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Spatial analysis of solid waste collection sites in Abakaliki metropolis

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Abstract

Waste management is becoming more difficult as a result of the growing population and increased waste generation. Waste collection is a crucial step in the waste management process. This study mapped out the locations of the current waste collection sites in Abakaliki metropolis, analyzed their spatial distribution using the Average Nearest Neighbor (ANN) tool in GIS software, and looked into the implications of these sites. The results showed 373 waste collection sites within the metropolis, of which 77.5% of them were unofficial. In addition, the analysis demonstrated that the distribution of the waste collection sites within the metropolis increases with a residential density waste/area ratio of 15.41, 1.63, and 0.76 for high, medium and low residential density areas respectively. The average nearest neighbor result also revealed that the distributions of the waste collection sites within the metropolis are clustered in three (3) out of the Six (6) classified land uses namely, high residential density areas, medium residential density areas and the commercial areas whereas the administrative and public areas showed dispersed distribution. The study concluded that waste collection sites within Abakaliki Metropolis were not selected based on empirical studies.

Keywords; Metropolis; Solid Waste; GIS; Nearest Neighbor Analysis; Residential Density; Collection Sites.

1. Introduction

Cities in developing countries are experiencing population growth. As a result of this population growth, there is an increase in waste generation, thereby increasing the complexity of waste management. Waste collection is a strategic step in the waste management process. One of the most important environmental and health issues facing African city governments is municipal solid waste management. This is because only 20–80% of the waste is collected in many cities, despite solid waste management consuming 20–50% of their budget [1].

According to [2], a crucial aspect of waste management is placing bins in an easily accessible location so that waste may be collected and disposed of regularly. This is the primary goal of this investigation. Abakaliki Metropolis, like most cities in undeveloped countries, generates numerous tons of municipal solid waste. These wastes are usually transported from their point of generation to a site where they will be collected for disposal. Examining the sufficiency and functionality of these sites within the study area is important to Sustainable Development Goal (SDG) 11 which focuses on "sustainable cities and communities."

There is a vital need for waste collection sites to be readily available to a city's inhabitants as it is the bedrock of an adequate waste management system. Therefore, this study aims to produce relevant information on the analysis of waste collection sites in the city of Abakaliki using the GIS (Geographic Information System) approach.

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Statutory institutions such as Ebonyi State Environmental Protection Agency (EBSEPA) in charge of waste collection often create designated sites for waste disposal within cities [3]; [4]. However, the question of whether those sites are selected based on empirical studies in Abakaliki is a gap that this study tends to explore.

1.1. Aim and Objectives

The study aims to examine the spatial distribution of the existing waste collection sites in Abakaliki metropolis by identifying the existing waste collection sites, analyzing their spatial distribution, and examining the implication of the waste collection sites within Abakaliki metropolis.

1.2. Study area

Abakaliki is the capital city of Ebonyi State in southeastern Nigeria. The metropolis cuts across four Local Government Areas (LGAs): Abakaliki, Ezza North, Izzi, and Ebonyi LGAs. It is estimated that the population of Abakaliki will be 1,179,280 in 2021 [5]. The Northeastern Igbo of the Afikpo-Abakaliki axis make up most of the population [6]. Abakaliki's residents are essentially agrarian and create primarily household waste [7].

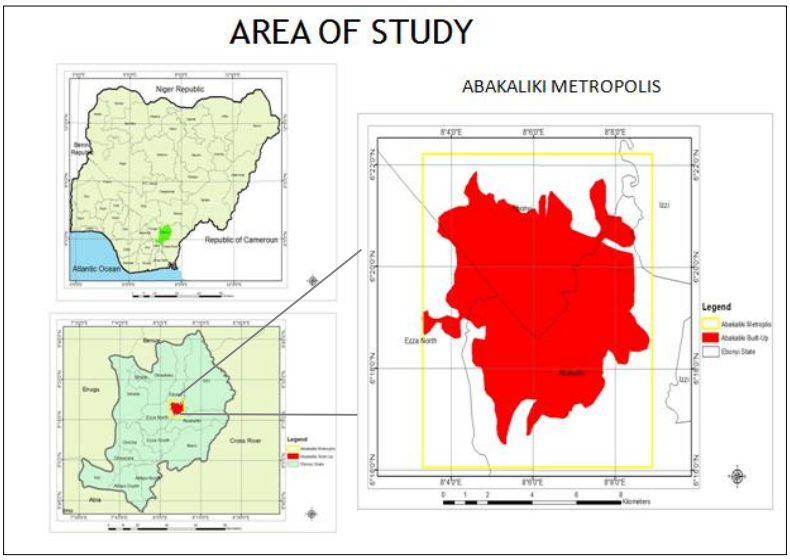


Figure 1 Map of Abakaliki Metropolis

2. Materials and methods

This study utilized different types of datasets and tools to examine the spatial distribution of the existing waste collection sites in Abakaliki metropolis which include; Geo-Referenced Infrastructure and Demographic Data for Development (GRID^3), Google Earth Imagery and GIS software (ArcGIS 10.3 version).

Table 1 Data and Data source

S/N	Data	Source/Link	File format	Date
1	Abakaliki Metropolis Map	Digitized From Google Map	Vector	2021
2	Residential Area	Digitized From Google Satellite Image	Vector	2021
3	Road Network	Digitized From Google Satellite Image	Vector	2021
4	Waste Collection Sites	GRID^3 Data	Vector	2020
5	LGA Administrative Boundaries	GRID^3 Data	Vector	2020

Table 1 includes all information about the datasets used in addition to their format. The table represents the various geospatial data types and their sources in the data processing stages to identify the existing waste collection sites.

2.1. Spatial Data Analysis

The Abakaliki metropolis boundary map was digitized from Google base map using the ArcGIS software. This was done by using the editor tool from the toolbar in the ArcMap environment to produce a shapefile for the study area.

2.2. Land-use classification

Different land-use were digitized and classified from a high-resolution image using the ArcGIS software. The land-use classification that was specifically carried out for this study includes Major Roads, Residential Areas (based on density), Administrative Areas, Public Areas,and Commercial Areas.

2.3. Identifying existing waste collection sites and analyzing their spatial distribution using Average Nearest Neighbor Analysis

To achieve the first objective of this study, the solid waste collection points data was acquired from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID^3) and represented as point features to show the solid waste collection sites. These waste collection sites on GRID^3 show records of the coordinates, legality, locations, and addresses of the waste collection site. Geometry corrections were carried out on some of the point data to ensure adequate positioning of waste collection sites on the high-resolution image of the study area.

The GIS software was used to run the network analysis on the waste collection point data to ascertain the spatial distribution of the waste collection sites around the Abakaliki metropolis. Figure 2 illustrates the methodology of the spatial analysis for waste collection sites.

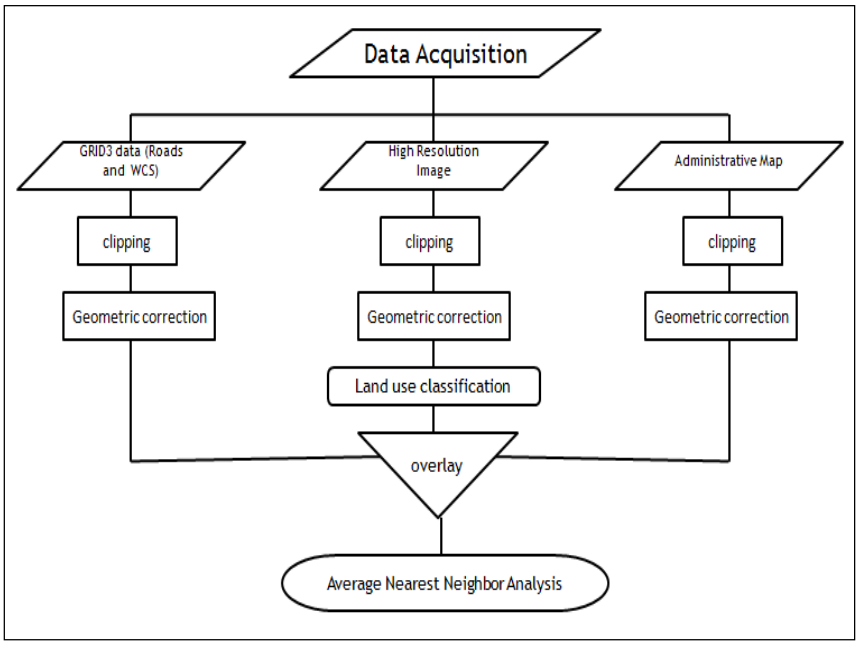


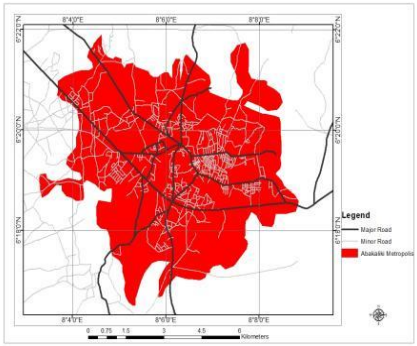
Figure 2 Methodology Workflow

3. Results and discussion

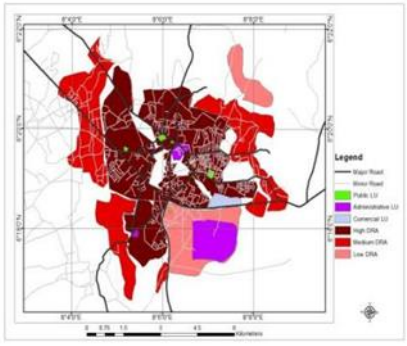
The various maps as seen in Figure 3 below show the digitized major roads within Abakaliki metropolis, the different land-use classifications within the metropolis, the distribution of the waste collection sites across the metropolis, and the distribution of waste collection sites across the different classified land-use.

The Solid Waste Collection sites in Abakaliki metropolis (including the official and unofficial sites) were identified and summed up to a total of three hundred and seventy-three (373) across the metropolis (table 2), with 84 official waste collection sites and 289 unofficial sites at 22.5% and 77.5% respectively. The high residential area has about 86.06% of the total waste collection sites in the entire metropolis. However, 75.07% of the waste collection sites in the high

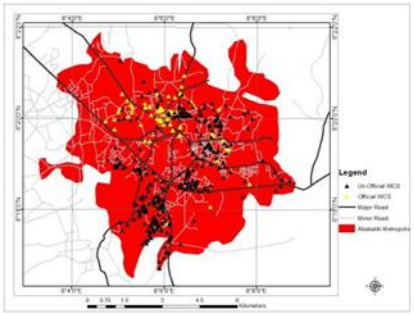
residential area are unofficial sites, this is to say that the population in the high residential area is not adequately served with waste collection facilities, hence the populace resorts to the illegal dumping of waste in the environment giving rise to the high number of unofficial waste collection sites.



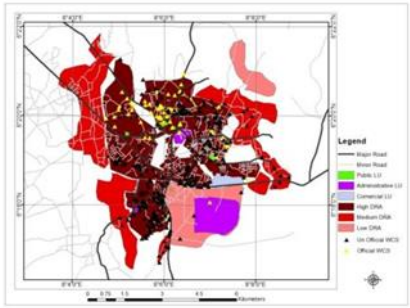
Major roads within Abakaliki Metropolis



Administrative, Commercial, Public and Residential areas within Abakaliki Metropolis



Distribution of the waste collection sites across the metropolis



Distribution of the waste collection sites across the different land use

Figure 3 Major Roads, Land Use and Distribution of Waste Collection Sites

Table 2 Total number of waste collection sites in Abakaliki metropolis

WCS Classification	Number of WCS	Percentage (%) of WCS
Official Waste Collection Sites	84	22.5%
Unofficial waste collection sites	289	77.5%
TOTAL WCS	373	100%

3.1. Distribution Pattern of Waste Collection Sites Within Abakaliki Metropolis

The average nearest neighbor result (figure 4) revealed that the distributions of the waste collection sites within the metropolis are clustered. Furthermore, three (3) out of the Six (6) classified land-use namely, High Residential Density (HRD) areas, Medium Residential Density (MRD) areas and the Commercial areas had clustered distribution whereas the Low Residential Density (LRD) areas, Administrative and Public areas showed dispersed distribution as summarized in table 3.

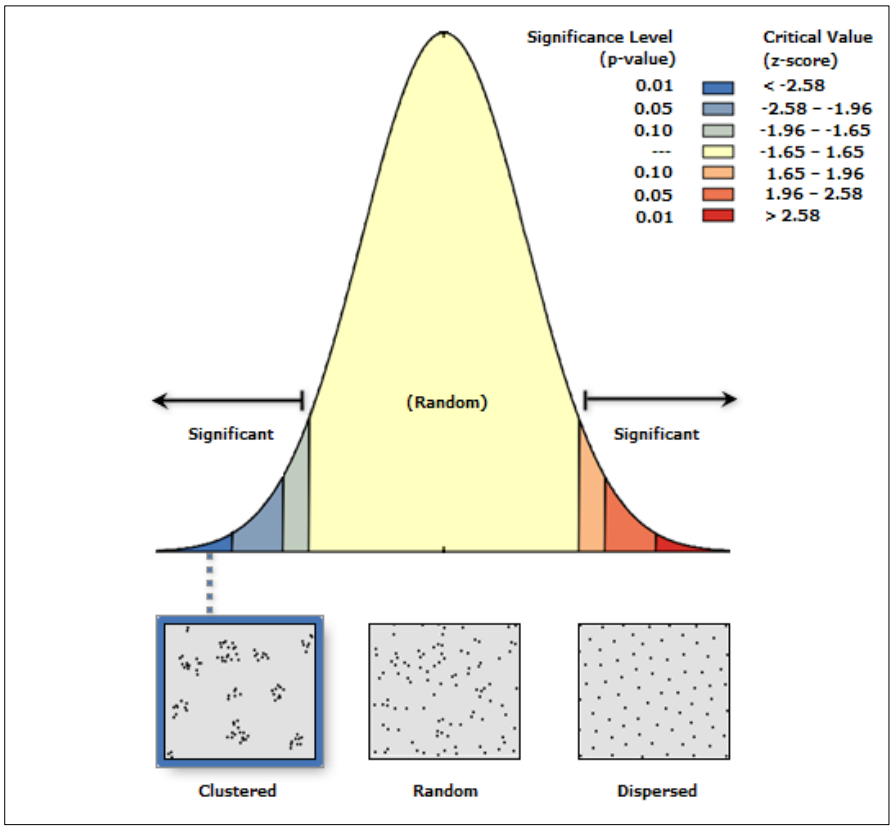


Figure 4 Distribution of waste collection sites within Abakaliki Metropolis

Table 3 The Summary of the Distribution of Waste Collection Sites and Average Nearest Neighbor Results on Different Land-Use

Land-Use	Area (Km^2)	No. Official WCS	No. Unofficial WCS	Ratio of Official WCS	Ratio Of Unofficial WCS	General Ratio	Average Nearest Neighbor Result
Abakaliki metropolis	53.74	84	289	1.56	5.28	6.81	Clustered
Low Density Residential Area	8.00	1	6	0.13	0.75	0.76	Dispersed
Medium Density Residential Area	13.53	0	22	0	1.63	1.63	Clustered
High Density Residential Area	20.83	80	241	3.84	11.57	15.41	Clustered
Administrative Area	2.80	2	1	0.71	0.36	1.07	Dispersed
Commercial Area	0.92	0	8	0	8.70	8.70	Clustered
Public Area	0.16	3	0	18.75	0	18.75	Dispersed

3.2. Implications of Waste Collection Sites Within Abakaliki Metropolis

The results of the analysis carried out in the research were considered, and the results of the distribution of waste collection sites in the metropolis showed that:

- Distribution of waste collection sites within the metropolis increases with residential density.
- Over seventy-seven percent (77%) of the waste collection sites in the metropolis are unofficial.
- The unofficial waste collection sites increase with residential density.

4. Conclusion and recommendation

From the findings of the research, it can be concluded that the waste collections sites were not selected based on empirical studies. This is because over seventy-seven percent of the waste collection sites are unofficial. Indiscriminate dumping of wastes by the residents due to the lack of waste collection facilities has influenced the growing number of unofficial waste collection sites.

GIS can be used as a planning tool for solid waste management. Therefore, this study recommends that:

- GIS for solid waste collection is encouraged to be institutionalized and introduced to the Contractors, municipal and city council officials to ease information management for both spatial and non-spatial data.
- The government should assist waste management agencies such as Ebonyi State Environmental Protection Agency (EBSEPA) by equipping them with more advanced facilities and machinery for a proper waste collection to be carried out within the metropolis.
- Enlightenment campaigns should be organized to educate the residents of the metropolis on the dangers of unsustainable waste management to the environment and the public health.
- The provision of waste collection containers to the residents of the metropolis and not just the commercial business owners will help to reduce random indiscriminate dumping of waste as well as the buildup of waste at the waste collection sites.
- GIS can be used as a planning tool for solid waste management.
- On the other hand, the spatial and non-spatial data can be updated from time to time to support decision-making.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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