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Assessment and Selection of Suitable Sites for Solid Waste Disposal using Surveying and Geoinformatics Techniques

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Abstract: - The study is on assessment and selection of suitable sites for solid waste disposal. The research was done using Surveying and Geoinformatics techniques. Waste has become an environmental issue in the world today due to the increasing growth in human population and their activities, urbanization, and industrialization. The aim is to identify suitable sites for solid wastes disposal in Gidan-Kwano campus of Federal University of Technology, Minna. Application of GIS for the selection of suitable site for waste disposal is based on the overlaying of datasets and places that satisfy certain suitability criteria. The methodology therefore combined the spatial tools provided by GIS to integrate and evaluatecriteria in order to determine potential waste sites. The principal sub-criteria that were used for spatial analysis include slope, built-up-area, road networks, geological maps, etc. , hence, the exact operations of the methodology was approached in the following sequence: Investigation of solid waste disposal in Gidan –Kwano, Data Acquisition, Conversion of the criteria into GIS layer, Data processing. Global Positioning System receiver was used to acquire all the positions and locations data required to accomplish the research, such as the solid waste points. All the data acquired through GPS and other sources were processed and manipulated in computer system. ArcGIS software is an efficient tool for spatial relationship principles of connectivity, contiguity and overlay methods. The results from this study identified three potential sites suitable for solid wastes disposal.

Key words: Waste, Geoinformatics, Geographic Information System, Global Positioning System, Surveying

I. INTRODUCTION

Waste can be defined as any substance or material which is not useful to human beings. Human activities generate waste materials that are usually disregarded as they are considered useless. These wastes are usually in solid, liquid or gaseous form. Waste has become an environmental issue in the world today due to the increasing growth in human population and their activities, urbanization, and industrialization. It is important to know that the danger and environmental hazard that results from waste has made it imperative for us to adopt measures for proper waste disposal and management. According to Howard and Irwin, as cited by Anifowose, Omole and Akingbade , "an ideal waste disposal site is the one that is located reasonably close to the source of the waste, has convenient transportation access, is not situated in a low-lying area or floodplain, and is underlain by geologically stable, strong and competent rock material."[2]. In order to achieve the goal of proper waste disposal, a site has to be chosen for the disposal based on some factors and the kind of wastes such as solid waste, organic or inorganic waste, etc.

This research paper is focusing on the selection of suitable sites for solid wastes disposal in Federal University of Technology, Minna, Gidan-Kwano Campus, using Spatial Multi-criteria Evaluation (SMCE). Some literature cited are saying that solid wastes are non-liquid, non-gaseous residue from manufacturing industries, construction firms, cooking, recreation centers or agriculture. Hence, solid wastes that are generated from homes, business center, hospitals, schools, market and so on are referred to as "municipal solid wastes." Municipal solid wastes include: paper, plastics, glass, wood, metals, textile, organic waste such as food and garbage. It is important to mention that there are different types of solid waste disposal systems in use and the systems to be adopted are determined by some factors or criteria. The factors which shall be considered in choosing a suitable site for solid waste disposal in this research will include the gradient of the terrain(terrain slope), present and future land use of the campus, the road network, the distance from the neghbouring settlement and nearness to the surface water (e.g rivers, lakes, streams).

II. AIM AND OBJECTIVES

AIM: To identify suitable sites for solid wastes disposal in Gidan-Kwano Campus, F. U. T. Minna, Niger State, that will satisfy the specification laid down by the Ministry of Environment.

Objectives:

- To identify the solid wastes collection points in Gidan –Kwano campus.

- To select the most suitable sites for solid wastes disposal in Gidan --Kwano using Multi-Criteria analysis in GIS.

III. STUDY SITE/ AREA

The site considered in this research is the Federal University of Technology permanent site Gidan – Kwano, Minna, Niger State. It is approximately 11,000 hectares in land mass, and located at about 15 km from the city of Minna. It lies within the Latitude of 9° 27¹ 00¹¹ and 9° 37´ 40´´and longitude 6° 22´ 00´´and 6°28¹ 00¹¹.It has a population of not less than 25,000 people which comprises the students and staff (both academic and non-academic).

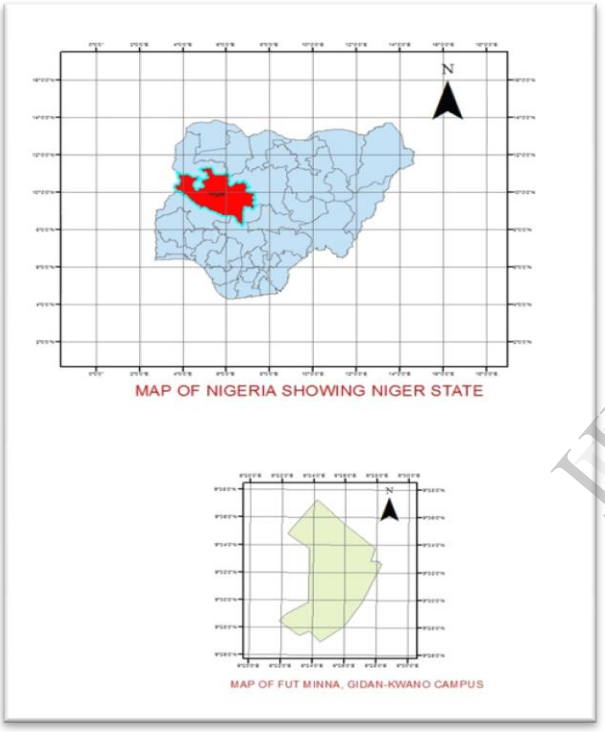

Figure 1: Map of the Study area

IV. PROBLEM STATEMENT

It will be a disturbing issue for the people around the University community if the management failed to provide a sound and reasonable measure for the disposal of solid waste despite the various activities within the campus community. These activities, such as the educational research, printing and photocopying, buying and selling of food, snacks and drinks, etc. generated solid waste of various kinds in large proportion. However, in order to create a clean, neat and hygienic environment for the campus community, it is incumbent on the University management to provide suitable sites for the disposal of solid wastes generated in the campus. Thus, this research is being carried out to facilitate the selection of ideal solid waste disposal sites.

V. SIGNIFICANCE OF THE RESEARCH

The main benefit of this study is to provide an assessment of sites for solid waste disposal within the campus, in terms of present and future capacity that will create an ideal environment for the campus community. Locating a suitable site or land fill within the campus will also reduce the cost of transporting solid wastes to town for disposal. This will reduce the damage caused by pollution and provide a facility which would not endanger any environmentally sensitive areas or have a negative impact on existing or future land use within the campus.

VI. JUSTIFICATION OF THE PROJECT

Federal University of Technology, Minna, Gidan-kwano campus is currently experiencing rapid development and growth with the creation of new schools, building of new lecture theatres, new hostels, etc. As a result, increasing amount of wastes are being collected daily in and around the campus. This project is aimed at selecting a suitable site for proper and safe disposal of solid wastes. The kind of solid wastes mostly found are plastic wastes, (bags, containers, bottles), cans, food residues, card boards, etc. In order to ensure good and healthy environment, there is the need to select a suitable site for solid wastes in the campus.

VII. LITERATURE REVIEW

Waste management involves several activities like: waste disposal, collection, treatment, recycling, composting, incineration and dumping. The report described how the waste can effectively be managed using computerizing process. Waste has been classified into the following categories: Solid waste (domestic, industrial and hospital waste), academic and research institutiion's waste, liquid waste, and trans-boundary waste. The most serious effects which result from improper solid waste management according to the report are; air pollution, contamination of drinking water supplies, and the spread of human disease. It has been reported that most site selection methods lack practical application which is as a result of number of variables and complexity of the mathematical models which include the factors and constraints required in decision making. [1] identified the problem associated with waste management, collection and disposal as Universal. [10] Examined hazardous waste management: He described it as a global environmental problem in the world presently which has negative impact on the environment. Hazardous solid waste management is considered as one of the most serious environmental problems confronting municipal authorities in developing countries. Several methods have been adopted for the selection of sites for proper waste disposal by several people; this is due to various factors or criteria being considered during

the process of selection. It has been established and reported that some researchers have considered the following factors for the selection of land fill sites: site capacity, adjacent land uses or land cover, airports, surface water, ground water, local topography, soils, climate, unstable areas, infrastructure, local flora and fauna, distance from environmentally sensitive areas, distance from urban area and population. [10] employed GIS technique for site selection which is prepared by using map overlay technique based on the selected criteria and sub-criteria.

VIII. METHODOLOGY

A - General Framework

This project basically centered on determining suitable site for solid waste disposal in F. U. T. Minna, Gidan-Kwano campus. To achieve the objectives of the study, investigation about the existing solid waste disposal system in the campus was carried out in the course of which enquiries were made and information obtained from FUTMIN Ventures, the Geology Dept, and Niger State Environmental Protection Agency about the planning and operations of proper solid waste disposal system.

Application of GIS for the selection of suitable site for waste disposal is based on the overlaying of datasets and places that satisfy certain suitability criteria. It therefore combined the spatial analysis tools provided by GIS to integrate and evaluate criteria in order to determine potential waste sites.

The principal sub-criteria that were used for spatial analysis include slope, built –up-area, road networks, geological map, e.t.c hence, the exact operation of the methodology was approached in the following sequence:

1. Investigation of solid waste disposal in Gidan-Kwano

2. Data Acquisition (Data Collection)

3. Conversion of the criteria into GIS layer

4. Data processing

B - Investigation of Solid waste disposal in Gidan-Kwano

The solid waste disposal system in Gidan –Kwano campus was investigated, by making enquiries and getting information from the solid waste management officers and visitation around the campus premises. Various points where bin drums were stationed for solid waste collection across the University premises were identified and noted. The solid wastes collected in these drums are transferred to a truck which is used to transport them to a dump site. It was noted that the volume of solid waste generated per day is approximately 2.25 cubic meters. The location for the various collection points in the school are shown in the table below.

Table 1 Showing Coordinates Dump Sites And Waste Collection Points In Gidan – Kwano Campus Collected Through Hand-Held GPS Receiver.

LOCATION	EASTINGS	NORTHINGS	CATEGORY
GIRLS HOSTEL	219145	1054676	DUMP SITE
ALONG STAFF QUARTERS ROAD	218870	1054584	DUMP SITE
HOSTEL ROAD JUNCTION	219319	1054694	COLLECTION POINT
HOSTEL MOSQUE	219376	1054689	COLLECTION POINT
CLINIC	219591	1054720	COLLECTION POINT
STUDENTS AFFAIRS	219605	1054826	COLLECTION POINT
FOOTBALL PITCH	219608	1054810	COLLECTION POINT
BUS PARK	220045	1054895	COLLECTION POINT
ENGINEERING COMPLEX	219984	1054771	COLLECTION POINT
HOSTEL ROAD	220261	1054723	COLLECTION POINT
SHOPPING CENTRE	220279	1054882	COLLECTION POINT
SCHOOL OF ICT	220218	1055004	COLLECTION POINT
SCHOOL OF AGRIC	219145	1054676	COLLECTION POINT

C - Information Acquired for proper waste disposal from the Niger State)

Environment Protection agency (NISEPA)

The information gathered showed that in selecting sites for solid waste disposal for a University Community, there are some issues to be considered such as population, life style – which includes the type of food they consume, and socio-economic background and so on. It was also learnt that wastes are sorted into various waste particles like

combustible wastes, non-combustible wastes, degradable wastes, non-degradable wastes and garbage wastes. This process of sorting is said to be the classification of solid wastes according to their characteristics, nature, and structure.

D - Instrumentation and Software

This study employed GPS receiver to acquire all the positions and locations data required to accomplish the research, such as the solid waste points. The data captured through the GPS receiver and other available data from existing map, satellite imageries, were processed and manipulated in computer system. The following software were employed in the process:

- AutoCAD 2012 ,
- Sufer II : a grid-based mapping, contouring program that interpolates irregularly Spaced XYZ data into a regularly spaced grid.
- ArcGIS 10: an integrated suite of professional GIS application.
- Microsoft Excel: is spreadsheet application developed by Microsoft.
- Global Mapper

E - Data Sources

- Existing Maps of Federal University of Technology, Minna, Gidan-Kwano.
- Google Map of Federal University of Technology, Minna, Gidan –Kwano.
- Satellite imagery of 0.6 resolution (Quikbird).
- Geological Map of Federal University of Technology, Minna, Gidan Kwano.
- Soil Map of Federal Univesity of Technology, Minna, Gidan-Kwano.
- ASTER GDEM Worlwide elevation data (1.5 arc-sec resolution).

The existing map provided the information about the existing features and the features to be developed in future. These features include buildings, road networks, and other facilities like school clinic, stadium and so on. This information was used in specifying the appropriate distance away from the habitation required as one of the criteria in selecting sites for solid waste disposal. Also, Google earth and the satellite imagery complemented the existing maps to provide an up to date and detailed data of the information. The importance of the geological map is to provide information that will ensure that the geological structure of the soil or the rock type of the area to be selected for solid waste disposal sites are appropriate and will prevent the seeping of water from the ground water by the solid waste. Soil map provided information that will guide us about the sites selected for solid waste disposal, to choose the sites containing the best soil for degradable wastes.

F - Spatial Data Acquisition

The spatial data include those obtained through ground observations (ground survey) of the sites, the detail map of the University which features the buildings, road network, satellite imagery (Quickbird), and other spatial details that are shown in the report. The spatial data are such that describe geographic location of features; they include the longitudes and latitudes or X and Y grid coordinates.

G - Attribute or Non-spatial Data Acquisition

The attribute data are the descriptive information that defines the specification, nature,

and criteria required for the selection of suitable sites for solid waste disposal. The main attribute data were obtained from the University work's department and other information that is related to waste management in the University environment. The attributes data include: the amount of waste collected, type of waste, and the number of waste points in the University. Other related data were acquired from the ministry, internet and publications.

H - Field Work

Global Positioning System (GPS) was used to obtain coordinates of existing and potential waste collection points. Also investigations were carried out from various departments in the school and other places like ministry. The data gathered were then integrated into ArcGIS for evaluation, processing and analysis.

I - Site Selection

When selecting suitable sites, balance is required among the competing multi-criteria factors that are going to be considered, so as to satisfy or meet the socio-environmental need for waste disposal by the University community. It is important to note that some of the criteria are in high preference than others in site selection. Thus, values were attributed to the criteria preferentially for evaluation in ArcGIS software to give optimum sites. In the process of evaluation, the attributed values were weighted, overlain to come out with best decision.

J - Data Processing

The data acquired from the field and from existing data were manipulated, evaluated and analysed using different available software mentioned above. Data processing in this study is basically System and Software based. All the points, and or other details captured from the school environment were plotted using AutoCAD and exported to ArcGIS to depict the acquired details from the site in a computer format for the data processing. The existing features were digitized and geo-referenced from the existing master plan of the Federal University of Technology, Minna, using the existing control points and point symbols. Also, the features that cannot be found in the master plan were digitized from the Quick bird satellite imagery. ASTER GDEM imagery was downloaded using global mapper software, thereafter spot heights data was generated and converted into Digital Elevation Model (DEM) before being imported int ArcGIS environment for further spatial evaluation and analysis.

The Digital Elevation Model (DEM) has to be generated before the slope can be derived, and this is one of the considerations for selecting suitable sites for solid waste disposal. The slope parameters were derived using ArcGIS software. Furthermore, the geological map obtained was also geo-referenced and digitized in ArcGIS environment before being used for solid waste disposal site evaluation. All these data were integrated in ArcGIS software for proper spatial evaluation and analysis, both the numerical and descriptive approach were also used for the data evaluation and analysis.

IX. ANALYSIS AND RESULTS

The use of geographic information system as a decision making tool for selecting a suitable site for waste disposal is advantageous. It uses spatial information to certify the eminence of the selected site. The use of GIS for choosing waste sites is time-saving and cost-effective compared to conventional approaches.

A) Criteria

In order to achieve the aim of choosing a site for solid waste disposal for F. U. T. Minna, a number of criteria were taken into consideration; some of these criteria include social life of the people around the University community. Other criteria such s proximity to road distance from built- up areas, and nature of underlying rock, surface slope were evaluated in ArcGIS software. To accomplish the objectives of this project concerning the selection measures for potential sites for waste disposal, related literature and opinion were sought from relevant departments.

Table 2: Showing the criteria used for the analysis

S/N	Criteria Specification
1.	Buildings 500 m - 2000 m
2.	Road network 80 m - 800 m
3.	Slope ≤ 20º
4.	Geology

B) Analysis

The ability of using Arc GIS software as a tool for decision making is based on its efficiency for spatial relationship principles of connectivity, contiguity, proximity and overlay methods. Arc GIs therefore employs spatial analysis tool to provide a comprehensive series of powerful spatial demonstration and analysis capabilities. This enables the creation, querying mapping, and analyzing of cell-based raster data; performing integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrated cell-based raster data with traditional vector data sources. In using ArcGIS software for spatial analysis, all the vector spatial data or features were converted to raster data. It operates only on software-specific raster data like ESRI grids in ArcGIS. The raster data were then reclassified to create a simplified raster and a new raster that contains a special or unique value that will show the ranking of cell values in the input raster data.

C) Distance from Built –up Areas

Existing features such as lecture theatres, faculties, hostels and other buildings have been taken into consideration. In this study, a maximum distance of two kilometers (2Km) was used in which five hundred meters (500 m) was considered the most suitable, based on the level of development in Gidan –Kwano campus. This would create a protection zone around the buildings and other facilities to sitting waste disposal system. This was done in order to avoid pollution, ecological disturbance,and other health related issues and concern.

Fig. 2 shows result of Euclidean distance from built up areas (at 2 Kilometers)

D) Distance from Roads

Road networks inside the campus is not much, however, accessibility to the disposal sites is very important. Therefore, the sites closer to road are given a priority to help in reducing the cost of transporting solid waste to the disposal sites, for this reason the minimum distance of road

is chosen as 80 m away from the disposal sites. In order to achieve this, a Euclidean distance of 800m maximum was specified for the road distance criterion. This range of distance was chosen so as to aid the transportation and better accessibility and cost-effectiveness to the disposal site.

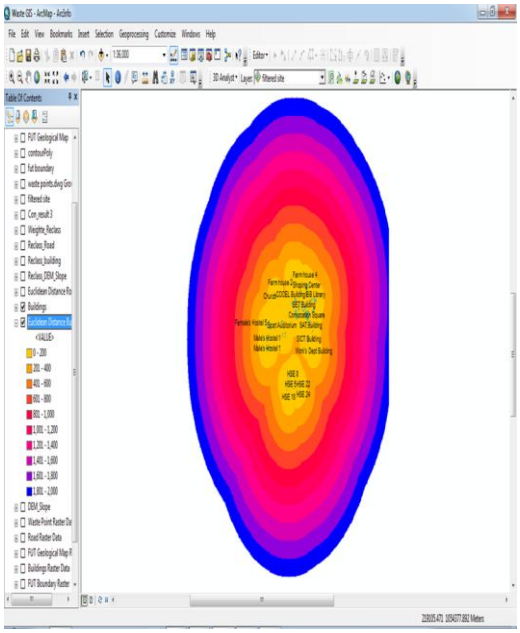

Fig. 2: Result of Euclidean Distance from built –up areas.

E) Land Slope

Another factor considered is land slope. Slope is the inclination or steepness of the surface of an area; it is used for the analysis of the surface considered in this project to determine which area may be prone to erosion. It has been specified that waste site should be situated on surface with slope less than twenty degrees (20º). Therefore a slope map was created from digital elevation model (DEM), and the DEM was converted to raster data format before it was used for spatial analysis. From the output of the slope datasets generated below, it follows that the area with lesser steep slope are shaded green while the steeper slope are shaded red.

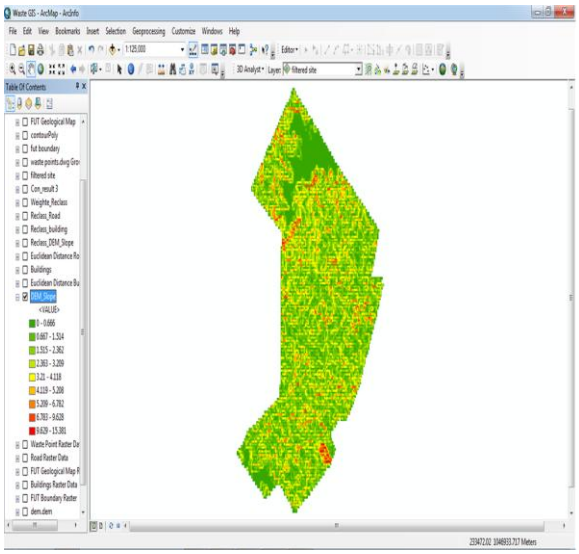

Figure 4.4 Result of Slope derived from Digital Elevation Model

F) Reclassification

In order to create suitability map that will show potential sites for solid waste disposal, datasets were created and integrated. However it is not possible to associate them in their present form because all the criteria are not in the same unit, for example, the slope cell value is represented in degrees, while Euclidean distances cell from road, and built-up area are presented in meters. Therefore from 1 to 10. There are two methods of reclassification; the first one is " one-to –one change" and the second one is "assigning a new value to a range of cell values in the input raster." The second method was adopted for the reclassification in this project, as the method made it easy for us to get the reclassified datasets weighted and overlaid for further analysis.

G) Weighting and Combining Datasets

The weighted overlay tool was employed; it enhanced the merging of all the datasets into a discrete, integer value. Any data which has its cell already in discrete value is added into weighted overlay tool. These data together with other datasets which cell are not in discrete value were combined together to assign each cell a new value of common scale measurement of 0,3,4,5 and 6. The values of the derived datasets obtained through the weighted overlay tool reclassified the cells of the datasets to a common measurement scale which are more suitable for solid waste disposal. From the figure 4.6 below, values representing the range of Euclidean distance to building, road and the range of slope specified above were restricted and this was represented on different colour with common scale measurement of 0, 3, 4, and 5. And the common scale measurement represented on Lake Colour is suitable sites for the solid waste disposal which has a value of 6.

H) Data Evaluation

Conditional tool was used to perform this evaluation in order to control the value of each cell according to the

specified conditional statement. In this study, the sites that have been considered most suitable must have a suitability value of 6. This imply that all area with value 6 will retain its original , while other area that have value that is less than 6 will change to "No Data" as shown below.

I) Analysis on Neighbourhood Cell

This analysis was achieved using Majority Filter tool in ArcGIS. This tool replaces cells based on majority value in their contiguous neighbourhood, and removes the cells that are considered small because there are many single cells representing the suitability of the sites for solid wastes disposal. Also the tool ensures that the spatial connectivity of the cells improves the cellular spatial pattern. The figure below shows the output of the analysis.

After performing the analysis on neighbourhood cell using the Majority filter tool, the output cells generated was converted to polygon where the area for each polygon was determined using the geometry calculator.

According to the output of the study, three polygons that indicated sites suitable for solid wastes in Gidan – kwano campus were obtained with the following geographic coordinate values and area as listed below.

Table 3: Coordinates and areas of selected suitable sites

S/N	Eastings(m)	Northings(m)	Area (m^2)
1	221269.649	1055910.089	1512
2	221625.706	1056088.471	11745
3	221661.665	1055977.775	38997

X. SUMMARY

This research used spatial multi-criteria evaluation approach based on Geographic Information System (GIS) analysis, map and priority in order to locate optimum sites for solid waste disposal in Gidan-Kwano campus. The results obtained from this study show that GIS and application of multi-criteria analysis can produce the best sites that are suitable for solid wastes disposal which is a vital component in solid wastes management generally. This approach has been demonstrated by studies locally and internationally.

Importantly, the results from this study identified three potential sites suitable for solid wastes disposal, and could be useful for the University management who could be looking for appropriate sites for the disposal of solid wastes generated within the campus premises.

A - Conclusion

Suitable site location for solid wastes disposal is very important, especially for University community where a lot of activities that generate solid wastes take place. In Nigeria, site selection for solid wastes has been one of the most challenging problems that require extensive effort in order to locate and manage an appropriate place for their disposal.

Additionally, GIS has been proven to be one of the best tools for decision making, planning and also the selection of optimum from multiple choices in spatial analysis. This GIS can be used to select suitable sites for solid wastes disposal in the possible time.

B - Recommendations

1. It is recommended that the site selected as a result of this study should be adopted for the disposal of solid wastes for the campus.

2. GIS approach is recommended to be adopted to accomplish similar projects in the future.

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