Waste Disposal Site Selection using Remote Sensing and GIS: A Study of Akure and its Environs, Southwest-Nigeria

[1]Anifowose Y. B., Omole K. E. and Akingbade O.

Department of Applied Geology, Federal University of Technology, P.M.B. 704, Akure, Nigeria.
[1]Corresponding author; E-mail: aybanifowose@futa.edu.ng,yanifowose@yahoo.com; Tel: 0803-667-0047

Abstract

Waste disposal has been a serious challenge in Nigerian cities especially as rural-urban migration intensifies. While overwhelming scientific evidences abound that global warming is taking a significant toll on the Earth and its occupants, Nigeria is striving to join other countries in mitigating the effects. One way of intensifying the mitigation is through appropriate and environmentally-friendly waste disposal and management. All manners of wastes are usually disposed of without any serious consideration for the environment. Open incineration is a very common means of waste disposal in developing countries. In spite of the meager contributions of this group of nations to industrial growth, open incineration method of waste disposal hugely adds to the problem of climate change. It has been observed that there is the tendency to dispose wastes indiscriminately and in an uncoordinated manner, thereby resulting in unhealthy environment. In this study, a satellite imagery covering Akure and its environs was analysed using ArcView GIS 3.2a to develop a user interface for selecting a waste disposal site with special emphasis on geologically suitable conditions. This study aims at demonstrating the potential and efficiency of using GIS in selecting sites for the storage of biodegradable solid wastes. Results show suitable areas where landfill sites can be safely and aesthetically located within the study area, putting urban growth rate into consideration.

Keywords: Remote sensing, GIS, Waste disposal, Urbanization

Introduction

Waste can be defined as any substance or article which requires to be disposed of as being broken, worn out, contaminated or otherwise spoilt. Source reduction, recycling and waste transformation are methods widely used to manage solid waste. However, in all these methods there is always a residual matter to be disposed of even after the recovery process. The technique of getting rid of these wastes in an economic and environmentally friendly approach is called "sanitary landfilling" (Tchobanoglas and Kreith, 2002). Sanitary landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. Urbanization can be regarded as the quality or state of becoming a city, and therefore having the characteristics pertaining to, and related to being a city. Among the several advantages of urbanization is industrialization which in turn brings about the growth of population within cities and thus the generation of wastes in its different forms, types and quantities. Therefore, as a city grows, the need arises for a suitable and efficient waste disposal scheme to be put in place to manage these wastes. To achieve this, an efficient waste disposal site should be created where wastes can be safely dumped or better still, recycled.

According to Howard and Irwin (1978), 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. It is therefore imperative that many factors must be incorporated into sanitary landfill siting decisions; Geographic Information System (GIS) is ideal for this kind of assessment study due to its ability to manage large volume of spatial data from a variety of sources. With growth in population and attendant increase in the amount of waste generated, appropriate disposal is fast becoming a serious problem within urban centres. For example, Akure has been growing in terms of population, infrastructure, commerce and industry since it became a state capital in 1976; this has consequently resulted in more waste generation. While refuse burning has been the most common means of waste disposal, it visibly poses environmental health hazards. During the rains most of the poorly disposed of refuse block drainages, spill onto roads, and occupy adjacent water bodies, thereby rendering the surrounding filthy and repulsive.

Some guidelines have been proposed for the siting and design of sanitary landfills in developing countries (Diaz, 1997). Some of these guidelines include geological and hydrogeological considerations. Based on these guidelines and using remotely sensed data in a GIS environment, Atejioye and Anifowose (2005) carried out a study on selecting a suitable waste disposal site within the main campus of the Federal University of Technology, Akure. The study was used as a pivot for the current investigation which is extended to other parts of Ondo and Ekiti States.

Study Area

The study area is bounded by Latitudes 7^0 and $7^030'$N, and Longitudes 5^0 and $5^030'$E covering parts of Ondo and Ekiti States in southwestern Nigeria. Towns covered by the study include Akure, Emure, Idanre, Ijare, Iju, Ikere, Ilara, Isarun, Ise-Ekiti, Ita-Ogbolu, Oba-Ile and Owena. The area is underlain by Precambrian rocks comprising Migmatite-Gneiss-Quartzite complex; the rocks include migmatites which grade into banded gneiss, and intruded by granites, prophyritic granites and charnockites (Anifowose, 2000). Some bands of quartzites also exist as residual hills and ridges within the study area. The rocks also exhibit varieties of structural features such as foliations, folds and fractures. The general trend of the rocks is in the NNE-SSW direction, while several short fractures trend N-S (Atejioye & Anifowose, 2005). These rocks have been variously subjected to intense deformation resulting in their folding and fracturing (Oluyide, 1988). The drainage pattern is generally dendritic with southward flow of the rivers and their tributaries. The area enjoys two alternating seasons in a year - the rainy season which spans about nine months from March to November with a brief break in August, and the dry season thereafter. The rainy season is marked by heavy rainfall with mean annual ranges between 1000mm and 2000mm. Temperature in this area is generally high and ranges between 25°C and 30°C, with a relative humidity of about 80% (Udo, 1978). Majority of the occupants are subsistence farmers who also cultivate cash crops like cocoa, kolanuts and oil palm, while civil servants and petty traders live mostly in the cities.

Materials and Methods

A satellite imagery covering the study area (Figure 1) was downloaded from Google Earth™; a topographical map of Akure area on a scale of 1:100,000 and a geological map covering the area on a scale of 1:250,000 were also obtained (Figure 2). During ground truthing, a Garmin™ hand-held GPS was used to measure the coordinates of some points in the study area for the purpose of georeferencing the maps which had earlier been scanned into ArcView™3.2 GIS environment. Towns and other major settlements were extracted from the satellite imagery while major road network were extracted from both the topographical map and the imagery (Figure 3); fractures, rivers and quartzite bodies were extracted from the geological map (Akingbade, 2010; Omole, 2010). Buffer zones were created for each of the considered factors at specific, environmentally safe predetermined distances away from potential landfill sites (Sener *et al.,* 2006). The distances were 500m, 250m, 250m, 2km and 500m for rivers, fractures, quartzite bodies, settlements and major road network, respectively. The map layers for the buffered zones were combined (Figure 4) to delineate unsuitable and potentially suitable landfill sites.

Results and Discussion

Numerous fractures were identified and delineated particularly in the granitic rocks in parts of Idanre, Iju, Ita-Ogbolu, Iresi, Ijare and Ikere (Figure 3). Other areas which are equally fractured were observed to have been underlain by massive quartzites which exist in parts of Igbara-Odo, Igbara-Oke, Ibuji and Ero areas. Such fractures are known to act as passageways for underground flow (Langer, 1995); hence the selection of such an area as landfill site may lead to groundwater pollution. Other areas underlain by migmatite-gneisses are preferred because they are more geologically suitable. The potential landfill sites delineated in the study area are situated on migmatite gneiss because an ideal landfill, according to Yildrim (1997), must be situated over a competent rock of limited permeability; then the probability of groundwater pollution either chemically or microbially will be very low.

The most suitable site for Alade and Idanre areas is about 7km and 11.5km southwest from the settlements respectively around $7^{0}14^{'}$N/$5^{0}04^{'}$E coordinate, in an area that is underlain by migmatite-gneiss. The most suitable site for Owena, Ilara and Ijare areas is about 6km, 6.6km and 4km away from the town centres respectively around $7^{0}37^{'}$N and $5^{0}06^{'}$E coordinate, and also underlain by migmatite-gneiss. For Ikere, Iju and Ogbese areas, the most suitable site is situated about 8.5km, 7.5km and 5.4km away from the town centres respectively at $7^{0}45^{'}$N and $5^{0}30^{'}$E coordinate, with migmatite-gneiss as the bedrock. Finally, the most suitable site for Akure, Oba-Ile and Oda areas is 9km, 13.5km and 6.8km away from the centre of the settlements respectively at $7^{0}17^{'}$N and $5^{0}18^{'}$E, with the bedrock being migmatite-gneiss.

Conclusion

Solid waste disposal in open places should be abandoned because of its inherent potential for air and groundwater pollution coupled with its obvious linkage with serious health, aesthetic and environmental problems. A number of potential sites which generally satisfy the minimum international requirements were identified for the purpose of effective sanitary landfill-type waste disposal. Among these areas, selection should be made through careful field checks. The integration of GIS in Multicriteria Decision Analysis (MCDA) is a powerful tool in solving landfill site selection problem, because it provides efficient spatial data manipulation and presentation. It helps to situate and design landfill in such a way that no harmful substances as a result of incineration reach the atmosphere, biosphere and hydrosphere in unacceptable quantities, thereby ensuring that climate change-induced gases are drastically reduced. While it is important to emphasize that GIS analysis is not a substitute for geological/geotechnical field exploration, it is efficient in identifying areas that are more suitable and directs efforts to such areas for detailed field studies. Finally, the selection of the final sites requires further geotechnical and hydrogeological analyses to ensure conformity with the stringent standards required for design and construction of such facility.

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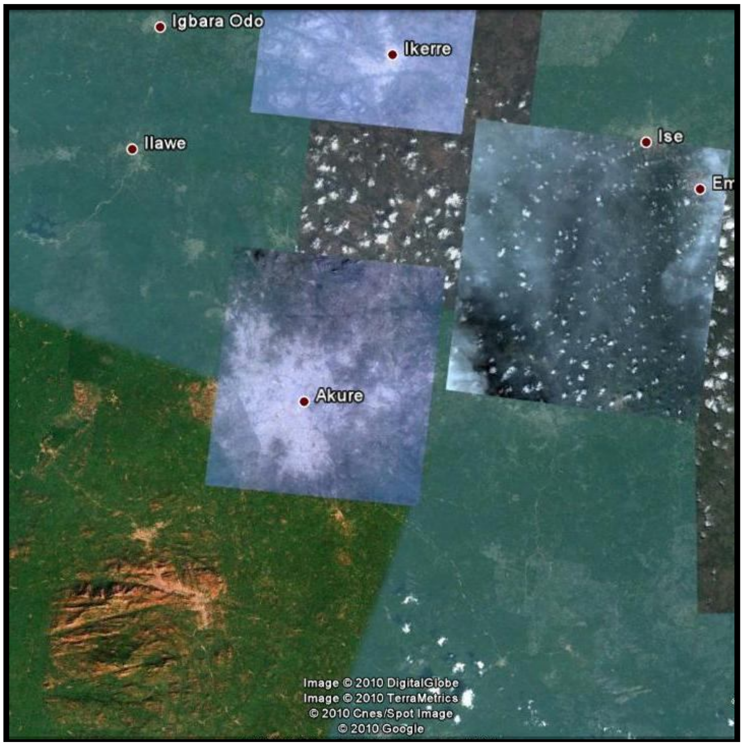

Figure 1: Satellite imagery covering the study area (Source: www.googleearth.com)

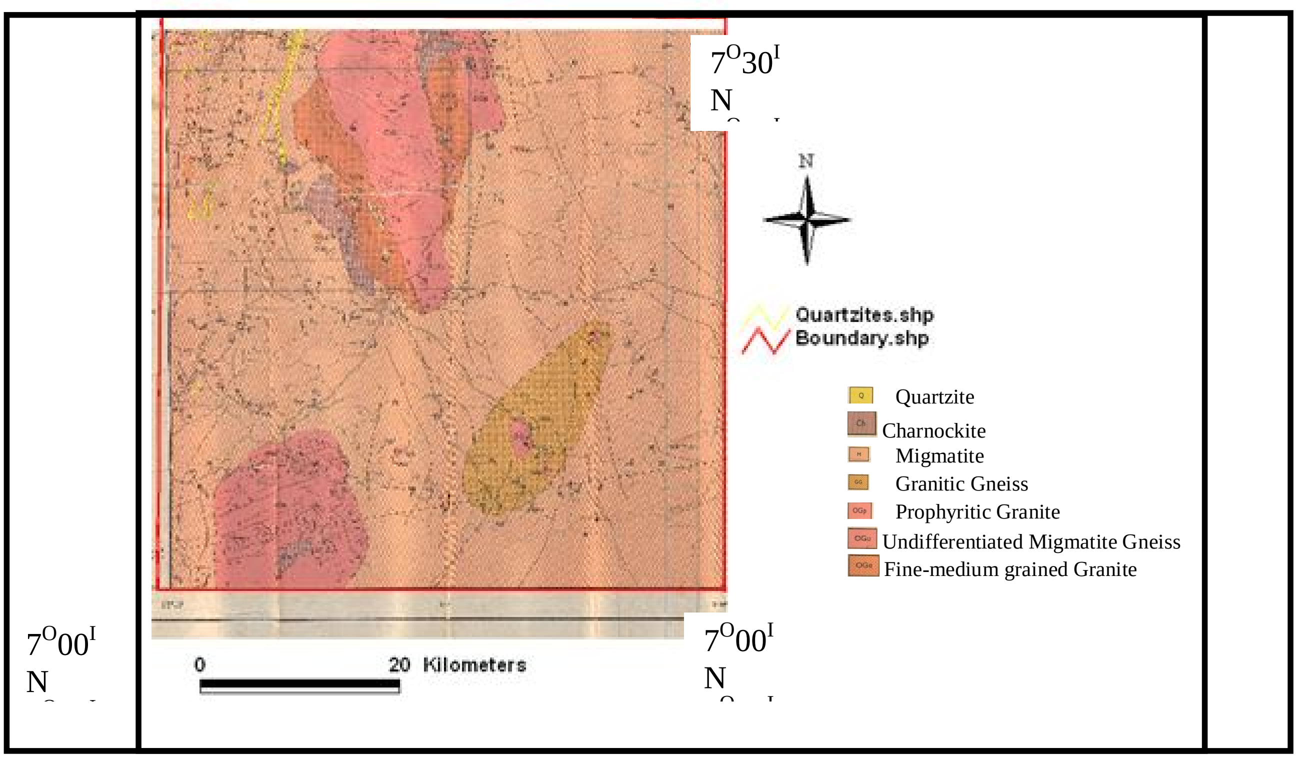

Figure 2: Geological map of the study area

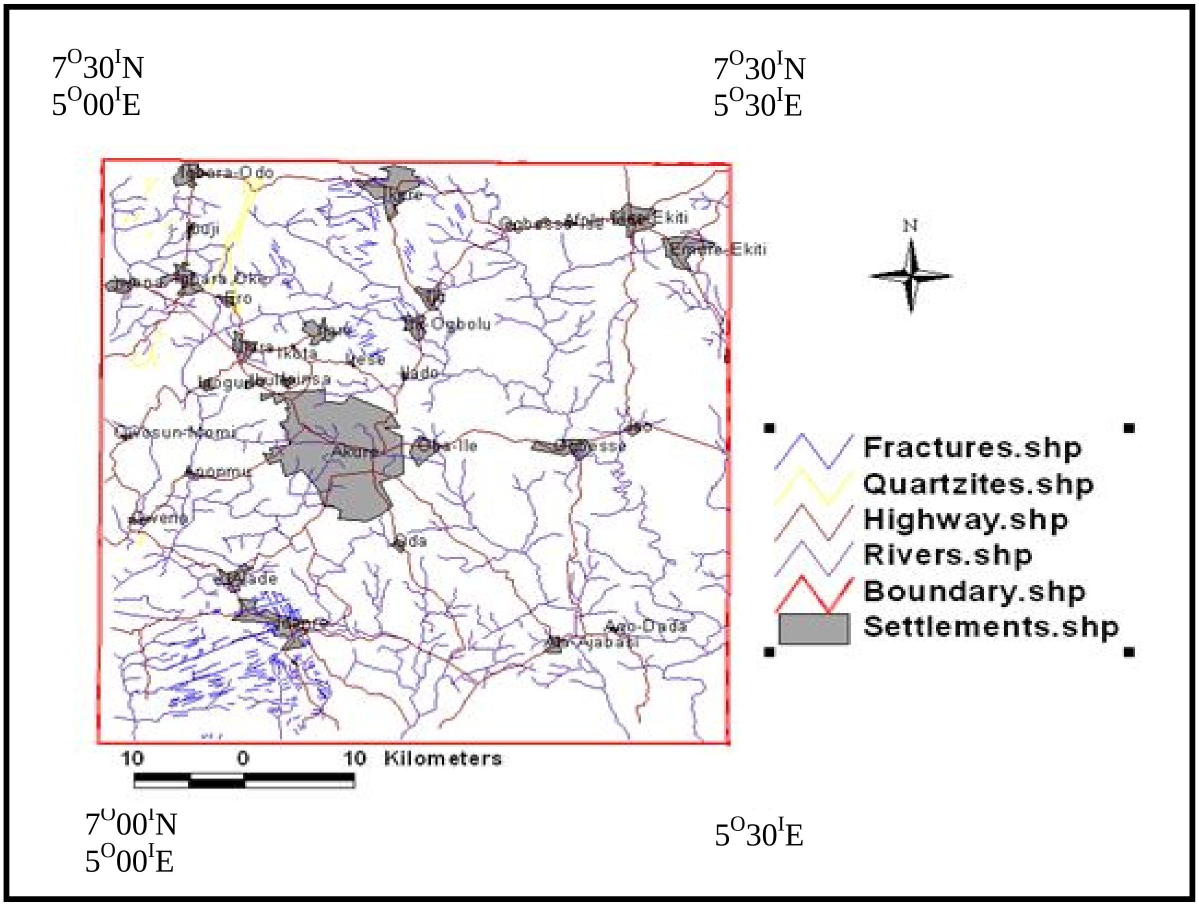
$7^{O}30^{I}N$
$5^{O}00^{I}E$
$7^{O}30^{I}N$
$5^{O}30^{I}E$
N
Akure
Ogbolu
Oda
Emure-Ekiti
Fractures.shp
Quartzites.shp
Highway.shp
Rivers.shp
Boundary.shp
Settlements.shp
10 0 10 Kilometers
$7^{O}00^{I}N$
$5^{O}00^{I}E$
$5^{O}30^{I}E$

Figure 3: A map of the study area showing delineated quartzite bodies, fractures and drainage system

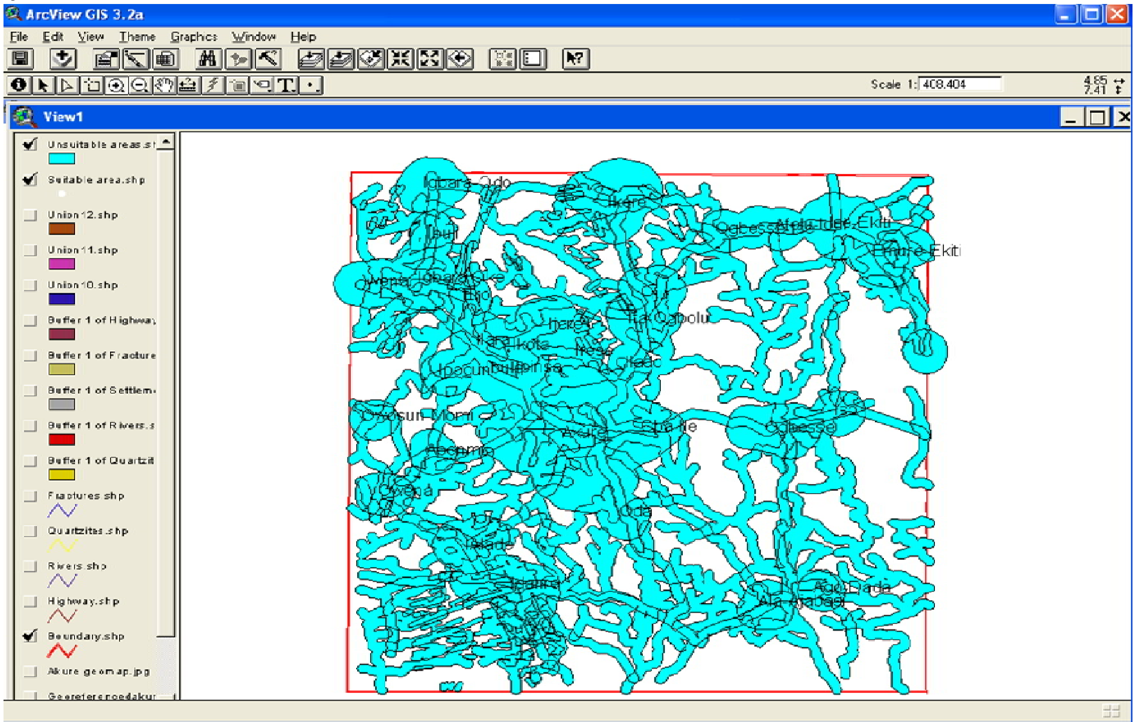

Figure 4: Suitability map based on the buffering factors.