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Geo-Information for Urban Waste Disposal and Management: The Case Study of Owo LGA, Ondo State, Nigeria

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----------ABSTRACT----------
Management of waste is a global environmental issue that requires special attention for the maintenance of quality environment. It has been observed that amount, size, nature and complexity of waste generated by man are profoundly influenced by the level of urbanization and intensity of socio-economical development in a given settlement. The problem associated with its management ranges from waste generation, collection, transportation, treatment and disposal. The study involves a kind of multi-criteria evaluation method by using geographical information technology as a practical instrument to determine the most suitable sites of landfill location in Owo Local Government Area of Ondo state. Landsat Enhanced Thematic Mapper plus (ETM+) 2002 and updated 2012 were used to map the most suitable site for waste disposal in Owo LGA. The result indicates that sites were found within the study area. The most suitable sites in the study area are located at 200metre buffer to surface water and 100metre to major and minor roads. The selected areas have 2500metres buffer zone distance from urban areas (built up areas). The study purposes acceptable landfill sites for solid waste disposal in the study area. The results achieved in this study will help policy and decision makers to take appropriate decision in considering sanitary landfill sites.

KEYWORDS: *Solid waste disposal, GIS, landfill, Landsat.*

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I. INTRODUCTION

Solid waste management is becoming a major public health and environmental concern in urban areas of many developing countries. The situation in Africa, particularly cities is severe. The public sector in many countries is unable to deliver services effectively, regulation of the private sector is limited and illegal dumping of domestic and industrial waste is a common practice. In general, solid waste is a low priority in these countries. As a result, many limited funds are provided to the solid waste management sector by the governments, and the level of services required for protection of public health and the environment are not attained. The problem is acute at the local government level where the local taxation system is inadequately developed and therefore, the financial basis for public services including solid waste management is weak (Alexandra, 1993). Improper solid waste management leads to substantial negative environment impacts such as pollution of air, soil and water, and generation of greenhouse gases from landfills and health and safety problems such as diseases spread by insects and rodents attracted by garbage heaps, and diseases associated with different forms of pollution. Municipal authorities charged with the responsibility of providing municipal solid waste management services have found it increasingly difficult to play this role (Bartome, 1995).One environmental feature associated with rapid urbanization in Nigeria has been the rising volume of solid waste generated in the urban areas that has to be managed in a way that is not detrimental to urban population. As a result, the objective of solid waste management is to collect, transport, treat and finally dispose the waste in a hygienic and aesthetically acceptable manner at the lowest possible cost (Onokerhoraye, 1995). Before an effective management of solid waste can be carried out, an inventory of the current solid waste generation composition and rate should be known. Although comprehensive studies of the nature of solid wastes in Nigerian cities have not been undertaken, there is evidence that the volume has been quite high in the major urban cities. At the same time, their composition has been changing (Onokerhoraye, 1995).

The problem of solid waste disposal, especially in the urban centers has become one of the most intractable environment problems facing urban management in Nigeria at present. There has been a phenomenal increase in the volume and range of solid wastes generated daily in the urban centers of the country largely due to the increasingly rate of population growth, urbanization, industrialization and general economic development (Onokerhoraye, 1995).

In the future, Nigeria wants to achieve not less than 80% reduction in the volume of municipal solid waste generated at all levels. It also wants to ensure environmentally sound management with an increasing population and rising land values, Nigeria needs to minimize wastes generated to reduce the volume of waste destined for disposal. The country also needs to promote basic sanitation; ensure environmentally sound management of municipal solid waste; eliminate litter on Nigerian streets and secure a quality of environment for all Nigerians adequate for their health and well being (Onibokun and Kumuyi, 1999). Rapid population growth impinges urban solid waste generation in two ways: Direct and Indirect. The direct arises from the growth in urban population itself as a result of its own excess of birth over death. This direct effect is a more important factor which accounts for 50-80% of the growth in volume and magnitude of solid waste (Olanrewaju 2009). The indirect impingement of rapid population growth on solid waste generation occurs through the effect of massive rural-urban migration. The influx of rural dwellers into cities and their eating habits affect the volume, type and disposal generated (Ajayi, 2002). The municipal service that has seemed to fail most strikingly is waste collection and disposal. The service is frequently inadequate with a proponent proportion of refuse generated remaining uncollected and with large particularly low income areas receiving little or no attention. In most towns, the services is unreliable, irregular and inefficient (Oghawa, 2000). The ineffectiveness of contemporary municipal solid waste management practices which culminates in a number of health and environmental problems has prompted the need to find effective and pragmatic solutions to waste management problems in our cities (Bartone, 1995). Waste disposal by landfill remains the way in which almost all waste in Africa and other developing countries is currently disposed. Consequently, landfills and the provision of landfill airspace remain essential elements in most waste management systems and strategies (Kao et al, 1997).

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The integrated waste management approach recognizes the above situation, so that the final step in the hierarchy is thus endorsed, provided appropriate standards are ensured to protect the environment, public health and quality of life. Proper landfill site selection is the fundamental step in sound waste disposal and the protection of environment, public and quality of life (McGraw et al, 1999). Geographic Information System is a tool that can be used to help solve spatial problems associated with the waste management process. The capability of GIS to provide, capture, manage, manipulate, analyze, modulate and display spatially referenced data for solving complex planning and management problems makes it relevant in a wide range of waste related areas. The use of a GIS- based framework can be incredibly useful in locating the most appropriate site for a number of operations to ensure the quality of the location selected in a cost effective and timely manner (Javaheri et al, 2006).The aim of this paper therefore is to explore the utility of GIS as a tool to determine the optimum and most suitable location for siting of landfill facility in Owo Local Government Area of Ondo State with a view to checking indiscriminate waste disposal. The aim of this paper will be achieved with the following objectives:

[1] Identification of the methods of collection and disposal of solid waste in the study area.
[2] To identify the types and composition of solid waste generated in the study area.
[3] To determine criteria for locating the most suitable landfill site in the study area.

II. THE STUDY AREA

The study area is Owo; headquarter of Owo Local Government of Ondo State. It lies on latitude 7°11´N of the equator and longitude 5°33´E of the Greenwich Meridian. Owo Local Government is one of the 18 Local Government Areas of Ondo State. It is bounded by Emure-Ise- Orun Local Government Area of Ekiti State to the North, Akure and Idanre to the East and South respectively, while Ose Local Government forms the border to the West and part of the South. River Ogbese and Ose form the natural boundaries between Owo and a few of these neighbouring Local Government Areas. The establishments of Federal Medical Centre, the State (Rufus Giwa) Polytechnic, the State Technical and Achievers University has contributed to a rapid increase in population and by 1991, the population had risen to 157,181 (NPC, 1991) and to a projected population of 253,061 by the year 2012 (NPC, 2006) (See map 1a, 1b and 1c).

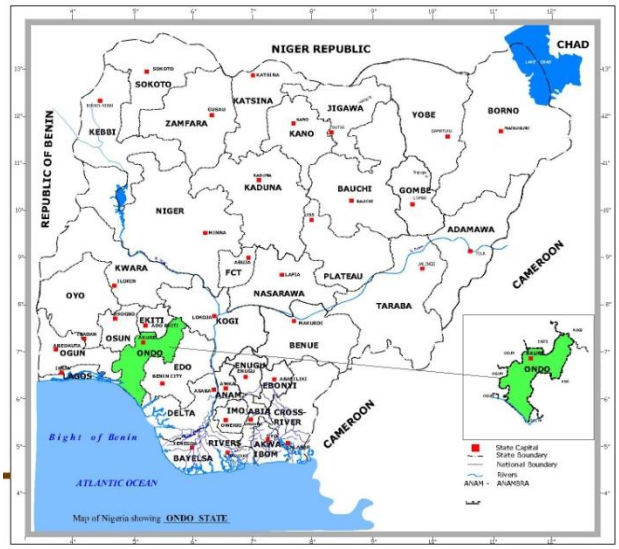

Figure 1a: Map of Nigeria Showing Ondo State

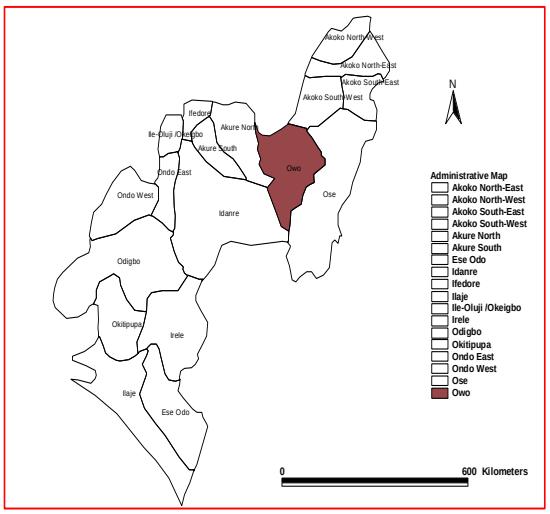

Figure 1b: Map of Administrative Map of Ondo State Showing Owo LGA

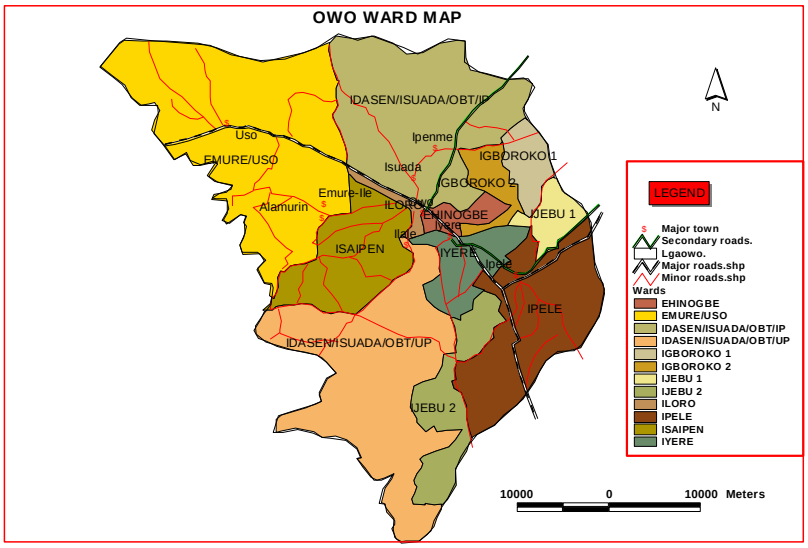

Figure 1c: Map of Owo Local Government showing the Eleven (11) wards

III. DATA ACUISITION AND METHOD

This study was interested in locating the most suitable site for waste disposal in Owo Local Government Area of Ondo State. It also seeks to use the capabilities of GIS and Remote Sensing (RS) to locate most suitable site of waste disposal in the study area. To achieve this, two satellite imageries were used namely; Landsat Enhanced Thematic Mapper Plus (Landsat ETM^{+}) of the year 2002 and updated 2012 respectively. The landuse/ landcover serves as a constraint map digitized to different classes of land which are: the built up areas, open space, bareland/cultivated area, rock-out crop and vegetation from the required images maps, Triangulated Irregular Network (TIN) and the most suitable site for landfill was generated. Criteria used to determine the most suitable site for landfills have been identified. The criteria were both constraints and factors for ideal siting of landfills. The constraints were related to roads, open water, residential areas, permeability and soil type, land use/landcover and distance to transportation routes. These criteria were re defined according to the existing and available data. The questionnaire method was used to generate attribute data to further enhance our information on the study area. In administering the questionnaire, the stratified sampling technique was used. In doing this, the local government was divided into wards as seen in table 1. Five percent (5%) of the total households in the study area were administered questionnaire to 295 (16.4%) in Ehinogbe, 162 (8.9%) in Igboroko 1, 171 (9.5%) in Igboroko 2, 15 (0.8%), in Ijebu 1, 49 (2.7%) in Ijebu 2, 159 (8.5%) in Iloro, 164 (9,1%) in Ipele, 207 (11.5%) in Isaipen, 258 (16.7%) in Emure/Uso based on the housing and population density.

Table 1: Owo Local Government Wards

Ward name	No of H/Hold	5 % of H/Hold	No of Building	5% of Building	Interval Per building	% Admin
EHIOGBE	5891	295	1410	70	5	16.3
IGBOROKO 1	3241	162	723	36	4	8.9
IGBOROKO 2	3412	171	1076	54	6	9.5
IJEBU1	304	15	450	22	30	0.8
IJEBU 2	973	49	1104	55	22	2.7
ILORO	3189	159	801	40	5	8.8
IPELE	3276	164	1035	52	6	9.1
ISAIPEN	4137	207	2152	107	10	11.5
IDASEN/ISUADA /	5164	258	1476	74	6	14.3
IYERE	2370	118	878	44	7	6.5
EMURE/USO	4194	210	1121	56	5	16.7
TOTAL	**36,151**	**1,802**	**12,226**	**610**		**100%**

The data collected using this medium was processed using the statistics package for social scientists software. Results obtained were presented in form of tables and graphs among others. The area covered by the questionnaire include demographic and socio-economic questions specifically focused on the age, marital status, religion, income, occupation, type of building, household sizes, type of waste generated, waste disposals methods, frequency of waste collection and facilities for waste collections and disposal. All these questions were carefully analysed and considered to GIS analysis to arrive at our conclusion on the most suitable site for land fill in the study area.

IV. RESULTS AND DISCUSION

The most suitable sites for landfill as shown by the GIS outputs and the results of the questionnaires administered. The following multi-criteria are taken into consideration in the final suitability map. They are land-use/ land-cover type, distance to surface waters, proximity to urban areas; distance to transport route, geology and soil type of the study area. The landuse/land cover map of the study area was shown in figure 2. Over 50% of the land use is for vegetation while over 30% is used as bareland or cultivation only about 10% is used as built-up area.

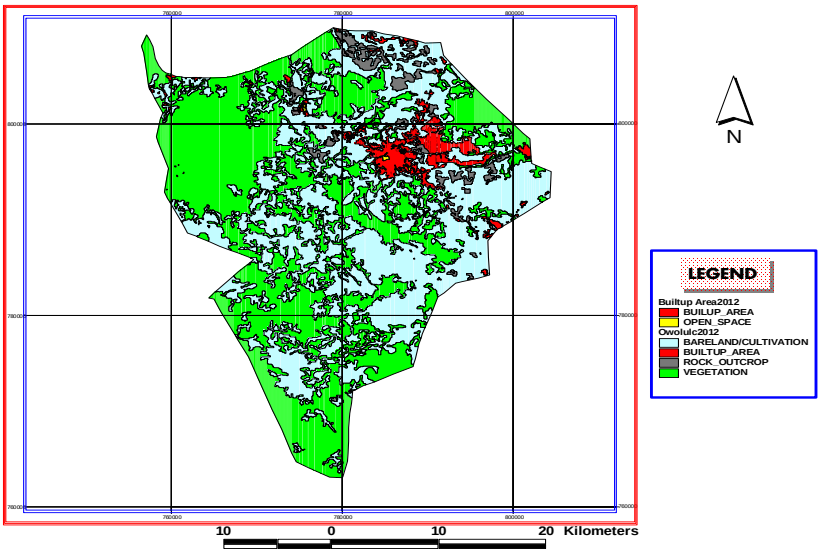

Figure 2: Landuse/Landcover Map of Owo LGA

The built-up area of the study area was buffered by 2500 meters and the purpose is to create adequate setback between dwelling or residential areas and the landfill site to avoid any form of pollution. Those areas outside the buffered zone are potential areas for the siting of the landfill because as they are out of the restricted areas (see figure 3).

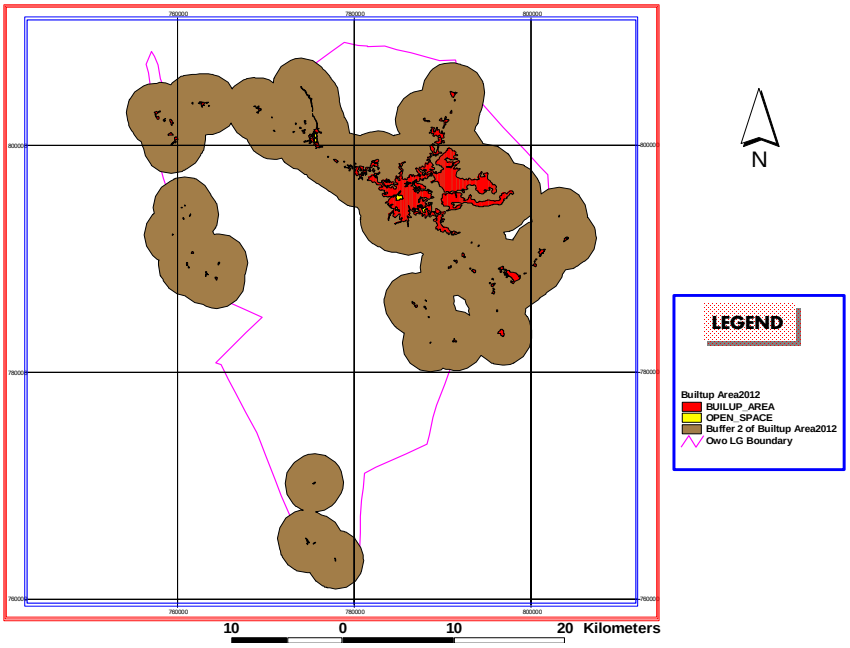

Figure 3: Buffered Built-Up Area Map of Owo

All the categories of roads in the Owo LGA were buffered by 100 meters. The choice of 100 meters buffer is to give adequate consideration to aesthetics and safety and this is generally acceptable in the study area (see figure 4). Also, the power line passing through Owo LGA from Benin was also buffered by 100 meters.

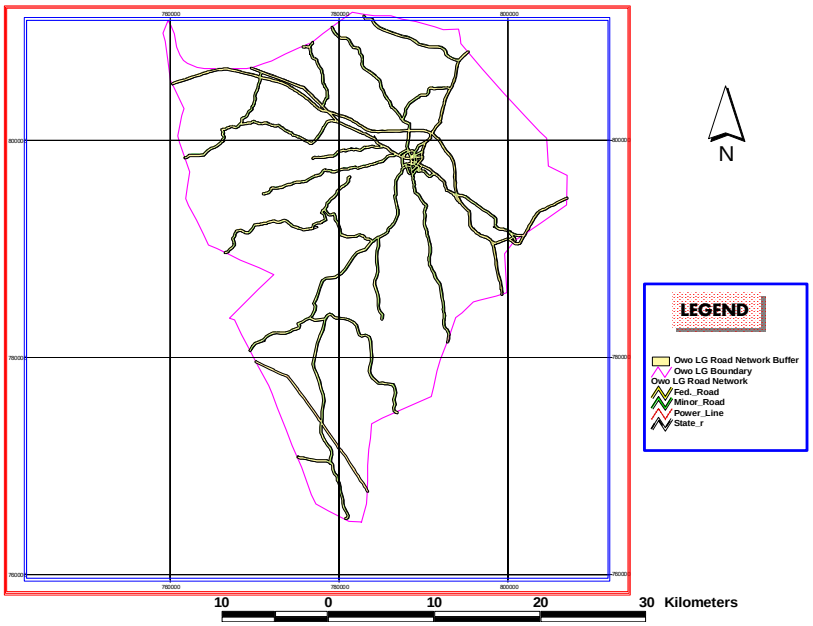

Figure 4: Buffered Road Network Map of Owo LGA

Figure 5 shows streams and rivers that constitute the drainage system of an area were buffered at a distance of 200 meters in order to mitigate conflicts relating to the contamination of sources of water supply. This becomes imperative in order to guard against health problems, noise complaints, odour complaints, decreased property values and animal – perpetrated mischief due to scavenging creatures.

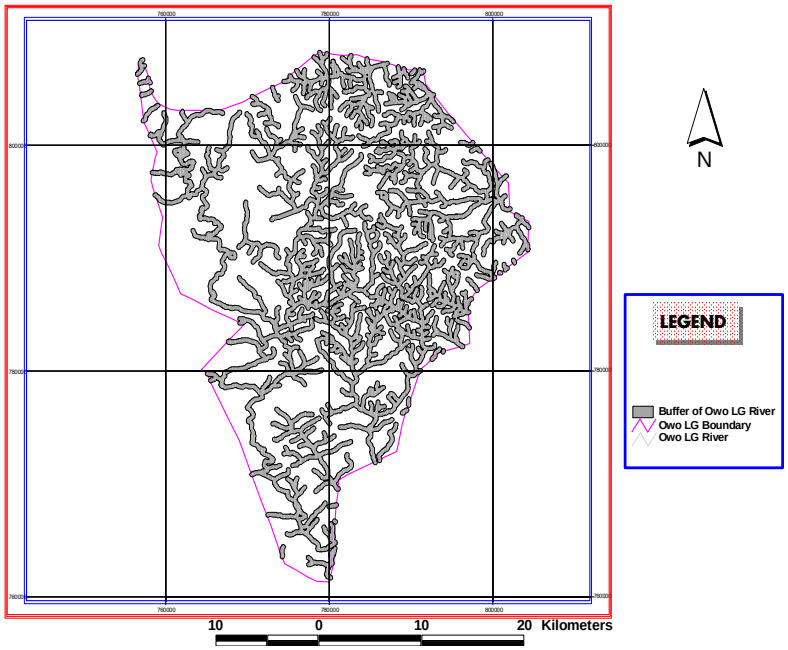

Figure 5: Buffered Drainage Map of Owo LGA

Figure 6 shows the three (3) major geological characteristics in Owo LGA. These 3 are the **Migmatite** which is a coarsely crystalline rock composed of a mixture of bands of metamorphic and igneous rocks, the **Granite Gneiss** which is a metamorphic rock formed at high pressures and temperatures and is made up of feldspar, mica and at least 20% of quartz and the third is the **Quartzite Schist** which also a metamorphic rock composed mainly of quartz formed by the action of heat and pressure on sandstone, the quartzite schist is a rock that splits into layers whose minerals have aligned themselves in one direction .One constant characteristic of the 3 geological types is that they all contain fracture, meaning that they allow water percolation.

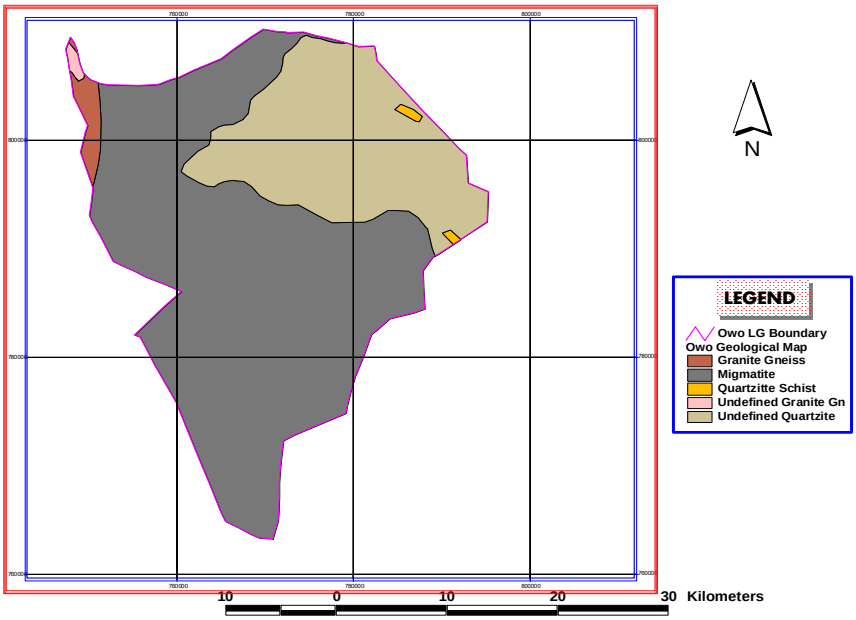

Figure 6: Geological Map of Owo

In figure 7 shows the buffered built-up area was overlaid on the buffered drainage map, this is to screen out unsuitable areas and leave areas that could be suitable for the landfill site.

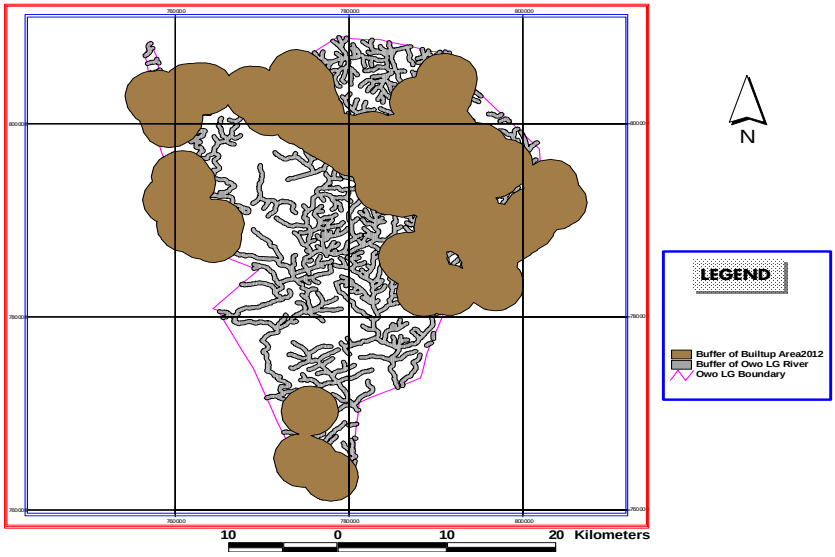

Figure 7: Map of Owo LGA Showing Overlay of built up and Drainage

Figure 8 shows the overlay analysis of the buffered built-up map overlaid on the landuse/land cover map. The purpose of this analysis is to determine the available area that can be used as a landfill site, bearing in mind that areas covered by the buffer are unsuitable, area covered with rock-out crop are unsuitable and areas housing the forest reserves are also unsuitable, that leaves us with whatever areas left being the potential suitable areas for the landfill site.

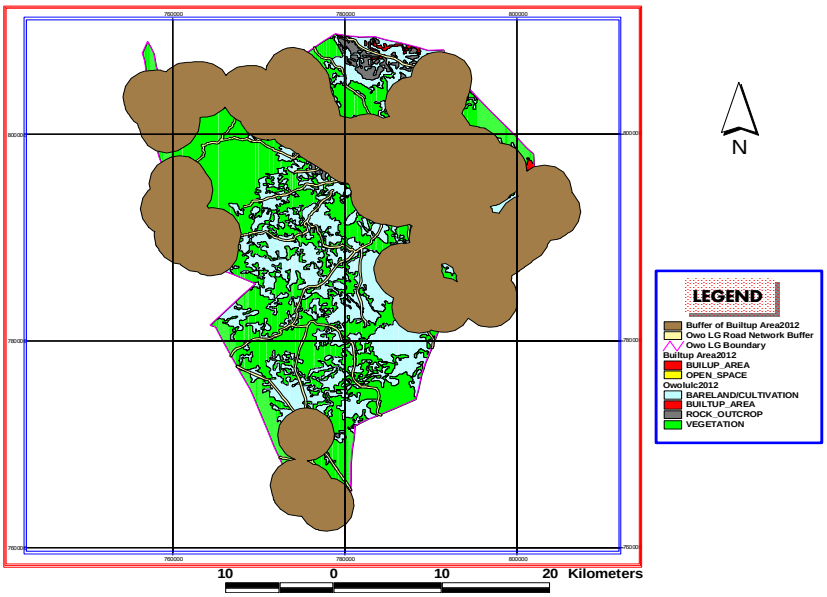

Figure 8: Map of Owo LGA Showing buffered build up overlaid on the land use/landcover

A spatial and attribute query was then performed on the erased map for areas covering 99 hectares and above. After the query, five (5) areas in figure 9 were identified as having more than 99 hectares. The reason for choosing areas covering 99 hectares or above is to ensure continuity. More often than not, it is observed that when a sanitary landfill site is used up to its capacity it is abandoned and a new site is the sought.

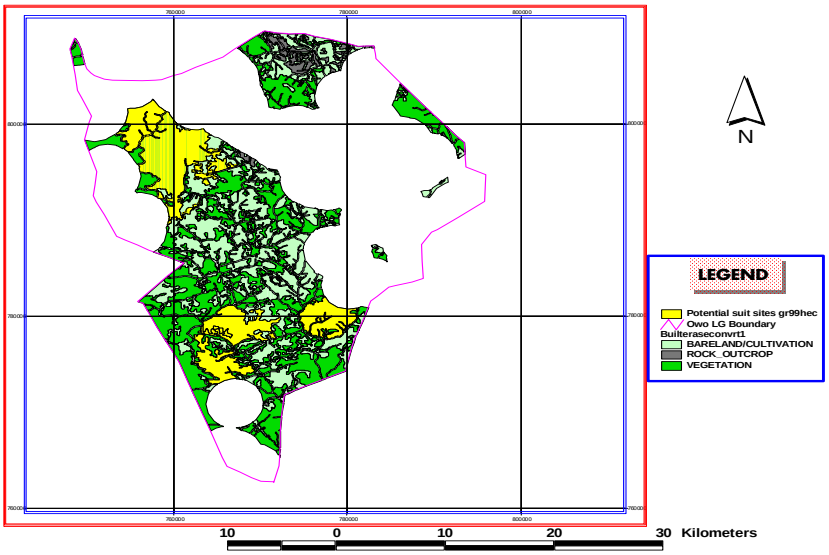

Figure 9: Potential Suitable Site 2: Landuse/Landcover Showing Potential Suitable Sites ≥ 99 Hectares

The five area having over 99 hectares of land were separated using unique colours and their corresponding land area were identified. The site at Emure covers an area of 369.223 hectares, the site at Ijebu covers 137.204 hectares, the site at Ipele covers 120.847 hectares, the site at Idasen covers 112.455 hectares while the site at Uso covers 99.967 hectares. Figure 10 shows a vivid illustration of the area of the various potential site as well as where they are located.

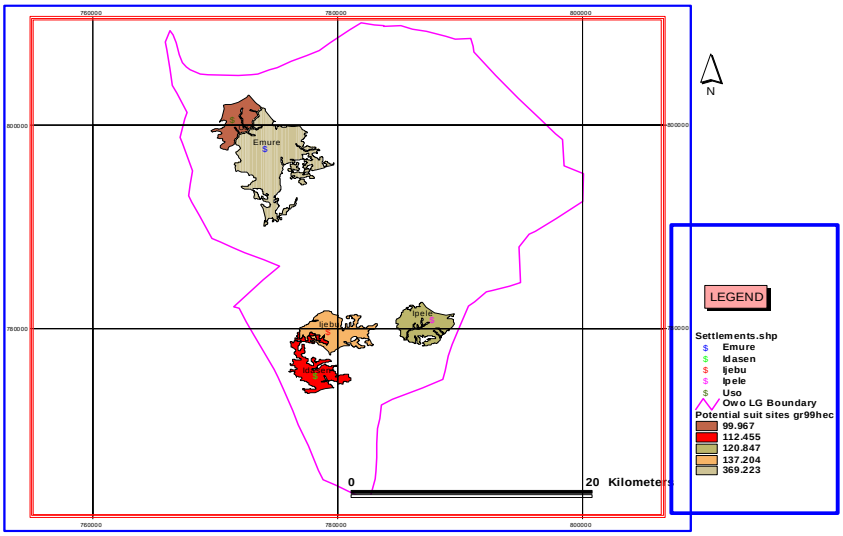

Figure 10: Map of Owo LGA Showing Potential Suitable Sites for the Landfill Site

Figure 11 shows the road network map overlaid on the potential suitable sites to show the route connectivity in order to identify the site with the most routes. It is pertinent to state here that accessibility is key to site selection, the site that would eventually be chosen as the most suitable site for the landfill must be very accessible; this would ensure that wastes collected would eventually be easily transported to its final destination. Figure 11 is a pictorial view of how the road network in the study area links the various sites to further help the researcher in identifying the best site.

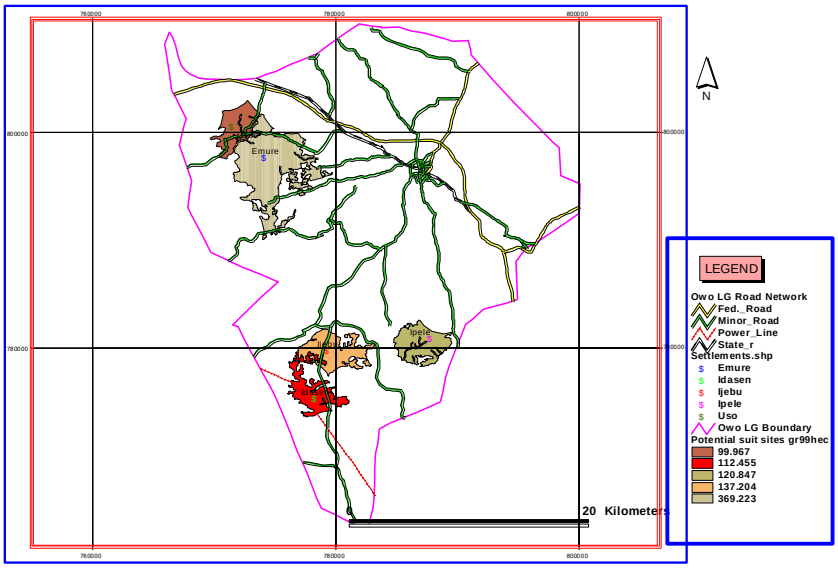

Figure 11: Potential Suitable Site Showing Route Connectivity.

Figure 12 shows the triangulated irregular network map (TIN). It was derived from the contour map of the study area using surface analysis in Arcview 3.3. The map shows the elevation of the area. Areas with elevation range of 150m to 300m are suitable areas while those below or above it are unsuitable. This is because sanitary landfill site ought to be sited on low to moderate relief, gentle to moderate slope or uniform slope while steep slope should be avoided even in areas of low relief. Areas with abrupt changes in relief and steep slopes are erosion-prone and make moving equipment difficult to operate. There is also possibility of mass movement of materials down slope in such terrain.

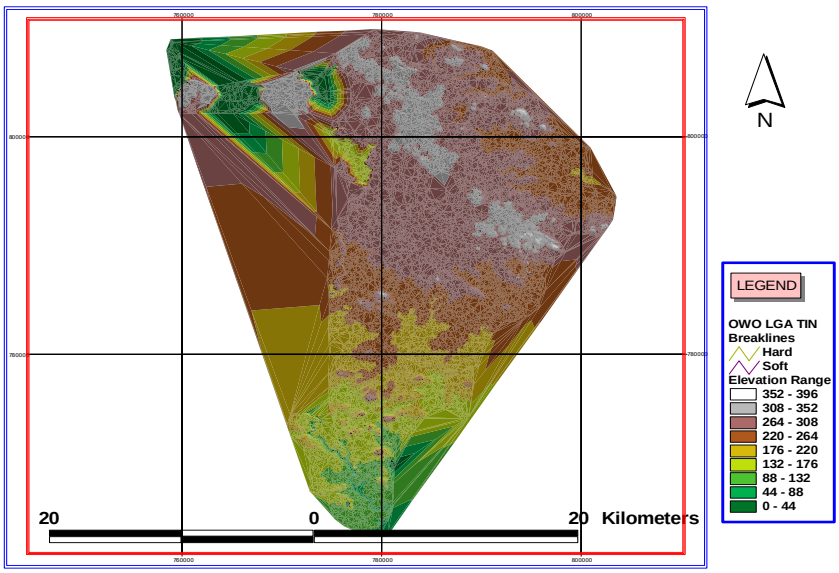

Figure 12: Triangulated Irregular Network Map of the Study Area (TIN)

Figure 13 is the overlaid analysis of figure 10 and figure 12, where the five (5) Potential suitable sites are overlaid on the elevation map (TIN). From figure 13 it can be observed that the area with 369.223 hectares, falls within the suitable area (Emure), however, potential suitable sites located at Ijebu, Ipele and Idasen fall within the forest reserve area making them unsuitable, that leaves suitable sites located at Uso and Emure. The suitable site in Uso falls within an unstable relief with elevation ranging between (44-220m).

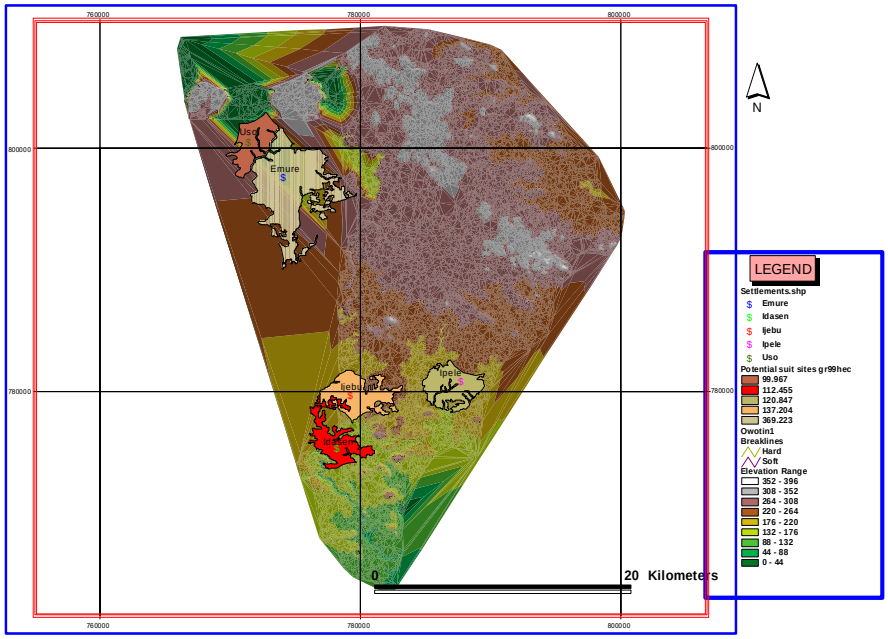

Figure 13: Map Showing Overlay Analysis of Potential Suitable sites and Triangulated Irregular Network (TIN)

The last suitable site being Emure, is considered the most suitable site for the siting of the sanitary land fill site in the study area as shown in figure 14

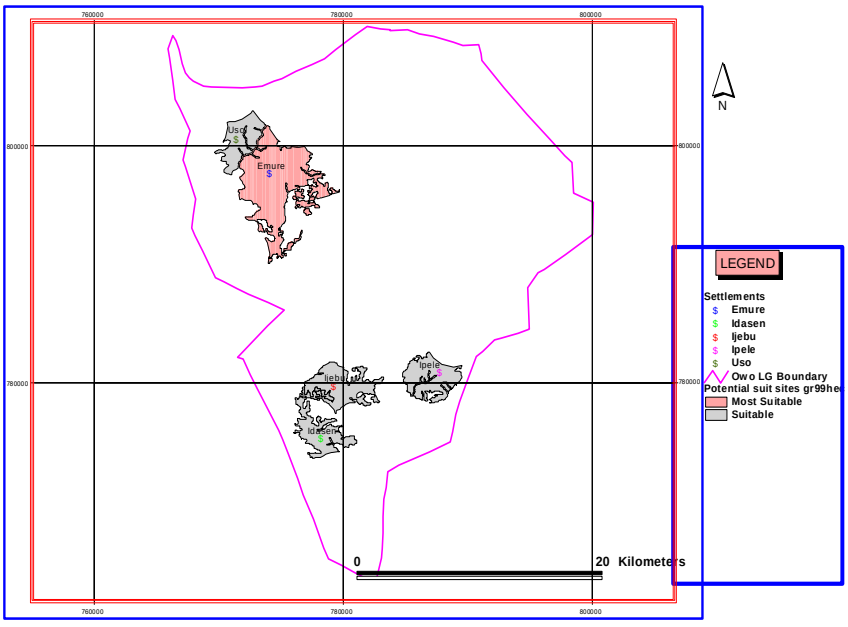

Figure 14: Map of Owo LGA Showing the Most Suitable Landfill Site

The variables that are responsible for urban waste disposal include: type of building; household sizes; type of solid waste; solid waste disposal methods; solid waste collector; and frequency of solid waste collection (see tables 2-6).

Table 2 shows that 797 respondents (44.2%) live in face-to face buildings, 427 (23.7%) live in traditional courtyards, 513 (28.5%) live in flats while 65 (3.6%) were located in other types of building such as self contain apartments, commercial buildings, market stalls etc.

Table 2 Type of Building use

Type of Building	Frequency	Percentage
Face To Face	797	44.2
Traditional Courtyard	427	23.7
Flat	513	28.5
Others	65	3.6
Total	1802	100.0

The number of household sizes per building also determines to a large extent the volume of refuse generated. Table 3 shows that 43.6% of the respondents have a household size of 3-5 persons, while 26.3% have household size of 6-9. However, 22.7% have household size of less than 3 and 7.4% of the respondents have household size of above 10 person

Table 3 Household Sizes

Household Size	Frequency	Percentage
Less than 3	409	22.7
3-5	786	43.6
6-9	474	26.3
10+	133	7.4
Total	1802	100.0

Table 4 shows that the most common solid waste generated in the study area are organic waste constituting 44.9%, while garbage waste constitutes 40.2% and inorganic waste making up 14.9% of the total respondents. This result buttresses the fact that Owo LGA is primarily an agrarian region

Table 4 Type of Solid Waste Generated

Solid Waste Generated	Frequency	Percentage
Organic Waste	809	44.9
Inorganic Waste	268	14.9
Garbage	725	40.2
Total	1802	100.0

Table 5 shows that 715 respondents out of the 1802 respondents (39.7%) result to open dumping of their waste while 900 (49.9%) dispose their waste by open burning and 187 (10.4%) have their waste collected by the municipal waste collector (Local Government) epileptically. The result shows that a large a large percentage of those serviced by the vehicles of the Waste Management Authority are resident in the core areas with some at the new inner centres while majority of residents that burn refuse within their compounds or dump in bush or vacant plots reside at the periphery where the services of the authority is not extended to.

Table 5 Solid Waste Disposal Methods

Solid Waste Disposal Methods	Frequency	Percentage
Open Dumping	715	39.7
Open Burning	900	49.9
Municipal Solid Waste Collection	187	10.4
Total	1802	100.0

Table 6 shows the frequency of waste evacuation from premises by the Waste Management Authority. 26.2% is evacuated daily, 66.5% weekly and 7.2% fortnight. The fact still remains that the evacuation of these wastes are not regular as they only specified the time without actually carry out their duty as expected.

Table 6 Frequency of Solid Waste Collection

Frequency of Solid Waste Collection	Frequency	Percentage
Daily	473	26.2
Weekly	1199	66.5
Fortnightly	130	7.2
Total	1802	100.0

V. CONCLUSION AND RECOMMENDATIONS

The study shows that various items ranging from leaves, food remnants , clothes, paper, plastic of different forms, metal scrap etc are generated in Owo LGA and that these waste products are mostly stored in dustbins, polythene bags, baskets or plastic containers. The only method adopted in the management of solid waste in the study area is the collection and disposal method. The study also revealed that Ondo state Waste Management Authority which was established with the purpose of riding the state of refuses plastron the sole responsibility for the management of waste within study area with no involvement of private operators. Waste is collected by the vehicles of waste Management Authority on pre-arranged days while areas not serviced disposes their refuse either by burning, dumping or vacant plots, dumping in canals, gutters and dumping on roadsides. Over the years, people suffered from various diseases arising from waste disposal problems.

The study shows that there is no proper means of identifying all sources of waste generated and the actual volume of waste generated and the area on a daily basis. Lack of data has made this difficult and the culture of data gathering and processing is yet to entrench the system.GIS could effectively be used as a management and an analysis tool that facilitates planning processes. In this study, GIS was used to locate the most suitable landfill sites in Owo LGA by creating maps according to scientific criteria and standards. Also by superimposed the two thematic maps, the result was the most suitable location for a landfill site taking all the mentioned criteria and standards into consideration. The site located to the city centre with a total area of 369.223hectares mapped as the most suitable site. From the results, the following recommendations were made. For a proper waste disposal system to be maintained in a city, the government and the community must work hand in hand. The capacity of our municipal authorities to manage wastes in our cities should be increased so as to reduce the problem of environmental pollution in and around our cities. Since the soil is not good for siting of a sanitary landfill, synthetic material should be used to pre-lay the sanitary landfill in order to prevent the percolation of leachates (wastewater) into groundwater. This will help in preventing the pollution of groundwater. Incinerators can be built at the landfill site to destroy the waste collected. Adequate infrastructure such as loading trucks, waste disposal bin at strategic places should be provided. It is also very important to boost the capacity of the local government staff in charge of collecting the waste by employing more workers to cover the whole local government. It is quite obvious that the government cannot do it alone; the private organisations and firms should be encouraged and given the necessary incentives to engage in the collection of the solid waste in the Local Government Area so as to put an end to indiscriminate waste disposal. GIS technology is a powerful tool that aids facility siting process should be used and taught by both government waste management and private agencies for sustainable landfill siting of waste disposal sites.

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