
4	moderate plus
5	strong importance
6	strong plus
7	very strong or demonstrated importance
8	Very, very strong
9	extreme importance

Source: Saaty, 1980

The AHP also provides mathematical measures to determine inconsistency of judgments. Based on the properties of reciprocal matrixes, a consistency ratio (CR) can be calculated. In a reciprocal matrix, the largest eigen value (λmax) is always greater than or equal to the number of rows or columns (n). If a pair-wise comparison does not include any inconsistencies, $\lambda max = n$. The more consistent the comparisons are, the closer the value of computed λmax to 'n'. A consistency index (CI) that measures the inconsistencies of pair-wise comparisons can be written as:

$CI = (\lambda max - n)/(n-1)$ ... (2.1)

And a measure of coherence of the pair-wise comparisons can be calculated in the form of consistency ratio (CR)

$CR = (CI/RI)$ ... (2.2)

Where:

RI is the average CI of the randomly generated comparisons.

As a rule of thumb, a CR value of 10% or less is considered as acceptable. Otherwise, a re-voting of comparison matrix has to be performed.

i. Identification of Existing dumpsite coverage/spatial distribution

The dumpsite coverage was determined by the coordinates as it exists on ground. The location of the existing landfill site was displayed in GIS environment using the GPS field record that was gotten with the Handheld GPS.

3.0 RESULTS

3.1 Landfill Suitability Results

In the analysis of the results, all data map layers in vector format were rasterized. Raster data are made up of picture elements (pixels) which is in form of a grid (rows and columns0 whereby each pixel has a digital number (brightness value) that ranges between (0-255)) thus representing information. Candidate sites for landfill siting were selected using GIS and multi-criteria (AHP) evaluation and overlay analysis. The criteria for site selection that were considered in the work were evaluated individually in GIS environment and in pairwise comparison (AHP) and the results were combined as overlay to produce map of suitable sites for landfill siting. The result is shown in figure 3.1 and Table 3.1.

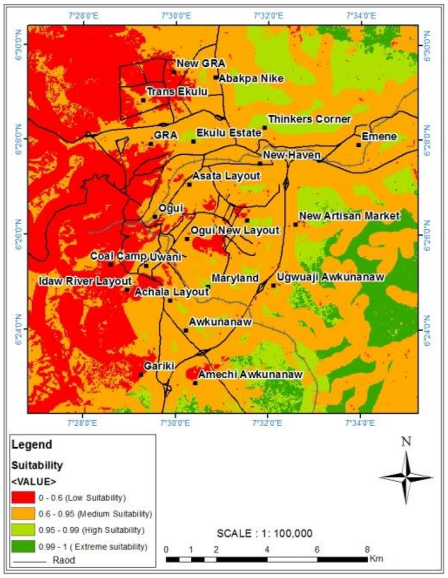

Figure.3.1. Landfill Site Suitability Map for Enugu Metropolis

Table.3.1. Suitability Area Analysis

Suitability	Area Hectares	% Area
Low Suitability	5,850.630	25.53
Medium Suitability	12,729.510	55.55
High Suitability	2,686.410	11.72
Extreme Suitability	1,649.250	7.20
Total	22,915.800	100

From the table 3.1 above, out of the total area 22, 915.800 m^2 (approximately 23,000 hectares), 25.53% is seen to be of low suitability, 55.55% is of medium suitability, 11.20% is high in suitability while just 7.20% was of extreme suitability. Looking at figure 4.7, one can confirm that there is no way location of landfills can be evenly distributed in the study area because the suitable areas are just within the North East and South Eastern parts while the North Western and South Western areas are low suitability as those places are filled with built-up area and are on very high slopes. The forest areas in the low suitable areas are on high slopes and unfavourable soil for landfill site location.

3.2 Assessment of the Existing Landfill Site

The Enugu State Waste Management Agency (ESWAMA) revealed to the team that only one landfill site is inexistence in the study area. The site is located at the New Artisan along the Enugu Port Harcourt Road. The site was visited and 3 coordinates were collected with Hand-Held GPS e-Trex 10. The coordinates recorded from the site are shown in table 3.2 below:

Table 3.2: Coordinates of the Existing Landfill Site

POINT ID	X (m)	Y (m)
1	339809.253	711752.147
2	339791.251	711760.433
3	339726.053	711752.433

The coordinates were imported into ArcGIS 10.5 as a text file and then converted to shapefile to show the location of the landfill. Overlay operation was carried out by superimposing the points on the suitability to ascertain the suitability of the existing landfill site. From the result, it was observed that existing landfill is within the high suitability area but with a concern of the future as built-up areas are already extending towards the area. The position of the existing landfill is shown in figure 3.2 below:

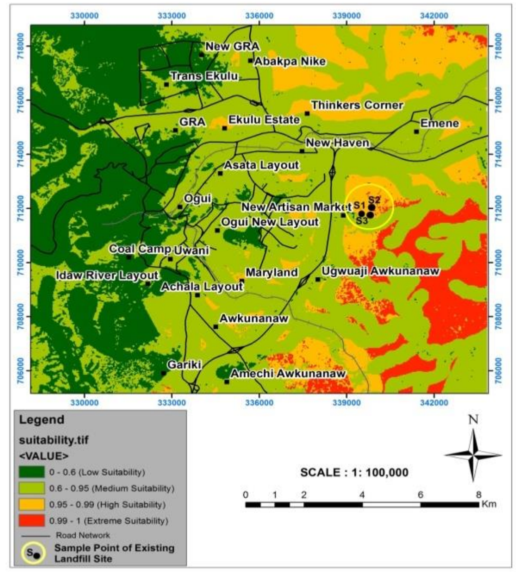

Figure.3.2. Position of the Existing Landfill Site in the Suitability Map

4.0 CONCLUSION

Open dumping site has been posing negative impacts on the environment and public health like downstream water pollution, soil pollution and health problems to the surrounding community. A landfill is an environmentally acceptable way of disposing solid waste on ground. The main purpose of establishing landfills is to protect the safety of the environment by reducing the consequence on resources and community health. This study demonstrated that GIS and MCDA are important tools for the selection of appropriate landfill locations which are needed for sustainable urban waste management. Using tools for locating sites is an economical and practical way as it shows capabilities of producing useful, high-quality maps for landfill site selection in a short period of time. Suitable alternative sites for dumping solid waste has been selected on the basis of different factors performed on Arc Map 10.5, Erdas Imagine and through AHP analysis for fulfilment of decision maker's expectations. The research shows that the model used for landfill site selection in other areas can be modified to fit any given location.

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