Application of Remote Sensing and Geographic Information System for selecting Dumpsites and Transport Routes in Abeokuta, Nigeria

[1]Adeofun C. O., [1]Achi H. A., [2]Ufoegbune G. C., [1]Gbadebo A. M. and [3]Oyedepo J. A.

[1] Department of Environmental Management & Toxicology, College of Environmental Resources Management, University of Agriculture, Abeokuta
[2] Department of Water Resources Management and Agrometeorology, College of Environmental Resources Management, University of Agriculture, Abeokuta
[3] Institute of Food Security, Environmental Resources and Agricultural Research, University of Agriculture, Abeokuta

Abstract

Waste management problems result from indiscriminate waste disposal which stems from inadequate planning and implementation. This fact led to the present study which applied the techniques of GIS and RS to disposal sites and transport route selection in the emerging megacity of Abeokuta. Spatial data such as land-cover types; road and drainage networks of the city were extracted from a geo-referenced high resolution satellite image through on-screen digitizing using GIS softwares such as ILWIS and ArcView 3.2a. The existing dumpsites were geo-located and added as a layer to the map of the city. The land-cover, drainages, and roads were buffered at 30, 160 and 200 meters respectively using preset criteria such as distance of site from a street at 30 m, surface water at 160 m, major roads at 200 m and absence of important economic or ecological features; to determine candidate sites from the land-cover types. Four legal dumpsites in *Saje*, *Olomore, Totoro* and *Ita-Oshin* and patches of illegal dumpsites were identified. GIS analysis gave a total of nine sites out of which only four met the preset criteria. *Saje, Ita-Oshin, Sam-Ewang,* and *Ita-Ika* areas were the most appropriate sites having an area of 19.64 km^2 out of the total study area of 79.95 km^2. The shortest route connecting the proposed dumpsites gave a total Travel Cost (in distance) of 27.30 km while the cost of making a round-trip (Tour Route Cost) was 36.00 km. It was therefore concluded that *Olomore* and *Totoro* dumpsites should be relocated, while *Sam-Ewang* and *Ita-Ika* dumpsites should be upgraded and made to function as legal waste disposal sites.

Keywords: Geographic Information System, Remote Sensing, Dumpsite, Transport Route.

Introduction

The current global trend of waste management problems stems from unsustainable methods of waste disposal, which is ultimately as a result of inadequate planning and implementation. The practice of direct dumping of wastes into water bodies, open, abandoned lands and any other

"appealing" sites without proper treatment have led to serious environmental pollution and health-related problems.
Solid Waste according to The United State Environmental Protection Agency (USEPA, 2005) is defined as any garbage, refuse, sludge from a waste water treatment plant, water supply treatment plant or air dried material, including solid, liquid, semi-solid or contained gaseous material resulting from industrial, commercial mining and agricultural operations and from community activities.

Municipal solid waste disposal is an enormous concern in developing countries across the world, as poverty, population growth, and high urbanization rates combine with ineffectual and under-funded governments to prevent efficient management of wastes (UNDP, 2004).
Waste management issues should be confronted in a more generalized manner, which means that new strategies need to be designed for considering diverse and variable urban models. This fact demonstrates the necessity of developing integrated, computerized systems for obtaining more generalized, optimal solutions for the management of urban solid waste (Karadimas et al, 2004). Geographic Information System (GIS) and Remote Sensing are such computerized systems which can be integrated to get optimal solutions for sustainable management and planning of solid waste.

Geographical Information System (GIS) is any system that captures, stores, analyzes, manages, and presents data that are linked to location(s). It is the merging of cartography, statistical analysis, and database technology for informing decision making. It is a tool that allows users to analyze spatial information, edit data, maps, and present the results of any operations (Wikipedia, 2011).

Remote sensing is the small or large-scale acquisition of information of an object or phenomenon, by the use of either recording or real-time sensing device(s) that are wireless, or not in physical or intimate contact with the object (such as by way of aircraft, spacecraft, satellite, buoy, or ship). In practice, remote sensing is the stand-off collection through the use of a variety of devices for gathering information on a given object or area (Wikipedia, 2011).
This study emanated from the obvious problems of population and city expansion as a result of rural migration to urban centres; increase in solid waste generation as a consequence of over-population; distance of location of dumpsites from residential areas which encourages indiscriminate waste disposal at illegal locations; insufficient dumpsites leading to a creation of patches of dumpsites all over the places; and an inadequate organized system of waste handling for a major part of the city.

The study focused on identifying the present locations of refuse dumps and assessing their suitability; determining other locations best suited as landfill sites across the study area; and determining the most appropriate, efficient, and least-cost routes for transporting waste to landfills or recycling centres.

Solid Wastes

Characterization of municipal solid wastes (MSW) are impacted by a number of factors, including climate, population, season, income level, social behaviour, the size of market for waste materials, the extent of urbanisation, effectiveness of recycling, work reduction and the presence of industrial activity. Wastes from tropical areas generally contain a relatively high concentration of organic matter (Diaz et al, 2005).

Solid waste generation is a part of every human activity or process stream. Nigeria, having a population of 120 million (Adewumi et al., 2005), generated 0.58kg solid waste per person per day. Several factors influencing solid waste generation in Nigeria and the city of Abeokuta include the following: inadequate technology, facility for separation at source, strength of solid waste management policy and enforcement (Sridhar and Adeoye, 2003). Also are education, income and social status (Abel, 2009).

Solid Waste Disposal and Disposal Options

Disposal of solid waste generated in a community is the ultimate step in a solid waste management system. In the advanced technologies, disposal is preceded by engineering activities such as sorting, volume reduction and / or receding. The open dump method of solid waste disposal is considered as both naïve and dangerous. This is because of the leachate effect (i.e the chemical and biological contaminant in wastes) which could constitute a direct risk to human health (Lasisi, 2007). In some parts of Nigeria, refuse is generally buried, though some heedless burning is sometimes observed (Igoni, et al., 2007).

An extensive research was carried out by Diaz et al. (2005) in which he succinctly classified the various types of waste disposal into the following: Uncontrolled open dump; Controlled open dump and Controlled and sanitary landfills.

Disposal Site Selection

Daneshvar *et al*. (2005) ascertained that GIS is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analyses and displays information according to user-defined specification.

To arrive at the selection criteria for choosing a site for landfill, relevant literature and decision makers' opinion should mostly be sought. Adeofun et al (2006) and Sani et al (2010) gave some of the following specifications:

- Site must be close to at least a street with a buffer of 30 m
- Site must be 3 km from residential areas, with the exception of areas with barriers (trees, hills, etc.)
- The site should be located on a terrain with a slope less than 20
- Site should be located more than 160 km away from surface water, within 200 m of a major road, 2 km from the Local Government
- Site should be constructed in areas which do not have an important economic or ecological value

Furthermore, a decision hierarchical structure using the Analytical Hierarchical Process (AHP) can be developed and implemented to rank between suitable sites according to their suitability for disposal site location. This is to assist in identifying and weighting selection of criteria and expediting the process of decision making, coming out with the best alternative (Sener, 2010).
In addition, the use of GIS is found ideal for preliminary waste disposal site selection studies. Shrivastava and Nathawat (2006) explained the possibility to relate the groundwater of a site with the health parameters of its inhabitants. The ability of overlay was also stated to have a unique power in helping to make decisions about the identification of waste disposal sites. Once a GIS database is developed, it can provide an efficient and cost-effective means of analyzing the best site for disposal of solid waste.

Designing Transport Routes for Waste Collection and Transport

Designing short routes for waste collection is possible within a GIS system. The application of GIS in route planning and designation of collection points in some experiments has brought up a number of lessons. First, GIS is capable and can help improve waste collection in residential neighbourhoods in urban areas.

Secondly, in order to have an efficient solid waste management system, GIS may be adopted because it is capable of handling both spatial and non-spatial data necessary for effective solid waste collection system.

Thirdly, solid waste collection contractors prefer routes which are short and cheap, with high rate of return within a short period. However, traditional methods of handling data are incapable of identifying the least cost routes for solid waste collection.
Fourthly, GIS has been proved to be a tool that provides the alternative method of minimizing operational costs for contractors (Kyessi and Mwakalinga, 2009).

Methodology

The study was conducted in Abeokuta, Ogun State. Abeokuta is both the capital and administrative headquarters of Ogun State situated in the South-Western part of Nigeria with coordinates between latitude 7° 09′ N and 7° 19′N and longitude 3^0 29′E and $3^0$41′E .

Materials

A Satellite Image (IKONOS, December 2006) of Abeokuta metropolis was obtained from the GIS unit of Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), University of Agriculture, Abeokuta (UNAAB).

Land-use / land-cover map, road map, topographic map, drainage map, and other relevant maps were obtained from relevant agencies including the Water, Environmental and Sanitation (WES) department of the Local Governments, Cartography Laboratory at the Department of Water Resources Management and Agrometorology and the GIS Unit of IFSERAR, UNAAB. Global Position System (GPS) device was used to determine the coordinates of existing dumpsites.

Hardware and Software

The hardware used in this study include Compaq Presario CQ 60, HP DeskJet 1220C color printer, HP Scan Jet 2400, Logic Trace Digitizer, Garmin 12x Global Positioning System (GPS) device and Sony digital camera (8mp). The software used in preparing and analysis of the data include ILWIS 3.2, ArcGIS 9.3 and ArcViewGIS 3.2 with Network Analyst extension.

Data Analysis

Five major GIS spatial operations were performed to achieve the set of objectives for this research. These are digitizing, buffering, overlay, query and network analysis (Sani et al, 2010).

Results

Location of Existing Dumpsites in Abeokuta

The dumpsites in Abeokuta were located on a map in Fig 1. The legal dumpsites are located at Saje (Old Quarry Site) which happens to be the largest dumpsite in Abeokuta; Olomore, Totoro and Ita-Oshin areas while the illegal dumpsites are arbitrarily located at any available space. Some of them as shown in Fig 1 include Lafenwa, Oke-Efon, Ilugun, Ita-Eko, Akinolugbade e.t.c. areas.

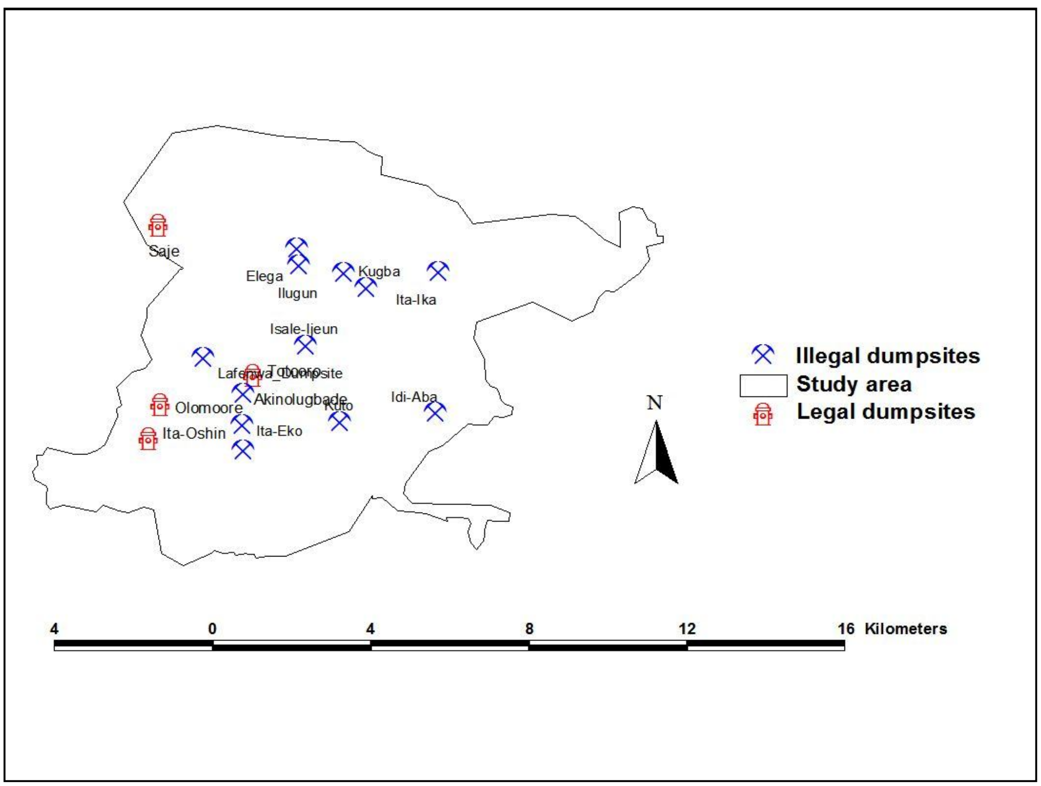


Fig. 1: Map of Study Area Showing the Legal and Illegal Dumpsites in Abeokuta

Road and Drainage Networks in Abeokuta

The road and drainage networks in Abeokuta were located on a map in Figs 2 and 3 respectively. The road network consists of the streets, major roads, railway and express road while the drainage network consists of the major river – Ogun River as it cuts across the study area and the surrounding tributaries.

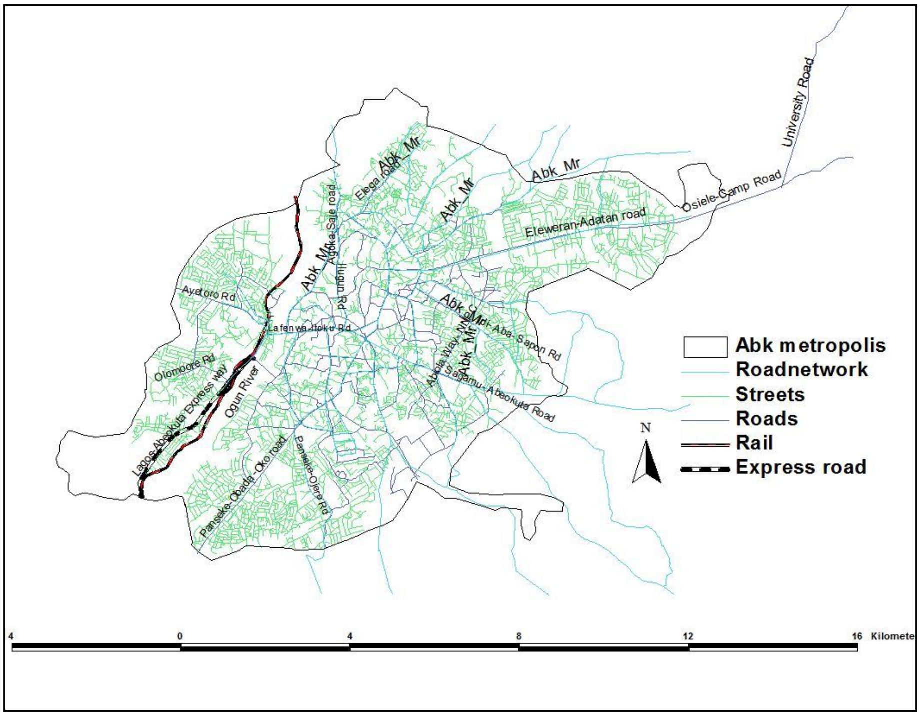


Fig. 2: Map of Study Area Showing the Road Networks in Abeokuta

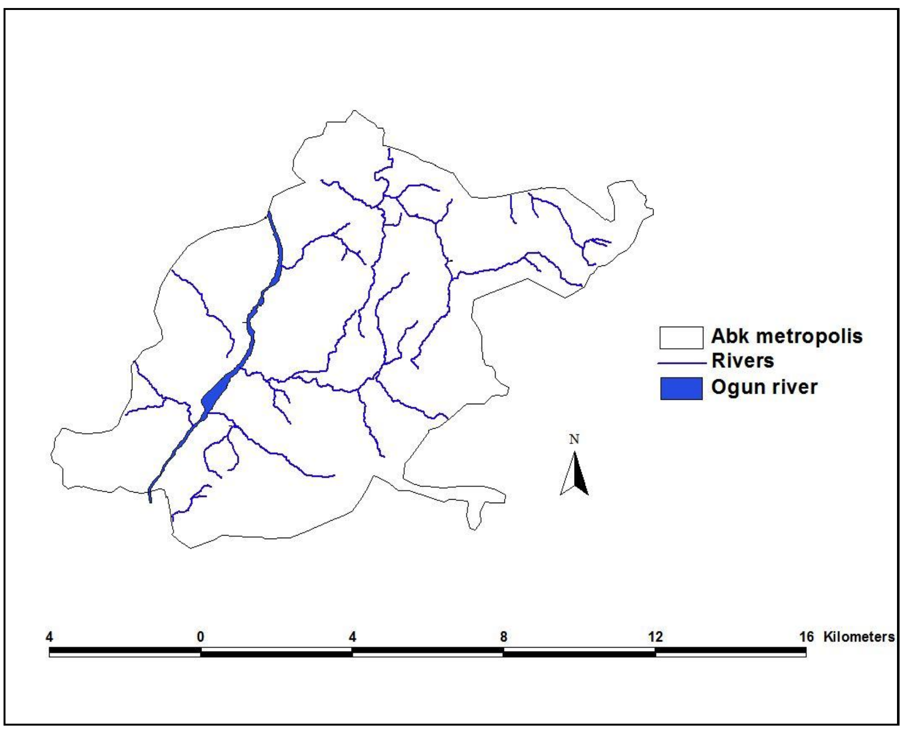


Fig. 3: Map of Study Area Showing the Drainage Networks in Abeokuta

Land-Cover Types in Abeokuta

The land-cover types in the study area are given in Fig 4 below. Land-cover types in Abeokuta include the following: modern and indigenous residential layouts; sports centres; water bodies; religious centres; parks and gardens; commercial centres; barracks and military zones; industrial areas and undeveloped lands among others.

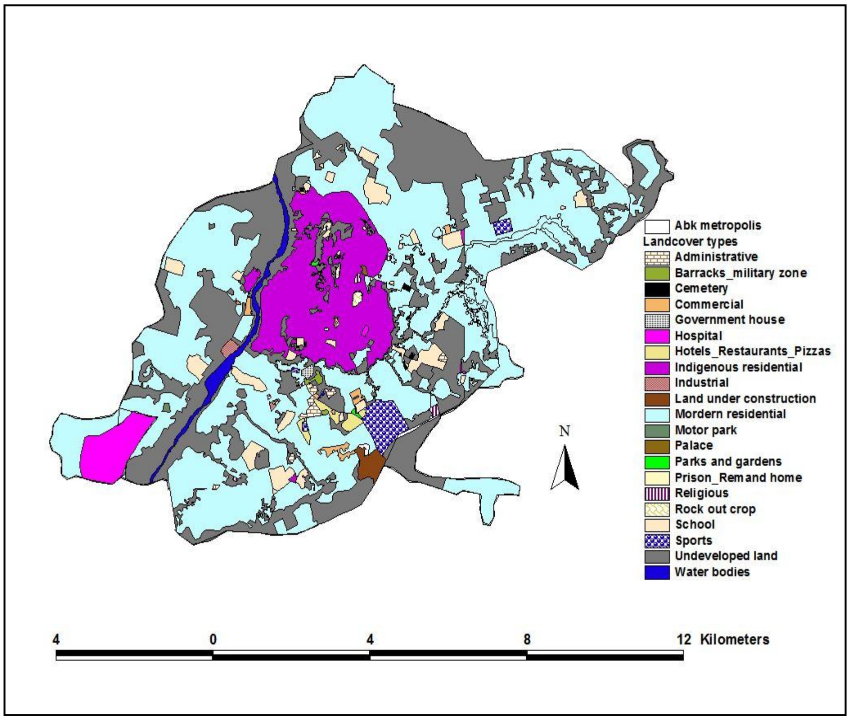


Fig. 4: Map of Study Area Showing the Land-Cover in Abeokuta

Buffering Analysis

In determining the most appropriate locations for siting dumpsites in Abeokuta, a set of buffering analysis were performed on the drainages, land-cover and roads as depicted in Figures 5, 6 and 7 respectively. The distances for creating the buffer zones were adapted from the specifications given by Adeofun et al (2006) and Sani et al (2010). The drainages, land-cover and roads were buffered at 160m, 30m and 200m respectively.

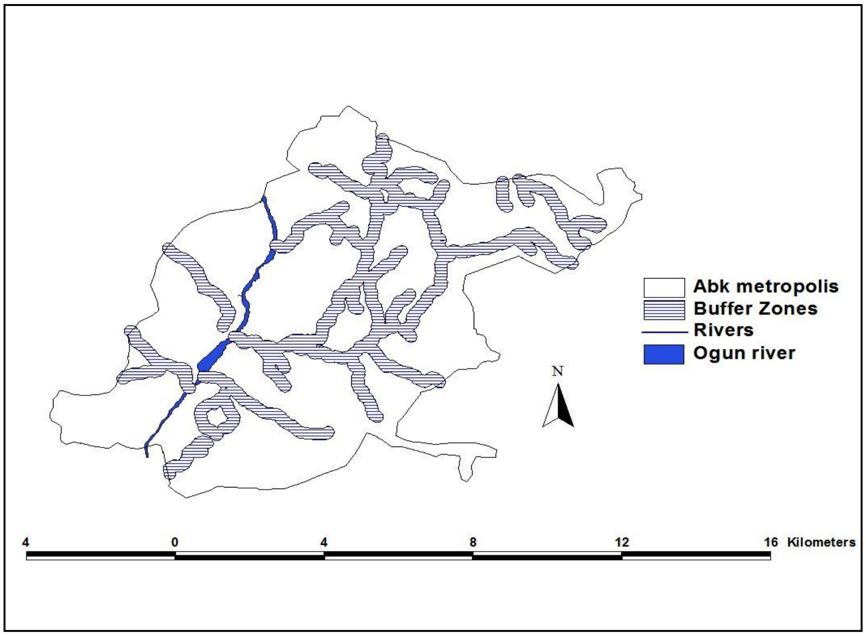


Fig. 5: Map of Study Area Showing the Drainage Buffered at 160m

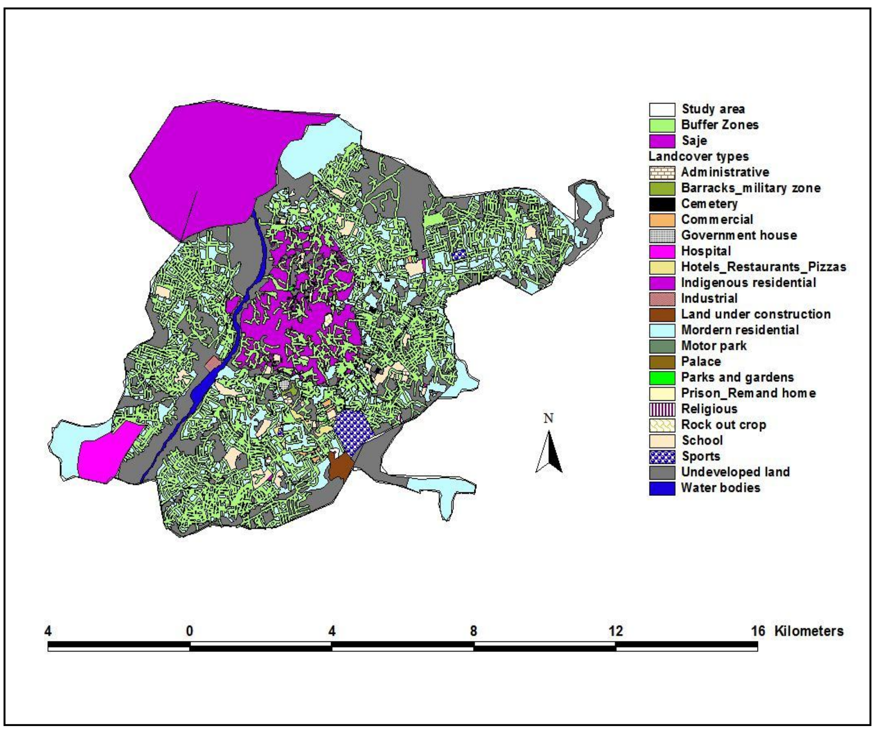


Fig. 6: Map of Study Area Showing the Residential/Land-Cover Buffered at 30m

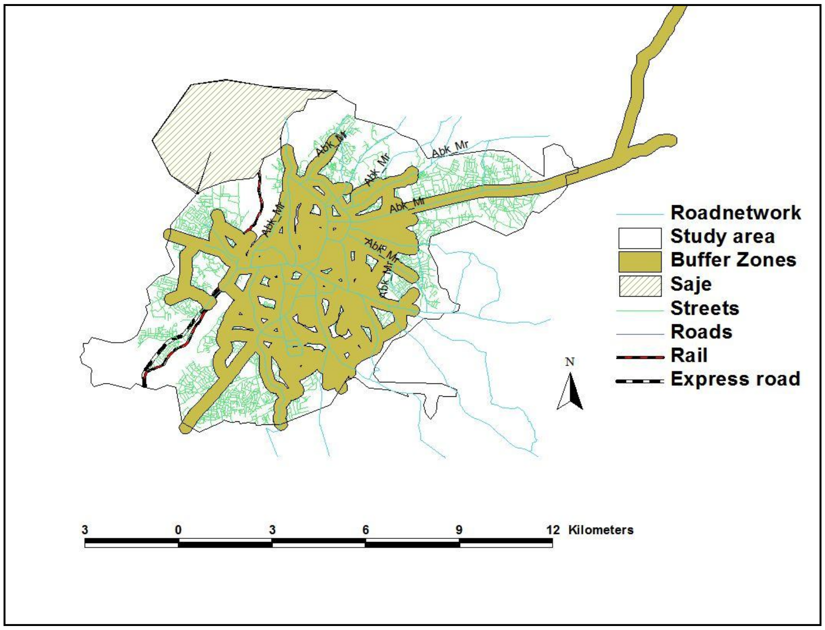


Fig. 7: Map of Study Area Showing the Major Roads Buffered at 200m

Fig 8 shows the initial results of the buffering analysis; the candidate dumpsites (unbuffered areas) overlaid with important resources such as Ogun River, railway, express road and the other tributaries. It can be seen that some of the candidate sites are overlapping these important resources with economical / ecological value. Hence, these sites were digitized to exclude parts of the resources.

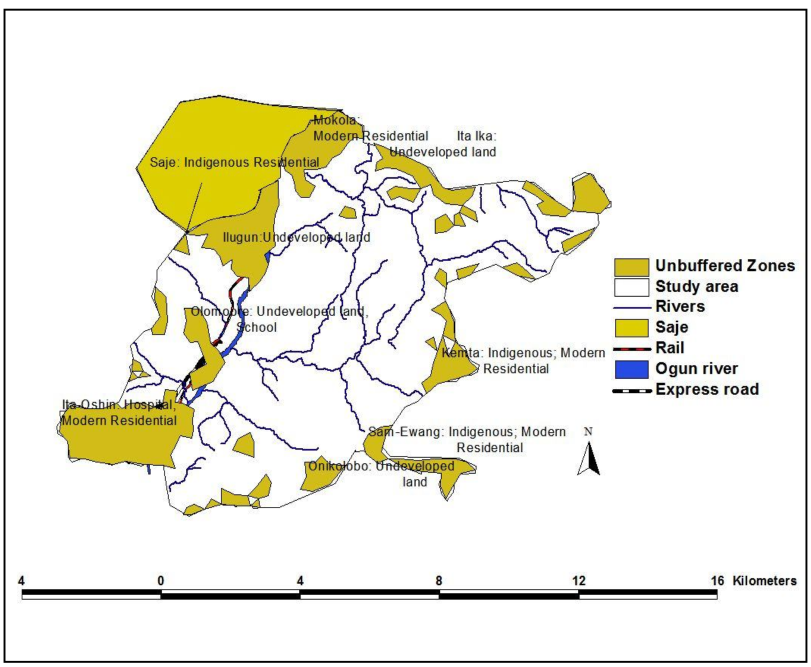


Fig. 8: Map of Study Area Showing the Candidate Dumpsites (Unbuffered Zones) Overlaid with Important Economic / Ecological Resources

Fig 9 shows the combination of all the buffered zones, i.e. the drainages, land-cover and roads, and clearly illustrates the areas left 'unbuffered'. The areas left after buffering can be seen from the legends on the various maps. These areas are the digitized "candidate dumping sites" which were subjected to further analysis to determine the most suitable locations.

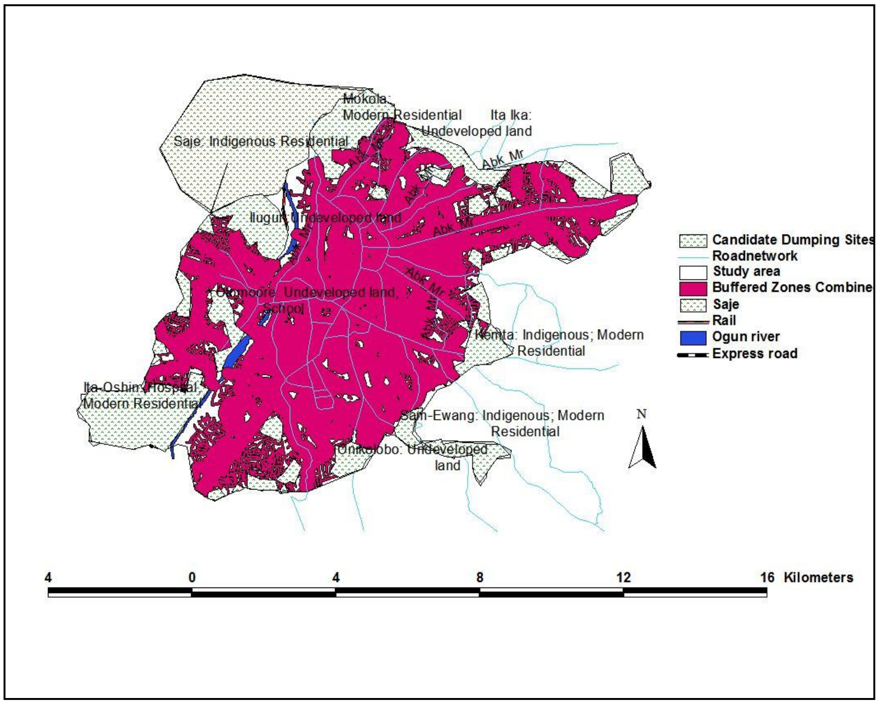


Fig. 9: Map of Study Area Showing the Combination of all the Buffered Zones and Candidate Dumpsites ("Unbuffered Zones")

Determining the Most Appropriate Dumpsite Locations

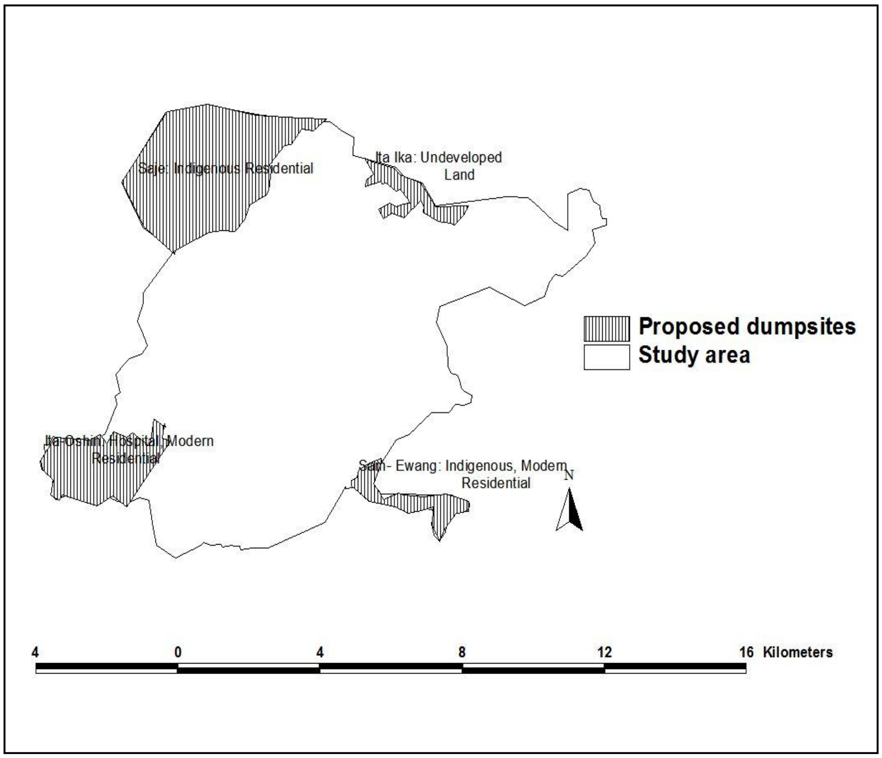
The locations proposed as dumpsites in Abeokuta as shown in Fig 9 include *Saje*, *Ilugun*, *Olomore*, *Ita-Oshin*, *Mokola*, *Ita-Ika*, *Onikolobo*, *Sam-Ewang* and *Kemta*. The areas of the candidate sites are given as 12.06km^2 for Saje being the largest site; 4.64km^2, 2.66km^2, 2.14km^2, 1.47km^2, 1.47km^2, 1.44km^2, 0.87km^2 and 0.71km^2 for Ita-Oshin, Mokola, Ilugun, Ita-Ika, Sam Ewang, Kemta, Olomore and Onikolobo respectively.

Saje, with an area of 12.06km^2 and an indigenous residential area located far away from any resource of economical / ecological value, can be described as one of the most appropriate site.
Ilugun has an area of 2.14km^2 and is described as an undeveloped land. It is however situated some few kilometers near a railway station and is not readily accessible.
Olomore has a small area of 0.87km^2 and overlaps the railway station, express road and the Ogun River and is described as "undeveloped land".

Ita-oshin with a fairly large area of 4.64km^2 is described as a modern residential area and has a notable hospital. It is also overlapping the railway station, express road and the Ogun River which are resources of important economic / ecological value.

Onikolobo and *Ita- Ika* are areas described as ‘undeveloped land’ with areas of 0.71km^2 and 1.47km^2 respectively and located away from resources of economic importance.
Sam Ewang, Kemta and *Mokola* have areas of 1.47km^2, 1.44km^2 and 2.66km^2 respectively and consist of indigenous and modern residential areas with no attachment to any resource of economic / ecological importance.

From the descriptions above, the most appropriate sites are given in Fig 10 as follows: *Saje, Ita-Oshin, Sam-Ewang,* and *Ita-Ika*. The total area of the four most appropriate sites is 19.64km^2 out of a total area of 79.95km^2 for the study area.



Fi.g 10: Map of Study Area Showing Locations of the Proposed Dumpsites in Abeokuta

Determining the Shortest and Least Cost Routes

The proposed transport routes are depicted in Fig 11. These gave directions which are the shortest distances between the proposed dumpsites and are also cost-effective. It was found out that the first “stop” is Saje and it is cost-effective to travel through Ita-Ika and Sam-Ewang before making a final stop in Ita- Oshin and vice-versa if Ita-Oshin becomes the first stop.
The total cost for the “stop” routes which is the shortest route that connects the stops is 27.30km as shown in Table 1 while the total cost to make a round-trip (Tour Route Cost) is given as 36.00km. The difference which is 8.70km represents the cost for making a straight trip from “stop” 1 (Saje) to “stop” 4 (Ita-Oshin).

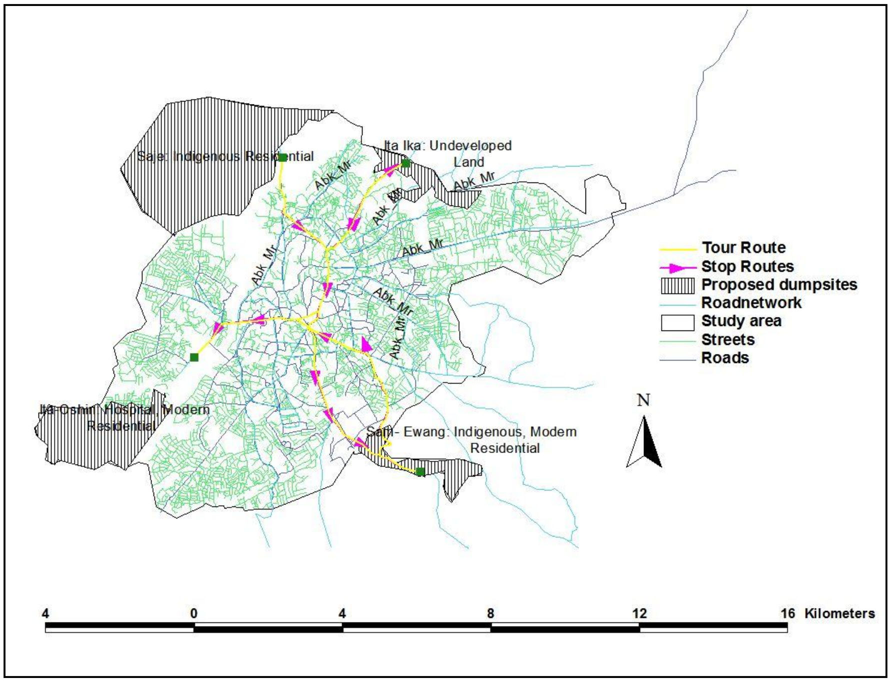


Fig. 11: Map of Study Area Showing the Proposed Transport Routes in Abeokuta

Table 1: Attributes of Tour Routes Theme in Network Analyst

Shape	*Path_Id*	*Proposed Dumpsite*	*F_label*	*T_label*	*F_Cost (km)*	*T_Cost (km)*	*Distance (km)*
PolyLine	1	Saje	*Stop 1*	*Stop 2*	0.000	0.058	0.00
PolyLine	2	Ita-Ika	*Stop 2*	*Stop 3*	0.058	0.158	6.39
PolyLine	3	Sam-Ewang	*Stop 3*	*Stop 4*	0.158	0.247	17.49
PolyLine	4	Ita-Oshin	*Stop 4*	*Stop 1*	0.247	0.326	**27.30**

Path_Id = An Identifier *F_Label* = "From" Label *T_ Label* = "To" Label
F_Cost = Cost of Reaching the F_Label Point
T_Cost = Cost of Reaching the T_Label Point

Discussion

The arbitrary and indiscriminate siting of dumpsites in Abeokuta has led to the creation of so many patches of unsightly mountains of refuse scattered around the city. Four major areas which are Saje, Olomore, Ita-Oshin and Totoro are currently regarded as legal dumpsites while the others are termed as arbitrary. Burning still remains the most applied method of waste disposal especially for the illegal dumpsites, because the frequency at which waste is burned is higher when compared to that of the legal dumpsites (Ogwueleka, 2009).

The final selection of the dumpsites after various analyses in ArcViewGIS is influenced by several factors including the size (area) of candidate sites, nearness to resources having ecological / economical importance, accessibility to roads and type of development activities that have taken place in such a location (Adeofun et al, 2006; Sani et al, 2010 and Sener, 2010).
Saje, one of the proposed sites, is preferred for its large size and distance from areas with important economical/ecological value; and will serve *Ilugun* and *Mokola* which were initially selected but later eliminated. *Ilugun* and *Mokola* were eliminated during the selection process because they were closely located to *Saje* which is large enough to serve the areas. Furthermore, *Ilugun* is overlapping the railway, Ogun River and express road and would not be large enough if any attempt is made to reduce it farther away from these obstacles; it is also not on the road network i.e. not currently accessible to other locations.

Sam – Ewang is another proposed site lying between *Onikolobo* and *Kemta* which were both eliminated as well due to the clustered nature of their locations. It is therefore intended that *Sam-Ewang* will serve both locations as it lies in-between and is accessible from both locations.
Ita-Oshin was favoured in the selection process even though it overlaps some obstacles because of its large area. It is therefore advised that about 1.5km – 2km of its 4.64km should be carved out from the obstacles before siting the dumpsite in the area. It will also serve Olomore area which was initially selected but later eliminated because of its nearness to resources of important value and very small size.

Determining transport routes for waste collection and transportation services is very essential in order to reduce travel costs and increase efficiency in transferring wastes to disposal sites (Ogra, 2003). The most appropriate route from the starting point, *Saje,* is through *Ita-Ika, Sam-Ewang* and finally to *Ita-Oshin* and vice-versa.

Conclusion and Recommendation

It has been demonstrated beyond every reasonable doubt that GIS is a very important tool for determining the most appropriate locations for siting dumpsites and finding the least-cost travel routes for waste transportation and disposal. Therefore, the proposed dumpsites should be considered as appropriate waste disposal / landfill sites and as such, approved for location.
Locating disposal / landfill sites should not be arbitrary and its management should be deliberately planned and consistent to ensure a continuous and efficient waste management program. Transport routes should be short to allow for multiple trips, efficiency in waste collection and transportation and cost-effectiveness. Also, the following recommendations are made:

- *Saje* dumpsite should be retained and considered a possible location for siting landfill.
- *Olomore* and *Totoro* dumpsites should be relocated while *Sam-Ewang* and *Ita-Ika* dumpsites should be upgraded and made to function as legal waste disposal sites
- The road network should be expanded to enable a wider coverage of inaccessible areas for efficient waste collection and transportation

References

Abel, O. A. (2009). An Analysis of Solid Waste Generation in a Traditional African City: The Example of Ogbomoso, Nigeria. *Environment and Urbanization, SAGE Journals,* **19** (2): 527- 537.

Adeofun, C.O. and Nwagu, C.J. (2006). Selection of Solid Waste Landfill Site Using Remote Sensing and GIS Techniques. Asset Series A (2006) **6 (2)**: 301-310.

Adewumi, I. K., Ogedengbe, M. O., Adepetu, J.A. and Fabiyi, Y.L. (2005). Planning Organic Fertilizer Industries for Municipal Solid Wastes Management. *Journal of Applied Sciences Research,* **1(3)**: 285-291.

Daneshvar, R., Fernandes, L., Warith, M. and Daneshfar, B.(2005). Customizing Arcmap Interface to generate a user- friendly Landfill Site Selection GIS tool. *Journal of Solid Waste Technology and Management,* **31** (1):1-12.

Diaz, L. F., Salvage, G. M. & Eggerth, L. L (2005). *Solid Waste Management: Project cofounded by UNEP IETC* (Osaka, Japan) and CalRecovery, Inc. (Concord, USA). pp. 7 – 9, 128-129
http://en.wikipedia.org/wiki/Geographic_information_system
http://en.wikipedia.org/wiki/Remote_sensing

Igoni, A. H., Ayotamuno, M. J., Ogaji, S. O. and Probert, S. D. (2007). Municipal Solid Waste in Port Harcourt, Nigeria. *Applied Energy, Elsevier* **84** (6): 664-670.

Karadimas, N.V., Loumos, V and Mavrantza O. (2004).Quality of Service Ensuring in Urban Solid Waste Management, in Proceeding of the *2nd International IEEE Conference on Intelligent Systems*, Varna, Bulgaria, 288-292.

Kyessi, A. and Mwakalinga, V. (2009): GIS Application in Coordinating Solid Waste Collection:The Case of Sinza Neighbourhood in Kinondoni Municipality, Dar es Salaam City, Tanzania. TS 4B – SDI in Municipality and Natural Resources Management; 19pp.

Lasisi, K. S. (2007). An Appraisal of Municipal Solid Waste Management in Lagos State. Ibadan: Longman Press.

Ogra, A. (2003). Logistic Management and Spatial Planning for Solid Waste Management Systems using Geographical Information System. *In: Map Asia 2003 India.*

Ogwueleka, T.C. (2009). Municipal Solid Waste Characterization and Management in Nigeria. *Iran J. Environ. Health. Sci. Eng*, **6** (3): 173-180.

Sani, Y., Christopher I., Shittu W. and Jibril, E. (2010) Land Fill Site Selection for Municipal Solid Waste Management using Geographic Information System and Multicriteria Evaluation. *American Journal of Scientific Research **10***:34-49;

Sener, S. (2010). Solid Waste Disposal Site Selection with GIS and AHP methodology: A Case Study in Senirkent-Uluborlu (Isparta) Basin, Turkey. *Journal of Environmental Monitoring Assessment* ***(10)***:1010-1023.

Shrivastava, U. and Nathawat, M .S. (2006). Selection of Potential Waste Disposal Sites around Ranchi Urban Complex using Remote Sensing and GIS techniques File://E:\mypro\waste%20disposal.htm

Sridhar, M. K. and Adeoye, G. O. (2003). Organo-mineral fertilizer from urban wastes: Development in Nigeria. *The Nigerian Field,* **68**: 91-111.

United Nations Development Programme (UNDP) (2004). Municipal Solid Waste Management in Developing Countries: A policy Framework. Geneva. *Technical paper, 12,* Geneva.

United State Environmental Protection Agency (USEPA) 2005. Municipal Solid Waste Basic Facts, Retrieved 23rd March, 2011 from http://www.epa.gov/epaoswer/non-hw/muncpl/reduceh.htm