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Department of Geography and Meteorology
Nnamdi Azikiwe University, Awka

Evaluating the Solid Waste Dump Site within Lokoja Metropolis using Geospatial Techniques

Agada D.U.,[1*] Johnson N.G.,[1] Yaya A.L.[1], Abraham S.S.[2] & Ejikeme, J.O[3]

[1]Department of Surveying and Geoinformatics, Kogi State Polytechnic, Lokoja
[2]Department of Urban and Regional Planning, Kogi State Polytechnic, Lokoja
[3]Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka.
*Corresponding author email: ejikemejoseph2@yahoo.com

Abstract

Solid waste management has become a complex global environmental problem in both developed and less developing Countries. The problem is widely noticeable in Lokoja area of Kogi State, Nigeria. This is mostly caused by poor planning and lack of adequate information need to tackle urban solid waste management. Therefore, adequate information on solid waste dump site (SWDS) is required to mitigate future hazards that may emanate from these wastes within Lokoja Metropolis. This study applied Geospatial Techniques to assess the trend of the Solid Waste Dump site within the period of three years. Due to different parameters involved, the study adopted the principle of Separation Distances as recommended by the Environmental Protection Authority (EPA) Landfill Manual 2006. The separation distances parameters considered in the monitoring of the Dump Site include; the distance of the dump site to water body (>960m), the slope of the Dump Site (0^o-5^o), distance of the dump site to the road (100m-1000m), and distance to the residential areas (>8000m). LandSat ETM imagery of 2014, 2016, and 2018 of the study area was used for the supervised classification as well as the distance analysis over the years. ASTER imagery, and Quickbird satellite imagery were used to generate the slope, extraction of the roads/buildings and delineation of rivers within the study area. The study revealed that the distance of the dumpsite to the road accounted for 160m in 2014, 57m in 2016, and 14m in 2018. The distance of the dumpsite to the built-up areas accounted for 1547m in 2014, 1287m in 2016, and 876m in 2018. It can be seen from the analysis that the slopes were 3^0 in 2014 and 2016, and 5^0 in 2018. It is recommended that the existing dumpsite be relocated to another area. Suitability analysis should be carried out before siting new dumpsites.

Key words: Solid Waste, Dumpsite, Geospatial Techniques, Waste management

1.1 Introduction

Waste can be defined as any product or material which is useless to the producer (Basu, 2009). Waste includes any scrap material, outflow or unwanted surplus substance or article that requires disposal because it is broken, worn out, contaminated or otherwise spoiled *(CIPS, 2007).* Muhammed *et al*, (2013) categorizes waste into: 1) municipal waste which includes, household waste, commercial waste and demolition waste 2) hazardous waste which includes industrial waste 3) biomedical waste which includes clinical waste and 4) special hazardous waste which includes radioactive waste, explosive waste and electronic waste.

Municipal Solid waste (MSW) normally termed as "garbage" or "trash" is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Aibor and Olorunda, 2006).The amount of solid waste produced by human activities is increasing in most parts of the world due to population and economic growth, urbanization, industrialization and problems of waste disposal.

Solid waste disposal is one of the most vital aspects of waste management system. Most solid waste disposal sites are situated around settlements, water bodies, roads thereby posing both environmental and health challenges to residents. Some countries have adopted various approaches to waste collection and disposal. For example, the United States of American (USA) uses the methods of landfills and incineration, Australia uses landfill, while Japan uses incineration and recycling (Hammer, 2003). The common mode of waste disposal in Nigeria is through open dump. According to El-Fadel *et al*, (1995), dump sites are historically the most used method for waste disposal in the world. It has the longest history, the widest range of capabilities and in most instances, is the least expensive waste disposal method (Weiss, 1974).

Dump Site; when not often monitored for a long time, could cause health hazards, (emanating from bad offensive odour, pollution of the underground water etc.), and also deface the environment (Federal Ministry of Environment).The inability to monitor and manage the solid wastes Dump effectively in Nigeria has becomes an issue of great concern. This is because apart from the destruction of aesthetics of landscape by the waste dumpsites, some of the municipal solid wastes contain both organic and inorganic toxic pollutants (such as heavy metals) that threaten the health of humans and the entire ecosystem (Nwosu and Godswill, 2016).

Proper management of solid waste is critical to the health and well-being of urban residents (World Bank, 2003).Location of dumpsites in urban areas is beneficial in as much as they provide the most efficient and safe means of disposal of waste generated; however, the perceived environmental costs, health-related hazards, social and economic impacts associated with waste dumpsite are often confined to the immediate zone of influence of dumpsites and extends up to few kilometres (Arimah and Adinu 1995). Before 2012, the Lokoja metropolis has no central solid waste disposal sites, rather wastes are dumped anyhow within the metropolis causing blockage on water ways and also polluting the water bodies.

Remote sensing data from satellite image offers an improved observation and added systematic analysis of the separation distances as recommended by Environmental Protection Authority (EPA). Geographic Information System (GIS) being one of the most important tools for integrating and analyzing spatial information and multidisciplinary database of any resource development, environmental protection, scientific research and investigations can be used in assessing the trend of the Solid Waste Dump site as well as deducing a better separation distances. Several studies (Nkwocha *et al*, 2019; Njoku and Okeniyi, 2014; Uzoezie, *et al*, 2018; Emmanuel *et al*, 2017) have demonstrated the effectiveness of GIS in analyzing and managing the distribution and disposal of solid waste.

This study tends to use GIS to evaluate the solid waste dump Site within Lokoja Metropolis with a view to determining the suitable locations for the dump sites. Lokoja is located between latitude 7^{o} 45’ 27.56’’ N and 7^{o} 51’ 04.34’’ N and Longitude 6^{o} 41’ 55.64’ E and 6^{o} 45’ 36.58’’E of the equator. It is situated on the western bank of the confluence of Rivers Niger and Benue at an altitude between 45 – 125 meters above sea level towards the north-south and the foot of the Patti Ridge, which reaches its altitude of 400 meters above sea level. Lokoja used to be a small urban Centre and the headquarters of Kogi Local Government until 1991 when it became the head quarter of a new State.

This town which had at some point in its rich history been the Capital of the Northern Protectorate and later Nigeria is presently the headquarters of Lokoja Local Government Area and the Capital of Kogi State.

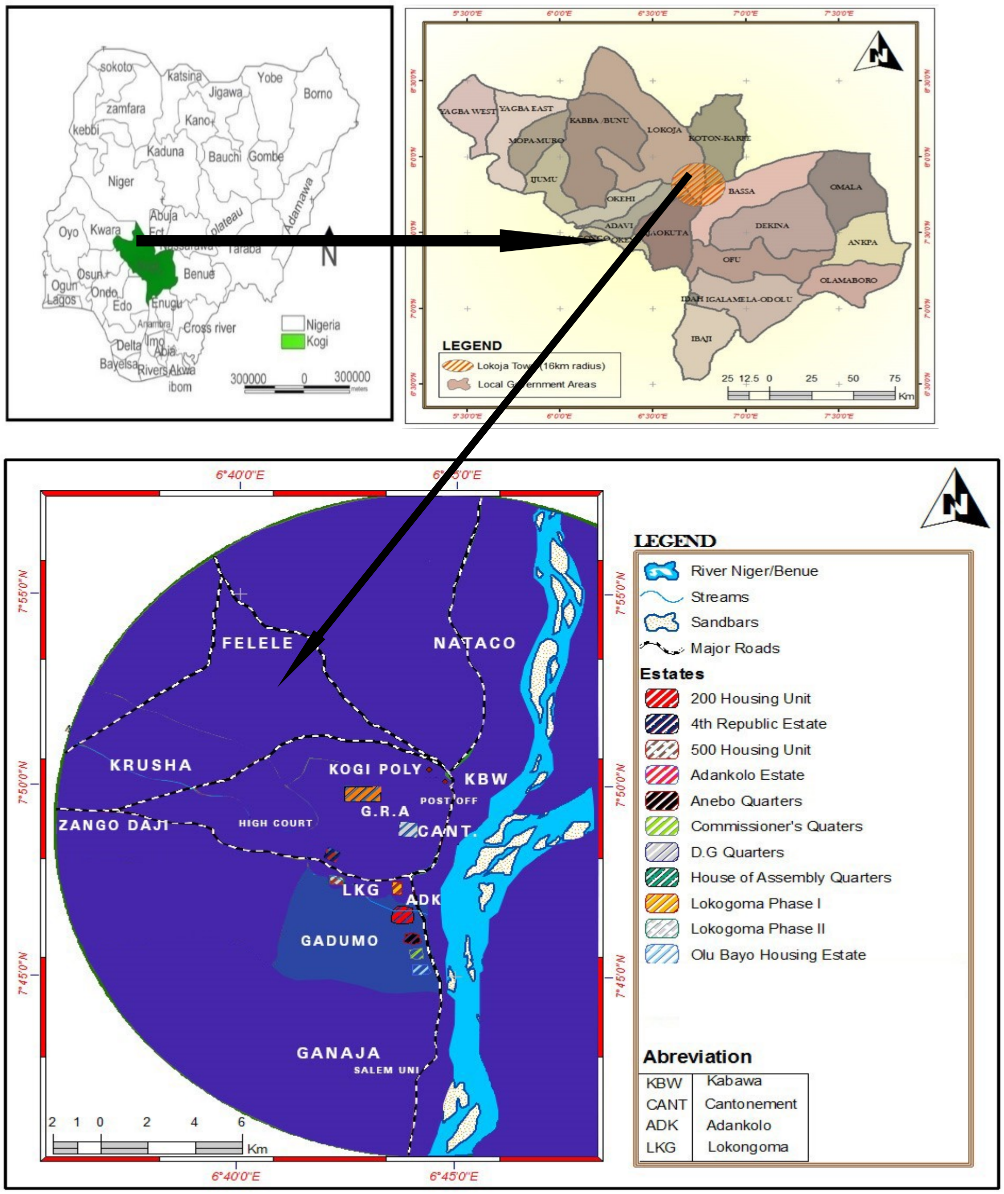

Figure 1**:** The Study Area

Lokoja serves as the connecting town for many parts of Eastern, Northern, Western and Southern Nigeria. Lokoja town has a land mass of 63.82Km^2 with a population of 132,363.

2.1 Methodology

The data and materials used for this research are the 30m spatial resolution LandSat ETM+ covering three epochs (2014, 2016, and 2018) for image supervised classification. Also the ASTER imagery of (30m resolution) covering the study area was also used in the research to generate elevation and slope of the study area. Quick bird (2014, 2016, and 2018 at 0.61m resolution) of the study area was used to extract the road network and demarcate the water bodies within the study area.

The study employed the EPA separation distances standards to monitor the trend as well as the behaviour of the solid waste dump site within the period of five years (covering 2014, 2016 and 2018) considering four parameters namely: Slope, buildings, water bodies, and roads.

Each of these parameters is generated as a layer in GIS Environment (ArcGIS 10.5) using a number of data acquired from different sources. The information compiled from EPA Landfill Manual about the separation distances of the dump site to each of the parameters (slope, buildings, roads, and water bodies) were compared with the ones obtained within the period of five years. This was done in order to determine the buffer zones and their varying degree of suitability within each layer. Below is the flow chart of the research methodology.

The location of the existing dumpsites within the study area was acquired through field survey using Global Navigation Satellite System (GNSS) receiver. The coordinates of the existing solid waste dumpsite collected during fieldwork were imported into the ArcGIS 10.5 as a text file then converted to shape-file to show the location of the dumpsite on the satellite imagery for different epoch. This was carried out in order to determine the extent as well as the trend of the solid waste dump site over the years. These coordinates are shown in table 2.1.

Table 2.1: Coordinates of the Existing Dumpsites

POINT	X (M)	Y (M)
1	246243.622	869050.847
2	245936.223	868839.375
3	246089.137	868875.951
4	246228.077	869052.863

Supervised image classification was carried out to derive the land use/land cover types of the study area for the period of 2014, 2016 and 2018. The three years epoch was used due to availability of other data such as Quickbird image and ASTER image required for the study. Slope analysis was carried out on the ASTER DEM to generate the slope of the terrain which was converted to Degree.

The Quickbird image was used to extract the road networks and settlements in the study area. Buffering analysis was carried out to determine the proximity of the dump sites to various criteria considered (road network, residential area and water body) using the separation distances standard formulated from Environment Protection Agency (EPA) Landfill Manual 2006.

3.1 Results and Discussions

The results are presented in form of maps and statistical table. The classified map of the study area for the period under investigation (2014, 2016 and 2018) is shown in figure 3.1, 3.2 and 3.3 respectively.

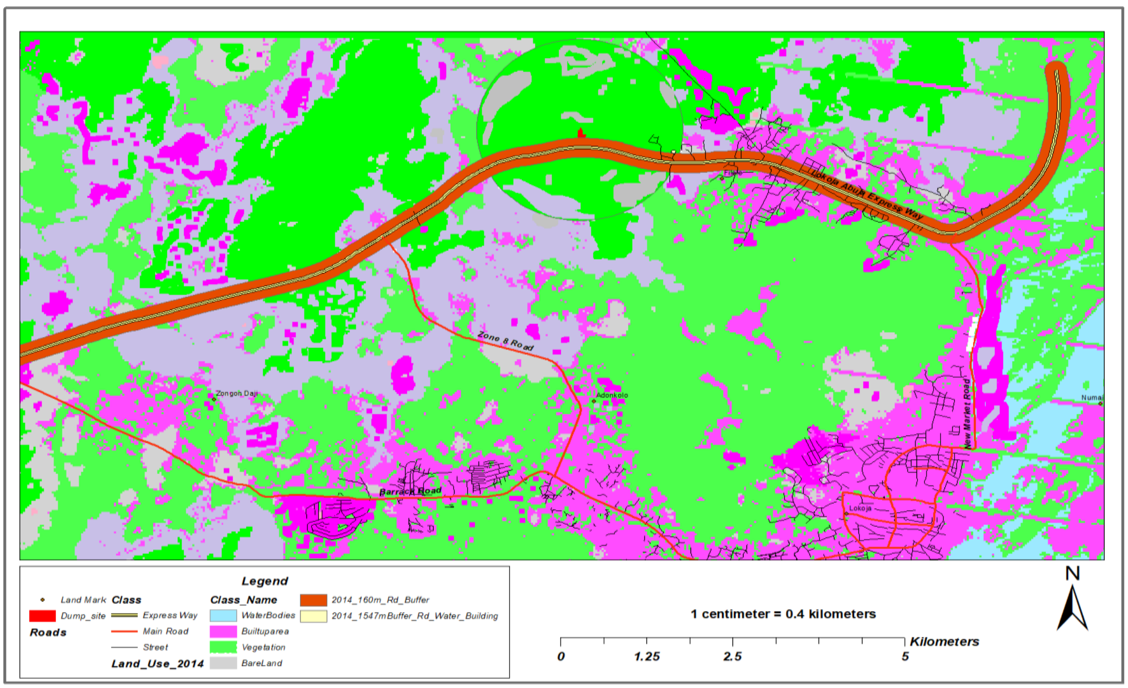

Figure 3.1: Classified Map of Lokoja Metropolis, 2014

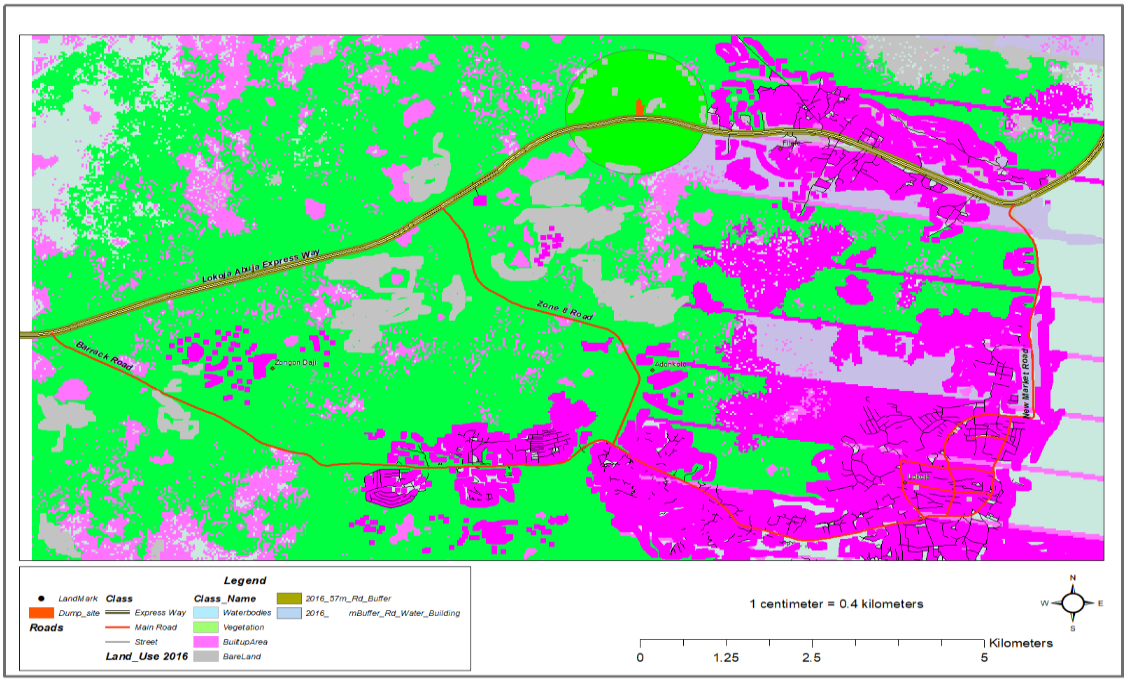

Figure 3.2: Classified Map of Lokoja Metropolis, 2016

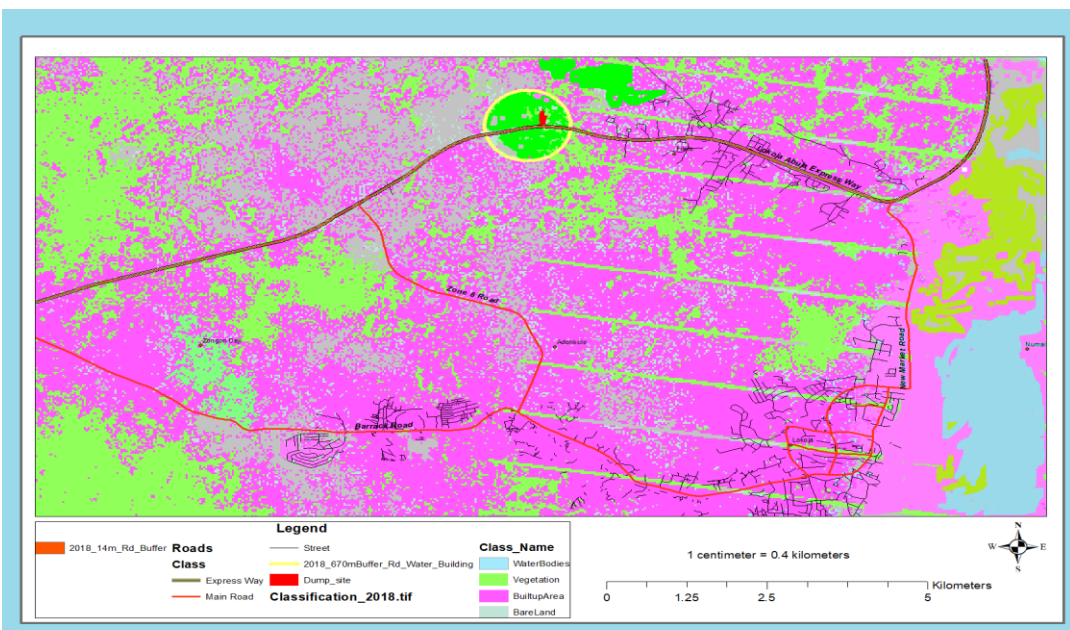

Figure 3.3: Classified Map of Lokoja metropolis, 2018

The results shows an increase in the built up area land cover classes and diminishing vegetation classes. The slope map generated from the ASTER imageries for the year 2014, 2016 and 2018 are shown in figure 3.4, 3.5 and 3.6 respectively.

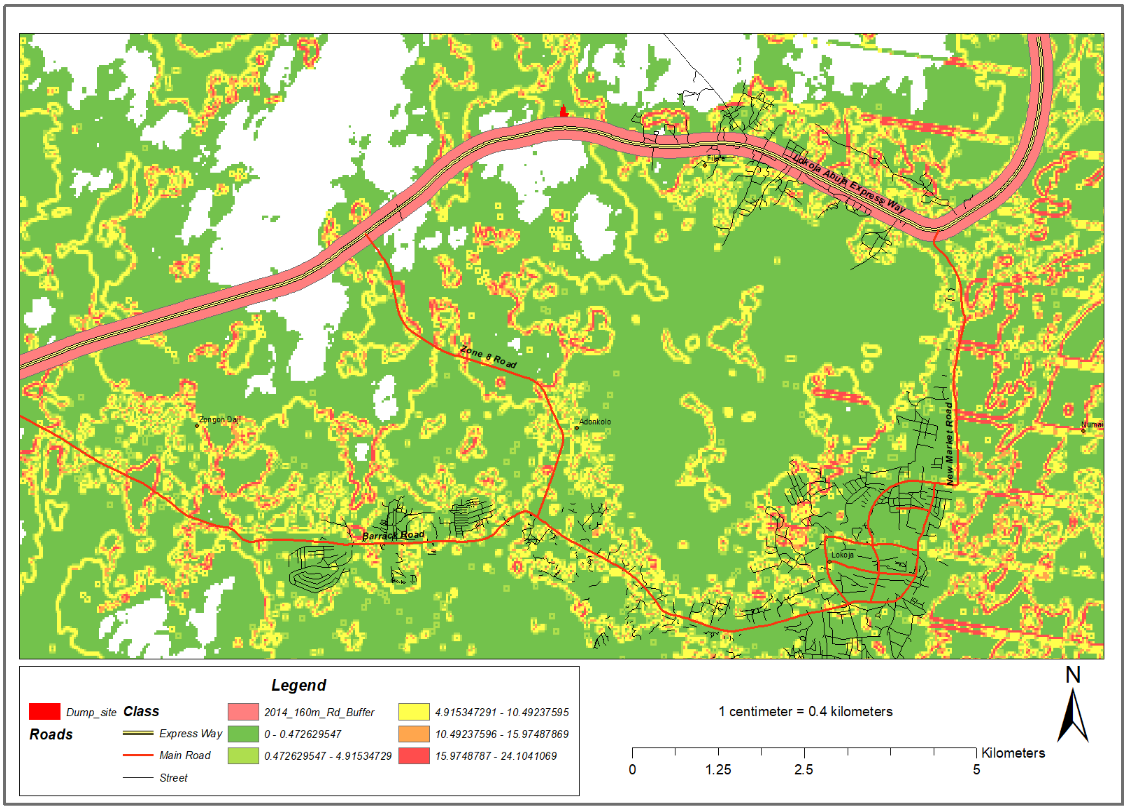

Figure 3.4: Slope Map of Lokoja Metropolis, 2014

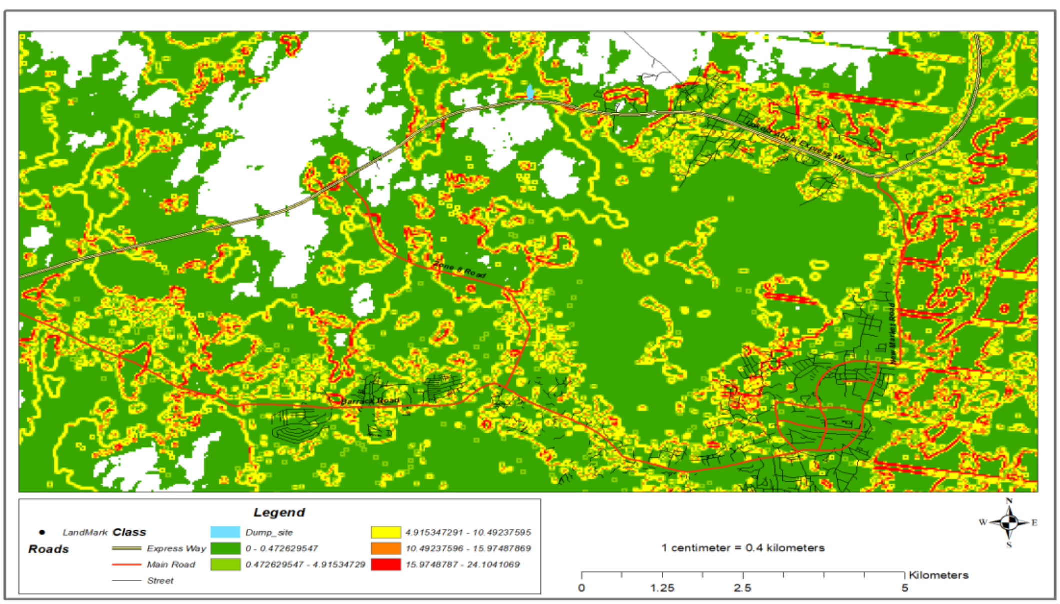

Figure 3.5: Slope Map of Lokoja Metropolis, 2016

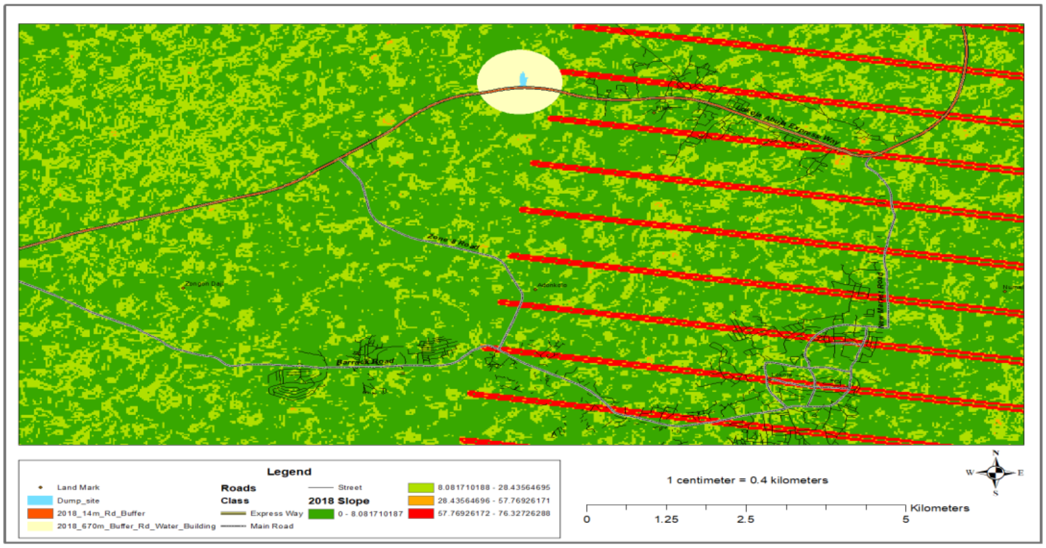

Figure 3.6: Slope Map of Lokoja Metropolis, 2018

Table 2.2 shows the extent of the dump site within the period of 5years. In 2014, the dump site covered 6129.419sqm (0.613Ha.) of land mass which is about 0.349skm with a total length of 349.297m. In 2016, the dump site further occupied 16497.132sqm (1.649 Ha.) That is, 0.564sqkm with a total length of 563.985m. The result show that the dump site increased geometrically in 2016 with difference of 10364.713sqm which is about 1.036Ha.

2018 marks the period of overflow of the dumpsite where the total area of the dumpsite increased to 31013.505sqm (3.101Ha.). The result shows that the dumpsite had increased with a land mass of about 24884.086sqm (2.488Ha.) over the years. This result attest to the fact that waste generation is on the increase within the Lokoja metropolis.

Table 2.2: Dumpsites Extents over the Years

*OBJECT ID **	*Shape **	*Year*	*Area_sq_m*	*Length_sq_km*	*Length_m*	*Area_Sq.m*	*Area_Ha*
1	Polygon	2018	31011.32	1.201	1200.82	31013.505	3.101
2	Polygon	2014	6128.987	0.349	349.297	6129.419	0.613
3	Polygon	2016	16492.97	0.564	563.985	16494.132	1.649

Table 2.3 shows the result of the buffering analysis from the location of the existing dumpsites to nearby road, water body and buildings for the year 2014, 2016, and 2018. The buffer analysis for

year 2014 shows the distance of the dumpsite to the road to be approximately 160m. comparing this result with the constraint table in table 2.4 (referring to EPA Standard); it can be seen that the dumpsite was still within acceptable separation distance to the road (moderately suitable).The separation distance of the dumpsite to the water body was not captured because they were no water body within the buffer radius of the dumpsite. The distance between the dumpsite and the built-up area accounted for 1547m (1.547km) making it unsuitable based on the EPA standard.

Table 2.3: Buffering Results

Year	**Distance to Road(m)**	**Distance to Water (m)**	**Distance to Building(m)**	**Slope (^{0})**
2014	160		1547	≈ 3^0
2016	57		1287	≈3^0
2018	14		876	≈5^0

Table 2.4: Constraint Criteria Table Formulated from EPA landfill manual 2006

Criteria	**Least Suitable**	**Moderately Suitable**	**Highly Suitable**
Distance to Road	<100m	100-1000m	1000-2000m
Distance to water	160-480m	480-960m	>960
Distance to building	3000-5000m	5000-8000	>8000m
Slope	10^0-15^0	5^0-10^0	0^0-5^0

In 2016, the distance of the dumpsite to the road and building accounted for 57m and 1287m (1.287km) which also fall below standard. This rapid increase in waste generation over the years can be attributed to uncontrolled development tending towards the dumpsite. In 2018, the distance of the dumpsite to the road accounted for 14m and 876m to built-up areas. This is owing to the fact that most wastes are now dumped closed to the road having exhausted some meters away from the center of the dumpsite. The decrease in distance of the dumpsite to the built up area can be attributed to a leap-frog pattern of development being witnessed around the dumpsites. This is also evident in the classified map shown in figure 3.3.

The slope gradient of the study area accounted for 3^0 in 2014 and 2016, and 5^0 in 2018. Comparing these values with the EPA standard (table 2.4), it can be seen that the slope of the study area is within the standard separation distance.

4.1 Conclusion and Recommendations

This study specifically shows spatial analysis of the dumpsite to enable proper decision making for subsequent siting of dumpsite. The considered criteria include distance from water bodies, distance from major roads, built-up areas, and the slope. The increase in commercial, residential and infrastructural development due to the population growth and urban expansion within Lokoja Metropolis is directly affecting the amount of waste generation in the area. This study is therefore considered very important because it will serve as a catalyst in the area for further improvement on waste dump siting and management.

Having capture the various distances of the parameters considered in this study, with reference to the EPA standard as well as guide line for separation distances, it is recommended that the existing dumpsite be relocated to another area. Suitability analysis should be carried out before siting new dumpsites.

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