



ORIGINAL RESEARCH ARTICLE

Geospatial Assessment of the Spatial Distribution of Municipal Solid Waste Collection Points in Sabon Tasha Ward, Chikun Local Government Area, Kaduna State, Nigeria

Halima Ande Habu¹, Salahu O. Ganiyu¹, Edwin N. Grandpa¹ & Abubakar Aminu Usman²

¹Department of Geography, Nigerian Defense Academy Kaduna, Kaduna State, Nigeria

²Department of Cartography and GIS, Kaduna Polytechnic, Kaduna State, Nigeria

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*Corresponding Author:

E-Mail:

halimaandehabu90@gmail.com

Phone: +234806552991

ABSTRACT

Rapid population growth and unregulated urban expansion in many Nigerian towns have outpaced the capacity of municipal authorities to provide adequate and well-sited waste collection infrastructure. This study applied Remote Sensing (RS) and Geographic Information System (GIS) techniques to identify, map, and analyze the spatial distribution of Municipal Waste Collection Points (MWCPs) in Sabon Tasha Ward, Chikun Local Government Area, Kaduna State. Coordinates of existing collection points were acquired with a handheld GPS device during a field survey and overlaid on high-resolution satellite imagery within an ArcGIS 10.5 environment. Kernel Density Estimation and Nearest Neighbour Analysis were employed to characterize the pattern of distribution, while attribute data on disposal technique were captured for each site. A total of fifty-three (53) MWCPs were identified, of which thirty-nine (39) were unauthorized and fourteen (14) were authorized. Disposal at these points was dominated by open-field dumping (40%), followed by roadside dumping (32%), refuse containers (26%), and abandoned buildings (2%). The southern and central axes of the ward carried the highest concentration of collection points, while the northern axis had the fewest. Nearest Neighbour Analysis returned an R-ratio of 1.09 and a z-score of 1.29, indicating a randomly dispersed distribution pattern rather than a planned or clustered arrangement. The findings suggest that MWCP siting in the study area has been driven largely by ad-hoc resident behaviour rather than deliberate spatial planning by the responsible agency. The study recommends that the Kaduna State Environmental Protection Agency adopt GIS-based site-selection and monitoring tools to guide the planning, authorization, and management of waste collection infrastructure in the ward

Introduction

Solid waste comprises the discarded, unwanted and often hazardous residues of household, commercial, industrial and institutional activity, including refuse

generated within municipal and metropolitan boundaries (USEPA, 2005, as cited in Usman, 2015). In Nigeria, the scale of the solid-waste challenge has prompted the Federal Government to establish an Integrated

Municipal Solid Waste Management Intervention Programme across seven pilot cities, while several state governments, including Lagos, have introduced policies that bring private operators into collection and haulage (Ogwueleka, 2009).

Sabon Tasha Ward, in Chikun Local Government Area of Kaduna metropolis, has experienced sustained population growth driven by its concentration of markets, administrative offices and tertiary institutions. This growth has, in turn, generated demand for waste collection infrastructure that successive local interventions have struggled to satisfy (Kaduna State Environmental Protection Authority (KEPA), 2017). Where the location of waste collection points is not guided by spatial analysis, sites tend to emerge informally, often in locations that are convenient for residents rather than optimal for environmental management. Remote Sensing and GIS offer a practical means of building an inventory of such sites, visualizing their spread across a ward, and testing statistically whether the observed pattern is clustered, dispersed or random.

Although several Nigerian studies have applied GIS to municipal solid waste in cities such as Kano (Naibbi and Umar, 2017), Katsina (Danbuzu et al., 2014) and Enugu (Ugwuishiwi et al., 2020), the recent distribution of authorized and unauthorized waste collection points within Sabon Tasha Ward had not previously been examined using Kernel Density Estimation and Nearest Neighbour Analysis. This study addresses that gap.

The study was guided by the following objectives: (i) to identify the location of Municipal Solid Waste collection sites in the study area; (ii) to determine the type of disposal method employed by residents at each site; and (iii) to establish the spatial

distribution pattern of the collection sites within the ward.

GIS has been described as a powerful set of tools for capturing, storing, retrieving, transforming and displaying spatial data drawn from the real world for a defined purpose (Burrough, 2018), and as a database system in which spatially indexed data support queries about spatial entities (Sumathi et al., 2008). Its application to solid waste management spans site inventory, route optimization and landfill monitoring (Kontos et al., 2003), and its use has been documented in jurisdictions ranging from Montgomery County, Maryland, since 1996 (Chen, 2004), to a number of Nigerian metropolitan areas.

Naibbi and Umar (2017) combined QUICKBIRD imagery, GPS-collected coordinates and topographic mapping to analyze the spatial distribution of 300 waste disposal sites in Kano metropolis, finding a fairly even overall distribution but with clustering toward the city centre, and noting that around 80% of sites sat close to roads, settlements or water bodies. Danbuzu et al., (2014) inventoried 741 collection points in Urban Katsina using Arc GIS, of which only about 13% were designated, and reported Nearest Neighbour R-values indicating clustering and randomness across different sub-areas. Fredrick (2016) used field survey and ArcGIS to map dumpsites in Yelwa Tsakani, Bauchi State, finding that a large majority of the waste generated was not properly managed by the responsible agency. Usman (2015) mapped designated and undesignated dumpsites in Doka and Gabasawa, Kaduna, using buffer analysis at 200 m, 300 m and 400 m to assess proximity to residences. Ugwuishiwi et al., (2020) identified 177 dumpsites in Enugu using handheld GPS and Arc GIS 10.2, distinguishing legal from illegal sites and proposing an optimum bin-distribution scheme. Collectively, this body of work

demonstrates the value of GPS/GIS integration for building a defensible spatial inventory of waste infrastructure, but also shows that the specific pattern of distribution differs from one urban area to another, underscoring the need for a locally grounded analysis of Sabon Tasha Ward.

Materials and Methods

The Study Area

Sabon Tasha Ward lies between latitudes 10°39'00" and 10°42'00" North and longitudes 5°4'00" and 7°4'00" East, and shares boundaries

with Narayi to the north-west, Rido to the east, Yelwa to the west and Kakau to the south-west, covering an area of approximately 28.47 km². The ward experiences a tropical wet-and-dry climate typical of the Guinea Savanna zone, with a dry season lasting from November to March and a wet season from May to October. Its population, projected at 88,520 for 2020 using an annual growth rate of 4.3% applied to the 2006 census figure of 48,917 (Kaduna State Bureau of Statistics 2020).

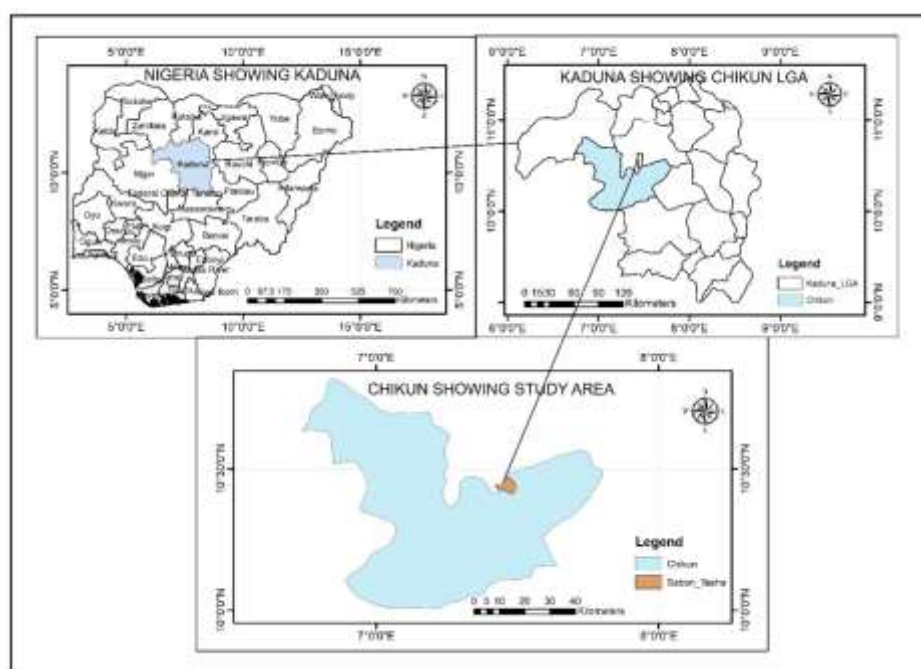


Figure 1: Map of the Study Area

Data Collection and Analysis

Data for the spatial component of the study were drawn from both primary and secondary sources. Primary data consisted of the geographic coordinates of existing waste collection points, obtained with a handheld GPS unit during a reconnaissance and field survey, together with site photographs. Secondary data comprised satellite imagery and the administrative boundary map of the ward, sourced from the Kaduna Geographic Information Service (KADGIS). Analysis was carried out on a personal computer using

ArcGIS 10.5, with Microsoft Excel used to organize the coordinate data prior to import.

Geo-locational mapping was used to plot each identified MWCP onto the digitized base map, with an attribute table created in ArcGIS to record the category (authorized or unauthorized), disposal method and address of every site. Kernel Density Estimation was then applied to characterize the clustering intensity of points across the ward: a smoothly curved surface was fitted over each point, and the density at each output raster cell computed

by summing the contributing kernel surfaces. Nearest Neighbour Analysis was subsequently used to test statistically whether the observed point pattern departed from complete spatial randomness, generating both an observed-to-expected distance ratio (R) and an associated z-score.

Results and Discussion

Geographical Location and Number of Collection Points

A total of fifty-three (53) Municipal Waste Collection Points were identified in Sabon Tasha Ward. Of these, fourteen (26%) were

authorized sites recognized by the Kaduna State Environmental Protection Agency (KEPA), located predominantly along roads in the southern part of the ward, while thirty-nine (74%) were unauthorized sites concentrated in the northern and central parts of the ward. Field observation showed that unauthorized points were frequently sited on drainage channels, along major roads, and close to markets, schools and open spaces, contributing to eyesore, offensive odour and reduced air quality in their immediate surroundings.

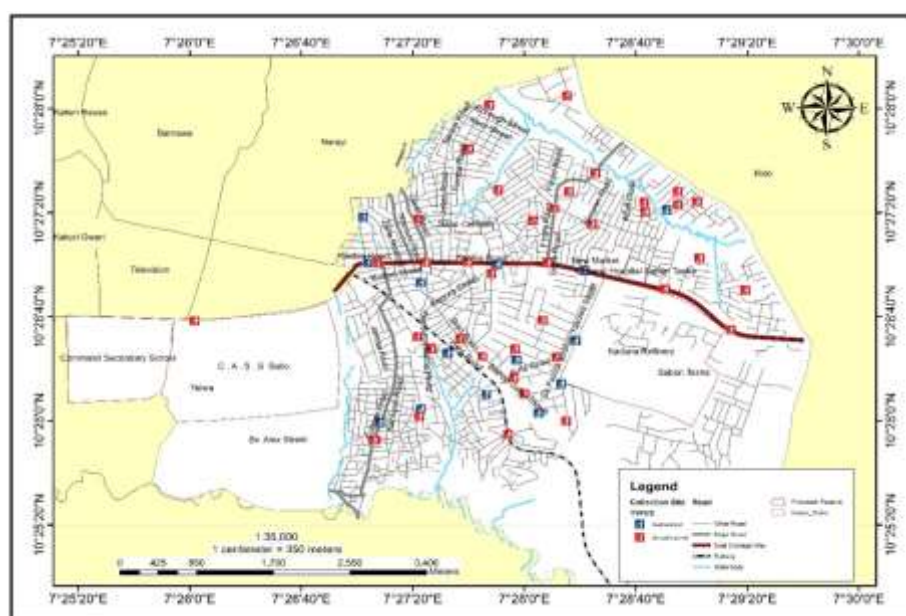


Figure 2: Location of Existing Waste Collection Points

Table 1: Distribution of Municipal Waste Collection Points by Authorization Status

Category	Number of Sites	Percentage (%)
Authorized	14	26
Unauthorized	39	74
Total	53	100

The prevalence of unauthorized points is consistent with findings from other Nigerian towns; Danbuzu et al., (2014), for example, found that only around 13% of collection points inventoried in Urban Katsina were designated. In Sabon Tasha Ward, the

shortage of authorized sites relative to the ward's growing population appears to be a key driver of informal dumping, as residents' resort to the nearest available open space rather than travelling to a recognized collection point.

Disposal Method

The disposal technique associated with each collection point was recorded and classified into open-field disposal, roadside disposal and refuse containers (including both government-provided and community-provided units), and abandoned buildings. Open-field disposal

accounted for the largest share of sites (40%, equivalent to 21 points), followed by roadside disposal (32%, equivalent to 17 points) and refuse containers (26%, equivalent to 14 points), while abandoned buildings accounted for the smallest share (2%, equivalent to 1 point).

Table 2: Distribution of Waste Collection Points by Disposal Method

Disposal Method	Number of Sites	Percentage (%)
Open field	21	40
Roadside	17	32
Refuse containers	14	26
Abandoned Buildings	1	2

Areas around Sabo GRA, which benefits from a more structured residential layout, recorded a comparatively higher share of refuse containers, whereas neighbourhoods such as Unguwar Sabo and Unguwan Bulus, characterized by market and commercial

activity, relied more heavily on roadside disposal. The dominance of open-field disposal is of particular concern, since it carries the greatest risk of uncontrolled waste spillage, land degradation and air pollution relative to contained methods.

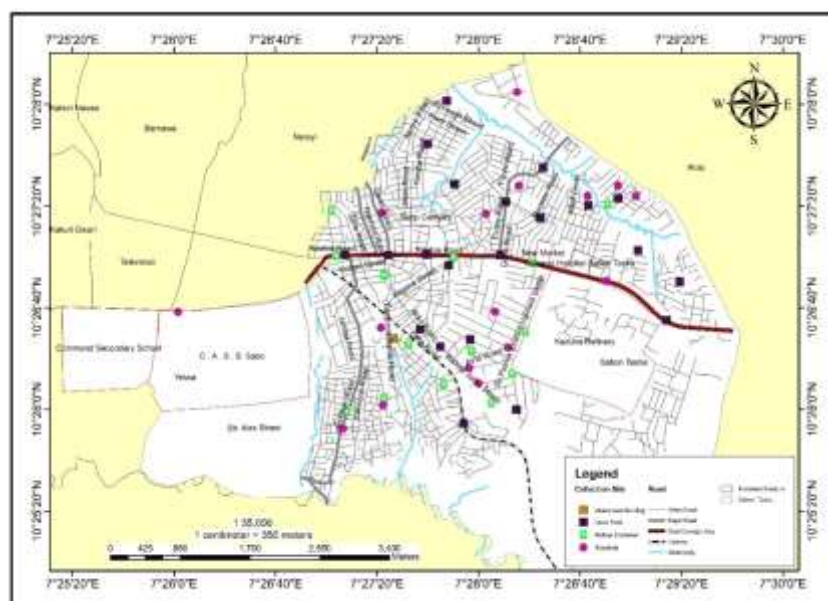


Figure 3: Distribution of Waste Disposal Method

Spatial Distribution Pattern

Kernel Density mapping showed that the southern and central axes of Sabon Tasha Ward carried markedly higher concentrations of MWCPs than the northern axis, a pattern

attributable to the presence of markets, motor parks and higher-density residential development in those areas.

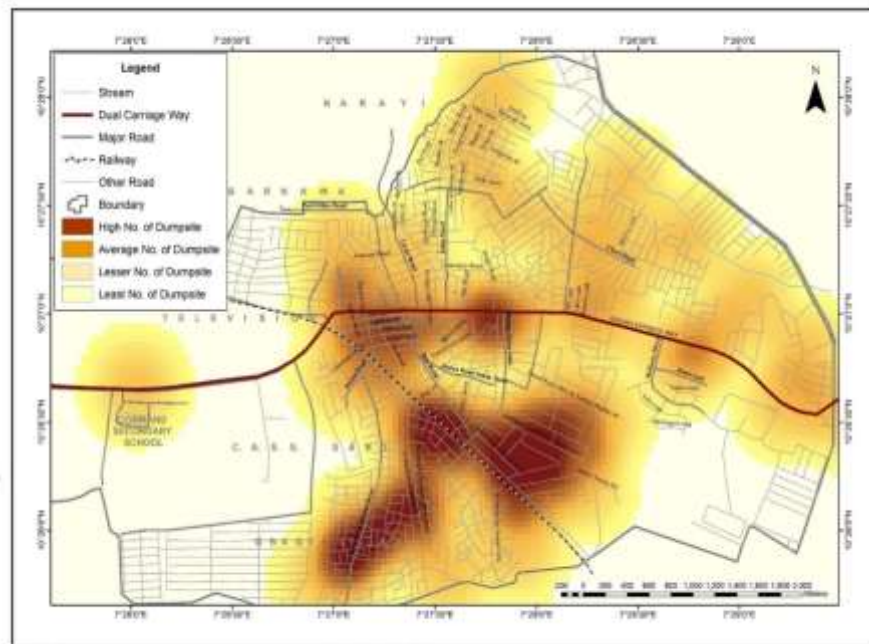


Figure 4: Spatial Distribution Pattern

Nearest Neighbour Analysis of the point pattern returned an R-ratio of 1.09 and a z-score of 1.29. Because this z-score falls within the range associated with a random pattern (rather than the significant clustering or significant dispersion indicated by more

extreme z-score), the distribution of MWCPs in the study area is interpreted as randomly patterned. This implies that the siting of collection points has largely followed ad-hoc resident preference rather than a deliberate, standardized siting policy.

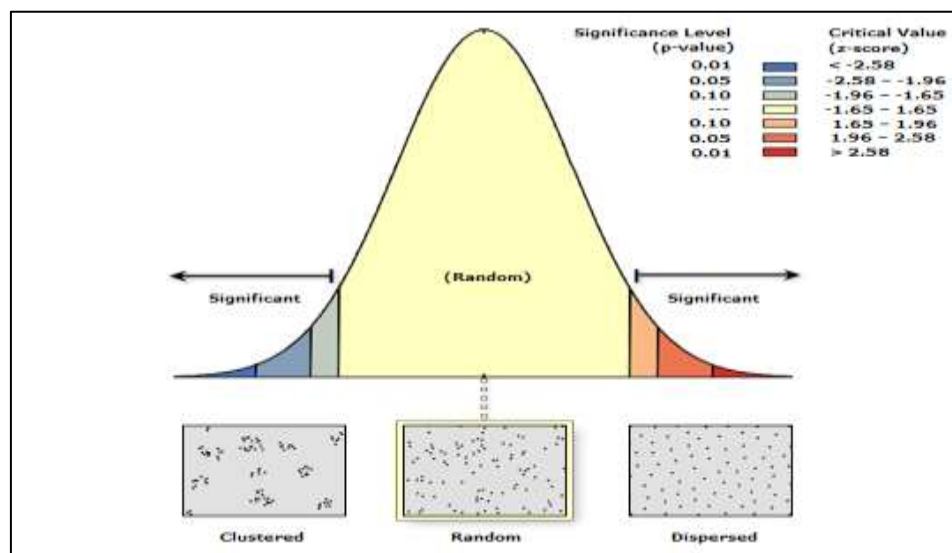


Figure 5: Nearest Neighbor Analysis of Existing Waste Collection Points

This result differs from the more strongly clustered pattern reported for Urban Katsina

by Danbuzu, Tanko, Ibrahim and Ahmed (2014, R-values of 0.67, 0.64 and 0.89 across

categories), underscoring that the spatial logic governing informal waste-point emergence is locally contingent and cannot be assumed to generalize from one town to another. It reinforces the case for GIS-based spatial planning tailored to each administrative ward rather than the uniform replication of siting standards across jurisdictions.

Conclusion and Recommendations

The integration of GPS field survey with GIS-based spatial analysis in Sabon Tasha Ward revealed 53 Municipal Waste Collection Points, most of which (74%) are unauthorized, and confirmed a randomly patterned distribution concentrated in the ward's southern and central axes. Open-field disposal, the least hygienic of the four methods identified, was the most prevalent, pointing to a shortfall in properly contained, authorized infrastructure relative to demand.

Based on these findings, it is recommended that: (i) the Kaduna State Environmental Protection Agency and related bodies expand the network of authorized, standard-compliant collection points, particularly in the underserved northern axis; (ii) GIS and Remote Sensing techniques be formally adopted by the relevant agencies as routine tools for siting, monitoring and managing waste collection infrastructure; and (iii) the spatial inventory generated by this study be maintained and updated periodically to support evidence-based planning and to serve as a reference for further research on solid waste management in the ward and comparable localities.

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