

**PERSPECTIVES IN REGIONAL
DEVELOPMENT IN NIGERIA.**

**A Festschrift In Honour of
PROFESSOR ADEBISI
FUNSHO ADEDAYO**

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CHAPTER TWENTY ONE

The Application of Spatial Analysis Approach for the Siting of MSW Landfills

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Abstract

A spatial methodology which involves geographic information systems, spatial analysis and spatial statistics is presented. The aim of this methodology is to evaluate the suitability of the study area in order to site municipal solid waste (MSW) landfills. The methodology uses spatial analysis techniques to establish the criteria for evaluation, which are based on local legislation. Several factors are used in the siting process including agricultural areas, aspect, commercial areas, educational areas, residential areas, road distance, sensitive sites, and water body. Adopting the simple additive approach, the suitability of the study area for landfill siting is evaluated. The final land suitability index report is on a grading scale of 0-5, which is from least suitable to most suitable land areas for landfill site in order to address the waste management problem.

Introduction

Besides recycling, biological treatment, reuse, and thermal treatment, landfilling is another form of municipal solid waste (MSW) management. Landfill method is the cheapest form of waste management and it is widely used and environmentally friendly (Kao and Lin 1996). As at 2006, Yobe state generates a total of 418,999 tonnes of solid wastes with about 78,145 collected, 96,849 approved public dump sites and 95,414 unapproved dump sites. Solid wastes are not properly dumped resulting in garbage littering the streets, blocked drains (Fig. 3) in uncompleted buildings, rivers and ponds. Damaturu town even though a state capital do not have any sanitary landfill in place. Establishing a landfill is therefore necessary in order to mitigate the increasing rate of solid waste generated in the city. However, siting a landfill is a difficult task as it must take into cognisance environmental, social, economic and technical factors. The objective of the process is to identify the areas that will pose minimal health challenges to the public and the environment and also economically efficient (Kontos et al. 2005). Several methodologies have been used for landfill siting; for example Muttiah et al., (1996)

applied the Markov chain based simulated annealing algorithm in geographic information system to locate potential sites in the Indian pine water shed of Indiana. The result reveals that, simulated annealing achieved an order of magnitude reduction in execution time over that of exhaustive search method. The study indicated that, the method gives the policy maker the option of selecting the final site based on social factors that are not combined in the numerical model.

Erkut and Moran, (1991) developed a model based on the analytic hierarchy process (AHP) to identify the position of obnoxious facilities. Kontos et al., (2005) presented a methodology for evaluating sites of a region for the optimal siting of Landfill. The methodology utilizes the AHP to determine the relative importance weights of the evaluation criteria. Similarly, Mahini and Gholamalifard, (2006) used the GIS weighted linear combination methodology to evaluate the suitability of a region for landfill. Huang et al., (2006) applied the remote sensing and GIS approach, while Silvestri and Omri, (2008) reported the importance of integrating remote sensing and GIS as a key instrument for environmental management. The system used provided information for the

identification of contaminated sites, as well as identify unknown landfill sites. Landfill sites in Al-qurain, Kuwait, was assessed using several remotely sensed data consisting of land sat multi-spectral scanner (MSS), land sat thematic mapper (TM), IKONOS, and synthetic aperture radar (SAR). Information like Spectral extent, Spectral reflectance, surface temperature and surface roughness from the satellite imagery were collected about the landfills. The result revealed a high temperature around the landfill sites compared to the immediate surrounding (Kwarteng and Al-Enezi, 2004). Most recently however research focus has shifted to the use of multi-criteria decision methods in a GIS environment. The result of these methodologies is the evaluation of the whole area for landfill suitability and location. This paper presents a GIS methodology for landfill siting in Damaturu town. The method

evaluates the entire city using a scale from 0-5, where 0 scales is for areas that are unsuitable for landfill siting and scale 5 is for the areas most suitable for landfill siting. Section 2 of this paper provides short information on the study area, Section 3, is the method used in the study, while Section 4 presents the results and discussions. Finally, Section 5 is the conclusion of the study.

Study area

Damaturu town is located in the northeast region of Nigeria, about 120km to Maiduguri the capital of Borno State with a total land area of about 400km². The main urban area constituting the city occupies an area of about 20km² with a population of about 255,895 (GeoNames2010). The town lays on a relatively flat topography with a relief usually less than 120 meters, and a wind speed of about 4.89m/s.

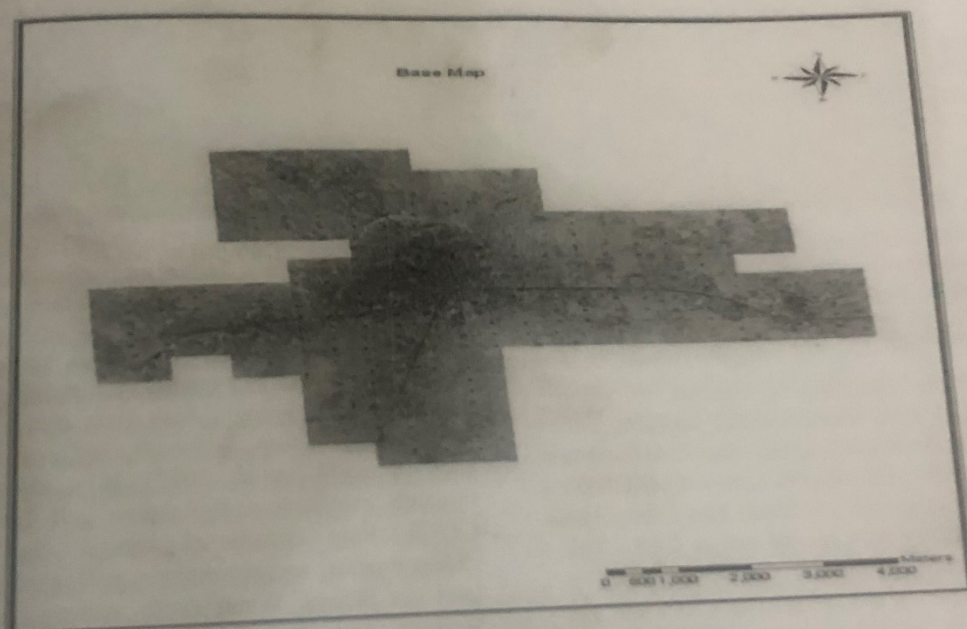


Fig.1 The city of Damaturu (Ikonos imagery)

In Damaturu, waste management is carried out by Yobe state environmental protection agency (YOSEPA) with the participation of the local environmental sanitation board and the state municipal (metropolitan) council. The rate of waste generated has increased tremendously due to the increase in population

and improved living standards. However, the waste disposal and management remain ineffective. Uncontrolled dumps sites exist in the town as wastes from residential areas, hotels, hospitals etc are dumped indiscriminately (Fig. 2, 4 and 5) and in drains (Fig. 3).



Fig. 2 Indiscriminate dumpFig.

3 Dumped on Drains



Figure 4. : Uncompleted building

Figure 5: Dumped on roads

Methodology

This paper describes a method of siting municipal solid waste landfill applying GIS spatial analysis considering Damaturu town in Yobe state. The digital data of IKONOS satellite imageries of 2005 was used. The ground survey was carried out in 2008. The methodology evaluates the area using a grading scale of 0-5, where 0 grades a site not suitable for landfill location while 5 grades a site highly suitable for landfill siting. The criteria for evaluation were obtained considering the local siting practice by EPA and relevant literature.

Results and Discussions

Criteria for the selection of site

Sites for the location of municipal solid waste (MSW) landfill must comply with lay down legislative guidelines and also meet environment, health, economic and social provisions. In evaluating sites for the location of landfill for waste management, many factors are consideration such as; lake and

ponds, rivers, water supply sources, groundwater table and quality, infiltration, air quality index, geology, fault line, elevation, land use, habitation, highways, and sensitive sites (Sumathi, et al, 2007). In a separate research carried out by Rahman and Hoque (2007), they considered natural physical characteristics, socioeconomic, ecological and land use factors. Water depth, recharge area, fracture and faults, soil, cover material, lifetime, water bodies, urban areas and communication, infrastructure, drainage, topography, conservation and inter-municipality has also been used as siting criteria. This study will consider agricultural areas, aspect, commercial areas, educational areas, residential areas, road distance, sensitive sites, and water body as the siting criteria.

The main data source for this study included an Ikonos satellite image. The land use map was generated through the image interpretation and classification from the satellite image of 4m resolution. Thereafter, the thematic maps of sensitive sites, residential areas, aspect, etc

were derived. Secondary data was obtained using ground truth with hand held global positioning system instrument. The thematic maps were digitized and analysed using ArcGIS^(R) software. Buffering indicating areas that are not inappropriate for the siting of landfill such rivers, roads, residential, sensitive sites, were generated. For example, land in the study area was classified creating buffer zones around features to be protected using the criteria earlier highlighted

Buffer Maps : Buffer zones surrounding surface water, roads, residential areas, sensitive areas indicate the allowable distance beyond which landfill can be located for different criteria utilising the buffer button in the ArcGIS^(R) software. Here areas within the buffer are not suitable for siting landfill. The buffer distances were produced based on established guidelines and criteria for landfill siting and existing local conditions.

Road network map: The road network map (Fig.9) delineating the major and minor roads in the study area were prepared. For this criterion, buffer distances were chosen (see table 1).

Land use/land cover map analysis: The land use map analysis was carried out using digital data of IKONOS of 2005 (Fig 1). This shows the land utilized by human and natural features in the study area. A buffer of about 500m around the urban areas is considered from municipal solid waste disposal facility. The urban areas are classified as unsuitable for the siting of landfills and are given a grade of 0. The most suitable areas are classified as areas of agricultural land and therefore given highest grade of 5 as shown in (Fig.8). The land use map was produced from the image interpretation and classification of the 2005

Ikonos satellite imageries covering the study area.

Water body: Disposal of solid waste close to or in any water body such as lake, spring, well or river is prohibited. A minimum distance of 500m from any of this source is required for the establishment of a landfill based on international standards. The buffer zones were draw around the water body using the buffer distance.

Sensitive areas map: This map was developed from digitization of the cultural and historical sites of the study area. These areas must be preserved and landfills sites must be located away from these areas. Here a buffer of about 500m was created around these areas (Fig.7). This is to avoid potential pollution of sensitive areas. Sensitive sites considered here are cultural sites, reservoirs, archaeological sites etc.

I. Aspect map

The slope or elevation of the study area is one major consideration for the siting of a landfill. In this study, the land elevation was evaluated using the slope gradient and measured in degrees. Areas found to be steep slopes are generally not suitable for landfill siting. The grading is based on the fact that flat areas are more suitable for landfill to avoid surface runoff. Areas that are very steep are graded 0 and not suitable and 2-3 are less suitable, while a grade of 4 indicates highly suitable sites for landfill (Fig.5)

Decision rules (Table 1): This was achieved considering established guidelines and existing local conditions of the study area. The table indicates the decision rules for the solid waste disposal site suitability analysis.

Table1. Decision rules

Objective	Criteria	Sub-criteria	Suitability
Accessibility	Minor roads	450m-1500m	Suitable
		1500-3000m	Less suitable
		>3000m	Not suitable
	Major road	600m-2000m	Suitable
		2000-4000m	Less suitable
		4000m	Not suitable
Land use	Residential		Suitable
	High dense	>500m	Less suitable
	Medium dense	200-500m	Not suitable
	Low dense	<200m	Suitable
	Commercial establishment	200-300m	
		300-500m	Less suitable
	Agriculture	500m	Not suitable
		300-500m	Suitable
		<300m	Less suitable
	Administrative off.	>500m	Suitable
		300-500m	Less suitable
		<300m	Not suitable
	Educational inst.	>500m	Suitable
		300-500m	Less suitable
		<200m	Not suitable
	Recreation	200m	Suitable
		200-300m	Less suitable
	Sensitive areas	>500m	Not suitable
		>500m	Suitable
Objective	Criteria	Sub-criteria	Suitability
	Pond	>200m	Suitable
		100-200m	Less suitable
		<100m	Not suitable
Natural	Topography	300-500m	Less suitable
		100-300m	Not suitable
		360m-370m	Suitable
		370-380m	Less suitable
	Slope	>380m	Not suitable
		0-5%	Suitable
		5-15%	Less suitable
		>20%	Not suitable

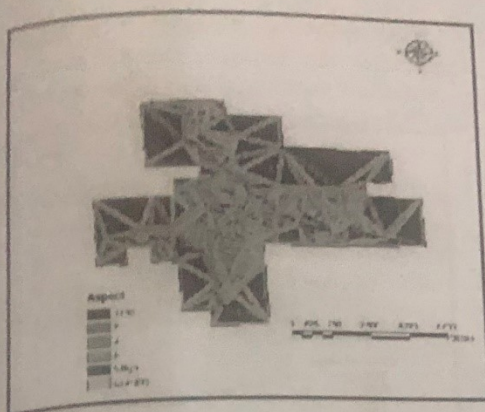


Fig.5 Aspect map

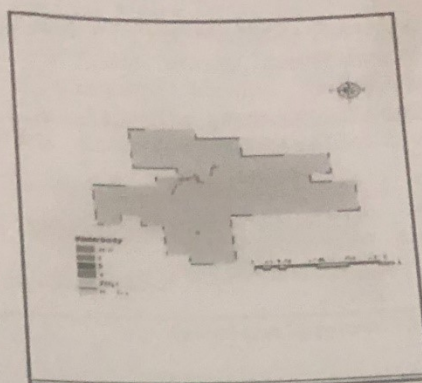


Fig.6 Water body map

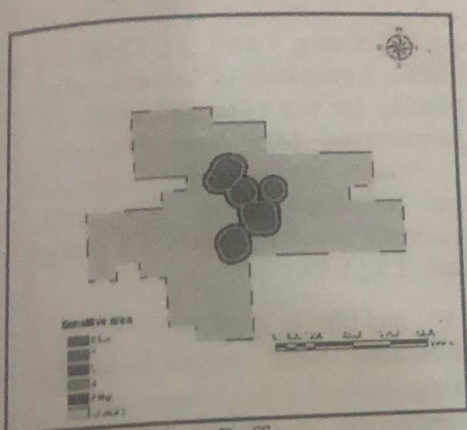


Fig.7 Sensitive area Buffer

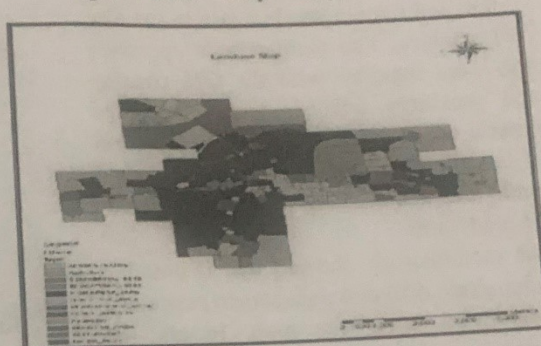


Fig.8 land use map

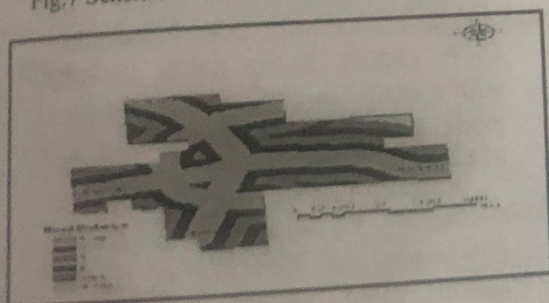


Fig. 9;

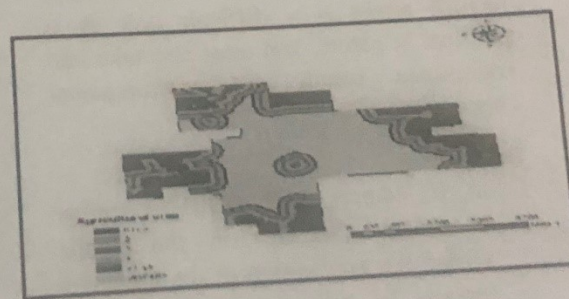


fig 10

Fig.11 Residential area buffer

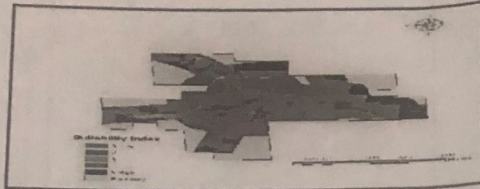


Fig.12 Commercial area buffer

Conclusion

This paper carried out the siting of a landfill using geographic information system and remote sensing data in the city of Damaturu. The multi-criteria approach was used together with the GIS overlay and proximity analysis techniques. The criteria used in this study for the selection of landfill was based on upon established guidelines and existing local conditions of the study area.

The methodology showed that it possible to integrate different data sets to produce a meaningful composite map. In all, the method can aid decision makers in making choices, select between conflicting alternatives and evaluate them. Finally, landfill siting is a difficult task, it is political in nature, and must also take into cognisance health and environmental concerns.

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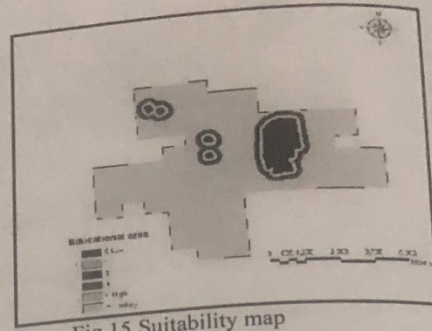


Fig.15 Suitability map

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