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Application of Geospatial Technique in Selection of Suitable Solid Waste Dumpsites in Aba, Abia State, Nigeria

By

[1]Nkemdirim, Victor U., [2]Enyinna, Gregory C. & [3]Isaac, Ogechi Lilian

[1&3]Department of Geography/Planning, Abia State University, Uturu, Nigeria
[2]Department of Project Management Federal University of Technology Owerri, Imo state Nigeria
Corresponding Author: Nkemdirim, V. U.
Email: princevic09@yahoo.com, pycongrego@yahoo.com, ogechi.lilian.isaac@gmail.com

Abstract

Solid waste disposal has been a serious problem in most developing countries, including Nigeria. For a suitable dumpsite to be identified and selected, it requires the adoption of careful and systematic procedures. Thus, this study looked at the application of geospatial technique in selection of suitable solid waste dumpsite in Aba, Abia State, Nigeria. The integration of GIS and MCDA provides a reliable platform for solving the site selection problem. The study relied on the existing spatial data of the study area such as land use maps, cadastral maps, and satellite imagery maps. The coordinates of the existing solid waste dumpsites were collected through field measurements. The digitized datasets were interpolated with Arc GIS (Software) to generate operation of different dataset layers. The spatial analysis were carried out to identify potential sites. A final composite map was then produced, which presents all areas suitable for waste land filling. The study revealed that, of the 27 dumpsites, 26 were not properly located while the only dumpsite is grossly inadequate for the quantum of waste generated in Aba. Secondly, the study revealed lack of management presence at the dumpsite. Furthermore, the study revealed that the government policy on ground is not effective enough to curb the indiscriminate disposal of these solid wastes in the study area. The study strongly recommend for additional dumpsites to be established in the area, especially areas identified as most suitable amongst others. The study concludes that if the recommendations are strictly implemented, solid waste would be collected and disposed-off in an effective and environmentally safe manners.

Keywords: Geospatial, Selection, Solid waste, Suitability, Dumpsites.

1. Introduction

Solid waste management is an important element in public health and environmental protection (Yesilnacar and Cetin, 2005). Its main purpose is to provide hygienic, efficient and economic collection, transportation, treatment and/or disposal of solid wastes without polluting the atmosphere, soil or water resources, and the management strategy should address the issue of aesthetic (UNDP, 2003).

The growth in municipal solid waste generation the world over has been reported to be a consequence of urbanization, industrialization, and population growth, together with improved living standard (Rao, 2007). It is estimated that the United Kingdom produces 35 million tons of municipal solid waste annually (Koshy, 2007) and in the United States of America, more than 140 million tons of municipal waste is generated annually, while Japan and Germany generates 50.2 million and 43.5 million tons respectively, in 2000 (Sakai, Chandler and Kosson, 2004).

The situation in Africa is similar to other parts of the world. Nigeria with a population growth rate of about 2.8% per annum and an urban growth rate of about 5.5% per annum (Imam, 2008) generates about 20 kg of Solid waste per capita every year (Olaleye and Sangodina, 2000). Also, solid waste generated by an average Nigerian per day is estimated to be around 0.49kg while commercial centres and households contribute almost 90% of the total waste found in urban centres (Solomon, 2009).

In Nigeria, open or uncontrolled dumping is largely used as waste disposal method but the benefit of sanitary landfill over the Open dumping methods cannot be overemphasized because it is pollution-free thereby eliminating any health or environmental risk that may result from solid waste disposal (UN-HABITAT, 2010). However, municipal landfill siting is becoming increasingly difficult considering the closeness of site to residential areas, river, water channel or other fragile ecosystem and could lead to adverse environmental pollution, degradation, as well as health hazards (UN-HABITAT, 2010).

Therefore, to protect the ecosystem from being disturbed and to ensure healthy environment for the survival of man, it becomes necessary to carefully locate landfills on environmentally suitable locations (Sakai *et al.*, 2004). Selection of sites for landfill involves an extensive evaluation process in order to identify the optimal available disposal location. In fact, different researchers have used varying criteria for site selection purposes due mainly to the fact that different criteria apply to different regions (Stinnette and Fadel, 2006).

It is evident that, many factors must be incorporated into landfill siting decisions and Geographic Information System (GIS) together with Remote Sensing is ideal for this kind of preliminary studies due to their ability to manage large volumes of spatial data from a variety of sources. GIS is practically effective in storing, retrieving and analyzing, and also displays information according to user defined specifications (Siddiqui, 2000). According to Kao and Lin (2007) large amount of spatial data can be processed using GIS and thus, it potentially saves time that would normally be spent in selecting an appropriate site using manual processing approach.

Multi-criteria Decision Analysis (MCDA) can be used to deal with the difficulties that decision-makers encounter in handling large amounts of complex information. The principle of the method is to divide the decision problems into smaller more understandable parts, analyse each part separately and then integrate the parts in a logical manner (Malczewski, 2000). The integration of GIS and MCDA provides a reliable platform for solving the landfill site selection problem, because GIS provides efficient manipulation and presentation of the data and MCDA supplies consistent ranking of the potential landfill areas based on a variety of criteria. Hence, the need for this study to apply GIS in the selection of suitable landfill sites for sustainable waste management in Aba, Abia State.

2. Study Area

The study area is Aba, in Abia State. It is located in the South Eastern Nigeria, and lies within approximately latitudes $4^{o}40^{1}$ and $6^{o}14^{1}$ North, and longitude 7^{o} 10^{1} and 8^{o} East. Aba is the biggest town/city and the commercial center of Abia State. Upon the creation of Abia state in 1991, Aba was divided into two local government areas namely; Aba South and Aba North. Aba south is the main city centre and the heartbeat of Abia State, south-east Nigeria.

Aba has a low and relatively even topography which could also be called Peneplain. Aba is generally drained by the Aba River and its tributaries such as Okpuloumuobu stream, etc (Nwoko, 2013). Aba falls within the humid tropical and rainforest climatic zone of South-eastern Nigeria. The average rainfall for the area is about 2285mm (Uma, 1989). Most parts of the area are flooded during the rainy season due to poor drainage system and construction. Temperature regime for Aba is also identical to the regional pattern, and is generally high and uniform throughout the year. The mean minimum air temperature of the area is 22.8°C, while the mean maximum is 32°C. The vegetation is ordinarily considered part of tropical rain forest which is the dominant natural vegetation in most parts of southern Nigeria. Aba and its environs have predominantly sandy and loamy soil which is characteristics of coastal areas. The geology of Aba Urban and the adjourning areas is made up of the coastal plain sand due to the areas proximity to the river. Aba is the largest commercial centre in the state with the famous Ariaria International market and others. Aba is famous for its handicraft such as in the shoe and bag production. The indigenous people of Aba are the Ngwa extraction. Basically, Aba is both a commercial and industrial town. See Fig. 1 and Fig. 2 for the maps of the study area.

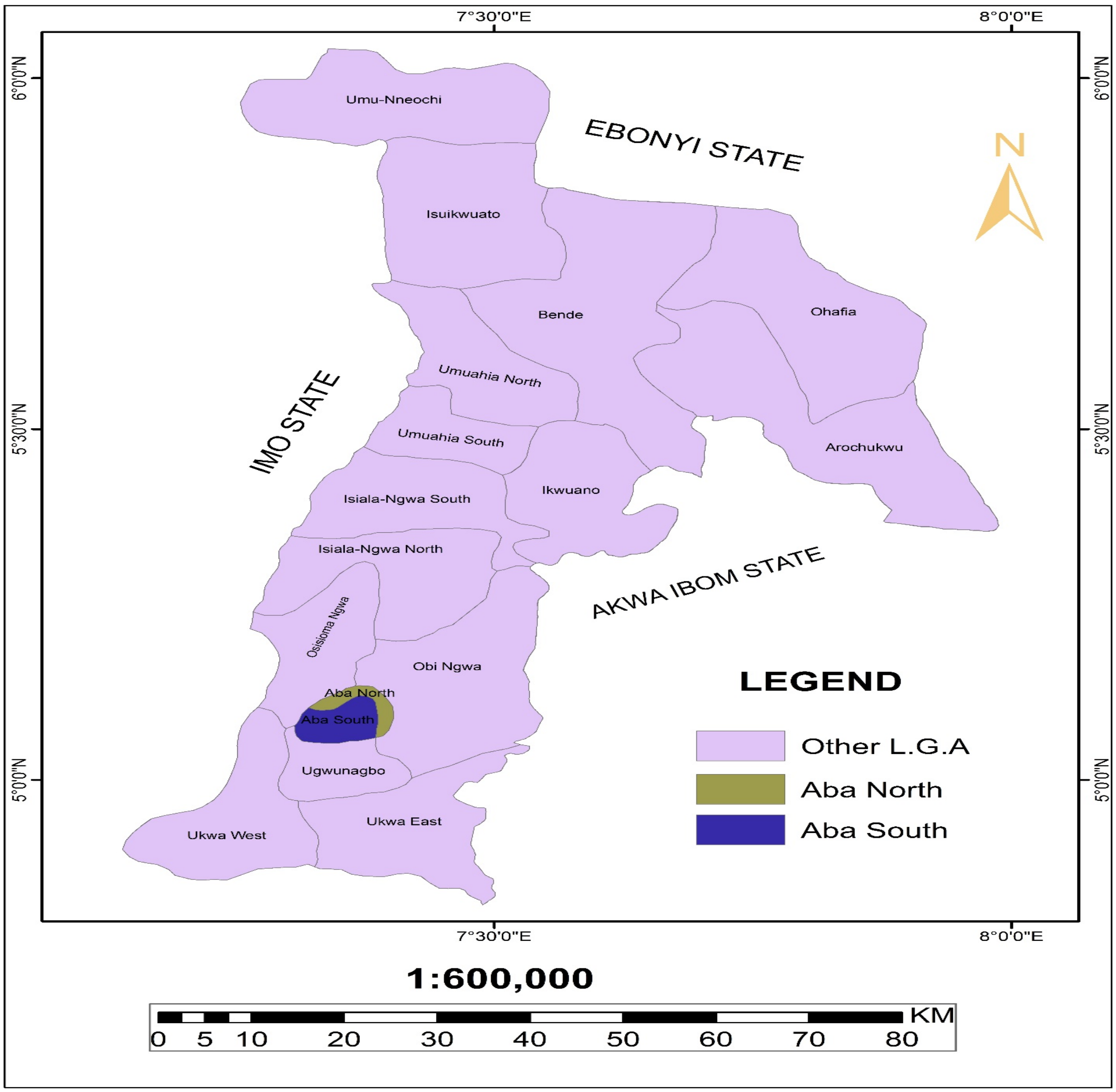

Fig. 1: Abia State, showing Aba South and Aba North.

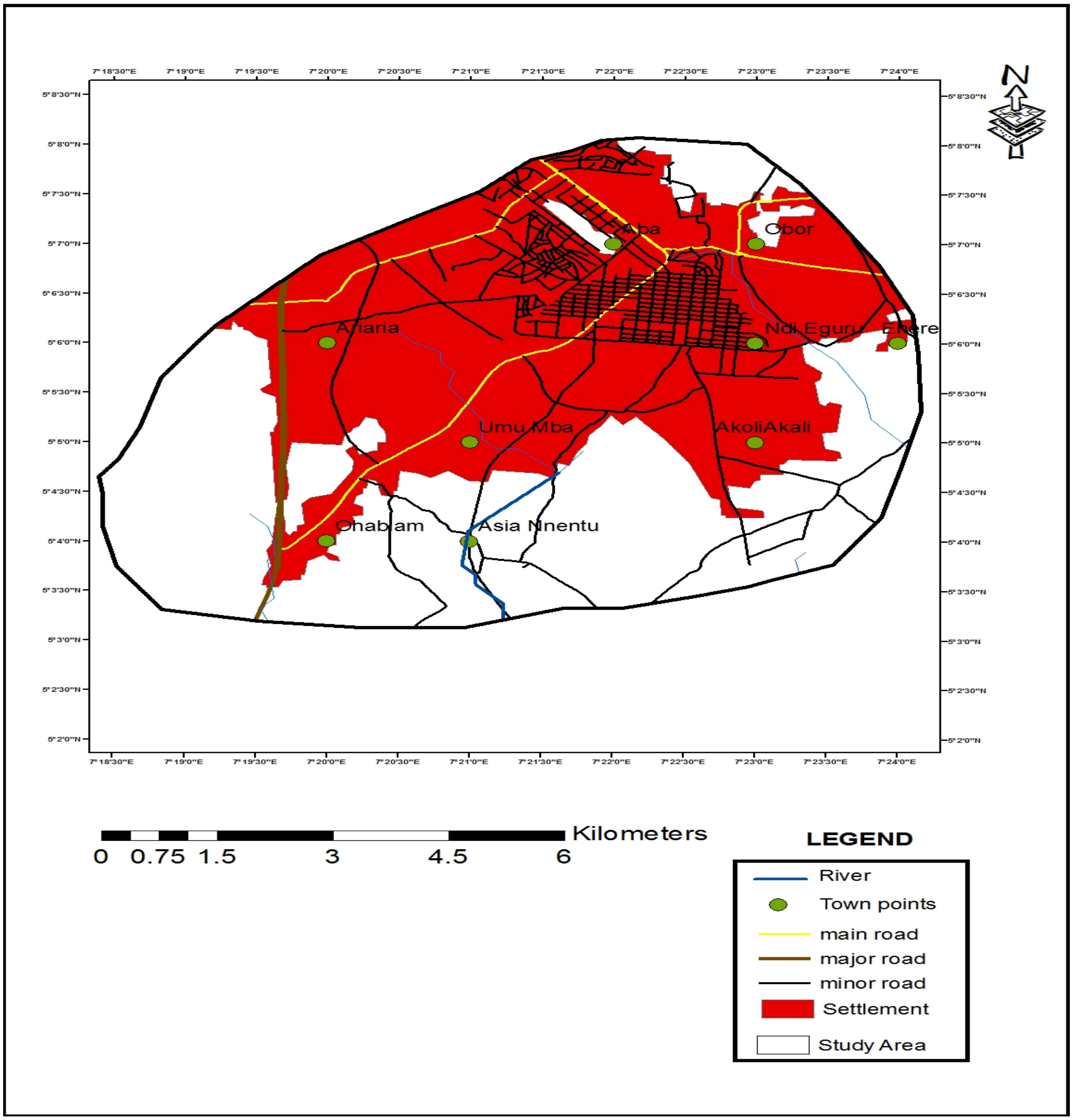

Fig. 2: The Study Area (Aba North & South)

3. Methodology

Application of GIS in this study is a relatively simple technique that is based on the overlaying of datasets and areas that satisfy certain suitability criteria. In this study, the GIS-based landfill site selection approach combines the spatial analysis tools provided by GIS to integrate and evaluate different datasets based on certain evaluation criteria in order to determine potential landfill sites.

The study relied on the existing spatial data of the study area. Data were extracted from land use maps, cadastral maps, and satellite imagery maps of the study area. The digitized datasets were interpolated with Arc GIS (Software) to generate operation of different dataset layers. The spatial analysis were carried out to identify potential sites. A final composite map was then produced, which presents all areas suitable for waste land filling.

Software structure used are the Erdas Imagine that performs advanced remote sensing analysis and spatial modelling to create new information and ArcGIS 10.2 developed by ESRI Corporation, USA, has an advanced geo-processing functionality which provides an environment for performing geographic information system (GIS) analyses. It is a robust multi-tasking GIS platform which is on a common modular component-based library of shared GIS software components (ESRI, 2014).

4. Method of Data Analysis

Converting Criteria into Vector Data (Shape file)

Criteria adopted for site selection (to delineate a suitable site for waste disposal in the study area with the use of GIS) were converted into map layers by digitizing the topographic map and updating it with earth explorer's image of the area to create shapefiles (Vector data) which was used for further analysis. The layers created through digitization and which form the basic dataset needed for appropriate site selection analysis include: Landuse/Landcover dataset; Road network dataset; Water surface dataset and Settlement dataset

GIS Spatial Operation

The data for GIS spatial operations were selected based on the criteria that must be satisfied to determine the most suitable location for a dumpsite in the study area according to the Environment Protection Agency Landfill Manual 2006. All the paper maps (Geological, Topographic and Soil maps) were scanned, geo-referenced, resampled and digitized to convert the analogue map to digital format useable in the GIS software. Soil, geology, water body, residential area, road layers were derived (Nwosu, 2014). See Tables 1 and 2 for the various criteria that were created as layer in the GIS environment:

Table 1: Constraint Criteria Table Formulated from EPA Landfill Manual 2006.

Criteria	Unsuitable Area
Distance to water body	Less than 160m
Slope	Areas with a slope greater than 15^{o}
Distance to Residential Areas	Less than 300m
Distance to Road	Less than 100m
Soil	Area with Alluvial soils

Table 2: Factor Criteria Table Formulated from EPA Landfill Manual 2006.

Criteria	Unsuitable	Less suitable	Moderately suitable	Highly suitable
Distance to water body	0-160m	160m-480m	480m-960m	>960m
Slope	15-20	10-15	5-10	0-5
Distance to road	500m	500m -1000m	1000m-1500m	>2000m
Distance to Residential	0 -2500m	2500m-4500m	4500m-5500m	5500m-7000m

5. Results

Assessment of the Existing Dumpsite

The coordinates of the existing solid waste dumpsites were collected through field measurements. Hand-held GARMIN GPS was used to obtain the coordinates. The coordinates of the existing solid waste dumpsite and disposal sites collected during fieldwork were imported into the ArcGIS 10.2 as a text file then converted to shape-file to show the location of the dumpsites. The points were superimposed on the result derived from the identification of potential solid waste dumpsites using multi-criteria analysis. This was to determine whether the existing dumpsites within the study area met the stipulated standards.

From the result derived, it could be concluded that the existing dumpsites within the study area were not properly located and thus, did not meet the stipulated standard. See Table 3 (coordinates of the existing illegal dumpsites), Table 4 (coordinate of the existing legal solid waste dumpsite) and Fig. 3 (existing dumpsite)

Table 3: Coordinates of the Existing illegal waste disposal sites

LOCATION	X (N)	Y(E)	ELEVATION (m)
Ehi Road	5°06'22.42"	7°21'35.33"	62
Ngwa Road	5°06'03.84"	7°21'28.19"	63
Portharcourt Road	5°05'51.97"	7°21'26.91"	60
School Road	5°06'14.03"	7°22'11.50"	62
Jubilee Road	5°06'35.44"	7°21'51.39"	64
Obohia Road	5°05'55.74"	7°21'52.02"	63
Milverton Road	5°06'47.15"	7°22'15.41"	63
Faulks Road	5°06'48.05"	7°20'21.07"	62
Along port Harcourt Express road	5°08'10.74"	7°19'33.24"	64
Ohanku Road	5°05'53.71"	7°22'30.85"	62
Immaculate Heart Avenue	5°08'06.79"	7°21'43.62"	67
Brass Road	5°07'31.62"	7°21'24.76"	66
Okigwe Road	5°06'54.63"	7°21'50.65"	63
Pound road	5°06'41.40"	7°22'10.73"	65

Factory road	5°06'54.78"	7°22'22.04"	63
Aba north road	5°07'37.72"	7°21'54.59"	60
Pound road	5°06'41.42"	7°22'06.84"	62
Market road	5°06'36.69"	7°22'06.23"	62
Azikiwe road	5°06'29.92"	7°22'12.10"	64
Asa road	5°06'34.57"	7°22'10.27"	65
Asa road	5°06'16.21"	7°22'54.11"	63
Asa road	5°06'03.57"	7°21'44.33"	62
Osusu road	5°06'51.67"	7°21'19.97"	66
Aba north road	5°07'41.63"	7°21'57.69"	66
Nweke street	5°07'53.48"	7°21'51.59"	67
Factory road	5°06'58.18"	7°22'19.28"	62

Source: Researcher's Field Survey

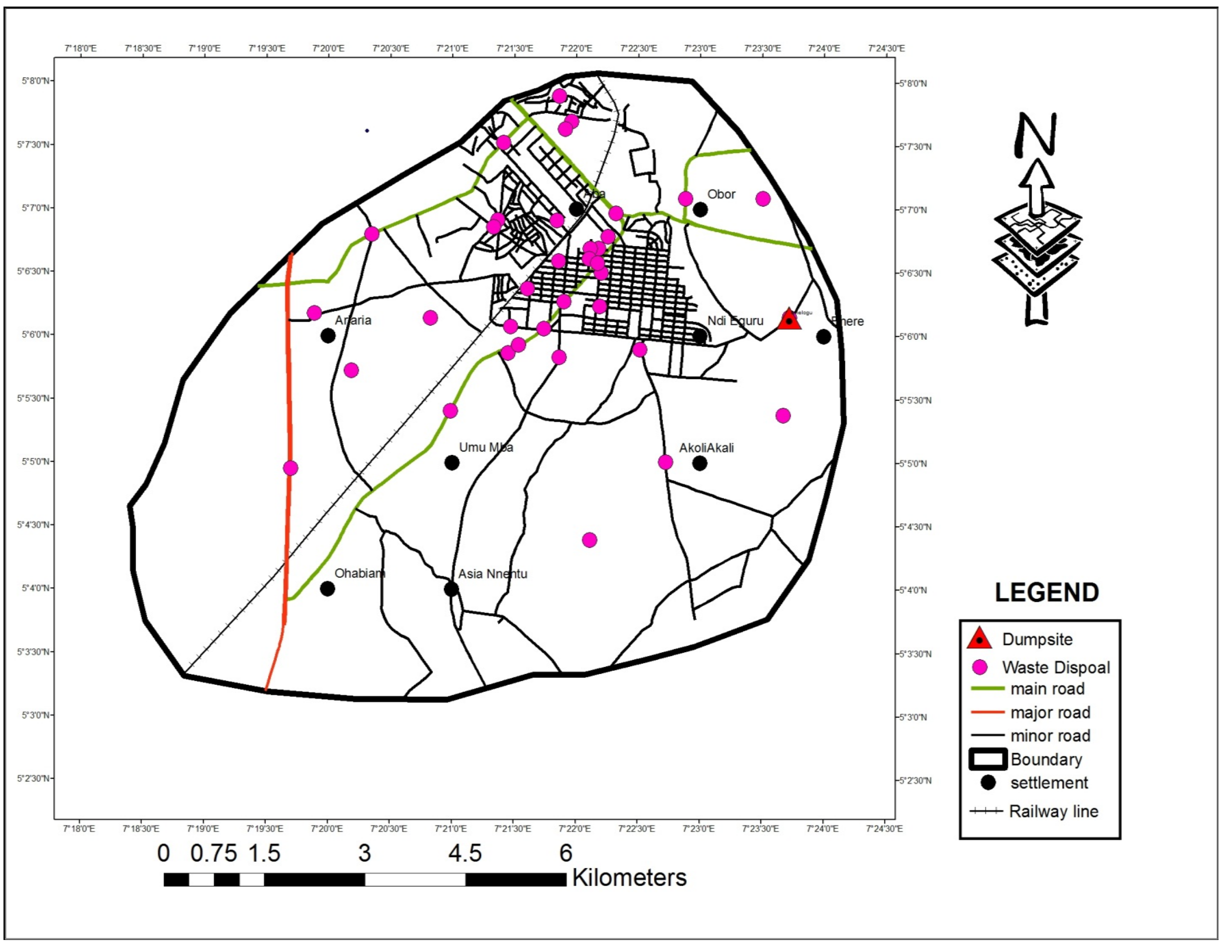

Figure 3: Map of the study area showing the existing dumpsite

Table 4: Coordinate of the Existing legal solid waste dumpsite

LOCATION	X	Y	ELEVATION
Along Emelogu Ogbor Hill road	5°06'58.18"	7°22'19.28"	55m

Source: Researcher's Field Survey

Analysis of Potential Solid Waste Dumpsites

First, all data map layers were converted from vector form to raster form. A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information. For several data map layers, this first step proceeded further with Euclidean distance analysis to apply the safe distance between dumpsites to several criteria that has been set up as indicators mentioned in suitability criteria.

The Euclidean distance output raster contains the measured distance from every cell to the nearest source. When all data map layers already set up in certain prerequisite for safety distance through Euclidean distance analysis, the values of classes were compared between layers by assigning numeric values to classes within each map layer so that they have equal importance in determining the most suitable location. Finally, all data map layers were overlaid by using weighted overlay method to create single rank map of suitability analysis (see Fig. 4).

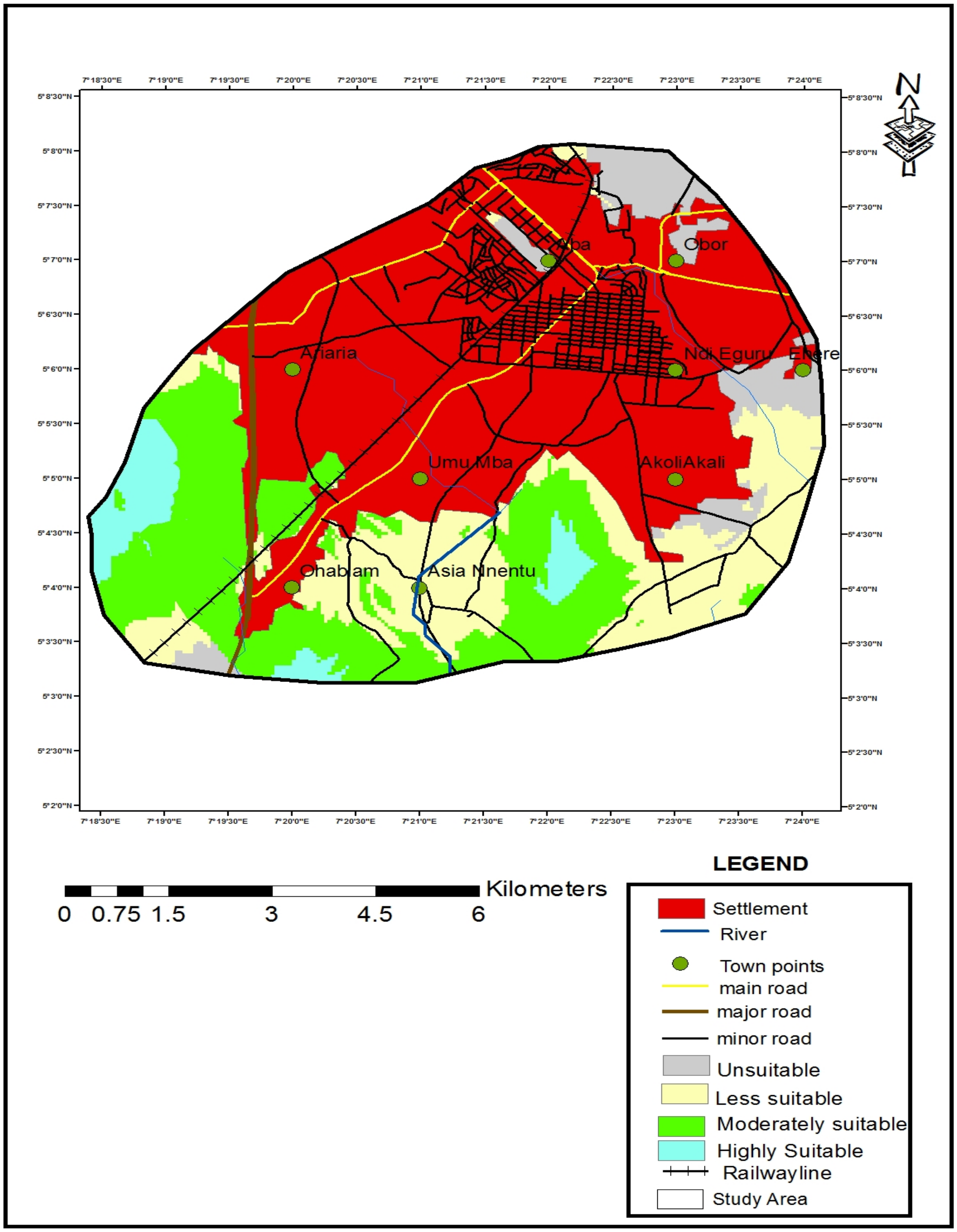

Figure 4: Potential Suitability Map of the study area

Some of the areas that were analysed suitable is little far from the major road. Receptacles are estimated to be placed along roads; for easy solid waste disposal and access to the final dumpsite. It will help to reduce cost and for easy transportation of the waste from areas of generation. Fig. 5 shows the location of receptacles along major roads and streets.

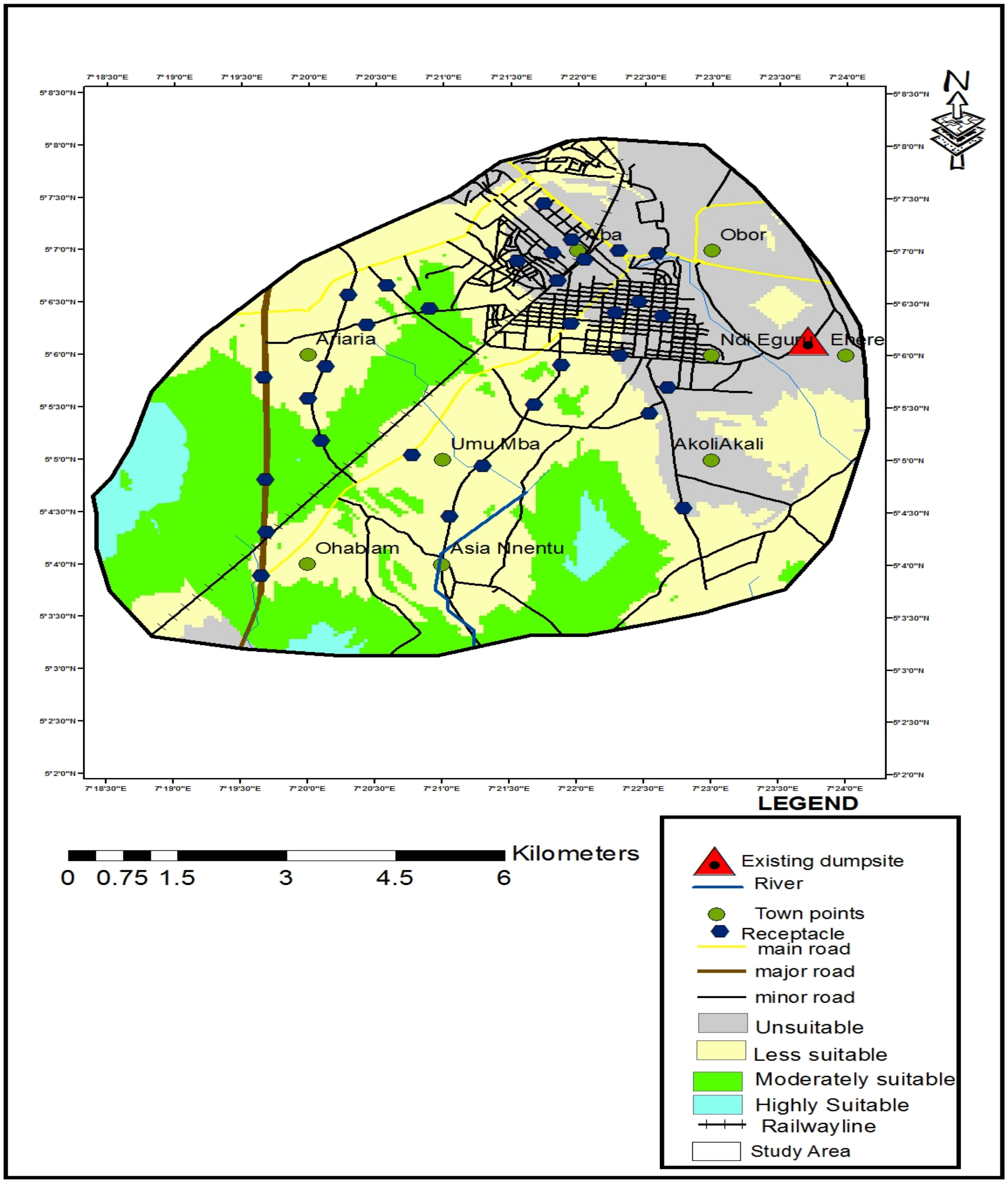

Figure 5: Map showing recommended placement of receptacles

Refuse Dumpsites

Many illegal dumpsites were observed during the fieldwork, but for lack of space, the researchers were able to showcase only three plates showing unapproved dumpsites (Plates 1-3).

Plate 1: Solid waste disposal site along Osusu road

Plate 2: Solid waste dumpsite along Ogbor Hill, Emelogu, road.

Plate 3: Solid waste dump along Ahia Ohuru road.

6. Findings

The study revealed one existing legal dumpsite. This dumpsite is grossly inadequate for the quantum of waste generated in Aba. Secondly, the study revealed lack of management presence at the dumpsite. Furthermore, the study revealed that the government policy on ground is not effective enough to curb the indiscriminate disposal of these solid wastes in the study area.

7. Recommendations

The study recommends as follows:

a. There is a strong need for additional dumpsites to be established in the area, especially areas identified as most suitable.
b. Proper management of the existing legal dumpsite need to be improved upon.
c. Waste managers should be made to be responsive to their duties.
d. Existing government policies on solid waste management should be implemented.
e. The Environmental Protection Agencies and the Town Planning Authorities within the study area should have the site suitability analysis model in their finger-tips to guide them on approval of suitable dumpsites.

8. Conclusion

The strength of this work lies in its simplicity, flexibility, and user- friendliness. This study has been able to expose the illegal dumpsites that deteriorates the quality of our environment. The use of Suitability Analysis Model has proved wonderful in proffering suitable locations for dumpsites. If the recommendations in this study are strictly implemented, solid waste would be collected and disposed-off in an effective and environmentally safe manners.

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