Geospatial Assessment of Site Suitability for Solid Waste Dump Sites in Ido Local Government Area Oyo State Nigeria

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Abstract. Finding suitable disposal sites is one of the most difficult aspects of solid waste management. Non-scientific and ineffective disposal methods have a harmful impact on the environment, lowering people's quality of life. An integrated Remote Sensing and Geographical Information System approach was applied to determine suitable solid waste dump site locations in Ido local government area, Oyo state, Nigeria. The dataset of the study area used for this research are Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for the year 2020 and of 30m resolution, Geo-Eye satellite imagery obtained from Google Earth, Shuttle Radar Topography Mission (SRTM) imagery of 30m resolution, geological map from Nigeria Geological Surveys, the soil map, data on road network obtained from Open-street map and the geometric data (Coordinates) of the existing dump site within the study area acquired through field survey using a Global Positioning System (GPS). From an extensive literature review and expert opinion combined with Environment Protection Agency (EPA) standards for identifying the best area suitable for dump sites, six criteria were adopted for this study: slope, proximity to road, proximity to water body, geology, soil type, and proximity to residential areas. These criteria were used with the EPA standard as the basis for processing and analysis of acquired data using ArcGIS 10.5 software. The result shows that out of the total 979 km^2 mapped for suitability for solid waste-dump site in the study area, 61.7km^2 has very low suitability, 262km^2 with low suitability, 334.6km^2 is moderately suitable and 320.7km^2 is highly suitable for waste dump site. The study concluded that the existing solid waste-dump site in the area is not suitably located and is not enough to serve the entire study area. The study recommended the data and findings in the study to be adopted as a site suitability analysis model that will serve as a guide for approval of dump site; a relocation of the existing dump site to areas with high suitability and a study on locating sites for industrial (hazardous) solid waste from clues obtainable from this study.

Keyword: Data, Dump Sites, Geospatial Assessment, Site Suitability, Solid Waste

Introduction

Due to economic expansion and development, an increasing level of municipal solid garbage has become a severe concern in urban places around the world. A high population growth rate and increasing per capital income have resulted in the generation of enormous municipal solid waste, culminating a serious threat to environmental quality and human health (Ogwueleka, 2009). This is especially true in developing nations like Nigeria, where according to Eberechi and Godwill (2016), enormous amounts of municipal solid waste are dumped indiscriminately due to a lack of infrastructure for proper waste treatment, putting a strain on scarce land, water resources, and air quality. At the same time as observed by Chakrabarti (2003), this adversely affects the health of human beings, mostly that of poor persons who invariably have greater exposure to it. Any substance released from human activities that has a negative effect on human health and the environment is referred to as waste. Solid wastes are non-liquid and non-gaseous products such as those from households, municipal, supermarket, construction and industries (Ajayi, 2019; Kapilan & Elangovan, 2018). Solid waste has become a global environmental and health issue in the contemporary world both in developing and developed countries (UNEP, 2005; United Nations, 2017). Such environmental challenges combined with social, economic and land availability issues raise concerns over land management and evaluation techniques (Coban, Ertis, & Cavdaroglu, 2018; Lein, 1990; Philippe & Culot, 2009). In developing countries, the increasing human population and associated anthropogenic activities have accelerated the process of waste generation at an alarming level. In recent decades, the waste management process used many Africa, Asian, American and European countries have shifted from landfilling to incineration (Lino & Ismail, 2017b; Rezaei *et al.*, 2018). Hence, it is essential to find out suitable waste management and disposal methods (Gizachew & Suryabhagavan, 2012; Ebistu & Minale, 2013; Abedi-Varaki & Davtalab, 2016).

Nigeria generates more than 32 million tons of solid waste annually, out of which only 20 – 30% is collected. The careless disposal of municipal solid waste (MSW) has resulted in sewer and drainage network blockages, as well as the choking of water bodies. Most of the wastes is generated by households and in some cases, by local industries, artisans and traders which liters the immediate surroundings (Bakare, 2014). Nigeria with a population growth rate of about 2.8% per annum and an urban growth rate of about 5.5 % per annum generates about 0.58 kg solid waste per person per day (Sridhar & Adeoye, 2003 in Babayemi & Dauda 2009). It usually includes organic material (such as paper and paperboard, wood, textiles, food residues and garden waste), as well as inorganic material (such as builders' rubble, metal, glass and plastics). Organic material consisting of cellulose, carbohydrates and proteins is readily decomposed by microbes into carbon dioxide (CO2) and methane (CH4), and contributes some between 6 and 18% to global methane production (Bingemer & Crutzen, 1987).

Waste generation scenario in Nigeria has been of great concern. Of the different categories of wastes being generated, solid wastes had posed a problem beyond the scope of various solid waste management systems in Nigeria (Geoffrey, 2005). Solid wastes are unwanted heterogeneous materials and residue from domestic, commercial, industrial, and agricultural activities (Leton & Omotosho, 2003). In today's Nigeria, Solid waste management is the most pressing environmental challenge faced by urban and rural areas of Nigeria. Nigeria with population exceeding 170 million, is one of the largest producers of waste in Africa (Bakare, 2014). This encompasses refuse, garbage, as well as construction and demolition debris (Ossai, 2006). At present, municipal solid waste generated in local districts are creating serious environmental threats as a result of the poor state of proper waste disposal and in many of these localities, heaps of MWS have been found along major roads, stream channels, river banks, bushes and in open spaces (Ogbonna *et al*., 2007).

In recognition of these challenges and the increasing waste generation, the government in Nigeria has attempted to tackle waste management issues through some approach such as consistent evacuation of waste, waste designation collection point, etc. (Ogbonna *et al.*, 2007). However, due to the lack of sustainable waste management system policies and techniques such as waste reduction, recycling, thermal treatment, and landfilling etc., the municipal solid waste management system has been inefficient (Ayo & Busu, 2010). Subsequently solid wastes in urban areas are often made up of plastics, glass, fabrics, metals, and kitchen waste, all of which have a complex composition and are slow to degrade, causing more environmental damage. In the recent years, Geographical Information System (GIS) has been playing a major role in the process of decision-making. The advantage of GIS-based approach site selection saves time and cost. It also provides digital data inventory for long-term monitoring of the site (Gizachew *et al.*, 2012; Kontos *et al*., 2005). Remote sensing can provide information about various spatial criteria such as land-use/land-cover (Emun, 2010), and GIS can utilize, create and analyze spatial or attribute data for solid waste dumping sites selection processes.

Material and Methods

The dataset of the study area used for this research are Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for the year 2020 and of 30m resolution, Geo-Eye satellite imagery obtained from Google Earth, Shuttle Radar Topography Mission (SRTM) imagery of 30m resolution, geological map from Nigeria Geological Surveys, the soil map, data on road network obtained from Open-street map and the geometric data (Coordinates) of the existing dump site within the study area acquired through field survey using a Global Positioning System (GPS). The land cover map of the study area was produced using the Landsat 8 (OLI/TIRS). The elevation and slope map of the study area was generated from the SRTM imagery. The geology of the study area was extracted from the geological map while the soil types was extracted from the soil map, the rail-road and the existing dump site site were mapped out from the Geo-Eye satellite imagery which was also used to verify the land cover types and other road network data in the Open-street map. The geometric data (Coordinates) of the existing dumpsites were used to establish their geospatial identity and to georeference. The equipment and software used in data acquisition, management and information presentations are Garmin GPS MAP 62 (Series), A host laptop computer with configuration Core 2 Duo, 500GB hard disk (memory space), 4GB of RAM for data storage, manipulation and retrieval hardware, Camera for snap shots (Camera model, Kodak C437). Window 8 Operating system, Arc MAP 10.2 for georeferencing, map preparation, spatial analyses etc. Microsoft Word 2013 for documentation. Environment for Visualizing Images (ENVI 5.0) for LANDSAT image processing.

The acquired datasets were used to produce criteria (Table 1 & 2) that must be fulfilled to determine the most suitable location for a dumpsite in the study area according to the Environment Protection Agency dump site Manual (2006). All analogue maps (paper maps) were converted to digital format usable in the GIS software by scanning, georeferencing and digitizing. The Environmental Protection Agency proposed some criteria or standard that must be adhered to in siting a dump site or dumpsite, which are listed in the Table 1 & 2).

Table 1. Constraint criteria table formulated for unsuitable areas from EPA dump site manual 2006

Criteria	Unsuitable Areas
Distance to water body	Less than 160m
Slope	Areas with a slope greater than 150
Distance to residential areas	Less than 300m
Distance to road	Less than 500m
Soil	Area with alluvial soils

Source: Environmental Protection Agency (2006).

All criteria used in Table 2 were reclassified based on their relevance to location of dump site, and a linear function was used to assign preference value to different classes of all criteria. The unified preference value ranges from 1 to 4, in which 1, 2, 3 and 4 represent unsuitable, least suitable, moderately suitable and highly suitable respectively, were used to draw a re-classified raster layer of all criteria.

Table 2. Constraint criteria table formulated for suitable areas from EPA dump site manual 2006

Criteria	Least suitable	Moderately suitable	Highly suitable
Distance to water body	160m - 480m	480m - 960m	>960
Slope	10° - 15°	5° - 10°	0° - 5°

Distance to road	500m - 1000m	1000m - 1500m	>1500m
Distance to residential areas	300m - 500m	500m - 800m	>800m
Soil	-	Alisols	Nitisols
Geology	Quartzite	Migmatite-Gneiss complex	Chamock/ Granite

Source: Environmental Protection Agency (2006)

Determinants of Suitable Waste Disposal Site Selection in the Study Area

The criteria for locating dump site in an area were adopted according to EPA (2006) as:

Slope

Slope was produced from SRTM DEM in the GIS environment in degrees. Degree of slope was classified into four classes and appropriate reference value were assigned to each degree based on their importance to selection of dump site site (Table 3).

Table 3. Criteria for slope

Slope (Degree)	Preference Value	Classification
0 – 5	4	Highly Suitable
5 - 10	3	Moderately Suitable
10 - 15	2	Least Suitable
> 15	1	Unsuitable

Source: Environmental Protection Agency (2006)

Proximity to Water Body

Dump sites create noxious gases and leakage that make them unsuitable to be in proximity to surface waters (Erkut & Moran, 1991; Dorhofer & Siebert, 1998). If any dump site were to leak waste-related chemicals into surrounding water, streams, or reservoirs, contamination would occur. The result would be the transfer of hazardous chemicals into drinking water, where reagents such as viruses and toxins could develop (Bodhankar & Chatterjee, 1994). This would pose a serious health hazard to all organisms' dependent on the water, and could also bio-accumulate chemicals within the tissue of the organisms. In order to reduce vulnerability to ground and surface water pollution from contamination, dump site should not be located near river. According to EPA (2006), areas less than 160m to the water body is unsuitable for dump site location. Buffer tools were used to prepare a buffer zone with areas <160m, 160-480 m, 481-960 m, and >960 m distance range (Table 4).

Table 4. Criteria for water body

W.B (Criteria Value)	PV	Classification
<160m	1	Unsuitable
160m – 480m	2	Least Suitable
480m – 960m	3	Moderately Suitable
>960m	4	Highly Suitable

Source: Environmental Protection Agency (2006)

The more distant from surface water, the more suitable for sitting dump site to reduce the negative effect on pollution.

Proximity to Road

Locating the dump site close to a road would help reduce costs related to transportation and new road access to the site. According to Environmental Protection Agency (EPA), areas less than 100m to the road are unsuitable for the location of dump site (Table 5). Areas between 100m – 1000m is the most suitable, 1000m – 2000m is moderately suitable and areas more than 2000m are least suitable for dump site location (Table 5).

Table 5. Criteria for road

Road (Criteria Value)	PV	Classification
0m – 500m	1	Highly Suitable
500m – 1000m	2	Moderately Suitable
1000m – 1500m	3	Least Suitable
1500m - 2000m	4	Unsuitable

Source: Environmental Protection Agency (2006)

Geology

There are two major geological layers in Ido LGA as obtained from Nigerian Geological Survey, which are quartzite schist complex and undifferentiated basement complex which are mainly composed of migmatite-gneiss. According to EPA 2006 manual, quartzite are the least suitable, migmatite-gneiss is moderately suitable and granite are highly suitable for locating of dump site (Table 6).

Table 6. Criteria for geological layer

Geological Layer	PV	Classification
Quartzite schist complex	2	Least Suitable
Undifferentiated basement complex	3	Moderately Suitable

Source: Environmental Protection Agency (2006)

Soil Type

Soil type is also one of most important criteria for locating dump site. The major concern is for water and other liquid leaching through the dump site and dissolving harmful chemicals that could enter the groundwater. So, the type of soil best for dump site would be the one that has the smallest particle size, so the particles are close together and provide the least permeability (doesn't allow the water to pass through easily). Soil layers dataset containing permeability characteristics, covering the study area was obtained from the Nigerian Geological Survey. The soil layers in Ido LGA are classified into three, based on their permeability (Table 7).

Table 7. Soil permeability

Soil Permeability	Soil Constituents
Least Permeability	Loam, loamy sand, sandy loam or sandy clay loam surfaces over gravelly sandy clay, clay loam, clay or sandy loam sub soils.
Moderate Permeability	Sand, loamy sand to sandy loam surfaces over sandy loam to sandy clay loam and sometimes gravelly subs soils.
High Permeability	Loamy sand surfaces over sandy loam to sandy clay loam and sometimes gravelly subsoils.

Source: Nigerian Geological Survey (2014)

Built up Area

In other to reduce bad odors and health risks of inhabitant of an environment, dump site should be at a safe distant from built environment. The Environmental Protection Agency (EPA) suggested in the year 2006 (Table 8) that dump site should not be located below 300m from built environment.

Table 8. Criteria for built up area

Built Up Area (Criteria Value)	PV	Classification
<300m	1	Unsuitable
300m – 500m	2	Least Suitable
500m – 800m	3	Moderately Suitable
>800m	4	Highly Suitable

The least suitable should be between 300m – 500m, moderately suitable should be between 500m – 800m and highly suitable areas for locating dump site should be above 800m from residential areas (Table 8).

Results and Discussion

Determinants of suitable waste disposal site selection in the study area were identified as slope, proximity to road, proximity to water body, geology, soil permeability, and proximity to built up area. The maps of these six were produced from their respective Tables 2-8 to give their visual representation for ease of interpretation (Figure 2).

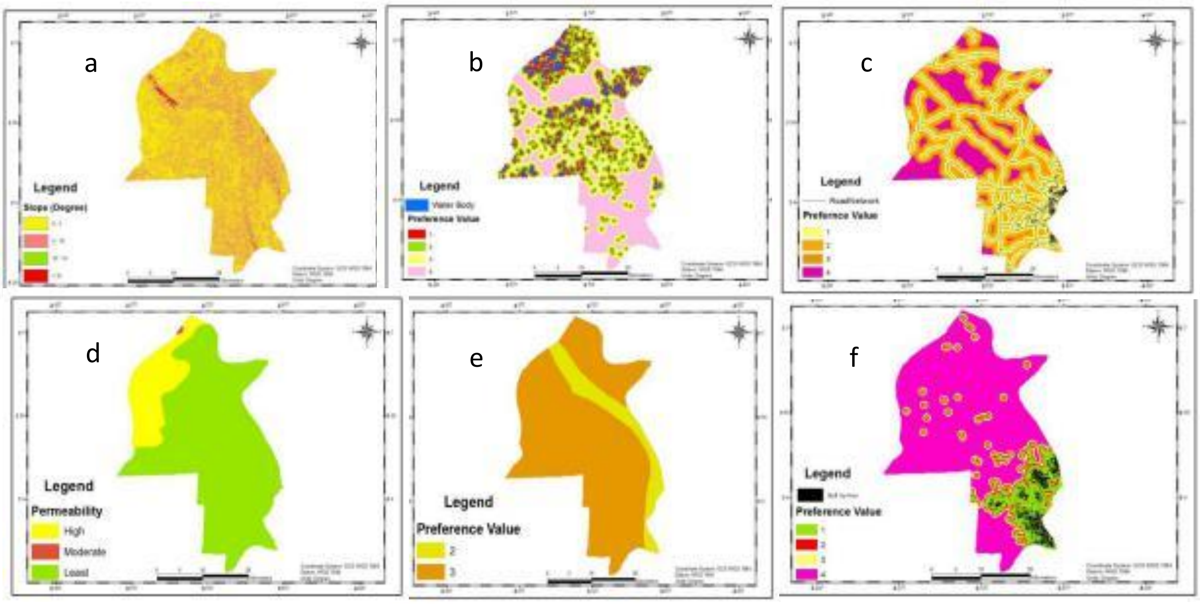

Figure 2. Land fill suitability criteria maps

Note: a – slope, b – proximity to road, c – proximity to water body, d – geology, e – soil permeability, f – built up area

A composite map of the maps in Figure 2 was generated by overlaying them to produce a dump site suitability layer map (Figure 3).

The result shows that an area of 61.7sqkm has a very low suitability, 262sqkm with low suitability, 334.6 sq.km is moderately suitable and 320.7 sq.km is highly suitable for dump site as shown in Figure 4.

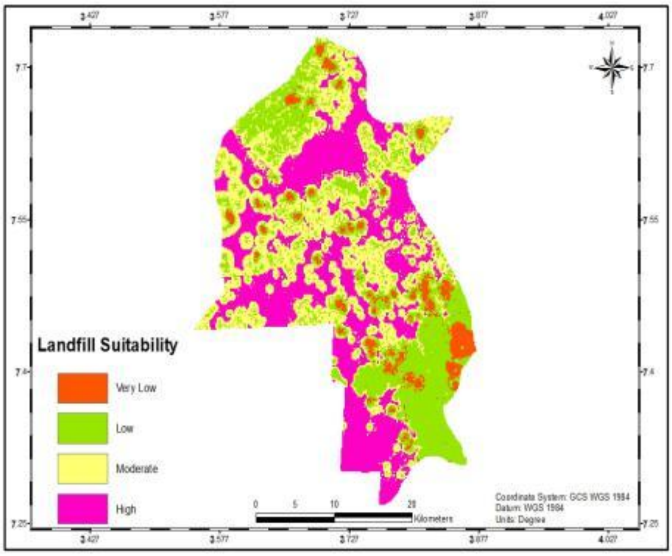

Figure 3. Dump site Suitability map of Ido Local Govt. Area

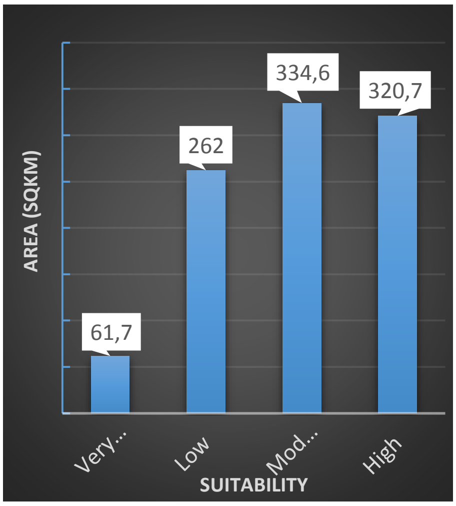

Figure 4. Area coverage of dump site suitability

From Figure 4, it is observed that there are higher coverage area for moderate and high suitability for dump site in the study area. This may be adduced to the fact that out of the total 979 km^2 mapped, water body, which is a no go area for location of dump site covers just about 20.33km^2 while the built environment covered only about 40km^2. Hence, the landmass covered by the built environment is very small compared to the total landmass, and the from the map it is observed that development is not evenly distributed. Therefore, there is an abundant space for location of dump site within the study area.

The slope, geology and soil layers suitable for dump site covers spread over the larger area of the study area.

Overlaying Existing Solid Waste Dump Site Map

Further investigation was carried out to validate the produced solid waste dump site suitability map by overlaying the existing solid waste dump site map in the study area on it.

The resultant map (Figure 5) revealed that existing dump site fell on a low suitability area. From physical observation it was noticed that the existing dump site is very close to residential area, which has a negative impact on the inhabitants of the environment.

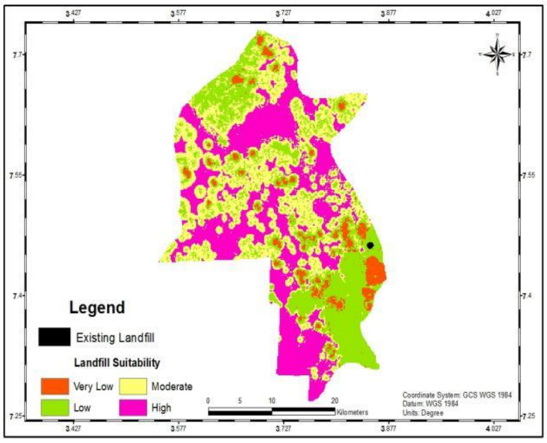

Figure 5. An overlay of existing dump site on produced suitability map of Ido LGA

In other to save the inhabitants from the dangers associating with dump site, the existing dump site have to be relocated thus validating the finding and the importance of the study.

Conclusion

Solid waste management is an obligatory function of the urban and local government authorities. However, a poorly sited dump site will result in health hazard and socioeconomic and environmental degradation. From the assessment of the suitability for solid waste dump site location within Ido LGA, using Environment Protection Agency (EPA) standards, the adopted criteria were slope, distance from water bodies, distance from major roads and geology, soil type, and distance from residential areas. The findings showed that out of the total 979 km^2 mapped, 320.7km^2, 334.6km^2, 262km^2 and 61.7km^2 areal extent of land were of high, moderate, low and very low suitability for location dump site within the study area. The study has produced data and information for effective identification of suitable solid waste dumping site that will help to minimize the environmental risk and human health problems especially in the study area.

Recommendation

Having studied the site suitability for locating dump sites in the study area, it is recommended that the data and findings in the study should be adopted by the Environmental Department of the Ido Local Government Area and Town Planning Authority as site suitability analysis model that will serve as a guide for approval of dumpsite. The existing dumpsite should be relocated to areas with high suitability area for dump site location from this study. The criteria used for this study focuses mainly on municipal waste disposal not industrial (hazardous) solid waste. Hence a study on locating sites for industrial (hazardous) solid waste is recommended from clues obtainable from this study.

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