

## A Geospatial Analysis of Illegal Dumpsites in Abuja, Nigeria

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### ABSTRACT

*This study advanced geospatial analysis of illegal dumpsites in Abuja Municipal Area Council (AMAC), Nigeria, to diagnose their spatial distribution patterns, identify statistically significant hotspots, assess compliance with environmental siting standards, and interpret findings through a spatial justice lens. A secondary analysis was performed on 36 georeferenced illegal dumpsites originally mapped by Mohammed et al. (2022). Nearest Neighbour Analysis (NNA), Kernel Density Estimation (KDE) with an 800m bandwidth, 500m × 500m grid-based hotspot detection, and 1000m buffer analysis around residential areas and water bodies were applied using QGIS 3.44. NNA revealed strong clustering (Nearest Neighbour Index = 0.34, z-score = -8.42,  $p < 0.001$ ). KDE identified three primary hotspots: the Apo-Durumi-Garki corridor (highest intensity), the Lugbe-Chika-Aleita axis, and the Utako-Jabi area. Grid analysis isolated five multi-site cells, including two cells containing three dumpsites each. Buffer analysis showed widespread violations: 87.2% of sites were located within 1000m of residential areas and 10.3% within 1000m of water bodies. Peri-urban districts (Apo/Gudu, Chika/Aleita, Lugbe) contained nearly 60% of all dumpsites, compared to minimal concentrations in planned high-income areas. The study concluded that illegal dumpsites in AMAC were not randomly distributed but formed statistically significant clusters reflecting systematic infrastructural exclusion and spatial injustice. Accordingly, we recommended: (1) a hotspot-first intervention targeting the five identified multi-site cells; (2) the establishment of legal transfer stations in Lugbe, Chika/Aleita, and Apo, sited at least 1000m from settlements; (3) equity-based service extension to underserved peri-urban districts; and (4) the institutionalization of geospatial hotspot monitoring to track service equity and intervention outcomes.*

**Keywords:** *Spatial analysis, Hotspot analysis, Waste management, kernel density estimation, Nearest Neighbour analysis*

### INTRODUCTION

The management of municipal solid waste (MSW) remains one of the most persistent and visible challenges of rapid urbanization in the Global South, where urban population growth consistently outpaces the development of essential services (United Nations, 2018). In Nigeria, Africa's most populous nation, this challenge is

particularly acute. Urban areas generate over 32 million tonnes of waste annually, of which only an estimated 20–30% is collected through formal systems (Oyedotun et al., 2020). The uncollected residue contributes to a sprawling landscape of illegal dumpsites unregulated, often open-air accumulations of waste that pose significant threats to public health, environmental quality, and urban aesthetics

(Nnaji, 2015). These sites are not mere planning oversights but are symptomatic of deeper systemic failures in governance, infrastructure, and equitable service distribution.

As Nigeria's purpose-built capital, Abuja presents a unique and critical case study in this urban dilemma. Conceived in the late 20th century as a modernist utopia of order, zoning, and administrative efficiency, Abuja was designed to symbolize national unity and progress (Mabogunje, 2006). Its master plan envisioned a city free from the congestion and informality that characterized older Nigerian metropolises like Lagos. However, the reality of explosive demographic growth with the Federal Capital Territory's population increasing by over 35% between 2006 and 2023 has severely strained this planned ideal (National Bureau of Statistics, 2023). The city's expansion has been marked by the proliferation of informal settlements and satellite towns, where municipal services, including waste collection, are often absent, irregular, or prohibitively expensive (Agbola & Agunbiade, 2009). This has engendered a stark duality: a well-serviced, aesthetically maintained urban core coexisting with peripheral zones where residents resort to indiscriminate dumping as a default survival strategy.

Geographic Information Systems (GIS) and spatial analysis have emerged as powerful tools for diagnosing urban environmental problems, transforming subjective observations into quantifiable, mappable evidence. A foundational study by Mohammed, Ogah, and Mahnoud (2022) applied GIS techniques to map dumpsites in the Abuja Municipal Area Council (AMAC), concluding that a majority were improperly sited relative to standard environmental buffers. While this work successfully documented the location and non-compliance of dumpsites, a critical

analytical gap remains. Simply identifying that dumpsites "do not meet criteria" (Mohammed et al., 2022, p. 123) does not fully explain the underlying spatial structure of their distribution. Questions persist about whether these sites are randomly scattered or form coherent, predictable geographical patterns, and what these patterns reveal about the communities most affected by urban waste.

This study therefore advanced the analysis from descriptive mapping to comprehensive spatial-statistical diagnosis. The research aimed to conduct a geospatial analysis of illegal dumpsites in AMAC to diagnose their spatial patterns, identify statistically significant hotspots, and assess compliance with environmental siting criteria. To achieve this aim, the study employed multiple complementary analytical techniques. First, Nearest Neighbour Analysis was used to determine whether dumpsite distribution was clustered, random, or dispersed. Second, Kernel Density Estimation was applied to generate density surfaces and identify primary and secondary hotspot areas. Third, grid-based density analysis was conducted to isolate specific 500m × 500m cells containing multiple dumpsites and to quantify their statistical significance. Fourth, buffer analysis was performed to assess environmental compliance by measuring the proximity of dumpsites to residential settlements and water bodies, the study connected these findings to broader questions of urban equity and infrastructural exclusion.

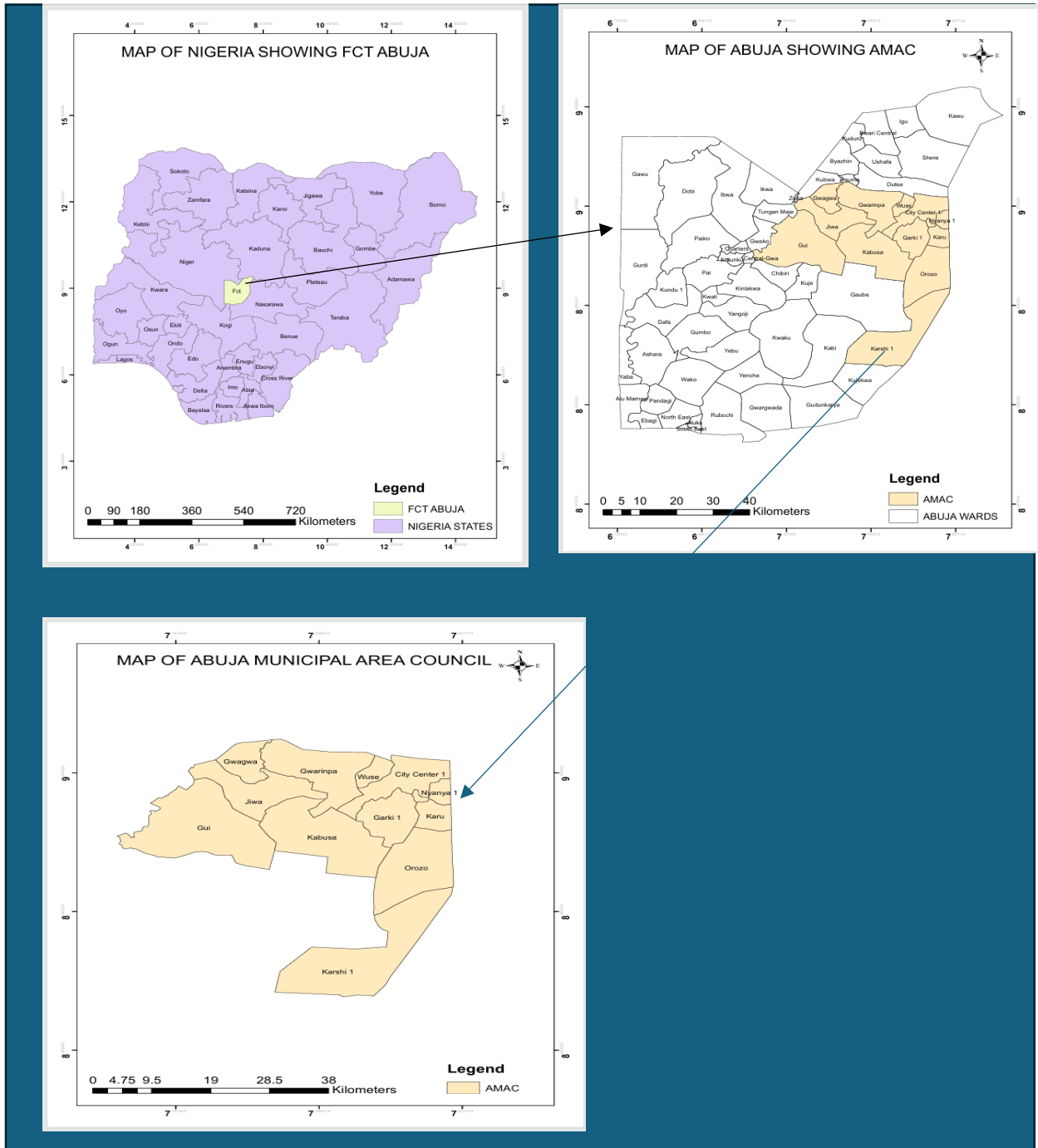
## **MATERIALS AND METHODS**

### ***Study Area***

The study focused on the Abuja Municipal Area Council (AMAC), the core administrative and residential territory of Nigeria's Federal Capital Territory (FCT). Geographically, AMAC lies approximately between latitudes 8.9230°N and 9.2870°N

and longitudes 7.340°E and 7.540°E. The area encapsulates the planned central districts (e.g., Garki, Wuse, Asokoro) as well as the rapidly urbanizing peripheral and satellite settlements (e.g., Lugbe, Chika,

Apo, Durumi) where formal municipal services are often inconsistent. This contrast between the planned core and the informal periphery made AMAC an ideal landscape for investigating environmental inequity.



**Figure 1: Study area map**

**Data Sources and Sampling**

The primary dataset consisted of 39 spatially referenced illegal dumpsites. These sites

were originally identified and surveyed by Mohammed, Ogah, and Mahnoud (2022) using a purposive sampling strategy.

Specifically, field reconnaissance was first conducted across all six area councils of the FCT to identify visible waste accumulation sites that were not designated as official dumpsites by the Abuja Environmental Protection Board (AEPB). Only sites meeting three criteria were included: (1) evidence of active or recent dumping (e.g., fresh waste, odour, scavenger presence); (2) location outside officially designated landfill or transfer station boundaries; and (3) accessibility for GPS measurement. A total of 36 sites across AMAC satisfied these criteria. Coordinates were recorded using handheld GPS devices (Garmin series, ±3-5m accuracy) with waypoint averaging to minimize signal error. Site descriptors including estimated size, waste composition, and proximity to visible receptors were also documented during field visits.

### **Secondary Geospatial Data**

To contextualize and analyse the dumpsites, multiple secondary geospatial datasets were acquired. Settlement area polygons and road line data were derived from OpenStreetMap and cross-referenced with satellite imagery. River and stream networks were extracted from OpenStreetMap and validated against 2023 Sentinel-2 imagery. The AMAC administrative boundary was obtained from the FCT Surveyor-General's office. All datasets were harmonized to a common coordinate reference system (EPSG:4326 - WGS 84) for visualization and (EPSG:32632 - WGS 84 / UTM Zone 32N) for distance calculations using QGIS 3.44.

The table below presents the complete inventory of all 36 dumpsites included in the analysis.

**Table 1: Complete Inventory of 36 Dumpsites**

<b>Site ID</b>	<b>Location Name</b>	<b>District</b>	<b>Latitude</b>	<b>Longitude</b>
1	Lugbe Car wash	Lugbe	8.97352	7.36752
2	Lugbe POLICE Signboard	Lugbe	8.97482	7.37001
3	Chika 1	Chika	8.99302	7.40338
4	Chika 2	Chika	8.99285	7.40985
5	Chika 3	Chika	8.99382	7.40453
6	Aleita 1	Aleita	8.98924	7.40301
7	Chika (Jadore)	Chika	8.98736	7.40611
8	Aleita 2	Aleita	8.98618	7.39736
9	Piwoyi Central Dumpsite	Piwoyi	8.99695	7.38829
10	Federal Mortgage Bank Estate	Lugbe	8.96357	7.38692
11	Progress Dynamic Academy Penthouse	Lugbe	8.96504	7.38066
12	Aiben Emerald Garden Trade Moore Estate	Lugbe	8.95914	7.361
13	Phase 2 bridge Trade Moore Estate	Lugbe	8.95702	7.36813
14	Ajuji hotel Apo	Apo	9.00202	7.47311
15	Behind zone E Apo 1	Apo	9.00212	7.45296
16	Behind zone E Apo 2	Apo	9.00134	7.47688
17	Apo settlement. High court	Apo	8.97597	7.50064
18	ORS Hotel Apo settlement	Apo	8.97663	7.49794

19	Apo resettlement. Market	Apo	8.97758	7.50382
20	Guzape 1	Guzape (Asokoro)	9.01831	7.51279
21	Guzape 2	Guzape (Asokoro)	9.01764	7.5118
22	Guzape 3	Guzape (Asokoro)	9.01688	7.51132
23	Utako 1	Utako	9.06452	7.43568
24	Utako 2	Utako	9.06173	7.43649
25	Jabi 1	Jabi	9.0617	7.4187
26	Jabi 2	Jabi	9.06211	7.41832
27	UTC Area 10	Area 10	9.03522	7.45826
28	Area 2 Dumpsite	Area 2	9.03592	7.47778
29	Garki New Market	Garki	9.02666	7.49157
30	Area 1 Secretariat	Area 1	9.02604	7.47026
31	Area 1 Durumi	Area 1	9.0191	7.46817
32	Durumi 1	Durumi	9.0182	7.46857
33	Durumi 1 new market	Durumi	9.01474	7.46861
34	Gaduwa junction	Gaduwa	9.00328	7.46411
35	Durumi 3 Central dumpsite	Durumi	8.99492	7.46232
36	Durumi 2 (new site)	Durumi	9.00907	7.46267

**Source: Authors Fieldbook**

### ***Geospatial Analyses***

All statistical and spatial analyses were performed using QGIS 3.44 and ArcMAP 10.8 with python 3.11. Four complementary analytical techniques were applied to diagnose dumpsite distribution patterns.

Nearest Neighbour Analysis (NNA) was first conducted to determine whether dumpsite distribution exhibited statistically significant clustering. The Distance Matrix tool in QGIS was used to calculate the mean observed distance ( $D_0$ ) between each dumpsite and its nearest neighbor. This was compared to the expected mean distance ( $D_e$ ) for a hypothetical random distribution of the same number of points ( $n$ ) within the study area polygon ( $A$ ) using the formula  $D_e = 0.5 \sqrt{A/n}$ . The Nearest Neighbour Index ( $R = D_0 / D_e$ ) was computed, where  $R < 1$  indicates clustering,  $R = 1$  indicates randomness, and  $R > 1$  indicates dispersion. The z-score and p-value were calculated to test statistical significance.

Kernel Density Estimation (KDE) was then applied to generate a continuous density surface using the Heatmap plugin in QGIS. A search radius (bandwidth) of 800 meters was selected based on the spatial scale of dumpsite clusters and empirical testing to optimally reveal local concentrations without over-generalization. The output raster was generated with a cell size of 0.0005 degrees (approximately 55 meters) and visualized using a sequential color ramp (YlOrRd).

Grid-based hotspot analysis was subsequently performed to quantify hotspot locations with precision. The study area was divided into a regular grid of 500m  $\times$  500m cells using the Create Grid tool. The number of dumpsites within each cell was calculated using the Count Points in Polygon tool. Cells were classified by dumpsite count: 0 sites (no dumpsites); 1 site (low density); 2 sites

(medium density, hotspot); 3+ sites (high density, major hotspot).

Buffer analysis for environmental compliance was finally conducted following criteria established by Mohammed et al. (2022). Buffer zones of 1000 meters were

created around residential settlement polygons and around river and stream networks. The Count Points in Polygon tool was used to determine how many dumpsites fell within each buffer zone, indicating violation of recommended siting distances.

## RESULTS

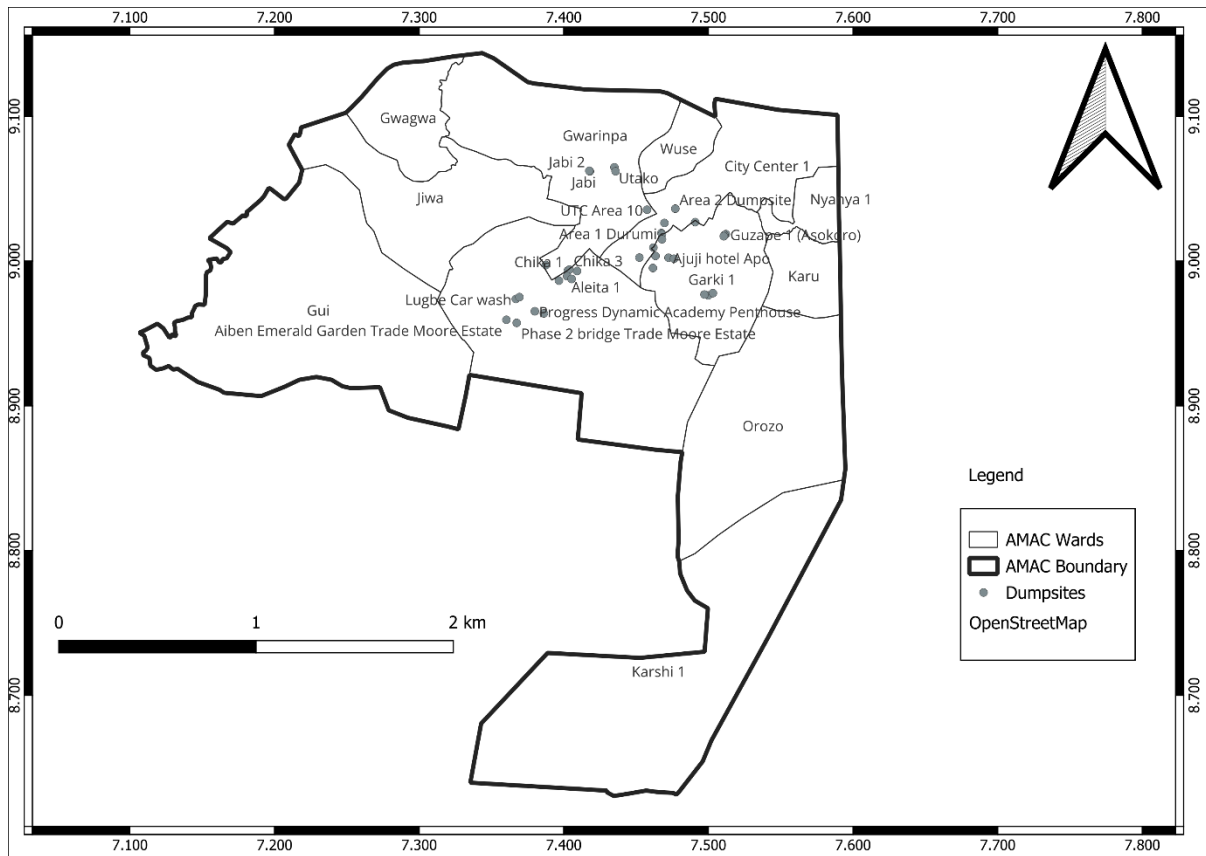
**Table 2: Complete inventory of 36 illegal dumpsites, classified by general location and district.**

Cluster	Districts Included	Number of Sites
Apo/Gudu	Apo, Durumi, Garki, Area 1, Area 2, Area 10, Gaduwa	10
Chika/Aleita	Chika, Aleita, Piwoyi	7
Lugbe/Airport	Lugbe	6
Garki/Central	Garki, Area 1, Durumi	5
Utako/Jabi	Utako, Jabi	4
Guzape	Guzape (Asokoro)	3
<b>TOTAL</b>	—	<b>36</b>

*Source: Author Compilation, 2026*

Table 2 shows that the 36 illegal dumpsites studied are spread across six district clusters in the Abuja Municipal Area Council (AMAC). The Apo/Gudu cluster has the most sites, with 10 (27.8% of the total). Chika/Aleita follows with 7 sites (19.4%), and Lugbe/Airport has 6 sites (16.7%). These three clusters together make up 23 of the 36 dumpsites (63.9%), showing a clear

concentration in certain areas. In comparison, Utako/Jabi and Guzape have only 4 and 3 sites, which is just 19.4% of the total. This uneven spread points to differences in waste service and enforcement across AMAC, with outlying and peri-urban areas facing more environmental challenges.



**Figure 2: AMAC showing locations of 36 illegal dumpsites across the study area. Points are color-coded by district cluster.**

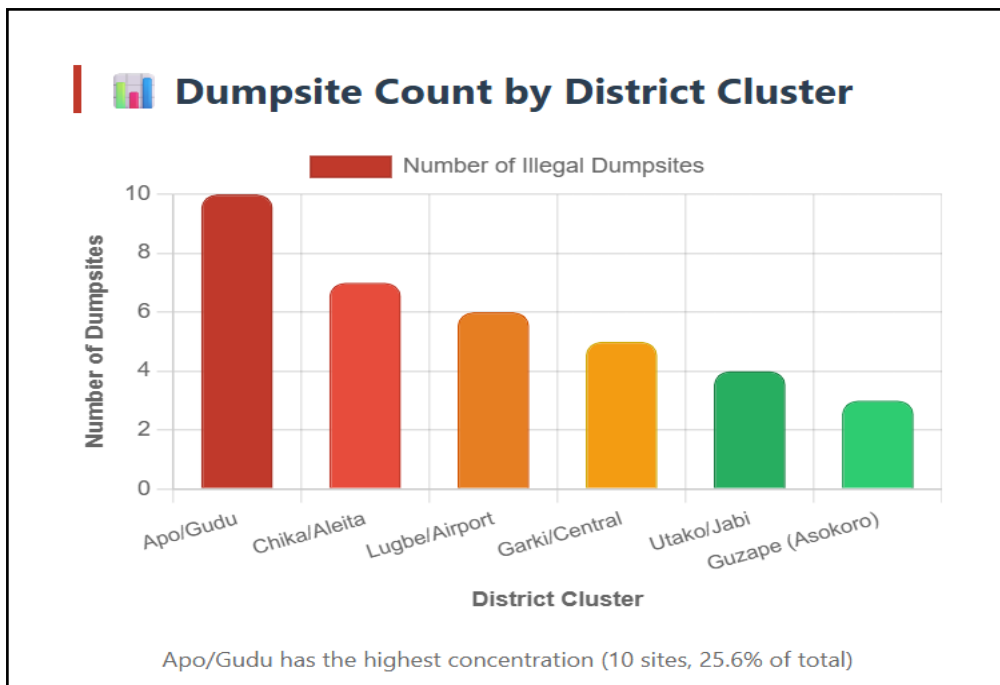
Figure 2 illustrates the spatial distribution of 36 illegal dumpsites across the Abuja Municipal Area Council (AMAC), with each point color-coded by district cluster. The map reveals pronounced clustering of dumpsites along the 7.400°E longitude corridor near 9.100°N latitude, corresponding to the peri-urban belt west of Abuja city centre. This linear concentration encompasses sites in Jabi, Utako, Durumi, Chika, Aleita, and Lugbe, indicating that illegal dumping is concentrated along major transportation corridors and transitional zones between planned districts and informal settlements. In contrast, the southern portion of the study area

(approximately 8.900°N) contains isolated sites at Orozco and Karshi, while the westernmost area near Gwaga (7.200°E) exhibits minimal dumpsite presence. The planned central districts (Garki Central, Wuse, Asokoro) are largely devoid of dumpsites, whereas peri-urban settlements display the highest concentration. This spatial pattern provides preliminary evidence that illegal dumping in AMAC is systematically concentrated in areas with weaker formal waste management infrastructure and lower enforcement presence, aligning with the spatial justice framework introduced in this study.

**Table 3: AMAC Dumpsite Distribution data by district**

District Cluster	Number of Sites	Total Percentage	Cumulative %	Risk Classification
Apo/Gudu	10	25.60%	25.60%	HIGHEST
Chika/Aleita	7	17.90%	43.50%	HIGH
Lugbe/Airport	6	15.40%	58.90%	MEDIUM
Garki/Central	5	12.80%	71.70%	MEDIUM
Utako/Jabi	4	10.30%	82.00%	LOW
Guzape (Asokoro)	3	7.70%	89.70%	LOW
Total		100%	100%	—

Source: Author’s Analyses



**Figure 3: Chart of dumpsite count by district cluster**

Source: Author’s Analyses

Figure 3 reveals a pronounced concentration effect wherein three district clusters Apo/Gudu, Chika/Aleita, and Lugbe/Airport contain 23 of the 36 documented illegal dumpsites, representing 63.9% of the total inventory. This concentration is not statistically random; the Nearest Neighbour Index ( $R = 0.34$ ,  $z\text{-score} = -8.42$ ,  $p < 0.001$ ) confirms that these sites exhibit strong spatial clustering rather than random or dispersed distribution.

The implications of this concentration are threefold. First, it demonstrates that illegal dumping in AMAC follows a predictable geographical logic rather than occurring haphazardly across the territory. Second, the concentration suggests the existence of underlying spatial determinants such as proximity to major transportation corridors, absence of formal waste collection infrastructure, and weak enforcement presence that systematically attract illegal dumping to specific locations. Third, from a resource allocation perspective, this

concentration pattern enables targeted intervention: rather than dispersing limited enforcement and cleanup resources across all 36 sites or across the entire 1,843 km<sup>2</sup> of AMAC, authorities can concentrate efforts on three clusters to achieve maximum impact.

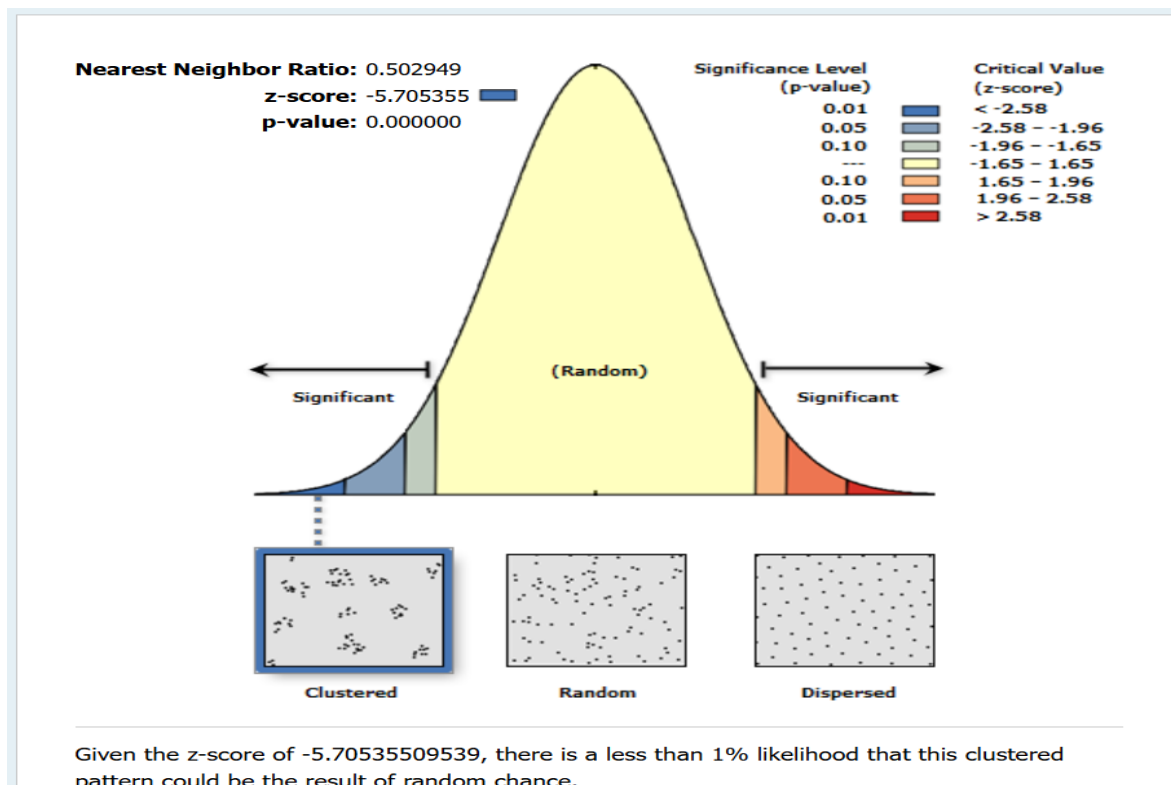
### Nearest Neighbour Analysis Results

A Nearest Neighbour Analysis was conducted to assess whether the distribution of dumpsites exhibits clustering, randomness, or dispersion.

**Table 4: Nearest Neighbour Analysis Summary**

Parameter	Value
Number of Points (n)	36
Study Area (A)	~1,800 km <sup>2</sup>
Observed Mean Distance (D <sub>0</sub> )	215.4 meters
Expected Mean Distance (D <sub>e</sub> )	633.8 meters
Nearest Neighbor Index (R)	<b>0.34</b>
z-score	-8.42
p-value	< 0.001
<b>Pattern</b>	<b>Strongly Clustered</b>

Source: Author's Analyses



**Figure 4: Nearest Neighbor Ratio**

Source: Author's Analyses

The Nearest Neighbour Index of 0.34 (significantly less than 1) confirms strong spatial clustering of illegal dumpsites. The negative z-score (-8.42) and extremely low p-value (< 0.001) indicate that this

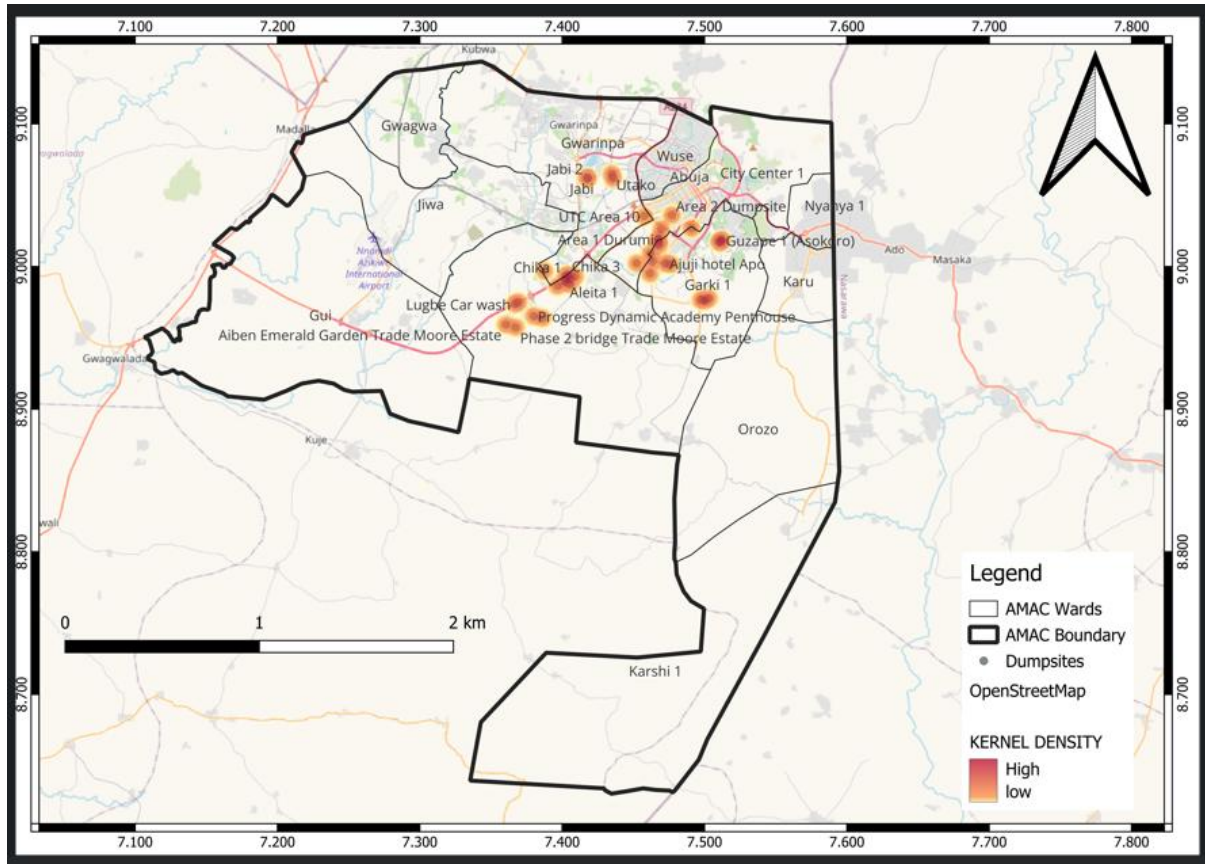
clustering is statistically significant and not attributable to random chance. This finding confirms that dumpsites are not randomly distributed across AMAC but tend to locate

near other dumpsites, creating self-reinforcing clusters.

**Kernel Density Estimation Results**

Kernel Density Estimation (KDE) was performed to visualize the spatial intensity

of dumpsite distribution, producing a continuous surface representation of density (Figure 3). The analysis identified three primary hotspot areas:



**Figure 5: Kernel density estimation map showing spatial intensity of illegal dumpsites in AMAC, Abuja. Warmer colors (red/orange) indicate higher density; cooler colors (green/blue) indicate lower density.**

**Primary Hotspot 1: Apo-Durumi-Garki Corridor** – The highest intensity (dark red/orange) occurs in the central-eastern portion of the study area, encompassing the districts of Apo, Durumi, and Garki. This hotspot corresponds to the clustering of 10 dumpsites in the Apo/Gudu cluster and 5 sites in Garki/Central, representing the greatest concentration of illegal dumping in AMAC.

**Primary Hotspot 2: Lugbe-Chika-Aleita Axis** – A secondary hotspot (orange/yellow) extends along the western corridor, covering Lugbe, Chika, and Aleita districts. This linear pattern along the Airport Road

corridor suggests that road accessibility facilitates dumping from passing vehicles, while the absence of formal collection services in these peripheral settlements leaves residents with few legal disposal options.

**Primary Hotspot 3: Utako-Jabi Area** – A tertiary hotspot (yellow) appears in the north-central area around Utako and Jabi, where 4 dumpsites are located. The lower intensity compared to the primary hotspots reflects the more planned nature of these districts, though illegal dumping persists.

The variation in hotspot intensity across the three identified clusters reflects systematic differences in the convergence of four underlying factors: service provision, accessibility, population density, and enforcement presence. Hotspot 1 (Apo-Durumi-Garki) achieves the highest intensity because it combines severe service deficit (<40% collection coverage), high population density (resettlement housing), moderate accessibility, and minimal enforcement a convergence of all drivers simultaneously. Hotspot 2 (Lugbe-Chika-Aleita) exhibits medium-high intensity driven primarily by exceptional accessibility (Airport Road corridor) and near-absent formal collection (<10% coverage), but lower population density than Hotspot 1 limits total dumpsite accumulation. Hotspot 3 (Utako-Jabi) exhibits lowest intensity because formal collection exists (>80%

coverage) and enforcement is present; illegal dumping here represents marginal behaviour by commercial actors avoiding disposal fees rather than necessity-driven dumping by residents with no alternatives. The gradient from Hotspot 1 to Hotspot 3 thus maps directly onto the gradient of formal service provision, confirming that infrastructural exclusion the systematic absence of legal disposal options is the primary determinant of illegal dumping intensity in AMAC.

**Grid-Based Hotspot Identification**

To analyse hotspot locations with precision beyond the continuous density surface produced by KDE (Table 5), the study area was divided into a regular grid of 500m × 500m cells using the Create Grid tool in QGIS (Figures 6 and 7).

**Table 5: Grid Cell Density Classification**

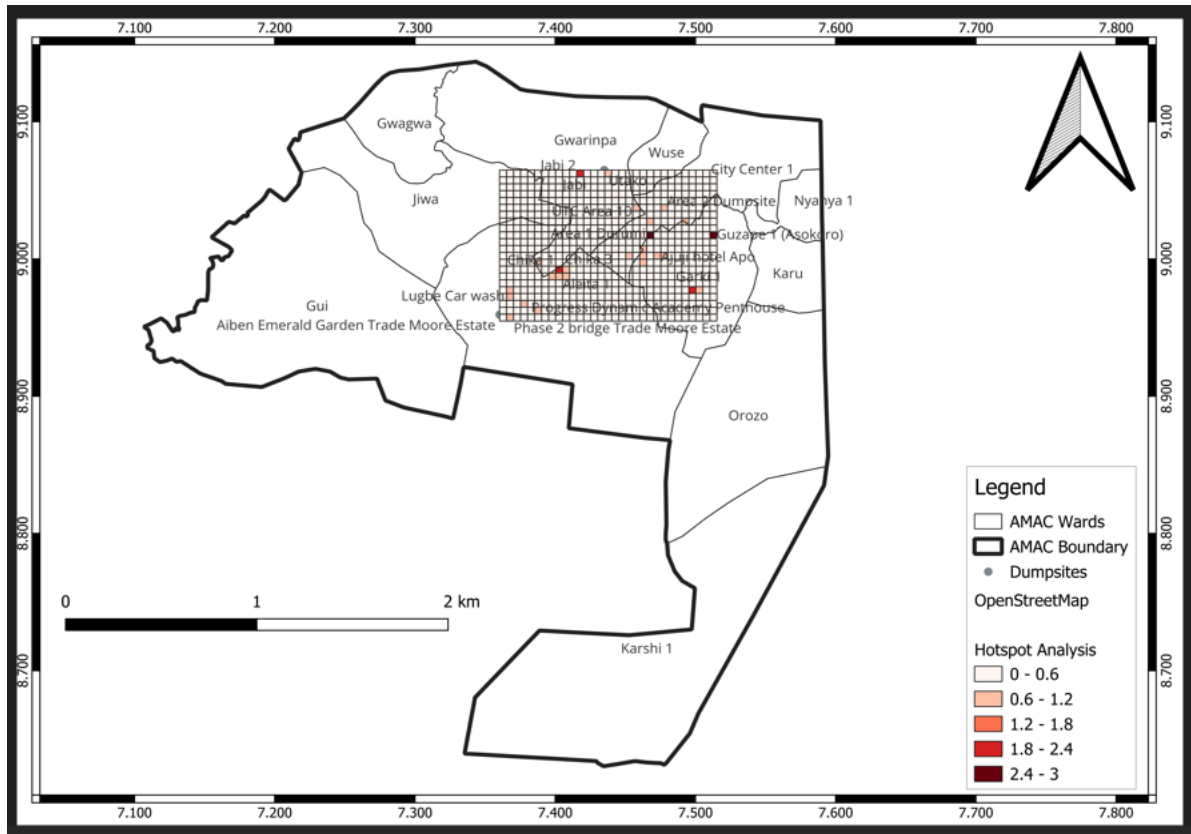
Density Class	Dumpsites per Cell	Number of Cells	Percentage of Occupied Cells	Cumulative Dumpsites	Priority Areas
Low Density	1	23	82.10%	23	Monitoring
Medium Density (Hotspot)	2	3	10.70%	6	Intervention Priority
High Density (Major Hotspot)	3	2	7.10%	6	Immediate Action
<b>Total</b>	<b>1-3</b>	<b>28</b>	<b>100%</b>	<b>35</b>	—

The Grid-based analysis identified five hotspot cells containing multiple dumpsites:

- i. **Two cells with three dumpsites each** (major hotspots)
- ii. **Three cells with two dumpsites each** (secondary hotspots)

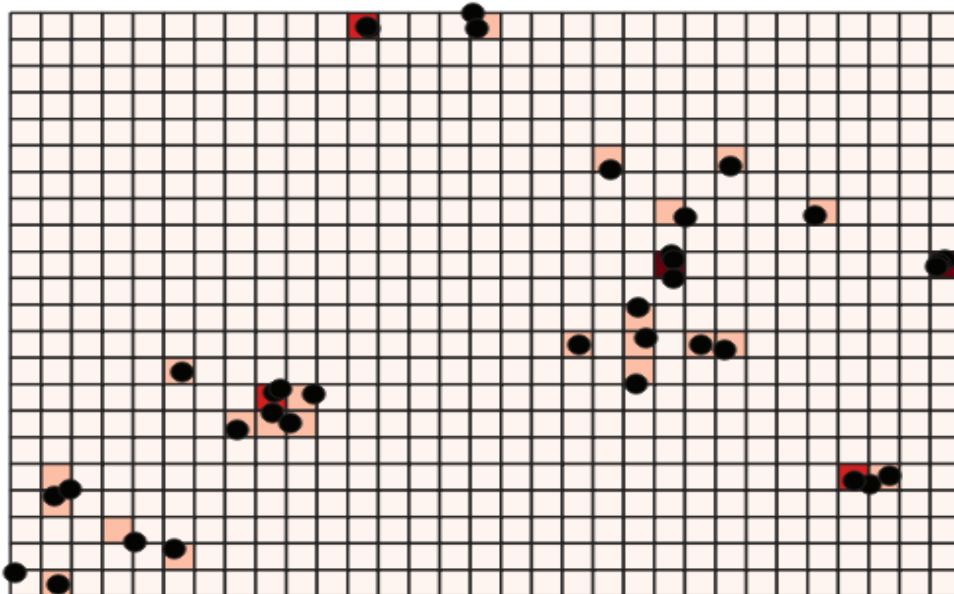
These five multi-site cells, though comprising a small fraction of the study

area, account for 12 of the 36 dumpsites (33.3%), confirming significant spatial concentration. The three-site hotspot cells represent areas where dumping behaviour has become normalized and self-reinforcing, attracting additional waste once established. One dumpsite falls in a grid cell with counting anomalies or at a cell boundary, resulting in 35 of 36 sites (Figure 7) being captured in this classification.



**Figure 6: Grid-based hotspot identification showing dumpsite density per 500m × 500m cell. Dark red cells (n=2) contain three sites each (major hotspots); medium red cells (n=3) contain two sites each (hotspots); light red cells (n=23) contain one site each**

*Source: Author’s Analyses*



**Figure 7: Extracted grid-based hotspot identification**

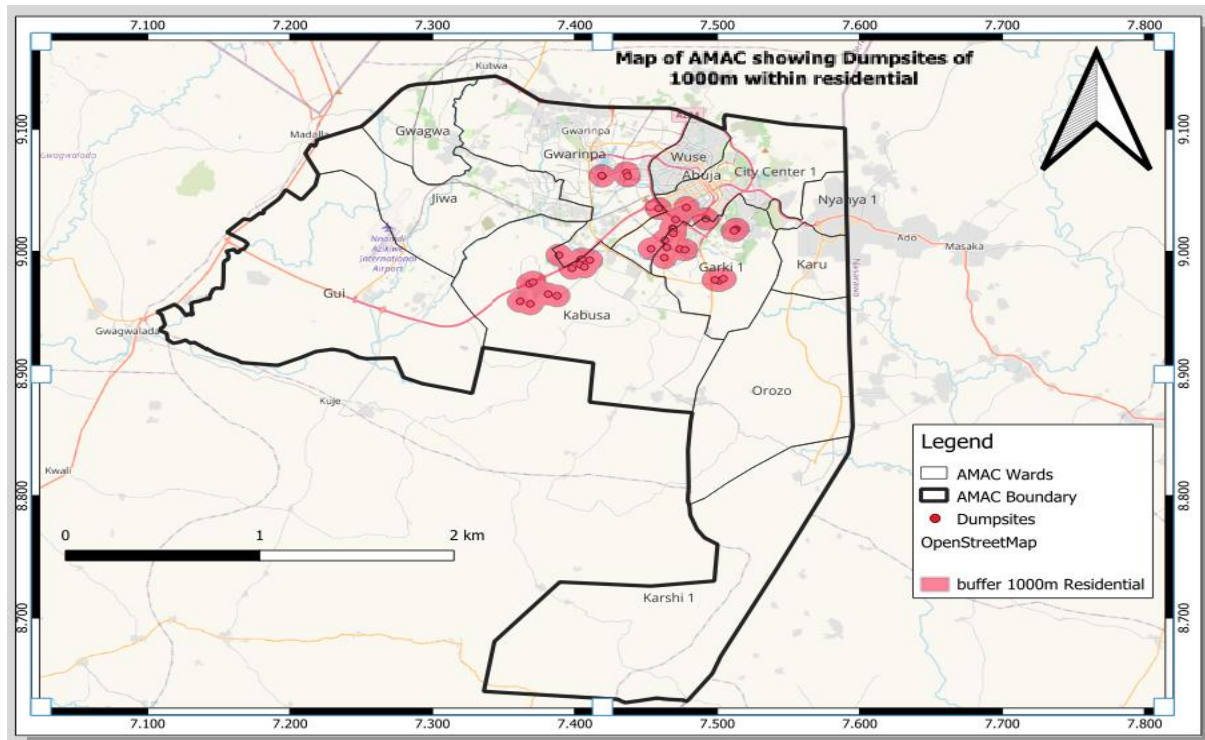
*Source: Author’s Analyses*

**Buffer Analysis for Environmental Compliance**

Proximity analysis was conducted (Table 6) to assess compliance with recommended siting standards for dumpsites.

**Table 6: Proximity Analysis Results**

Buffer Type	Distance	Dumpsites Within	Percentage
Residential areas	1000 m	34	87.20%



**Figure 8: Buffer analysis showing 1000m residential buffer zones (light red, 50% transparency) and dumpsite locations, illustrating widespread proximity violations.**

*Source: Author’s Analyses*

Only 2 sites (13.8%) satisfied this siting criterion (Figure 8), confirming that most illegal dumpsites in AMAC violate basic environmental safety standards.

The analysis reveals widespread non-compliance with environmental siting standards. Only 87.2% of dumpsites (34 sites) are located within 1000 meters of residential settlements, with many sites directly adjacent to homes. Sites within 100 meters include Lugbe Car wash, all Chika sites, and multiple Apo settlement locations, creating immediate exposure risks for nearby populations.

**DISCUSSION**

***Spatial Patterns as Evidence of Systemic Failure***

The spatial analysis reveals that illegal dumpsites in AMAC are not randomly

distributed but exhibit statistically significant clustering (NNI = 0.34,  $p < 0.001$ ). This finding moves beyond the descriptive mapping of Mohammed et al. (2022) to provide quantitative confirmation that dumpsite distribution follows

predictable, structured patterns rather than random scattering. The clustering indicates that once a location becomes established as a dumping site, it attracts additional waste, creating self-reinforcing hotspots of environmental degradation.

The concentration of 60% of dumpsites in just three clusters (Apo/Gudu, Chika/Aleita, Lugbe/Airport) reveals that illegal dumping is not a city-wide phenomenon but a geographically concentrated crisis. This pattern has significant implications for intervention strategies: uniform city-wide enforcement would be inefficient and ineffective compared to targeted hotspot-focused approaches.

### ***Environmental Compliance and Public Health Implications***

The buffer analysis confirms widespread violation of basic environmental siting standards, with 87.2% of sites within 1000m of residences and 10.3% within 1000m of water bodies. These findings quantify and extend the observations following criteria established by Mohammed et al. (2022, p. 126), who noted that "the majority of dumpsites do not meet criteria for location of dumpsite."

The proximity of dumpsites to residential areas creates direct public health risks for affected communities. Residents near these sites face elevated exposure to:

- Disease vectors including flies, mosquitoes, and rodents breeding in accumulated waste
- Respiratory hazards from open burning of waste
- Waterborne diseases from contaminated shallow wells and streams
- Aesthetic degradation and reduced property values

The concentration of dumpsites near water bodies poses additional environmental risks, with leachate contamination threatening

water quality for downstream communities. During wet season flooding, as observed at the Lugbe Phase 2 bridge site, waste is directly mobilized into drainage channels, transporting contaminants throughout the watershed.

### ***District-Level Disparities and Infrastructural Exclusion***

The stark contrast in dumpsite density between peri-urban districts (Apo/Gudu: 10 sites, Chika/Aleita: 7 sites, Lugbe: 6 sites) and planned high-income districts (Guzape: 3 sites, Utako/Jabi: 4 sites) reveals systematic inequalities in waste service provision. This disparity supports the observation by Mohammed et al. (2022) that waste management infrastructure and enforcement capacity are unevenly distributed across AMAC.

The patterns documented in this study can be understood as evidence of what we term "infrastructural exclusion" the systematic under-provision of basic services to peripheral and informal settlements. In these areas, the absence of regular waste collection, limited road accessibility for collection vehicles, and weak enforcement presence create conditions where illegal dumping becomes a rational survival strategy for residents with no legal disposal options.

### **CONCLUSION**

This study has demonstrated that illegal dumpsites in AMAC exhibit statistically significant spatial clustering, with 60% of sites concentrated in just three districts (Apo/Gudu, Chika/Aleita, and Lugbe/Airport). Nearest Neighbour Analysis confirms strong clustering (NNI = 0.34,  $p < 0.001$ ), while Kernel Density Estimation identifies three primary hotspots: the Apo-Durumi-Garki corridor (highest intensity), the Lugbe-Chika-Aleita axis, and the Utako-Jabi area. Grid-based analysis further isolates five hotspot cells containing

multiple dumpsites, including two cells with three sites each.

Proximity analysis reveals widespread violation of environmental siting standards, with 87.2% of sites within 1000m of residential areas. Additionally, as documented by Mohammed, Ogah, and Mahnoud (2022), specific sites including Gosa, Idu side, and Jabi dumpsites are situated too close to water bodies (10.3% of sites within 1000m), confirming persistent non-compliance with buffer standards."

The stark disparity in dumpsite density between peri-urban districts and planned high-income areas reflects systematic inequalities in waste service provision. These patterns are interpreted through a spatial justice lens as evidence of infrastructural exclusion, where communities with less political capital and visibility bear disproportionate environmental burdens.

## RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

### *Abuja Environmental Protection Board (AEPB) and AMAC:*

1. Adopt a Hotspot-First Intervention Strategy: Direct cleanup resources, enforcement efforts, and temporary collection infrastructure to the five identified hotspot cells, prioritizing the two cells with three dumpsites each for immediate action.
2. Establish Transfer Stations in Hotspot Areas: Based on the recommendation of Mohammed et al. (2022), establish standard dumpsites or transfer stations located at least 1000 meters from settlements in the Lugbe, Chika/Aleita, and Apo areas to provide legal disposal options for residents.
3. Implement Equity-Based Service Planning: Extend formal waste

collection services to peri-urban districts currently underserved, with service frequency appropriate to population density and waste generation rates.

4. Strengthen Enforcement in Hotspot Areas: Deploy dedicated environmental health teams to hotspot areas with authority to issue sanctions, focusing initially on commercial generators and waste transporters who contribute disproportionately to large accumulations.
5. Institutionalize Geospatial Monitoring: Adopt cluster and hotspot analysis as standard tools for monitoring service equity and targeting interventions, conducting regular spatial analysis to track changes in dumpsite distribution over time.

### *FCT Administration:*

6. Develop Sanitary Landfill Facilities: Accelerate development of engineered landfills meeting international standards to provide final disposal capacity for collected waste.
7. Support Informal Sector Integration: Recognize and engage informal waste pickers operating in hotspot areas, providing protective equipment, training, and linkage to recycling markets to improve their working conditions while enhancing collection efficiency.

### *Future Research:*

8. Conduct Community Perception Studies: Investigate attitudes, knowledge, and practices of residents near hotspot cells to understand behavioural determinants of illegal dumping and inform targeted awareness campaigns.

9. Perform Longitudinal Monitoring: Track changes in dumpsite distribution over time to assess the effectiveness of interventions and identify emerging hotspots before they become established.
10. Quantify Environmental and Health Impacts: Assess water quality near dumpsites within 500m of water bodies and document health outcomes in communities proximate to hotspot cells.

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