

Geospatial Assessment of Legal and Illegal Solid Waste Dumping Sites in Sokoto Metropolis, Nigeria

Ibrahim Abubakar Audu ¹; Ali Badema ²; and Alhaji Abatcha Bulama ³

¹Department of Environmental and Resources Management, Usmanu Danfodiyo University, Sokoto, Sokoto State. ²Department of Geography, Umar Sulaiman College of Education Gshua, Yobe State. ³Department of Surveying and Geoinformatics, The Federal Polytechnic Damaturu, Yobe State.

Corresponding author: ibrahim.audu@udusok.edu.ng

DOI: <https://doi.org/10.62154/ajesre.2025.021.01011>

Abstract

This study presents a geospatial assessment of legal and illegal solid waste dumping sites in Sokoto Metropolis, Nigeria. The aim was to create an inventory of existing dumping sites, classify them as authorized or unauthorized, and analyze their spatial distribution patterns. Data were collected through a field survey using a Garmin GPSMAP 76CSx receiver to record the coordinates of each site. Attributes such as location, size, and legal status were documented, and selected sites were photographed for visual validation. The data were processed and analyzed in ArcGIS 10.8, where georeferencing, digitization, and spatial statistical tools were applied. A total of 61 solid waste dumping sites were identified across the metropolis. Out of these, 14 (23%) were legal and 47 (77%) were illegal. The Average Nearest Neighbor (ANN) analysis revealed that legal dumping sites were spatially dispersed ($z = 63.19$, $p < 0.001$), while illegal dumping sites were highly clustered ($z = -6.03$, $p < 0.001$). This distribution indicates that residents are compelled to create unauthorized disposal points due to the insufficient number and poor accessibility of government-approved sites. Geographic Information Systems (GIS) play a vital role in urban waste policy and planning by identifying, analyzing, and optimizing the spatial distribution of dumpsites, thereby supporting evidence-based and sustainable decision-making. The study concludes that illegal dumping dominates waste disposal practices in Sokoto Metropolis, largely due to inadequate infrastructure and weak enforcement mechanisms. It recommends the establishment of additional legal dumpsites guided by population distribution, the adoption of GIS-based planning tools, stricter enforcement of environmental regulations, and continuous updating of spatial data to support sustainable waste management.

Keywords: GIS, Geospatial Analysis, Solid Waste Management, Dumpsite Distribution, Sokoto Metropolis.

Introduction

Solid waste management continues to pose a significant environmental challenge for rapidly urbanizing cities, especially in developing countries. Solid wastes consist of diverse materials such as food remnants, paper, textiles, plastics, construction debris, biomedical waste, and household hardware (Hosetti & Kumar, 1998). Unlike liquid or gaseous wastes, solid waste persists in the environment, often leading to pollution, aesthetic degradation, and health risks when improperly managed (Tirusew & Amare, 2013). Poor disposal

practices have been associated with contamination of soil and water resources, emission of greenhouse gases such as methane from anaerobic decomposition, and the spread of vector-borne diseases (Rahman et al., 2008).

Globally, waste generation has been increasing in response to urban expansion, industrial growth, and changing consumption patterns. UNEP (2022) estimates that approximately 11.2 billion tons of solid waste are collected annually worldwide, with developing countries struggling most with effective management. Nigeria, with a population exceeding 170 million, generates about 35 million tons of waste annually, of which only 10–30% is collected (Bakare, 2016). Consequently, indiscriminate disposal remains common across Nigerian cities, exacerbating flooding, degrading urban aesthetics, and creating serious health concerns (Ahmed et al., 2024).

Recent studies have highlighted the persistence of these challenges.

In Sokoto, waste management has been described as inefficient, with residents often resorting to informal and illegal dumping despite the presence of designated collection points (Ahmed et al., 2024). Similar findings have been reported in Abeokuta, where the geospatial distribution of dumpsites was shown to be influenced by socioeconomic factors such as population density, income level, and awareness of waste management practices (Ogunleye et al., 2025). Moreover, geospatial tools have been successfully applied in other Nigerian cities, such as Lagos, where GIS-based multi-criteria decision analysis was used to identify suitable landfill sites under the pressures of urban land conversion (Adedayo et al., 2024).

Beyond spatial distribution, the environmental consequences of uncontrolled dumping have also been widely documented. Groundwater contamination from leachates has been reported around dumpsites in Ogun State (Oladipo et al., 2024), while soil degradation and heavy metal accumulation were observed around the Orji municipal dumpsite in southeastern Nigeria (Chukwu et al., 2024). These findings reinforce the urgent need for systematic monitoring of both legal (authorized) and illegal (unauthorized) disposal sites.

In Sokoto Metropolis, rapid population growth and urban expansion since the creation of the state in 1976 have intensified solid waste generation (Eniolorunda & Dankani, 2012). While the Sokoto Environmental Protection Agency (SEPA) has established official collection points, illegal dumpsites remain widespread, often occupying open spaces, roadsides, and drains. This not only worsens flooding during the rainy season but also provides breeding grounds for vectors of diseases (Zakariya'u, 2010).

Given these challenges, Geographic Information Systems (GIS) offer a powerful tool for assessing the spatial distribution of dumpsites, identifying clustering patterns, and distinguishing between legal and illegal disposal sites. By applying geospatial analysis, this study seeks to evaluate the spatial distribution of public solid waste dumping sites in Sokoto Metropolis. Specifically, it aims to create an inventory of existing dumpsites, classify them as legal or illegal, and analyze their spatial patterns. The findings are expected to provide policymakers, urban planners, and environmental managers with evidence-based insights

to improve waste management strategies and reduce the environmental and health risks associated with indiscriminate dumping.

Despite several studies addressing solid waste management challenges in Nigeria, there remains a limited understanding of how legal and illegal dumping sites spatially interact within medium-sized Sahelian cities such as Sokoto. Most previous research has focused on general waste characterization, management practices, or environmental impacts, with minimal attention given to the spatial dimension of waste distribution and accessibility to legal disposal points. This knowledge gap constrains effective policy formulation and spatially responsive urban planning. Therefore, this study seeks to assess the spatial distribution of both legal and illegal solid waste dumping sites in Sokoto Metropolis using Geographic Information Systems (GIS). The specific objectives are to create an inventory of existing dumpsites, classify them based on legal status, and analyze their spatial distribution patterns. The study contributes to environmental spatial planning in Nigeria by demonstrating the application of GIS as a decision-support tool for identifying underserved areas, optimizing site allocation for waste management infrastructure, and providing empirical evidence to guide sustainable urban waste policy formulation.

Methodology

The Study Area

Sokoto Metropolis is the administrative center of Sokoto State located between Latitudes $12^{\circ}46'N$ to $13^{\circ}08'N$ and Longitudes $5^{\circ}14'E$ to $5^{\circ}30'E$, at an average elevation of 272 m above sea level. The metropolis has an estimated population of about 503,256 people as of 2015, with an annual growth rate of 3 percent (NPC, 2006). It comprises four Local Government Areas Sokoto South, Sokoto North, Wamakko, and part of Kware and lies within the arid and semi-arid region of northwestern Nigeria.

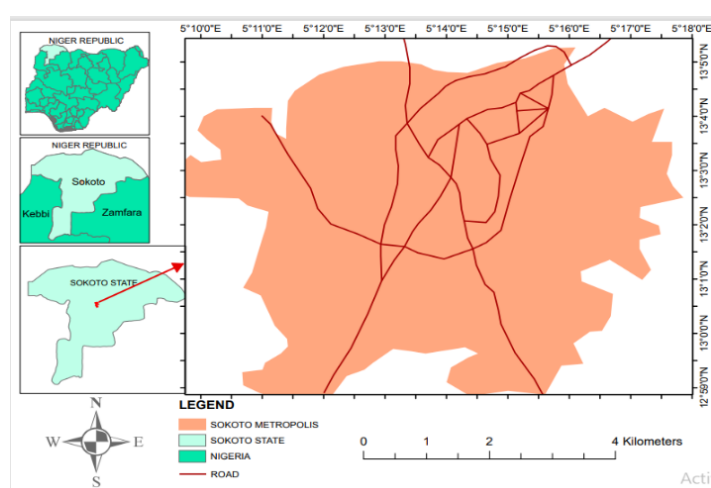


Figure 1: Study Area

Source: Adopted from Sokoto State administration map.

Research Design

This study employed a geospatial research design to assess the distribution of public solid waste dumping sites within Sokoto Metropolis, Nigeria. The approach combined field data collection using Global Positioning System (GPS) technology with spatial analysis in a Geographic Information System (GIS) environment. The design enabled the identification, classification, and spatial pattern analysis of both legal (authorized) and illegal (unauthorized) dumpsites across the study area.

Data Collection

Field data were collected between January and March 2025, a period selected to coincide with the dry season when dumpsites are most visible and accessible. A Garmin GPSMAP 76CSx receiver was used to capture the geographic coordinates (northing and easting) of each dumpsite. For every site identified, additional information was recorded, including address or descriptive location, approximate size (m²), and operational status (legal or illegal).

Classification into legal (authorized) and illegal (unauthorized) categories was based on verified institutional data and field confirmation. Specifically, dumpsites officially recognized and managed by the Sokoto Environmental Protection Agency (SEPA) were classified as legal, while those not appearing in SEPA's 2024 operational data list and identified through field observation or community reporting were designated illegal. Verification involved direct consultation with SEPA field officers and cross-referencing with SEPA's waste management inventory to ensure reliability of classification.

Data Processing

An administrative map of Sokoto Metropolis was digitized and geo-referenced in ArcGIS 10.8 using the WGS 1984 / UTM Zone 31N (EPSG: 32631) coordinate reference system to ensure accurate spatial alignment. Thematic layers such as neighborhoods, administrative boundaries, and dumpsite locations were digitized and integrated into a single geospatial database. The GPS coordinates collected during fieldwork were imported into ArcGIS and linked with the corresponding site attributes (address, size, and legal status) to create a comprehensive spatial dataset of waste disposal points across the metropolis.

Data Analysis

Spatial analysis was performed in ArcGIS 10.8 using the Average Nearest Neighbor (ANN) statistical tool to examine the spatial patterns of legal and illegal dumpsites. The ANN tool computes the ratio of observed mean distance to expected mean distance and produces a z-score and p-value to determine whether the distribution is clustered, random, or dispersed.

To ensure robustness, z-scores were validated through cross-comparison with randomly simulated point datasets generated within the same boundary of Sokoto Metropolis.

Additionally, a sensitivity analysis was conducted by re-running the ANN test after applying a $\pm 5\%$ variation to coordinate precision to assess the stability of clustering and dispersion results. The results showed no significant variation, confirming the reliability of the spatial pattern interpretation.

Results and Discussion

Inventory of Major Solid Waste Dumping Sites in Sokoto Metropolis

Field inventory and geospatial capture yielded 61 public solid-waste dumping locations across Sokoto Metropolis (Table 1). Sites ranged from small household-scale piles ($<100 \text{ m}^2$) to larger open dumping grounds ($>500 \text{ m}^2$) clustered near major open spaces and some arterial roads, such as those located near Shehu Kangiwa Square and Gidan Dare. A systematic on-ground inventory such as this provides the essential baseline for spatial analyses and planning, and parallels other Nigerian city inventories that combine GPS field surveys with GIS mapping to characterise the distribution and physical attributes of dumpsites (Ike, Ogechi & Chibunna, 2022; Olayiwola & Suleiman, 2022). The spatial inventory therefore provides a comprehensive database of waste disposal points within the metropolis.

Table 1

Inventory of major existing solid waste dumping sites within Sokoto metropolis

S/N	Address	Northing	Easting	Size (m^2)	Category
1	Adjacent to Sidi mammanasarakkawa, Koko road	742711	1442663	62.206	Illegal
2	Opposite Muhammad Bankanu Primary School, Koko road	742891	1442930	102.9	Illegal
3	Adjacent to Ministry for youth, sport and development, Mai kahon karo road	743269	1442997	374.09	Legal
4	Shehu kangiwa square, Filin sukuwa	743166	1443327	2136.8	Illegal
5	Shehu kangiwa square, Filin sukuwa	742742	1443198	2991.1	Illegal
6	Behind Shehu kangiwa square, maikahon karo road	743057	1443567	11.547	Legal
7	Almustapha road (refuse bunker)	743343	1444614	83.336	Legal
8	Garkansarkinsharabai refuse bunker, sultan bello road	743535	1445559	5.5612	Legal
9	Adjacent to Alu Jumu'at mosque, Western bypass	742305	1446434	93.464	Illegal
10	Western bypass	742782	1446545	9.2586	Illegal
11	Western bypass	742823	1446558	82.154	Illegal
12	Western bypass	742902	1446579	18.06	Illegal
13	Western bypass	742880	1446549	14.123	Illegal
14	Western bypass	743181	1446688	142.44	Illegal
15	Western bypass	743817	1447093	4.144	Illegal
16	Gidan Igwe	739027	1445806	2.8709	Illegal
17	Gidan Igwe	738886	1446190	85.591	Illegal
18	Gidan Igwe	738848	1446169	5.8641	Illegal
19	Gidan Igwe	738566	1446005	0.657	Illegal
20	Yabo road	740023	1445152	9.2163	Illegal
21	Iraqi refuse bunker, Sultan Abubakar road	743721	1445424	1.0283	Legal
22	Garkan dalatu refuse bunker, Sultan Abubakar road	743721	1444209	68.963	Legal
23	Behind Magajin Rafi Model primay school, Wurinyanshanu	744022	1444377	122.26	Legal

S/N	Address	Northing	Easting	Size (m²)	Category
24	GangarenTudunwada	744599	1444468	10.625	Illegal
25	Minnata area	745168	1443749	21.483	Illegal
26	Minnata area	745012	1443682	20.847	Illegal
27	Behind Ibrahim Gasau primary school, Minnata area	744613	1443352	125.62	Legal
28	Tudunwadaguestin along Lamido Adamawa road	744139	1444692	30.147	Legal
29	Dalatu road, tudunwada refuse bunker	744509	1444959	17	Legal
30	Hokon Idi refuse bunker	744981	1445554	33.629	Legal
31	Old kara market along mayujo road	741395	1445590	53.31	Illegal
32	Kasuwanyankowa refuse bunker	741412	1445750	31.128	Legal
33	Gidan Dare	740017	1444500	539.29	Illegal
34	Gidan Dare	739880	1444227	6.9844	Illegal
35	Kware road, gawannama area refuse bunker	741088	1441673	32.335	Legal
36	Yawuri road	741294	1440811	1.1728	Illegal
37	Yawuri road	741284	1440746	64.498	Illegal
38	Yawuri road	741361	1440731	21.635	Illegal
39	Yawuri road	741286	1440621	13.478	Illegal
40	Yawuri road	741335	1440555	36.755	Illegal
41	Masallacina 3	743864	1440310	48.983	Illegal
42	Masallacina 3	743935	1440169	0.893	Illegal
43	Trade fair road, old airport area	744272	1439851	32.534	Legal
44	Trade fair road, old airport area	744634	1439995	1.4411	Illegal
45	Adjacent to Ifeoma etensionguestin, old airport area	744592	1439804	34.523	Illegal
46	Opposite Sokoto trade fair complex	744757	1439918	6.324	Illegal
47	Old Airport area	745118	1439885	0.7548	Illegal
48	Opposite AlqalamIslamiya, Mabera area	744146	1440877	15.067	Illegal
49	Mabera area	743930	1441238	7.2161	Illegal
50	Mabera area	744317	1441879	24.408	Illegal
51	Mabera area	744401	1442414	15.638	Illegal
52	Mabera area	744706	1442453	20.307	Illegal
53	Mabera area	743445	1442378	108.19	Illegal
54	Opposite Darrul-fiquiwa-tahfizil Qur'an, koko road	742555	1443054	0.5901	Illegal
55	Koko road area	742729	1442511	0.2598	Illegal
56	Koko road area	742845	1442507	0.1589	Illegal
57	Koko road area	742961	1442418	3.98	Illegal
58	Koko road area	743027	1442486	4.897	Illegal
59	Koko road area	742928	1442650	8.576	Illegal
60	Behind Buhari DanshehuJumu;at Mosque	742940	1442772	37.054	Illegal
61	Koko road area	742763	1442751	5.148	Illegal

Source: Author's field work, 2025.

Such inventories are important because they reveal not only the number and size of sites but also attributes (access, containment, proximity to watercourses and settlements) that determine environmental and public-health risk and inform siting and service decisions (Ichipi & Senekane, 2023). Figure 2 (Public Solid Waste Dump Sites) presents the spatial distribution of all identified dumpsites, showing their spread across the four local government areas that make up Sokoto Metropolis (Sokoto North, Sokoto South, Wamakko, and part of Kware).

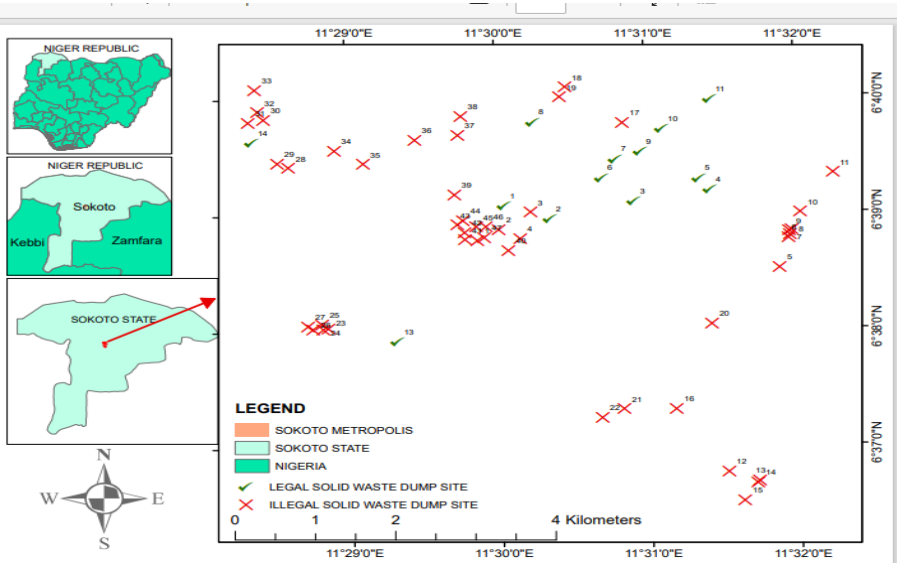


Figure 2: Public Solid Dump Site

Source: Author’s Analysis, 2025.

Legal and Illegal Solid Waste Dump Sites

The dumpsites were categorized into two groups, legal (authorized) and illegal (unauthorized). Legal sites refer to officially designated refuse bunkers established by government agencies, while illegal sites represent informal or unauthorized locations created by residents. Out of the 61 mapped locations, 14 (23%) were officially recognized/authorized sites while 47 (77%) were informal or illegal (Table 2). This imbalance between legal and illegal sites is consistent with studies in other Nigerian contexts where informal disposal is found to outnumber authorized infrastructure because of gaps in municipal coverage and service delivery (Ike et al., 2022; Syafrudin et al., 2023). Informal sites observed during the survey typically lacked containment, were sited near residential clusters or marginal lands, and showed signs of repeated, long-term use characteristics that increase the likelihood of leachate generation, vector breeding, and localised contamination (Ichipi & Senekane, 2023).

Table 2

Categories of solid waste dumping sites

Categories	Number of Dump Sites	Percentage (%)
Legal (authorized)	14	23
Illegal (unauthorized)	47	77
Total	61	100

Source: Author’s analysis, 2025.

Similarly, Ogunleye et al. (2025) in Abeokuta, Nigeria, found that socioeconomic factors such as low awareness and poor enforcement contribute significantly to illegal dumping. The predominance of illegal dumpsites in Sokoto may therefore be attributed to the inadequate number of legal collection points, weak enforcement of environmental laws, and entrenched community practices of indiscriminate dumping. This is consistent with earlier reports by SEPA (2004), which highlighted the proliferation of unauthorized dumps within neighborhoods, drains, and open spaces.

Spatial Distribution Patterns of Dumpsites

Average Nearest Neighbour (ANN) analysis produced contrasting spatial patterns for authorized versus unauthorized sites (Table 3 and Table 4). Legal/authorized dumpsites were highly dispersed (nearest neighbor ratio ≈ 9.83 , $z = 63.19$, $p < 0.001$), indicating these facilities are widely spaced relative to demand. Large positive z-scores and ratio $\gg 1$ (legal dumps dispersed). This signals inequitable placement of legal infrastructure: many residential zones lie far from legal disposal points, creating "service deserts." Planning responses include re-siting or adding legal collection points using multi-criteria siting (population density, road access, environmental constraints) an approach successfully applied in Lagos and other Nigerian case studies (Tella et al., 2024; Ike et al., 2022).

Table 3

Summary of Average Nearest Neighbor Statistics of legal public dump sites

Average Nearest Neighbor Summary	
Observed Mean Distance:	93341.3026 Meters
Expected Mean Distance:	9497.0521 Meters
Nearest Neighbor Ratio:	9.828450
z-score:	63.194512
p-value:	0.000000

Source: Author's Analysis, 2025.

By contrast, illegal dumpsites exhibited significant clustering (nearest neighbor ratio ≈ 0.54 , $z = -6.03$, $p < 0.001$), indicating concentrated hotspots of unauthorized disposal activity. Negative z-scores and ratio < 1 (illegal dumps clustering). These indicate spatial concentration of unmet disposal demand neighbourhoods where households face barriers (distance, cost, scheduling) to using legal facilities. Practically, they should be used to prioritise short-term interventions (mobile collection rounds, temporary skip bins, and focused clean-ups) and medium-term infrastructure placement. Du et al. (2023) demonstrated how coupling road-level risk models with hotspot mapping enables targeted monitoring and patrols, which is more cost-effective than blanket enforcement. These patterns mirror findings from recent geospatial research in West Africa and beyond. In Aba Municipal, for example, Ike et al. (2022) showed strong associations between

dumpsite occurrence, road proximity and dense residential settlements with illegal sites clustering where services are weak or absent. Multi-criteria suitability studies in Lagos (Tella et al., 2024) and site-assessment work in other Nigerian towns (Olayiwola & Suleiman, 2022) report similar mismatches between where legal facilities are placed and where population-driven demand is highest. The dispersed pattern of legal sites therefore commonly reflects service allocation decisions that do not align with current population distribution or informal settlement growth, while clustering of illegal dumps signals pockets of unmet demand and governance gaps (Tella et al., 2024; Ike et al., 2022).

Table 4
Summary of Average Nearest Neighbor Statistics of Illegal public dump sites

Average Nearest Neighbor Summary	
Observed Mean Distance:	258.9995 Meters
Expected Mean Distance:	479.1482 Meters
Nearest Neighbor Ratio:	0.540542
z-score:	-6.025958
p-value:	0.000000

Source: Author’s Analysis, 2025.

This clustering pattern indicates that illegal dumpsites are concentrated in particular neighborhoods, often located close to one another, especially in densely populated areas with limited access to legal disposal facilities. The clustering reflects residents’ tendency to establish unauthorized dumping points near their households or along roadsides and drains for convenience. Figures 3 and 4 illustrate the spatial distribution of legal and illegal dumpsites, respectively. Legal sites are widely dispersed, while illegal sites appear as concentrated clusters, confirming the ANN statistical results.

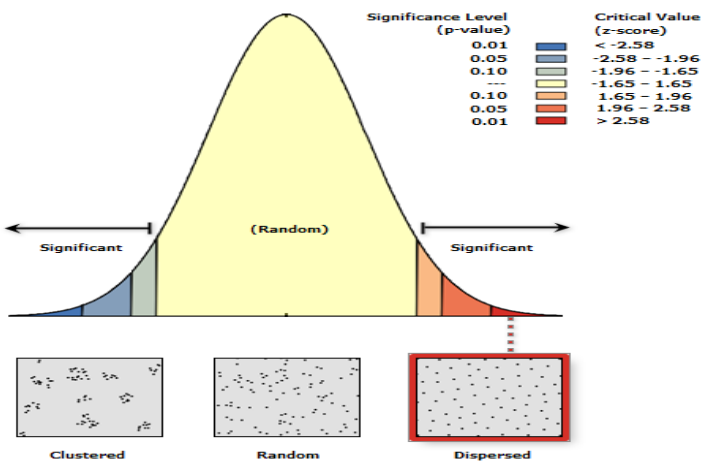


Figure 3: Pattern of legal public dump sites distribution

Source: Author’s Analysis, 2025.

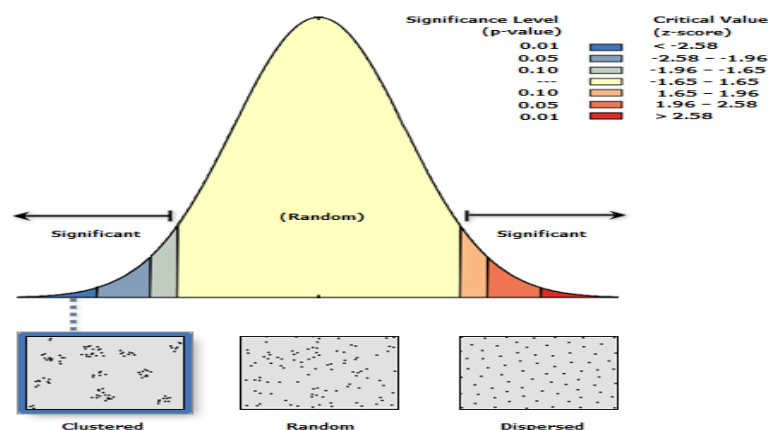


Figure 4: Pattern of Illegal Dump Sites Distribution

Source: Author's Analysis, 2025.

While proximity to roads and to existing dumps contributes to where people dump, clustering of illegal dumpsites is driven by multiple interacting factors such as socio-economic constraints. Low-income households frequently lack the ability to pay for private collection or to transport waste to distant legal facilities. Studies using spatial regression and socio-economic overlays show that lower income, higher household density and limited access to paid services significantly increase reliance on informal disposal (Syafudin et al., 2023; Ichipi & Senekane, 2023). When municipal collection is irregular, infrequent, or absent particularly at urban peripheries residents create informal dumps near their residences. ANN clustering therefore frequently signals not merely a preference for convenience but a response to insufficient and unreliable service provision (Ike et al., 2022; Tella et al., 2024).

Weak monitoring, understaffed environmental agencies, and low enforcement capacity allow illegal dumping to persist and become entrenched in specific localities (Ichipi & Senekane, 2023). Where enforcement is inconsistent, hotspots develop and stabilize because the perceived cost of illegal dumping is low. Urban fringe land, drainage corridors, vacant lots and other transitional spaces are attractive for illegal disposal because they are less controlled. Suitability analyses commonly show these zones as high-risk for informal dumps unless explicitly planned and monitored (Tella et al., 2024; Olayiwola & Suleiman, 2022).

These drivers interact, for example, high population density raises local waste generation, while low service frequency amplifies the effect, producing persistent clusters even when authorized sites exist elsewhere.

Conclusion

This study applied geospatial techniques to assess the distribution of legal and illegal solid waste dumping sites in Sokoto Metropolis, Nigeria. A total of 61 dumping sites were identified, of which 14 (23%) were legal and 47 (77%) were illegal. The analysis revealed that legal sites are widely dispersed, making them less accessible to many residents, while illegal sites are highly clustered, reflecting residents' tendency to create nearby informal dumps due to inadequate provision of legal disposal facilities.

The Average Nearest Neighbor (ANN) analysis confirmed these patterns: legal sites exhibited a dispersed distribution ($z = 63.19$, $p < 0.001$), while illegal sites showed a clustered distribution ($z = -6.03$, $p < 0.001$). These findings highlight the imbalance between official waste management infrastructure and community disposal practices. The dominance of illegal dumpsites indicates a failure of spatial planning and enforcement, which in turn contributes to health hazards, flooding, and environmental degradation. The study demonstrates the usefulness of GIS as a planning tool for evaluating and managing waste disposal systems.

Recommendations

Based on the findings, the following recommendations are proposed:

1. Government agencies, particularly the Sokoto Environmental Protection Agency (SEPA), should establish additional legal collection points across the metropolis. The siting of new facilities should be guided by population density, settlement patterns, and accessibility, ensuring that residents are within a reasonable distance of disposal facilities.
2. Spatial decision-support tools such as GIS and remote sensing should be institutionalized for urban waste management. These tools will enable planners to identify underserved areas, optimize the location of new dump sites, and continuously monitor the spatial dynamics of waste disposal.
3. While expanding infrastructure is critical, stricter enforcement of waste management regulations is also required to discourage illegal dumping. At the same time, public education campaigns should be intensified to raise awareness about the health and environmental risks associated with indiscriminate disposal.
4. Spatial and non-spatial data on waste generation and disposal should be updated periodically. This will ensure that decision-making reflects current realities and that interventions remain relevant as the city continues to expand.

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