

# Using Geographic Information System to Select Suitable Landfill Sites For Megacities (Case Study of Lagos, Nigeria)

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## ABSTRACT

Proper landfill site selection is the fundamental step in sound waste disposal and the protection of the environment, public health and quality of life. Proper landfill site selection determines many of the subsequent steps in the landfill process, which, if properly implemented, should ensure against nuisances and adverse long-term effects. For example, a well-selected landfill site will generally facilitate an uncomplicated design and provide ample cover material, which would facilitate an environmentally and publicly acceptable operation at a reasonable cost. The criteria involved in landfill site selection include environmental, economic and sociopolitical criteria, some of which may conflict. With increased environmental awareness, new legislation and certain other developments over time, the landfill site selection process has become much more sophisticated, as new procedures and tools have been developed (Ball, 2005). Increased environmental awareness and deepening environmental concerns in recent years have forced attention on the need to move towards a more sustainable society. These changes in attitudes in many parts of the world have been supported by changes in laws and policies on environment and waste disposal. In this context, the pressures and requirements placed on decision makers dealing with land fill by government and society have increased, as they now have to make decisions taking into considerations public satisfaction, environmental safety and economic practicality. This situation has created a need for more consistent and objective methods for making decisions; improved access to, and better management of environmental information. At the international level, criteria of differing degrees of detail exist as guidelines for the optimum siting of landfills (Baban and Flannagan, 1998). The role of Geographic Information Systems in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, Geographic Information Systems plays a key role in maintaining account data to facilitate collection operations; customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill. Geographic information system is a tool that not only reduces time and cost of the site selection, but also provide a digital data bank for future monitoring program of the site (Yagoub and Buyong, 2008). This research evaluates existing landfill sites in Lagos, establishes the need for new dumpsites and proposes candidate landfill sites, using Geographic information system as tool and World Bank standard of landfill siting as criteria.

**Keywords** - Social networks, threats, security, intrusion and attacks.

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## 1. INTRODUCTION

The absolute amounts of solid waste disposed of worldwide have increased substantially reflecting changes in consumption patterns, population, urbanization and transportation. Consequently, worldwide commercial, industrial and household wastes are now a bigger problem than ever. Despite increase in alternative techniques for disposing of waste such as composting and incineration, land filling remains the primary means of waste disposal. A sanitary landfill is a land disposal site for non-hazardous solid wastes in which wastes are spread in layers, compacted to the smallest practical volume, and covered with a material (sand or dirt or earth fill) at the end of each opening day (EMA, 1998).

Dumps are sites strategically located to serve as a collection place for solid wastes; the wastes are only either incinerated or compacted in the dumpsites. Increased environmental awareness and deepening environmental concerns in recent years have forced attention on the need to move towards a more sustainable society.

These changes in attitudes in many parts of the world have been supported by changes in laws and policies on environment and waste disposal. In this context, the pressures and requirements placed on decision makers dealing with land fill by government and society have increased, as they now have to make decisions taking into considerations public satisfaction, environmental safety and economic practicality. This situation has created a need for more consistent and objective methods for making decisions; improved access to, and better management of environmental information. At the international level, criteria of differing degrees of detail exist as guidelines for the optimum siting of landfills (Baban and Flannagan, 1998). In a complex society such as it is in many parts of the world today, there are many constraints to be considered. Many stakeholders could affect decisions on the use of a place. Players like government, the environment that must be protected, the people, demand and travel time amongst others have to be considered (Majaro and Abu, 2004).

Decision makers could affect the siting of a facility positively or negatively with respect to established criterion. Unprofessional service delivery and bureaucratic bottlenecks, often characterize the process of decision making in the location of public facilities in many developing countries sometimes by policy makers (Lonsdale and Enyedi, 1984; McNulty et al 1984). The task of siting of landfills, which are environmentally sensitive in nature and cannot be sited or located anywhere is even more daunting. For instance most waste disposal facilities (landfills) in Lagos state are now public hazards due largely to their location, design, operation and other logistics. Some of them have commercial and residential landuse adjacent to them. With urbanization closing in on these landfills, the health implication for the human population living and earning a living around the perimeter of the landfill sites are better imagined (Majaro and Abu, 2004). An inappropriate landfill site will have negative environmental, economic and ecological impacts. Therefore, it should be selected carefully by considering both regulations and constraints on other sources. Selection of suitable sites for waste disposal has been normally carried by traditional approaches i.e. disposing solid wastes at all types of vacant land in or around the city. A GIS can provide an opportunity to integrate field parameters with population and other relevant data, which help in the selection process. The use of GIS in selection process will reduce the time and enhance the accuracy (Rahman et al, 2008).

### 1.1 Problem in Perspective

The landfill site is one special area where the Lagos-State Waste Management Authority's (LAWMA) operational activities are carried out, in consideration of the geological, topographical and socio-economic nature of cosmopolitan Lagos. At the inception of Lagos-state waste management authority (LAWMA) (then known as Lagos-State Refuse Disposal Board) in 1977, there were five (5) existing land fill/dumpsites in the Lagos metropolis and within the outskirts of the Lagos Metropolis. These were located at pelewura (Adeniji Adele) in Lagos Island Local Government area, Gbagada in Kosofe local Government Area, Isolo-Oshodi Local Government area, Achako , Ipaja and Solous, in Ajerome Ifelodun Local Government area, and Ojota (Odo Iya Alaro) in Kosofe local Government area.

The environmental implication of waste management activities were of secondary importance to the waste being disposed. The health implications of leachates on underground waste were not considered. Consequently, five(5) of the seven(7)sites have been closed to waste operations since 1996 while the Lagos-state waste management authority(LAWMA) presently operates three(3) landfill sites (Lagos-State Waste Management Authority, 2000).

The landfill sites currently operational in Lagos-state are:

- a. Olushosun, Oregun-Ojota, Lagos – (42 hectares)
- b. Abule-Egba, Abeokuta Express Road – (10.5 hectares)
- c. Solous, LASU-Ojo road, Igando,Lagos – (9.3 hectares)

(Source: Lagos-State Waste Management Authority, 2009)

Majaro and Abu (2004) undertook a locational analysis of the three (3) Landfills in Lagos and arrived with these findings: With residential, commercial and industrial landuse found within 60 metres of the landfills, the landfill sites in Lagos are no longer suitable due to high risk and inconveniences they pose to the immediate environment. This is a total violation of the Federal ministry of environment's criteria for establishing landfills, which stipulates that no sensitive landuse should be found within 500metres of any landfill. It is speculated that between 500metres and 3kilometres, adverse effects could be experienced if any sensitive landuse is located within this range of distance. Sensitive landuse includes highways, commercial, residential landuse etc (Federal Ministry of Environment, 2009).

The health consequences of the three (3) landfill sites in Lagos on the repository communities include the incidence of malaria, typhoid and diarrhea. Respiratory diseases such as cough and catarrh are some of the inconveniences posed on the people. The Lagos landfills also have some environmental effects on the immediate surroundings with water quality having odour, taste and not good for drinking. Also evident is the account of people living around the landfills who expressed discomfort arising from the smoke and stench emanating from the landfills.

Lagos State status as a Mega City has created an Urbanization challenge of providing new infrastructure and maintenance of the existing ones sustainably. The challenges provide opportunities to explore creative and innovative ways of addressing the urban infrastructural deficit. (Lagos-State Public Private Partnership Brochure, 2008). As a result of the environmental treat and health risk posed by the existing landfills in Lagos-State, it is expedient to close down existing landfills in Lagos and select new sites that strictly meet up with global environmental standards required of a megacity.

## 2. RESEARCH OBJECTIVES

To identify the need for and potential areas for engineering landfills in Lagos state

The specific objectives include:

1. To establish the need for engineering landfills in Lagos state
2. To review existing landfill sites in the state using GIS
3. To use the world bank criteria in identifying potential landfill sites in Lagos

### 1.4. STUDY AREA:

Lagos State was created as a State in May 27, 1967 by virtue of States (Creation and Transitional Provisions) Decree No. 14 of 1967, restructuring Nigeria into 12 Federating Units. With a geographical size of 3,577 square kilometres, Lagos State is one of the smallest states in Nigeria, representing about 0.4% of the entire geographical area of the Country. The administrative machinery, prior to creation as a State was based on a 3-way structure (Lagos-state public private partnership brochure, 2008). .

- The Federal Government, through the Federal Ministry of Lagos Affairs as the Regional Authority, administered the Lagos Municipality

- Lagos City Council (LCC) was governed by the City of Lagos.
- Metropolitan areas (Colony Province) of Ikeja, Agege, Mushin, Ikorodu, Epe and Badagry were administered by Western Region.

Lagos State took off administratively in April 11, 1968, with Lagos Island doubling the role of State and Federal Capital. The establishment of a new Federal Capital City of Abuja (FCT Abuja) in 1976 paved way for the movement of the State Capital from Lagos Island to Ikeja. The final relocation of the Federal seat from Lagos to Abuja on 12<sup>th</sup> December 1991 marked the watershed, when Lagos ceased to be the Nation’s political capital. Nonetheless, Lagos remains the nation’s economic hub (Lagos-State Public Private Partnership Brochure, 2008). Lagos is located on the South-western part of Nigeria on the narrow Coastal flood plain of the Bight of Benin. The State lies approximately between longitudes 2°42’E and 3°42’E and latitudes 6°22N 6°52’. The Southern Boundary of the State is 180km long Atlantic Coastline, it is bounded in the north and east by Ogun State; The state is laced with several lagoons; Yewa and Ogun Rivers are the two main rivers in addition to other minor rivers and lagoons(Lagos-State Public Private Partnership Prochure, 2008).

The environment of Lagos State is characterised by a tropical climate, with the dominant vegetation of tropical swamp forest, comprising fresh waters and mangrove swamp forests. It has a double rainfall pattern, with two climatic seasons – the dry (November-March) and wet (April-October). The drainage system of the State is characterized by a maze of lagoons and waterways, which constitute about 22%, or 787 sq. km of the State total landmass. The major water bodies are the Lagos and Lekki Lagoons, Yewa and Ogun Rivers (Lagos-State Public Private Partnership Brochure, 2008).



Fig 1.1 Nigeria Showing Lagos And Other States

In terms of administration, Lagos is not a municipality and has therefore no overall city administration. The Municipality of Lagos, which covered Lagos Island, Ikoyi

and Victoria Island as well as some mainland territory, was managed by the Lagos City Council (LCC), but it was disbanded in 1976 and divided into several Local Government Areas (most notably Lagos Island Local Government Area, Lagos Mainland LGA and Eti-Osa LGA). The mainland beyond the Municipality of Lagos, on the other hand, comprised several separate towns and settlements such as Mushin, Ikeja and Agege. In the wake of the 1970s Nigerian oil boom, Lagos experienced a population explosion, untamed economic growth, and unmitigated rural migration. This caused the outlying towns and settlements to develop rapidly, thus forming the greater Lagos metropolis seen today. The history of Lagos is still evidenced in the layout of the LGAs, which display the unique identities of the cultures that established them.

Today, the word *Lagos* most often refers to the urban area, called "Metropolitan Lagos" in Nigeria, which includes both the islands of the former Municipality of Lagos and the mainland suburbs. All of these are part of Lagos State, which now comprises 20 LGAs. Lagos State is responsible for utilities including roads and transportation, power, water, health, and education. Metropolitan Lagos (a statistical division and not an administrative unit) extends over 16 of the 20 LGAs of Lagos State, contains 88% of the population of Lagos State, and includes semi-rural areas. Lagos City has a considerable amount of tall buildings, which makes up its skyline. Most of the tall buildings are located in around the downtown Central Business District.

Lagos was the former capital city of Nigeria but it has since been replaced by Abuja. Abuja officially gained its status as the capital of Nigeria on 12 December 1991, although the decision to move the federal capital had been made in decree no. 6 of 1976(Wikipedia, 2008). Lagos, which is the commercial nerve centre of Nigeria, had attained a mega-city status by 1984. Apparently, between 1984 and year 2004 (a spate of 20 years) the population of Lagos state has increased by 19 million people. According to the United Nations by the year 2015, going by 6% growth rate, Lagos will be the 3<sup>rd</sup> largest mega-city in the world (Olugbenga, 2006).

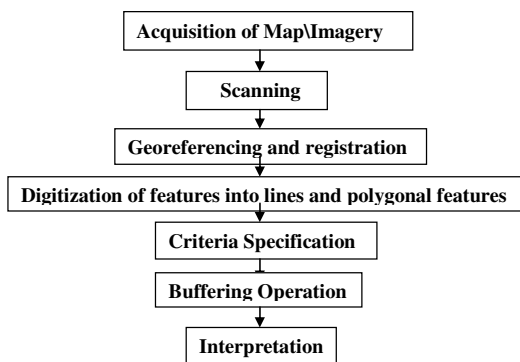
It is also estimated that by 2020 Lagos will consist of About 30.2 Million people composed of Pediatrics - 35%; Youths - 30%; Adults - 25% and Geriatrics - 10% (At a Growth Rate of 6% Per Annum using the 2006 Census Projection, by Office of Central Statistics, Alausa). About 592,000 Industries and Business (At an Expected Growth Rate of 5% per Annum using the 2008 figure (330,000). About 21,140 Metric Tons of Waste Daily at a Generation per Capital (GPC) of 0.7kg/Person/Day (Ola Oresanya, 2008). The estimated increase in the volume of waste generation as a consequence of population increase makes it imperative for waste management facilities (i.e. Landfills) to be well propagated in Lagos, in other to maintain a clean environment and maintain the mega-city status of Lagos-state.

Traditionally, Lagos-State is essentially a Yoruba speaking state. It is a Cosmopolitan City with an admixture of the traditional indigenous inhabitants and pioneer immigrant settlers. The Awori’s and Oguns in the Ikeja and Badagry Divisions inhabit Lagos-State. The indigenes of Ikorodu and Epe Divisions are mainly Ijebus with pockets of Eko-Awori settlers along the coastland and riverine areas.

The indigenous populations of Lagos are Aworis with a mixture of other pioneer immigrant settlers, collectively called Lagosians or Ekos. Due to its urban nature, and its status as former Federal Capital City, it became a socio-cultural melting pot attracting Nigerians and foreigners alike, giving it a cosmopolitan character (Lagos-State Public Private Partnership Brochure, 2008).

**3.0. RESEARCH METHODOLOGY**

Different data types and data sources were explored in a quest to give a robust expression to the outlined aim and objectives of this research. Frantzis (1993) observes that numerous criteria must be taken into consideration when prospective sites for landfills are being studied. This session has diagrammatically explained in figure 3.1 above, gives an insight into the methodological approach deployed in data acquisition, data interpretation, data analysis, and the presentation of results. It also gives an insight into the criteria used in the analysis, the buffering operation (proximity analysis) executed, and the entire qualitative and quantitative analysis carried out in the research.



**Fig. 2: Research Methodology Flowchart**

**Table 1: Data Source and Characteristics**

Data Type	Period	Scale	Source
Landuse map of Lagos covering Ikeja, Surulere, Mushin	1985	1:25000	Ministry of lands and survey
Landuse map of Lagos covering Yaba, Gbagada, Ketu, Ojota	1985	1:25000	Ministry of lands and survey
Landuse map of Lagos covering Lagos Island and environs	1985	1:25000	Ministry of lands and survey
Landuse map of Lagos covering Ikorodu area.	1985	1:25000	Ministry of lands and survey
Satellite Imagery	2009		Cnes Spot Imagery via Google Earth

**3.1 Data Access, Source and Characteristics**

Data availability is of prime importance when using GIS. In the current study, map sheets from the ministry of lands and surveys provided information on a comprehensive body of secondary information related to environmental (streams network and wetlands.), socio-cultural (municipal development area, historic and important conserved sites and land use), and economic factors (road network). Also, existing literature was used extensively and the internet also served as a provider of information. With reference to Table 3.1, the land use maps were acquired in four different map sheets due to the large areal size of Lagos used for the research. These map sheets were published in 1985. They consist of accurate co-ordinates that are current for map geo-referencing and registration.

Lagos being regarded by the United Nations as one of the fastest growing cities in the world makes the use of map sheets published in 1985 for landfill site purposes inexpedient as a result of rapid urban growth. The Cnes spot imagery was used for this research was acquired via the Google earth software. The Cnes spot imagery is reliable for its currency as the imagery was acquired in 2009. It shows current land use patterns. The obvious limitation of this data source is the existence of cloud cover at the point of acquisition.

**Materials:** Personal computer (pc), Map and Imagery, GPS, Arcview software

**3.2 Data Processing And Feature Extraction**

The different maps showing the land-use/land-cover of the locations in their analogue state were scanned then imported into the Arc-view environment for on-screen digitizing. These maps now serve as surrogate data from which a classification scheme was adopted for the study areas. The geo-referencing and transformation of the maps was subsequently done for the study areas.

The satellite imagery of select locations in Lagos was also imported into the arc-view environment for on screen digitization and subsequent land-use classification scheme.

**3.3 Data Integration**

Data acquired from secondary sources, maps and imageries were integrated in the arc-view environment by merging spatial and attribute data in a geo-data base. All parameters deployed for landfill sitting were linked to the extracted spatial features for spatial analysis.

**3.4 Data Analysis**

Prior the scanning and digitizing of the four map sheets that make up Lagos, the digital processing of the maps came to the stage of geo-referencing where tic point were picked on the maps and the necessary registering, geo-rectification and transformation were done in the arc-view environment. There after the four map sheets were aligned together in the arc-view environment and a software operation known as mosaic was undertaken to join the four geo-referenced map sheets into a single map.

In selecting candidate landfill sites, buffer zones which are circles of appropriate radii were drawn around features of economic and ecological importance stipulated by the World Bank. The geographical areas left out of the buffers (preferably grassland) were considered for candidate landfill sites.

**3.5 Result And Format Presentation**

The findings of the study were presented as map documents with the .mxd file extension. This helps in visualizing the result of the analysis that was carried out on the data.

**3.6 Software Used**

The following were used for this project viz:

1. Arc-view 3.3; this software was used for feature digitization and displaying. This software is packed with a powerful collection of spatial analytical extensions that was also used for geospatial analysis.
2. Microsoft word and Microsoft PowerPoint- this was used for the presentation of the research

**Table 2: World Bank Landfill Site Criteria**

NO.	CRITERIA	BUFFER ZONE
1	SURFACE WATER	500 METRES
2	RESIDENTIAL AREA	250 METRES
3	AIRPORT	3KM
4	PAVED ACCESS ROADS	LESS THAN 10KM ACCESS
5	ACCESS ROAD	250METRES
6	PROTECTED FORESTS	500METRES

**3.7 Landuse Classification**

Landuse refers to the use to which land is being put. The landuse classification adopted for the environment containing these landfill sites are built-up areas, which includes industrial areas, residential areas, commercial areas and the transportation routes.

**Table 3: LANDUSE CLASSIFICATION**

Category	Levels
Built up Area	i. Residential Area ii. Institutional Area iii. Commercial/Market Area iv. Industries v. Roads
Green Area	i. Bushes ii. Shrubs iii. Lawn
Wetland	i. Lagoon ii. Rivers iii. Swamps iv. Creeks
Open Space	

According to the World Bank criteria on landfill site selection, most impact of operating landfills on residential landuse will normally be experienced within one 250 meters of any landfill site.

It is defined residential Landuse” to include all types of residential development, commercial, institutional, agricultural-livestock and animal husbandry, airports, highways, special attractions such as zoos, playgrounds, beaches etc.

**4. ANALYSIS AND INTERPRETATION**

**Need For Engineering Landfill Sites In Lagos**

The need for engineering landfills in Lagos cannot be over-emphasised. As a matter of urgency, Lagos is in dire need of new and additional landfills considering its small geographic space and explosive population. Lagos is a geographical area of measuring 3,577sq.km (which is 0.4 percent area of the nation) making Lagos the smallest state in Nigeria and estimated to be the most populated.

Rapid population growth is directly proportional to rapid increase in volume of generated waste, which makes it imperative to create engineering landfills that will absorb the escalating volume of generated solid wastes and well located where they will not constitute a nuisance to the environment.

Population Estimate – 16.86m (27.4% of Country Urban/UN)

- ❖ Population Density – 4,193 persons/sq.km
- ❖ Population Growth Rate – Between 6-8% (Nigeria 2.9%)
- ❖ Rural Population Growth – 600,000
- ❖ Projectable Population – 20.19 (2010) 24.5m (2015) Source (UN Habitat)
- ❖ 20LGAs and 37 LCDA’s

The staggering urban growth and growth projection statistics revealed above on a limited space occupied by Lagos makes it expedient to create more landfills that will absorb the ever increasing solid waste volume and meet up with internationally accepted standards of landfill sitting. A cursory observation of table 4.1 above reveals a great deal about the solid waste management history and projection of Nigeria. The time under review spanning from 1945-2020, the areal extent of Lagos has extended in area from 200km<sub>2</sub> to 40,000km<sub>2</sub> in 2008 and is estimated to further extend in area by 2015 and 2020 to an area size of 60,000km<sub>2</sub>. The continuous extension of the areal limit of Lagos through time is evident in the continuous land reclamation of places that were considered rather uninhabitable by reason of their complex terrain. It is not uncommon today to see people in Lagos sand-filling swamps and drainage basins in order to develop properties without recourse to the environmental and ecological implications of such actions.

**TABLE 4.1 DEVELOPMENT OF WASTE GENERATION AND MANAGEMENT IN LAGOS**

YEAR	AREA	POPULATION	GENERATION RATE PER DAY	TON/DAY	TRUCKS
1945	>200km <sup>2</sup>	40000	0.1(E)	4+	1
1967	1200km <sup>2</sup>	1,500,000	0.12 (E)	180	6(2 trucks)
1976	10000km <sup>2</sup>	3,200,000	0.2	640	100(35 trucks)
1990	35000km <sup>2</sup>	5,000,000	0.25	1,250	210(70trucks)
2006	<40000km <sup>2</sup>	18,000,000	0.4	7,200	1200(400-500 trucks)
2008	<40000km <sup>2</sup>	18,000,000	0.5	9,000	1500(550-600 trucks)
2015	<60000km <sup>2</sup>	23,000,000	0.7	16,100	2500(800 trucks)
2020	<60000km <sup>2</sup>	30,200,000	0.7	21,140	(1,057 trucks)

Source: Lagos Waste Management Authority (LAWMA), 2008

Under this period in review, Lagos has geometrically appreciated in population from 40,000persons in 1945 to an estimated 18,000,000persons in 2008 and further projected to reach an estimated 30,200,000persons in the year 2020. Consequently, tonnage of waste generated in Lagos within the time under review has drastically increased from a little over 4tonnes to 9000tonnes per day as at 2008 with a projected estimate to reach 21,140tonnes. So also has these staggering statistics also reflected in the truck load of waste gathered per day in Lagos from 1 truck in 1945 to within 550-600 trucks in 2008 and a projected estimation to reach an estimated 1,057trucks in the year 2020.

For the whole estimated 9000 metric tons of solid wastes generated daily in Lagos, the existing landfills are inadequate to absorb the volume of waste generated in Lagos without any form of environmental abuse; it therefore becomes imperative to plan seriously ahead of time in creating new landfills in Lagos that will meet internationally accepted standards befitting of a megacity.

**4.1. The Existing Landfill Sites In Lagos**

The state government under the World Bank Assisted Project package of 1988 commissioned a consultant for the development of landfill sites for the state. The project gave rise to sites such as Olusosun, Abule-egba, and Solus. The Olusosun landfill site is about 42 hectares in size with a life span of 35 years receives an average of 1.2 million tons of waste annually. The Abule-Egba (Oke-odo) landfill is about 3.0 hectares. While Solus is about 3.0 hectares (Lasisi, 2004).

Against the background of problems that could erupt due to the presence of a landfill in an environment, it is quite necessary to make regulations concerning where a landfill can be located. With dangers of leachate formation, groundwater contamination and other environmental constraints, regulatory requirements regarding safe distance from sensitive components of the environment should be put in place ( Majaro and Abu, 2004).

This research is predicated on the need for the establishment of new landfills in Lagos as a result of the locational misplacement of existing landfill sites, based on World Bank criteria, with far reaching environmental consequences. This need for new landfills in Lagos cannot be over-emphasised as seen in the location of existing landfills in figure(s) 4.1, 4.2 and 4.3 which are Abule-Egba landfill, Olusosun landfill and the Solous landfill respectively.

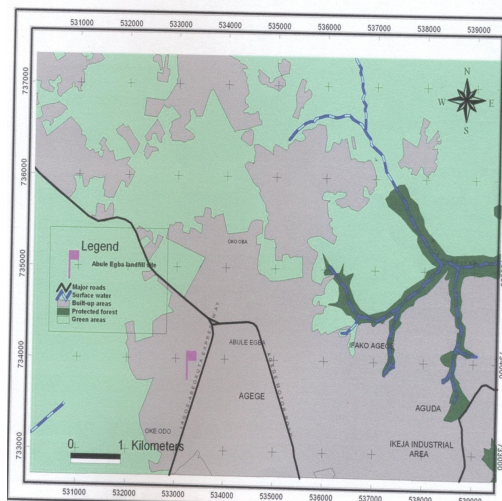
**4.2. Geographic Coordinates of Existing Landfills**

Landfill	Latitude(°N)	Longitude(°E)
Abule-Egba	6.641139°	3.302667°
Olusosun	6.591111°	3.381389°
Solous	6.570278°	3.253667°

According to the World Bank criteria on landfill site selection, most impact of operating landfills on sensitive landuse will normally be experienced within one 250 meters of any landfill site. It is defined “residential Landuse” to include all types of residential development, commercial, institutional, agricultural-livestock and animal husbandry, airports, highways, special attractions such as zoos, playgrounds, beaches etc.

**Landuse around Abule Egba Landfill**

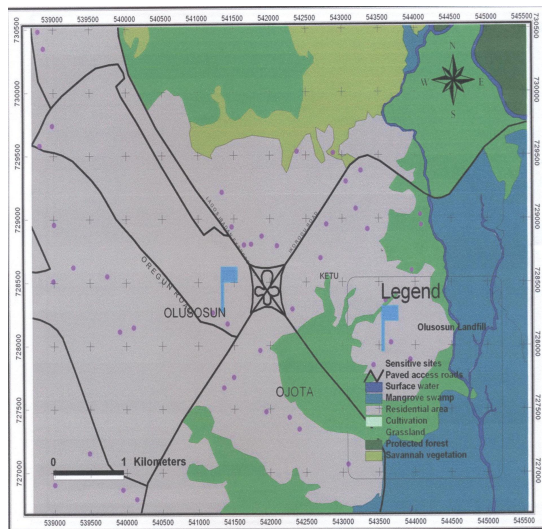
The above table shows that the Abule-Egba landfill site falls within residential landuse as against the World Bank criteria that stipulate a distance of 250 metres from residential landuse. The Abule Egba landfill is about 280metres from a major road which falls within the World Bank criteria that stipulates a distance of not more than 10kilometres from a paved road network. The distance of 280metres distance of Abule Egba landfill from the Lagos-Abeokuta Expressway may not be environmentally expedient because of the landfill system of burning landfill covers which generates smoke that creates visibility challenge to the motorist on the Lagos Abeokuta expressway resulting in traffic menace with grave consequences.



**Fig. 3: Landuse Around Abule Egba Landfill**

**4.2. Landuse around Olususun Landfill**

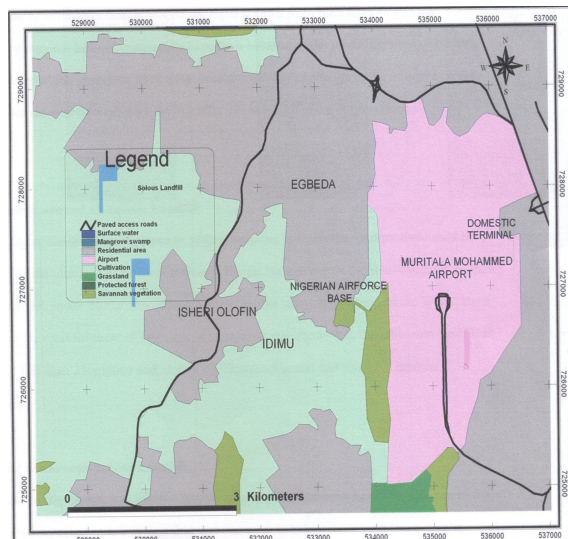
The capacity of Geographic Information System helps us to know the landuse that could be found within the olususun Landfill at a glance. Hence, we can assess the sensitive landuse that falls within 1kilometre buffer zone which contradicts the stipulated criteria of the World Bank concerning the establishment of landfills. With reference to figure 4, the Olususun landfill is within and less than 250metres and 1kilometre from residential and sensitive landuse respectively.



**Fig. 4: Landuse Around Olususun Landfill**

**4.3. Land use around solous Landfill**

With respect to Fig 3, just like the Abule Egba and the Olususun landfills, distance of the landfill to residential area is less than 250 metres which is below the World Bank criteria standard for establishing landfill sites. The location of the three (3) landfills presently operational in Lagos and their adjoining landuse justifies the need for the establishment of new landfills in Lagos.



**Fig. 5: Landuse Around Solous Landfill**

**4.4. A Review of Suitable Sites for Engineering Landfill In Lagos Based On Existing Criteria**

In locating suitable landfill sites in Lagos, existing spatial data which in the Fig 3 which is the landuse map of Lagos is used to analyze potential landfill sites using the World Bank criteria as criteria. A critical review of suitable landfill sites in Lagos is predicated on these World Bank indices:

**4.5. Land Availability**

By World Bank criteria, land required for landfill sites should have adequate land area and volume to provide sanitary landfill capacity to meet projected needs for at least 10years. A depth of 10-25 meters is required to accommodate solid waste density of 800-1000kg/cubic meter of waste. It is worthy to note that the Lagos geographical terrain is highly aquatic; this is evident in the presence of creeks, rivers, lagoons, beaches and swamps. A large area of Lagos, especially the metropolitan area which is the Lagos-island axis surrounded by water. Also, due to rainfall pattern, coastal proximity and rapid urbanization, Lagos is seasonally characterized by high incidence of flooding and run-off with perennial high water table. A required depth of 10-25 meters for accommodating solid waste density of 800-1000kg per cubic meter will be inimical to groundwater within the Lagos metropolis, which includes the island and mainland as depicted in Fig 5

**Travel Time**

Landfill site should be accessible within 30minutes travel time from the point of waste collection, but if greater than 30minutes, investment in large capacity At distances greater than 30 minutes travel, for collection operations to be economic, investment in either large capacity collection vehicles (5 tonnes per load or greater) or transfer stations with large capacity vehicles (20 tonnes or greater) would be necessary.

Taking the high incidence of traffic congestion in Lagos, a travel time of 30minutes of landfill location from waste collection points cannot be feasible, investment in large capacity collection vehicles (5 tons per load or greater) becomes inevitable.

**Accessibility**

A proposed landfill site should be accessible from a competent paved public road with adequate slope, visibility and construction within a distance radius less than 10km for large landfill serving secondary cities.

Basically, all parts of Lagos are accessible to a paved road network within a 3km distance.

**Proximity to Water**

Proposed landfill site to be at least 1.5meters below proposed base of any excavation or site preparation. All water bodies should be 500meters away from landfill sites.

In Lagos, 500meters away from water bodies as depicted in fig4.1 (Landuse map of Lagos) eliminates the possibility of landfills within Lagos Island and the mainland due to the heavy presence of swamps, lagoons and creeks.

**Land use**

This is the most important of the entire criterion required for selecting landfill since human habitation has to be taking in consideration when sitting landfills.

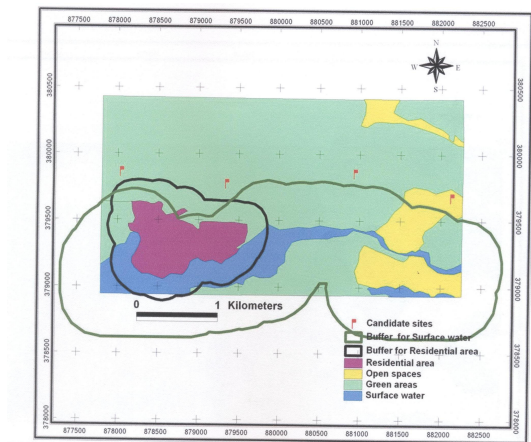
Basically, no residential development within 250meters from the perimeter of the proposed landfill cell development area, no visibility of proposed landfill cell development area from residential neighbourhoods within 1kilometer.

This criterion eliminates the chances of siting a landfill within the island and mainland area of Lagos due to rapid urbanization. Grasslands are best options for landfills and asuch, looking towards the Lagos outskirts for landfill sites becomes inevitable.

**4.6 Potential Sites For Engineering Landfills**

The urban stretch of Lagos does not leave a chance for a landfill within the cosmopolitan area of Lagos. Existing landfills as earlier researched upon by Majaro in 2004 revealed that these landfills have been pollutants to their host communities.

By international standards, the best location for engineering landfills is usually on open grasslands in conformity with other criterion stipulated by the World Bank. A cursory x-ray of Lagos land cover through current satellite imagery and complimentary ground truthing reveals that the environmentally acceptable location in engineering landfills in Lagos based on World Bank criteria in within the outskirts of Lagos.



**Fig. 4: Candidate Landfills Defined by World Bank Criteria**

Figure 4.6 shows a sizeable land area of about 10.25 sq.km which covers the large area of the Epe-Ikorodu axis of Lagos which border neighboring Ogun state. Over 7 sq.km area which represents about 70% of the land cover area is predominantly green area which have not been seriously affected by urbanization. This area is a good for engineering landfills as revealed through proximity analysis (buffering) carried out in figure 7.

With respect to Fig 7, future engineering landfills should be sited away from the urban stretch, which implies that Greenland spaces within the Epe and Ikorodu axis where infrastructural development is still distant from.

With the effective aid of a Geographic information system, four landfill sites where considered with Epe and Ikorodu beyond buffers of residential areas and surface water. These landfills are at co-ordinates 6°44'47.54N 3°32'16.00E, 6°41'43.14N 3°41'30.02"E, 6°40'06.53"N 3°50'06.46"E, and 6°39, 02.72"N, 3.57' 10.16"E.

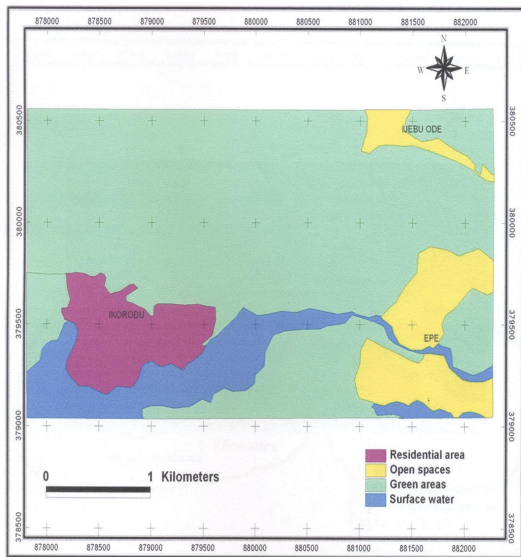
Presently, there are no major roads within the selected area in figure 4.7. This therefore makes it easy to plan access routes to landfills that will easily conform to the stipulated World Bank engineering landfills selection, and also create room for land use change and further urbanization/infrastructural development.

**5. SUMMARY**

This paper presents some salient points that have been unearthed by the study which have been bearing on the direction that the study took, thereby resulting in the under listed summaries, recommendations and limitations.

**Summaries:**

Firstly, the study has found that the increase in the amount of garbage production is no doubt positively correlated with the increase in human population and in turn increases the pressures on siting new landfills. During this study, the utilization of Geographic information system as a tool in siting the new landfill was employed and conclusions were drawn as to the effectiveness of its use.



**Fig. 6: Landcover within candidate landfill sites**

Using Geographic information system in landfill site selection for lagos, the most suited place for engineering landfill is within the geographic area around Ikorodu-Epe axis of lagos found within co-ordinates 6°40'08.91"N and 3°44'31.67"E.



Secondly, the results of the Geographic information system -based study showed that although highly suitable areas were limited, some site was still able to be chosen under the predefined parameters. The sites are not located on, or near, any environmental interest areas and is located a significant distance away from streams, urban areas, which minimizes social conflict and environmental impacts. The sites are also located close enough to major road which ensures that economic costs of implementation are minimal. The selected region has a slope less than 12%, which are both an infrastructural advantage and a means of minimizing environmental impacts.

Candidate Engineering landfills are located in an area 62 kilometers away from the city centre. The candidate sites are far from the city centre which is due to the rugged terrain of Lagos and the fact that environmental, social, and economic concerns as stipulated by the world bank have to be met.

Finally, Solid Waste Management is an obligatory function of the urban local bodies. However, if landfill sites are poorly located, they result in problems of health, sanitation and environmental degradation .With increasing annual growth in urban population and the rapid pace of urbanization in Lagos the situation will become more and more critical within the passage of time. There are various deficiencies related to solid waste management (SWM) which is seen in Lagos, such as no storage of waste at source, non-segregation at source, no system of primary collection of waste, use of inefficient tools, and inadequate transportation of waste.

## 6. CONCLUSION

With the summaries in context, conclusions are made both for theoretical and practical purposes. In other words, while the study would obviously use its findings to recommend how best landfill siting can be done in other contexts, need to shed light on how future studies on the matter can be designed to achieve optimal results cannot be ruled out. The recommendations, thus, are as follows:

- a. The use of a GIS model to find a suitable landfill site incorporating the evaluation of multiple criteria has many advantages. Firstly, GIS is a powerful tool that enables organized and systematic analyses of spatial data. Secondly, the results of the analysis can also be presented in the form of aesthetically pleasing and functional output maps. Finally, the model and its operational procedures can be visually simplified and represented as a schematic diagram (flow chart) thereby increasing the comprehension of the tasks performed.

- b. GIS technology has proved to be effective in handling large amounts of data and significantly aiding the facility siting process. Its ease of use and comprehensive display allows for user-friendly operational tasks. In the context of this study, the use of Geographic information system was crucial in narrowing down the potential sites for final selection. The arithmetic overlay was performed in producing final maps that were reflective of the initial criteria and satisfied the purposes of finding potential landfill site. Therefore, the use of Geographic information system effectively converts pre-existing data into a visual display which can be easily interpreted and assessed.
- c. Additionally, this research proposes a well-judged landfill site selection methodology taking Lagos as the study area. This research will contribute in developing Lagos spatial database of environmental and social information to assist in the formulation of available options. It is expected that such municipal GIS when planned and implemented efficiently with sufficient public awareness and support would be instrumental in bringing reforms at the local and national level, realizing a major improvement without much capital investment.
- d. Ultimately, this study can be used as a tool for facility site planners for locating landfill sites in the Lagos and used as a model for other emerging megacities

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### Authors' Brief



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