Application of Remote Sensing and Geographic Information System (GIS) Techniques in the Selection of Suitable Solid Waste Disposal Sites In Owerri and Its Environs, Imo State, Nigeria

Augustine .C. Emeribeole

Department Of Surveying and Geoinformatics, Imo State University, Owerri, Imo State, Nigeria
[1] acemeribephd@gmail.com

ABSTRACT

Solid waste disposal has become a serious and challenging problem in major urban centres in Nigeria including Owerri. The common sights of refuse that accumulates along the roads and market squares that make the road impassable to traffic are examples of the problem. Waste disposal problem often results from the inability of government and its agencies to match the collection and disposal with the generation of waste. Sometimes too, the problem could be as a result of lack of suitable disposal sites as against the arbitrary and illegal dumps with their attendant health hazards. Various techniques have been used to select solid waste disposal sites in different parts of the world. This work carried out the selection of suitable waste disposal sites in Owerri and its environs of Imo State using a high resolution satellite imagery and GIS technique. When remotely sensed data are used to produce a map, it takes a new form, encourage new uses, new users and cartographic visualization can be possible. The work specified data acquired such as SPOT 5 (2.5m) satellite imagery of Owerri, the 10m DEM and the Imo State Administrative map. The hardware used were laptop computer, hand-held GPS receiver, a scanner and a HP plotter. Software utilized were Arc GIS Desktop 10.1, ENVI 4.5, Google Earth, Global mapper and Microsoft word. The methodology included the scanning of the base map covering the study area using A0 scanner at a resolution of 300dpi in colour mode. These images were georeferenced to establish the relationship between the image coordinate system and the corresponding ground coordinate system. The images were visually analysed to determine generic and specific characteristics of various features. Features such as roads, water bodies, streams and built up areas were extracted by one-screen vectorisation. The satellite image was enhanced and classified. The enhancement operation was done by splitting the multispectral spot image composite into individual RGB channels and then re-composing these bands by changing their group. Supervised classification method was used to classify the features. Preprocessing of DEM was done and contour interpolation from DEM was achieved and subsequently converted to TIN. This GIS operation was done using Buffer operation, exclusion and overlay operation. The result of the analysis showed that, two locations namely Okuku and Emeabiam with 714.246 hectares and 329.294 hectares respective are suitable for the location of disposal sites. They satisfied the criteria. Solid waste disposal sites can be selected and established successfully using remote sensing data and GIS technique. This will help planners and decision makers in land use and budgeting of solid waste disposal and management. The study recommends that remotely sensed data and GIS technology be used to establish suitable disposal site rather than choosing disposal sites arbitrarily.

Keywords — Remote Sensing, GIS, solid waste, Imo State, Suitable Sites.

1. INTRODUCTION

In most developing countries, one of the most pressing environmental problems facing urban centres today is the disposal of accumulated solid waste materials. In Nigeria, for example, high population growth demands that land should be used judiciously. This increase in population is without any

corresponding increase in some urban services such as solid wastes management lead to land degradation. Also, the uncontrolled refuse disposal has always been associated with serious health hazards (UNCHS, 1989). For instance, waste materials in most open dumps are made up of organic materials. When they decay, they produce unpleasant gases and liquids. This condition attracts disease carrying insects like flies and heat generated by decaying wastes, offer a fine breeding environment for the survival of insects borne diseases (UNCHS 1989). Flies from solid waste can transmit typhoid fever, cholera, dysentery and other illnesses to the surrounding population.

In most of the urban centres of Imo State of Nigeria, such as Owerri, Orlu and Okigwe, oftentimes, refuse heaps are left to encroach on or completely block roads, thereby obstructing traffic, sometimes causing accidents especially near market areas. Solid wastes are left to block gutters and other drainage channels thereby causing flooding on the roads especially during rainy season. Solid wastes are dumped in burrow pits, at road junctions, near streams and litter the roads. The choice of burrow pit for a dump site is most arbitrary and are not scientifically done. No scientific study is carried out before these sites are selected for refuse disposal. There is no record to show that measures are taken to maintain certain level of aesthetics and the protection of the environment.

From the few existing dumps in Owerri and its environs, wastes are collected and transported to more or less open disposal sites in open tippers and other wastes disposal vehicles without any separation of the major constituents. It is therefore, evident that the most common form of solid wastes disposal sites in Imo State especially in Owerri and its environs is the crude open dumping system in the various burrow pits, natural depressions, gullies and even agricultural lands. This crude form of waste disposal which has been going on for several decades is not only environmentally unfriendly but also presents a high nuisance value and is detrimental to health of the people living close to these sites. This crude form of solid waste disposal in an area where land is a scarce resource is unacceptable and requires that a sustainable solution based on proper planning and careful research be adopted. There is need to properly select our landfill sites and adequately manage them and make them not only sanitary but also technically and scientifically acceptable in terms of operation and efficiency, adaptable to changing conditions. It is in view of this major concern and on this premise that this research is aimed at scientifically selecting a suitable site using remote sensing and GIS techniques.

1.1. Aim and Objectives of Study

The aim of this thesis is to select suitable solid waste disposal sites in Owerri and its environs of Imo State with the intention of locating suitable sites using remote sensing and GIS techniques.

To achieve the above aim, the following objectives would be pursued:

i) To map out the study area using spot 5 imagery for the selection of solid waste disposal sites.

ii) To determine the criteria for suitable locations as disposal sites using GIS as a tool.

iii) To determine the capacity of the selected sites

2. STUDY AREA

Imo State is located in the south east geopolitical zone of Nigeria. It was created on February 3rd 1976 from the former East Central State of Nigeria. The state extends between latitudes 5°10' and 6°00' North, longitudes 6°35' and 7°30' East. It is bordered on the north by Anambra state, on the South and West by Rivers state and on the East by Abia state. See fig. 1. The state comprises an area of 5,530km^2 or about 0.6% of the total land area of Nigeria. The population according to 2006 census was estimated at about 3,927,563 million inhabitants which is about 2.80% of the total population of the federation (Federal Office of Statistics 2006). However, the projected population in 2014 is 550,474 (See Appendix A)

2.1. Location and Site

The urban centre selected for the study is Owerri and its environs. Owerri is also the capital of Imo State. It is located between latitudes 5°33'N and 5°24'N and longitudes 6°58'E and 7°06'E. It has a population of 550,474. It is approximately 40 square miles (100km2) in area. Owerri has two rivers flow site namely Otamiri to the East and Nworie River to the South. Owerri is the capital city of Imo State of Nigeria. It has a

status of a municipality and is located approximately at latitude 5°29'N and longitude 7°2'E (see fig. 1).

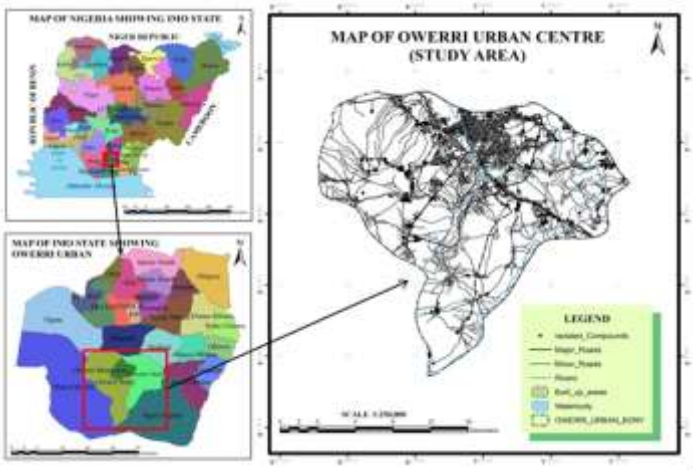

Fig. 1 Map showing the study area

Source: State and L.G.A map digitized from the Admin map of Nigeria while Owerri urban map was digitized from SPOT 5 satellite image 2012. All obtained from Office of the Surveyor General of the Federation (OSGOF) Abuja.

Table 1: Mean Monthly Rainfall and Temperature

Rainfall (mm)	Jan	Feb	Mar	Apr	May	June
Owerri	25.1	44.2	123.4	204	269.5	307.9
Temperature (°C) Owerri						
Maximum	33.6	34.1	34.0	33.0	32.5	29.6
Minimum	20.8	23.5	23.6	23.6	23.2	23.2

Table 1 contd.

Rainfall (mm)	July	Aug	Sept	Oct	Nov	Dec
Owerri	356.4	311.7	429.3	288.3	76.7	20.1
Temperature (°C) Owerri						
Maximum	28.7	29.1	29.9	30.6	33.6	34.0
Minimum	22.6	22.3	22.4	22.6	22.6	19.7

2.2. Climate and Vegetation

Owerri municipality has two seasons namely; the wet season and dry season. The wet season begins from April and ends in October. The dry season begins in November and ends in March. The mean monthly rainfall distribution in Owerri municipality has it peaks in July and September. The annual maxima relative humidity in Owerri municipality coincides with the peaks of monthly rainfall.

The abundant and constant insulation in Owerri municipality gives rise to high temperature. Mean daily maximum temperature ranges from 33°C to 34°C while mean daily minimum air temperature is from 20°C to 22°C (NIMET 2009).

Owerri municipality falls within the rainforest vegetation zone. It has according to (NEST 1991), the natural rainforest (Riparian forest and low land forest).

2.3. Social Economic Status

The Sam Mbakwe International Cargo airport is about 14 miles (23km) along Owerri – Aba Road. "Eke Ukwu" Owerri is the main market. It has also the 'new' market and the 'relief' market. Owerri has a number of educational institutions namely: Imo State University, Federal University of Technology, Alvan Ikoku Federal College of Education, Federal College of Land Resources (FECOLART), Federal Polytechnic, Nekede, Government College Owerri, Emmanuel College Owerri, Owerri Girls Secondary School, Federal Girls College Owerri, Owerri City College, Imo Girls College, Owerri. There are other privately owned secondary schools. Christianity is the dominant religion in Owerri. Catholics and Anglicans have the largest followership.

3. METHODOLOGY

3.1. Data Acquired and Source

For the study, SPOT5 2.5m natural colour satellite imagery of Owerri Urban center and its environ were acquired from the Office of the Surveyor General of the Federation (OSGOF) while the 10m DEM covering the study area was acquired from National Space Research and Development Agency in Abuja (NASRDA).

It is also important to state that Owerri Urban center which was carved out using the local government boundary map of Nigeria and the Imo State Administrative map was obtained from Ministry of Land and Survey, Owerri Imo State.

Table 2 shows the data acquired and source.

Table 2:Data Type and Source

S/N	DATA TYPE	PRODUCTION DATE	SCALE	SOURCE
1	SPOT 5 Satellite Imagery	2012	2.5m resolution	OSGOF
2	SPOT DEM	2012	10m	NASRDA

3	Admin Map of Imo State	2006	1:2,000,000	Ministry Of Land and Survey Owerri, Imo State
4	Google image	2014	1:1,340 (view scale)	Google maps.

3.1.1 Hardware Requirement

The choice of equipment (Hardware and Software) used was influenced by the specifications, the size of the project and the desired accuracy.

Thus, the hardware used for the successful completion of this project are:

(a) Hand held GPS receiver (etrex 20 Garmin)

(b) Dell Laptop Computer / Accessories (Windows 7)

(c) Scanner (Colortrac SmartlfCx 40)

(d) Plotter (HP Design Jet T1120)

3.1.2 Software Requirement

Basically, six software were used for the project viz;

(a) ArcGIS Desktop 10.1 – this was used for displaying and subsequent processing and enhancement of the image. It was also used for the carving out of Owerri urban center from the imagery using both the admin and local government maps and other mapping operations.

(b) ENVI 4.5 – This was used for the classification of the various vegetation types of the study area.

(c) Microsoft word – was used basically for the presentation of the research.

(d) ArcHydro – This was used for pre-processing the DEM

(e) Google Earth™ – This was used to capture the google image used

(f) Global Mapper 15 – This was used for the generation of contours from the DEM and subsequent conversion to Triangulated Irregular Network (TIN)

3.2. Data Processing

3.2.1 Methodology Workflow

The study used spatial multi-criteria analysis technique to identify the most suitable solid waste disposal site. Spatial multi-criteria approaches (SMCA) have the potential to reduce the costs and time involved in siting facilities by narrowing down the potential choices based on predefined criteria and weights and permitting sensitivity analysis of the results from these procedures (Higgs, 2006). The solid waste disposal site selection mapping was done using multi criteria evaluation and creating layers to yield a single output map or index of evaluation (Wiley and Sons, 2009).

The general site selection criteria that must be satisfied for the most suitable site for Solid waste disposal in Owerri Urban centre include (Brook, et al., 1999):

i. 200 meters buffer around all surface water.
ii. 100 meters buffer around all transport routes
iii. 2,500 meters buffer zones created around all urban areas (i.e. built-up areas).
iv. Soil with low permeability e.g. clay rich environment
v. A landform that has lower elevation and slope
vi. 3,000 meters away from protected areas such as churches, mosques, parks and others
vii. Land use/ land cover types such as grassland, forests and cultivated land.
viii. 3,000 meters away from the airport.

3.3 Outline of Methodology Workflow

1. Scanning
2. Georeferencing
3. Image Visualisation and Interpretation
4. On-screen Vectorisation and Feature Extraction
5. Satellite Image Enhancement and Image Classification
6. Preprocessing of DEM
7. Contour Interpolation from DEM and subsequent conversion to TIN
8. GIS analysis
    a) Buffer Operation
    b) Exclusion
    c) Overlay Operation

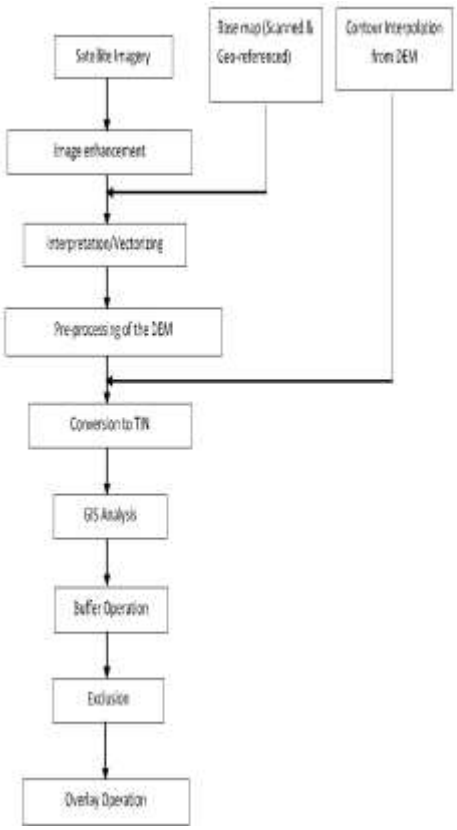

Fig. 2: Flow chart

3.3.1 Scanning

Scanning is the process of translating the paper map into a digital form that can be recognized by the computer. Scanning of the base map covering the study area was done using Colortrac SmartlfCx 40 A0 Scanner at a resolution of 300dpi in colour mode and was saved with tagged imaged file (.TIFF) extension which made it ArcGIS software compatible. See fig. 3

Fig.3: Scanned Admin map of Imo State

Source: Ministry of Lands and Survey, Owerri, Imo State (2006)

3.3.2 Georeferencing

Georeferencing of images establishes the relationship between the image coordinate system and its corresponding ground coordinate system. By georeferencing of an image, the image is related to the true or real position on the ground surface. The data frame of the Data view of the ArcMap was projected before inserting the Ortho-rectified SPOTS satellite imagery and the scanned topographic map sheet covering the area of interest.

3.3.3 Image Visualisation and Interpretation

There are several distinguishable variations on the satellite imagery produced by a multitude of combinations of colours. In classifying and interpreting land use and land cover from remote sensed data, the quality of the interpretation is improved by the integration of ancillary data. Manual interpretation of the SPOT image was therefore conducted based on the implicit and explicit use of collateral information which included old maps, photographs, reports and personal experience of the interpreter and was done using a predefined classification system. Colour, tone, pattern, texture, association, shape, size, shadows, and site clearly enabled photomorphic delineation of line and polygon features. The images were visually analysed to determine generic and specific characteristics of various features as supportive knowledge for the on-screen digitization and classification phases.

3.3.4 On-screen Vectorisation and Feature Extraction

Several features are easily distinguishable to a good degree on the image. These include roads, water bodies, streams, sand dunes and built up areas. These features were extracted by on-screen vectorisation. Point mode digitising strategy was adopted in this case. Some points were selected subjectively because some judgement is required on how to represent some lines. The default editing mode in ArcGIS is point mode. In this mode, a series of precise points, or vertices were digitized. ArcMap then connects the vertices to create the digital features.

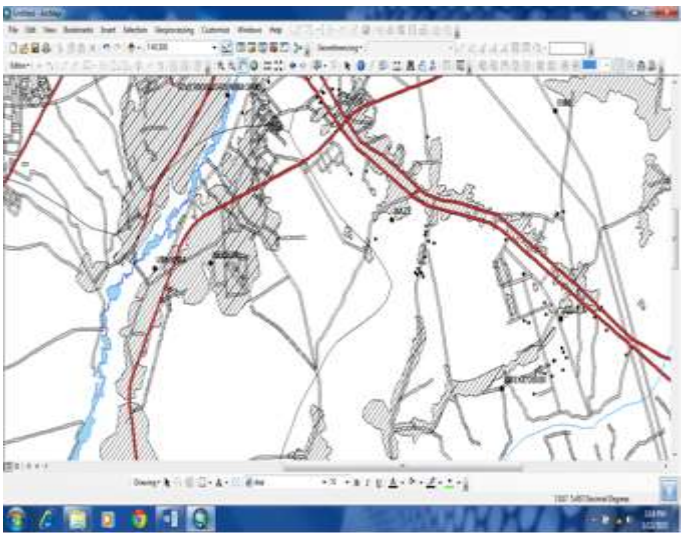

Fig. 5: On-screen vectorisation and feature extraction in the ArcMap environment.

3.3.5 Satellite Image Enhancementand Image Classification

The SPOT 2.5m imagery is a natural colour composite. The colours of natural features such as water bodies and vegetation appear as they are on ground and the image is fairly close to reality. However, due to insufficient contrast between and among many objects on the imagery, the vegetation types are not easily distinguished and some shallow water areas seem to have similar reflectance with the wetlands. The imagery is composed of 3 bands. The enhancement operation performed basically consisted in splitting the multispectral SPOT image composite into individual RGB channels and then re-compositing these bands by changing their grouping. Selecting the appropriate band combination to use in the composite does have a huge impact on increasing the contrast between features to aid easy detection and classification by our remote sensing system.

Preliminary image interpretation revealed such a multitude of features visible on the satellite image that it was deemed impractical to subject all of them to on-screen vectorisation. More so, the low contrast between some adjoining features even after enhancement would greatly task the human digitizer in trying to delineate their exact boundaries. As such, it was necessary to employ image classification. Image classification helps to process the image by categorizing the land into various use functions. The supervised and unsupervised methods were each put up for consideration.

In supervised land classification, the individual processing the imagery guides the image processing software to help it decide how to classify certain features. This is done by the use of a vector layer containing training polygons. In unsupervised classification, the software does most of the processing on its own generally resulting in more use categories than the user is interested in. This is the point where the user has to make decisions on which categories can be grouped together into a single land use category. In either case additional image processing may be used to help determine which method is better for a given situation.

3.3.6 Preprocessing of DEM

The preprocessing steps to use when preprocessing a terrain depend on the type of the terrain (dendritic, deranged, i.e. with sinks, combined) and on the type of analysis to be performed. In DEM preprocessing, two functions are implemented within the ArcHydro environment. The LevelDEM function modifies a DEM by setting the cells within the selected Lake Polygon features to the associated FillElev value. The function works on a selected set of polygon features or on all features if there is no selected set. The DEM Reconditioning function modifies a DEM by imposing linear features onto it (burning/fencing). It is an implementation of the AGREE method developed at the University of Texas at Austin in 1997. The function needs as input the raw DEM (or LevelDEM) and a linear feature class (e.g. river to burn in) that both have to be present in the map document.

The preprocessed DEM is now more hydrologically correct and has better terrain characterization.

3.3.7 Contour interpolation from DEM and subsequent conversion to TIN

The SPOT 10m digital elevation model (DEM) is basically a surface model with a rectangular grid of pixels with the digital numbers corresponding to height values. Several terrain parameters can be extracted from such a surface for the depiction of relief on the topographic map. The contours at 25m interval and spot elevations of mountainous peaks and low valley floors were extracted using GlobalMapper software.

One major requirement for deploying contours interpolated from DEMs for use in mapping is that the contours must be of

good cartographic quality. A smoothing function was applied to the contour lines to improve their aesthetic quality.

A suitable tolerance was selected and applied for use in the operation. The smoothing tolerance specifies the length of a "moving" path along an input line used to calculate the smoothed coordinates by PAEK algorithm. The longer the path, the more smoothed the resulting lines. Each new location is calculated using the information within the specified length of the path that is centered at the location. The process for contour extraction has the following characteristics:

1. The process is repeatable
2. The contours are spatially consistent
3. The contours are produced by a single method

The followng cartographic rules were followed as closely as possible:

1. Contours may not cross water bodies
2. Contours may pass through swamps
3. Depression contours should not cross line streams more than once
4. All elevations are expressed in metres

It is important to note that the output contours are not engineering contours. They are but one of a myriad of possibilities in the quest to represent topography.

The contours were then converted to TIN using the 3D analyst extension on ArcGIS.

3.3.8 GIS analysis

The GIS analysis and operations performed in the selection of the most suitable sites in this study involved the multi-criteria evaluation and overlay operations. The multi-criteria which is conducted by weighing all factor maps and combining them with the overlaid constraint map suitable site for landfills site in the study area. The following variables are taken into consideration in the final suitability map. They are land-use/land-cover type, distance to surface waters, proximity to urban areas; distance to transport route, geology and soil type of the study area.

3.3.8.1 Buffer Operation

The operation performed by the buffer command generates one or more polygons "BUFFER ZONE" surrounding geographic features. The following buffer operation was performed

i. 200 meters buffer around all surface water.
ii. 100 meters buffer around all transport routes
iii. 2,500 meters buffer zones created around all urban areas (i.e. built-up areas).

3.3.8.2 Exclusion

The buffered results were then excluded from the Owerri urban center extent using the erase tool on Arcmap leaving the potential landfill site.

3.3.8.3 Overlay Operation

The overlay analysis of the buffered built-up map overlaid on the landuse/land cover map. The purpose of this analysis is to determine the available area that can be used as a landfill site, bearing in mind that areas covered by the buffer are unsuitable, area covered with rock-out crop are unsuitable and areas housing the forest reserves are also unsuitable, whatever areas left are the potential suitable areas for the landfill site.

4. RESULTS AND DISCUSSION

This section takes a detailed look at the outcome of the data obtained in three with the view to presenting the results in form of user-interactive figures and maps.

4.1 Satellite Image Enhancement and Image Classification

The enhancement operation performed basically consisted in splitting the multispectral SPOT image composite into individual RGB (band 123) channels and then re-compositing these bands by changing their grouping into band 213. Figures 4 and 5 shows the satellite image before and after enhancement respectively while figure 5.3 shows the satellite image after classification.

Fig. 4: Satellite image before enhancement

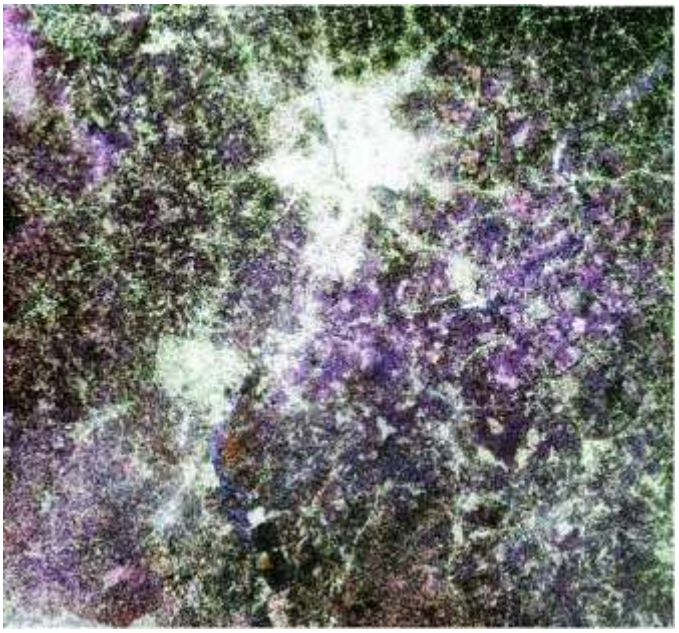

Fig. 5: Satellite image after enhancement

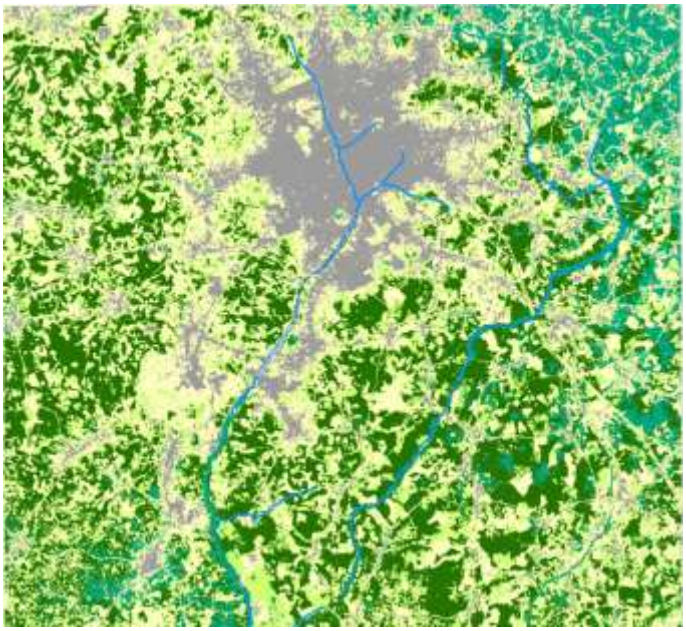

Fig. 6: Satellite Image after classification

4.2 Contour interpolation from Demand subsequent conversion to TIN

Figure 7 shows the contours interpolated from the DEM. It is important to note that the output contours are not engineering contours. They are but one of a myriad of possibilities in the quest to represent topography. The contours are not intended to be appropriate for every conceivable purpose.

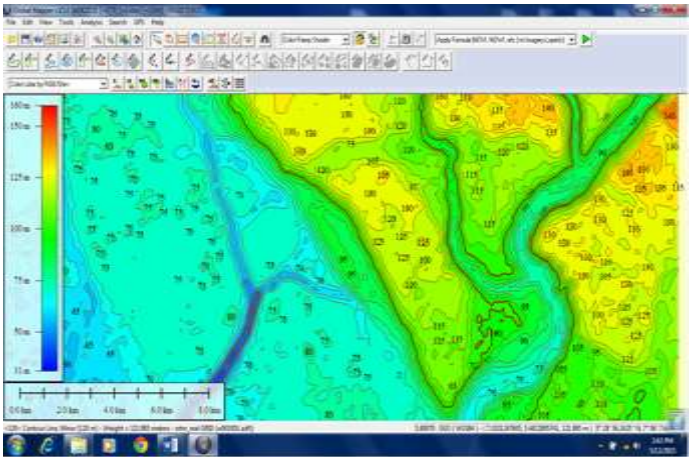

Fig. 7: Contours interpolated from DEM in the Global Mapper Environment

4.3 Land use/Land cover class suitability

Figure 8 shows the landuse/land cover map of the study area with 59% of the land covered by vegetation. Over 28% is used for cultivation while only about 13% is used as built-up area.

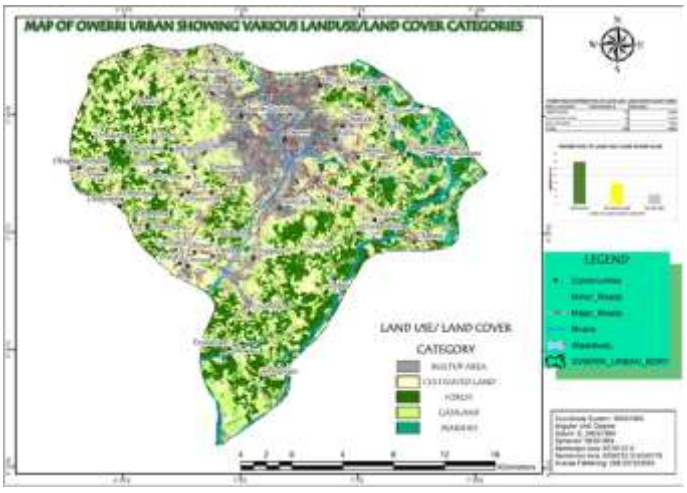

Fig. 8: Land use/ land cover map of study area

Source: SPOT 5 (2.5m) Satellite Imagery of Owerri, 2012

4.4 Soil suitability

Figure 9 shows that the study area lies within the high silt and clay region. These characteristics makes the soil type within the study area suitable for landfill site.

Fig. 9: Soil Map of Old Imo State

Source: Soil map of Old Imo State digitized from the Atlas of Imo State produced by G & G in collaboration with Kenting Africa Resource Service Ltd, 1984.

4.5 Suitable distance from rivers and lakes

Landfills should not be placed too close to streams and rivers that constitute the drainage system of an area in order to mitigate conflicts relating to the contamination of sources of water supply. This becomes imperative in order to guard against health problems, noise complaints, odour complaints, decreased property values and animal – perpetrated mischief due to scavenging creatures. These were buffered at a distance of 200 meters.

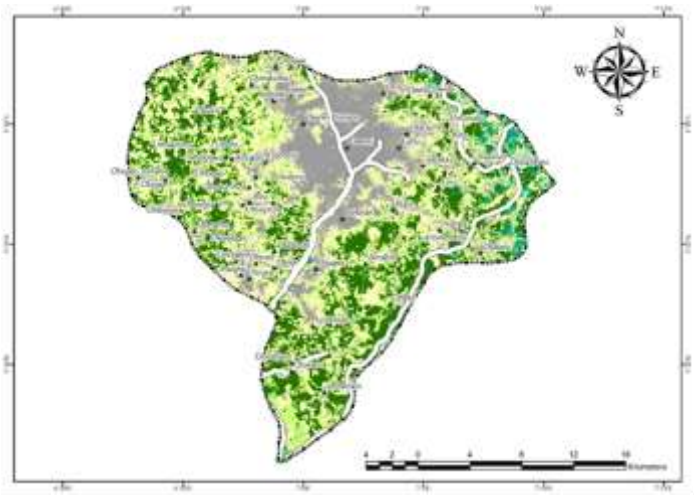

Fig.10: Buffered Drainage Map of Owerri Urban Centre

4.6 Suitable distance from roads to solid waste dumping site

As the general concept, the landfills shall not be located within 100 m of any major highways, city streets or other transportation routes. Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. The choice of 100 meters buffer is to give adequate consideration to aesthetics and safety and this is generally acceptable in Nigeria.

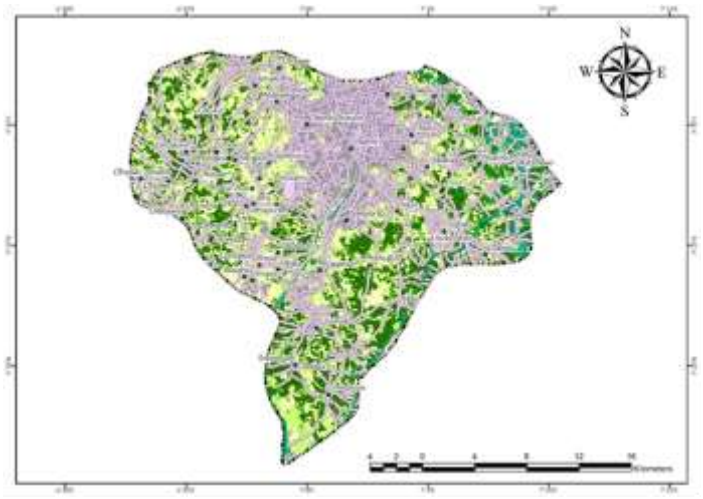

Fig.11: Buffered Road Network Map of Owerri Urban Centre

4.7 Suitability of built-up areas

The built-up area of the study area was buffered by 2500 meters, the purpose is to create adequate set back between dwelling or residential areas and the landfill site to avoid any form of pollution. The areas outside the buffered zone are potential areas for the siting of the landfill because they are out of the restricted area.

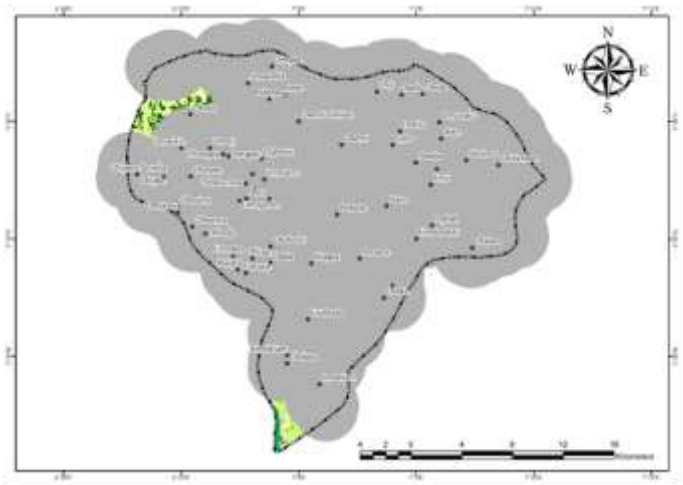

Fig. 12: Buffered Built-Up Area Map of Owerri Urban Centre

4.8 Suitability of Elevation and slope

The triangulated irregular network map (TIN) was derived from the contour map of the study area using surface analysis in ArcMap 10.1. The map shows the elevation of the area. This study considered the lower slope more highly suitable than the land with higher slope. Different research shows that areas with high slopes will have high risk of pollution and potentially not a good solid waste dump site. The majority of the study area falls under the low slope. Depending on this, most of the land is suitable for solid waste disposal site. Thus, Areas with elevation range between 30m to 50m are suitable areas.

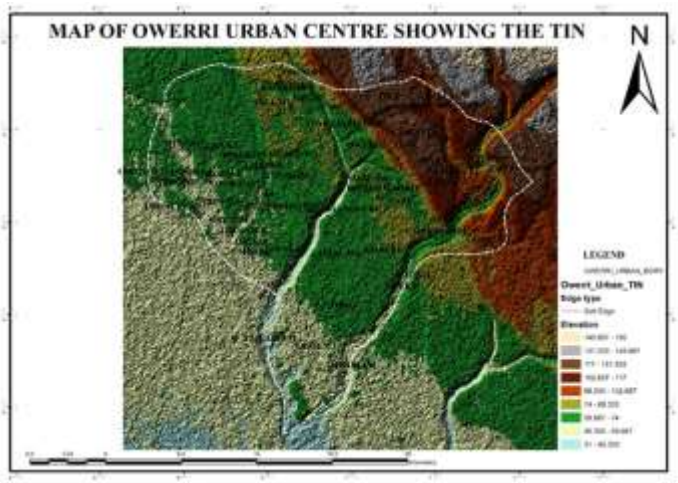

Fig.13: Triangulated Irregular Network Map of the Study Area (TIN)

4.9 Overlaying and identifying suitable sites

The site selection for solid waste disposal dumping site involves comparison of different options based on environmental, social and economic impact. Hence, based on experience and likely impact on surrounding environment. Figure 14 is the overlay analysis of figure 10 and figure 11.

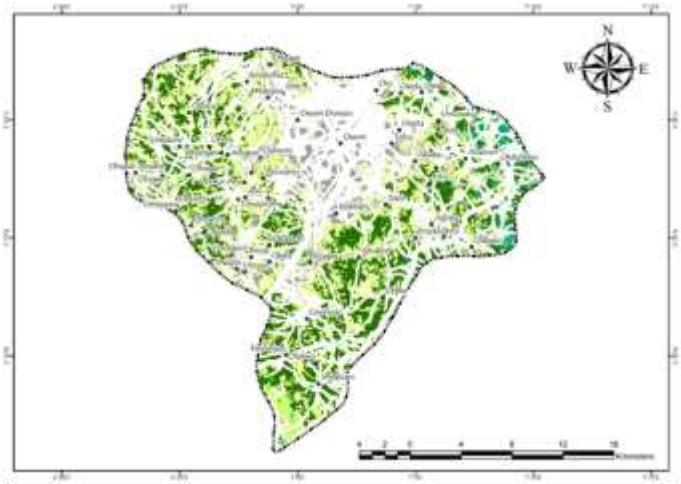

Fig. 14: Overlay of figure 10 and figure 11

Figure 15 is the overlay of figure 12, 13 and figure 14 leaving the potential site to be at Okuku and Imeabiam. Since Okuku and Imeabiam falls under the suitable areas based on the criteria used they are therefore considered the most suitable site for the siting of the sanitary land fill site in the study area.

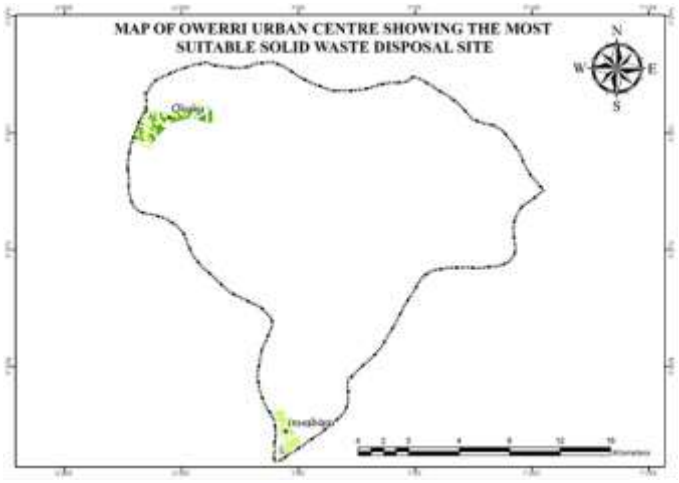

Fig. 15: Map of Owerri Urban Showing the Most Suitable Landfill Site

Table 3: Total Area of Most Suitable Landfill Site in Owerri Urban

MOST SUITABLE LANDFILL SITE IN OWERRI URBAN CENTER			
S/N	**LGA**	**LOCATION**	**TOTAL AREA(Ha)**
1	OWERRI WEST	IMEABIAM	**329.294**
2	OWERRI WEST	OKUKU	**714.246**

5. SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

The present practice of solid wastes disposal in Owerri Urban centres in Imo State is highly unscientific and poses a lot of problems.

i) Disposal sites in Owerri Urban centre were arbitrarily chosen with no systematic study in the selection of sites. Most of the disposal sites were formally burrow its, undeveloped plots, farm lands and hands adjoining streams.

ii) The disposal sites are poorly managed. There are no cover materials, no fencing etc.

iii) These open dumps are unsanitary and unhealthy. They create environment for disease vectors such as rats and flies. This unhealthy conditions result in health hazards for residents living close by.

As a result of these findings, a remotely sensed data with GIS technique has proved useful and efficient in site selection of solid wastes disposal sites in Owerri and its environs of the state.

5.2 Conclusion

Dumpsites can be established successfully if they are well sited and operated or managed properly. They have the potential to cause environmental harm if not sited and managed properly.

However, most of the disposal sites in Owerri and its environs are arbitrarily chosen. They are poorly located and they constitute environmental hazards to local population. This is as a result of the fact that no systematic study was carried out before they were chosen. Based on these limitations, this study has suggested a scientific and systematic method for the selection of solid wastes disposal sites in Owerri and its environs in Imo State. This systematic method and its application will help in the selection and management of solid waste disposal sites in Owerri and its environs. It will help planners and decision makers in government quarters in the budgeting of solid waste management.

5.3 Recommendations

Recommendations are based principally on the major findings of the work. They include the following:

i) The use of open dumps, empty land or land near streams used as solid waste disposal sites should be avoided.

ii) Solid waste disposal sites should be established using remotely sensed data and GIS technique instead of choosing site arbitrarily.

iii) The capacities of the disposal sites should be determined to ensure durability or long life cycle of the disposal site.

REFERENCES

[1] Higgs, G. (2006). Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation, Wales. Retrieved on 9(07) 2012: http:// www.epa.sa.gov.au/pdfs/swlandfill.pdf. downloaded on 10th January, 2014

[2] Igbozurike, U.M. (ed) (1987). Environmental Survey Report on the Imo State University Site, Okigwe, Okigwe: Imo State University Press.

[3] Kao, J., Chen, W., Lin, H. and Guo, S. (1996). Network Expert Geographic Information System for landfill siting. Journal of Computing in Civil Engineering, 122(10): 307-317.

[4] Navalgund, R.R. and Kasturirangan, K. (The remote sensing satellite – A programme overview.

[5] Nigerian Environmental Study/Action Team (NEST) (1991). "Nigeria's Threatened Environment – A National Profile. Ibadan: Intect Printers Ltd.

[6] Rush Brook and Michael Pugh (1999). Solid Waste Landfills in Middle and Lower Income Countries. A technical guide to planning design and operation. Washington, D.C. World Bank Paper, No. 426.

[7] United Nations Centre for Human Settlement (Habitat) (1989). "Solid Waste Management in low-income housing projects: the scope for community participation".

[8] Wiley J, Sons L. (2009). Essential image processing and GIS for Remote Sensing. Imperial College London, UK. http//:www.pelegiaresearchlibrary.com. Downloaded on 24th August, 2014

NOTE ABOUT THE AUTHOR

Augustine Emeribeole received his B.Sc. (Hons) Degree in 1992 and a Master Degree in 1996 from Enugu State University. He later received a Ph.D. in 2012 from Imo State University, Owerri and another Master Degree in 2015 from Nnamdi Azikiwe University, Awka. He is widely published. He is currently the Head of Department of Surveying and Geoinformatics, Imo State University, Owerri, Imo State, Nigeria.

