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Research Article

Analysis of Land Use/Land Cover (LULC) Influence on Kidnapping Incidents in Igabi Local Government Area, Kaduna State, Nigeria

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ABSTRACT

This study analyzes the influence of land use and land cover (LULC) on kidnapping incidents in Igabi Local Government Area (L.G.A.) of Kaduna State between 2019 and 2022. Kidnapping is conceptualized as the unlawful seizure, confinement, or abduction of a person, typically for ransom or political leverage. In recent years, Igabi L.G.A. has emerged as a kidnapping hotspot. This necessitates the application of geospatial techniques to assess its environmental dimensions and dynamics by examining how LULC patterns relate to the spatial distribution of abductions. Point data showing the location of incidents for this study were obtained from the Department of State Services (DSS), while satellite data were obtained from the European Space Agency (ESA) Sentinel-2 for classification, categorization, mapping, and analysis of LULC dynamics. Analysis revealed that 105, 358, 552, and 403 persons were kidnapped in 2019, 2020, 2021, and 2022, respectively. This amounts to a total of 1,418 victims over the four years, with approximately 26% fatalities recorded over the study years. Findings also indicated that a higher number of abductions occurred in locations outside built-up zones, made up of 96% vegetative cover as confirmed by the LULC classification of Igabi L.G.A. The study area consists of extensive open spaces which are largely cultivated, reinforcing the persistence of kidnapping as a major threat to agricultural and socio-economic activities in Kaduna State. Given the study area's strategic position as a transportation corridor linking several important cities and towns, the insecurity also poses broader national implications. The study therefore advocates for the systematic integration of Geographic Information Systems (GIS) in further analysis to enhance intelligence gathering, operational planning, and hotspot-based deployment, thereby improving security effectiveness and mitigating the kidnapping scourge in this volatile region.

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1 Introduction

Kidnapping, defined as the unlawful seizure, confinement, or abduction of a person, typically for ransom or political leverage (UNODC, 2023), has become a major security crisis in Nigeria's North-West, especially Kaduna State, disrupting socio-economic activities (Qiraat African, 2024; NHRC, 2026; Uzonu et al., 2024). Globally, and in sub-Saharan Africa, kidnapping thrives amid rapid urbanization, poverty, and ecological decline, as bandits exploit vegetated cover and highways in ungoverned peri-urban spaces (Majeed et al., 2023; Li et al., 2023).

In Nigeria's North-West, 662 incidents occurred between 2019 and 2023, surpassing the North-East and driven by poverty in Kaduna, Katsina, and Zamfara (Muhammad et al., 2025; Usman, 2025). In Igabi, hotspots concentrate in Rigasa, Kakau, Kwarau, and Turunku, with a linear annual rise of 44.3 cases and nationwide incidents exceeding 3,000 in 2024–2025 (NHRC, 2026; Uzonu et al., 2024).

In Igabi Local Government Area (LGA), Uzonu et al. (2024) applied GIS in analyzing kidnapping. The study revealed a nearest neighborhood Z-score of –43.92, confirming clustered hotspots in Igabi between 2019 and 2023. The findings emphasized socio-economic drivers, while neglecting land use/land cover (LULC) integration for risk prediction. Dangana (2021a) mapped hotspots along the Abuja–Kaduna highway (Dikko Junction to Kaduna City Gate). 20 km buffer was created along the highway (with linear settlements such as Kaduna Toll-Gate, Rijana, Katari, Jere, Tafa, and Sabon Wuse) against LULC. The study discovered 43.97% vegetal, assessing their proximity to police stations without time-series or change-detection (Dangana, 2021b). Both studies relate peri-urban sprawl, deforestation, and fragmented LULC as facilitators of bandit hideouts and mobility, grossly undermining food security.

Most Nigerian crime studies focus on socio-political causes and property crimes, rarely using geospatial technologies for modeling or explicit spatial-environmental links (Dangana, 2019; Olayinka & Iweala, 2014; Sypion-Dutkowska & Leitner, 2017; Udeh et al., 2025). Environmental criminology frameworks such as Routine Activity Theory and Crime Pattern Theory help explain why low-density, vegetated land use can increase concealment and reduce natural surveillance, while stronger urban guardianship can deter crime (Dangana, 2021a).

Routine Activity Theory emphasizes that crime is most likely to occur when a motivated offender, a suitable target, and the absence or weakness of a capable guardian

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converge in the same place at the same time, shifting the focus from offender pathology to the routine organization of everyday activities that structure such convergences (Cohen & Felson, 1979). In parallel, Crime Pattern Theory explains that offenders typically operate within awareness spaces formed around familiar activity nodes, the paths that connect these nodes, and the edges that mark transitions between areas, hence the tendency to commit offences in environments they regularly traverse rather than in unfamiliar locations (Brantingham & Brantingham, 1993). When these perspectives are integrated, the mode of spatial arrangement of land uses (residential, commercial, institutional, and transport functions), distribution, and connection plays a central role in shaping both the distribution of opportunities for crime and the movement patterns through which offenders encounter those opportunities. This makes urban form a critical mediator of where and when crime is most likely to materialize (Newton, 2015).

Against this background, Uzonu et al. (2024) identify crime hotspots without incorporating LULC-based risk prediction, and Dangana (2021a) does not explicitly model spatiotemporal dynamics. As a result, both studies risk ignoring how land cover influences accessibility, and temporal shifts which jointly structure bandit mobility and crime opportunity. A more grounded interpretation therefore links crime not simply to location alone, but to the interaction between land-use form, guardianship, and offender movement over space and time.

This study addresses these gaps in Igabi LGA from 2019 to 2022 by analyzing incident locations and the LULC–crime relationship, promoting an integrated, predictive framework for peri-urban risk mitigation in Nigeria's bandit-affected North-West. The study contributes to predictive modeling by identifying land use and land cover characteristics associated with kidnapping occurrence, thereby providing spatial predictors that can be integrated into geospatial risk models for hotspot forecasting.

2 Materials and Methods

2.1 Study Area

Igabi LGA spans latitudes 10°28′48.23″N to 11°0′57.64″N and longitudes 7°10′37.91″E to 7°53′29.25″E (Figure 1), covering an area of 3,222 km² (Abubakar et al., 2025). The region lies within the tropical savanna climate of the Northern Guinea Savanna zone, with annual rainfall of about 1,000–1,500 mm concentrated in the wet season and vegetation dominated by Guinea Savanna woodland and scattered trees (Audu et al., 2018). Its topography is gently undulating and marked by rocky outcrops, while the 2006 census recorded a population of 430,753 residents, with subsequent growth projections indicating a steadily increasing population base (National Population Commission, 2009).

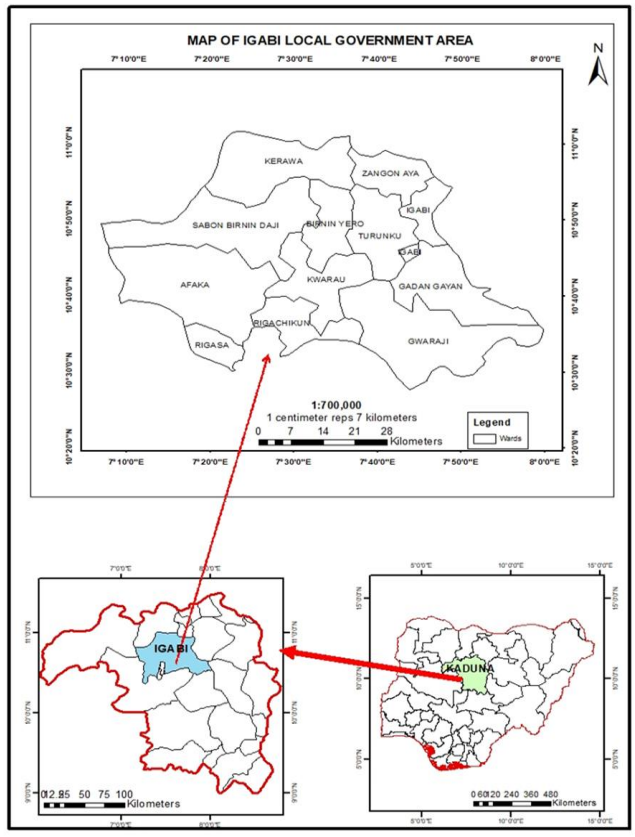


Figure 1: Igabi Local Government Area, Kaduna State Source: Adapted and modified from Grid 3, Nigeria (2025).

2.2 Data Sources

The data used in this study includes both primary and secondary data as elucidated in Table 1.

Table 1: Data Sources and Types

S/N	Type of data	Source	Purpose
1.	Coordinates of kidnapping Incidences	Department of State Security	Mapping and analysis
2.	Boundary shapefiles	KADGIS, Grid 3	Study area boundary
3.	Satellite image	ESA's Sentinel 2 (10 m resolution)	Land use/Land Cover mapping
4.	Relevant literatures	Journals, dailies, periodicals	Citation and references

2.3 Equipment and software

ArcGIS 10.8 was used for vector analysis, mapping, and modeling; ENVI 6.0 and ERDAS Imagine for raster/image processing; and Google Earth Pro for visualization, ground-truthing, and validation.

2.4 Data validation

Data validation involved verifying the completeness, consistency, and spatial accuracy of the kidnapping incident records obtained from the DSS before analysis. The Sentinel-2 imagery used for LULC classification was validated through field observations and ancillary spatial data. Some parts of the study area are inaccessible due to insecurity; therefore, visual interpretation using Google Earth Pro was undertaken to confirm the correctness of land cover labels and support reference sample selection. Classification reliability was then assessed using a confusion matrix, overall accuracy, producer's accuracy, user's accuracy, and the Kappa coefficient.

2.5 Data preprocessing

Data preprocessing for this study integrates GPS coordinates from the Department of State Services, KADGIS boundaries, Sentinel-2 imagery re-projecting to UTM 32N, applying Sen2Cor atmospheric correction, conducting supervised LULC classification with smoothing, performing spatial joins/buffers/heatmaps, and validation against existing literature.

2.6 Data Analysis

2.6.1 Locations and rates of Kidnapping incidents

Coordinates of kidnapping incidents from the Department of State Services (DSS) converted from Geographic Coordinate Systems (GCS) to Plane Coordinate Systems (PCS) UTM WGS 1984 were imported into ArcGIS 10.8 software as point events (x and y) and then converted to shapefiles for analysis.

2.6.2 Spatial relationship between LULC and kidnappings

LULC data obtained from ESA's Sentinel 2, 10m resolution, classified the study area into vegetation, water, open space, and arable land) via the Impact Observatory deep-learning AI classification model (Table 2). Spatial queries were applied to analyze overlaid kidnapping points within each LULC class, quantifying incidents inside and outside built-up areas to reveal land-use–risk linkages analogous to established GIS-based environmental-crime correlation studies.

Because the ESA Sentinel-2 LULC product contains several detailed classes, a reclassification procedure was applied to merge conceptually similar classes into fewer study-specific categories. The process involved recoding the original pixel values in GIS using the reclassify tool or attribute-based remapping, after which classes with comparable physical and functional characteristics were aggregated into broader groups such as built-up, vegetation/cultivated land, bare/open land, and water. This aggregation reduced thematic fragmentation, improved map readability, and made the LULC variables more suitable for hotspot and spatial correlation analysis.

Table 2: Land Use/Land Cover Classes

Value	Name	Description
1.	Water	Areas where water was predominantly present throughout the year; examples: rivers, ponds, lakes, oceans, flooded salt plains.
2.	vegetation	Areas of any type of vegetation with obvious intermixing of water throughout a majority of the year.
3.	Built-up area	Human-made structures; major road and rail networks; large homogenous impervious surfaces including buildings.
4.	Bare ground/open space	Areas of rock or soil with very sparse to no vegetation for the entire year; large areas of sand and deserts with no to little vegetation.

3 Results and Discussions

3.1 Location and rates of kidnapping incidences

Table 3 reveals the number of persons kidnapped and also the number killed in the year 2019, with percentages of the total for both.

Table 3: Persons kidnapped and killed in 2019

Wards	Persons kidnapped in 2019	Percent	Persons killed in 2019	Percent
Afaka	11	10.5	4	11.1
Birnin Yero	6	5.7	4	11.1
Gwaraji	2	1.9	1	2.8
Igabi	1	0.9	0	0
Kerawa	8	7.7	2	5.6
Kwarau	2	1.9	0	0
Rigachikun	1	0.9	0	0
Rigasa	43	40.9	13	36.1
Sabon Birnin	8	7.7	5	13.9
Turunku	21	20	7	19.4
Zangon Aya	2	1.9	0	0
Grand Total	**105**		**36**	**100**

Source: Department of State Security (DSS), 2022

There were 105 cases of kidnapping in all the eleven wards of Igabi L.G.A. Rigasa ward recorded the highest rate, followed by Turunku and Afaka with 43 incidents making up 40.9%, 21 incidents translating to 20%, and 11 cases, which make up 10.5% respectively. The lowest rates were Igabi and Rigachikun, recording 1 case each without any death; Kwarau, Gwaraji, and Zangon Aya had 2 incidents each, with only Gwaraji ward recording a single death. The total number of deaths for this study year was 36, representing 34% of the total number of kidnappings. Figure 3a shows the spatial distribution of kidnapping events in 2019, revealing a form of clustering in Rigasa and Afaka wards in the south-western corner of the study area, and also in the north and central part around Turunku and Zangon Aya wards, with isolated incidents in the south-west corner around Fanshanu, Kwarau, Rigachickun, Gwaraji and Igabi. Despite the 2020 COVID-19 lockdowns, cases jumped to 358, signaling a 42% increase; 136 deaths, which translates to a 38% fatality rate, as shown in Table 4.

Table 4: Persons kidnapped and killed in 2020

Wards	Persons kidnapped in 2020	Percent	Persons killed in 2020	Percent
Afaka	78	21.8	28	20.6
Birnin Yero	11	3.1	6	4.4
Fanshanu	22	6.1	5	6.7
Gwaraji	5	1.4	2	1.5
Igabi	9	2.5	3	2.2
Kerawa	10	2.8	4	2.9
Kwarau	63	17.6	24	17.6
Rigachikun	21	5.9	9	6.6
Rigasa	22	6.1	9	6.6
Sabon Birnin	39	10.9	17	12.5
Turunku	69	19.3	22	16.2
Zangon Aya	9	2.5	7	5.1
Grand Total	**358**	**100**	**136**	**100**

This is led by Afaka with 78 cases making up 21.8%, closely followed by Turunku with 69 cases translating to 19.3%. Kwarau recorded 63 cases, which is 17.6%; Gwaraji had the lowest incidents with 5 cases, which makes up 1.4% of all cases. Figure 3b shows a graphical illustration of these findings, revealing more incidences around the central part of the study area with some form of clustering around Afaka ward, which gradually spreads into Sabon Birni ward. It also shows an increase in Rigachikun, Igabi, Fanshanu and Gwaraji wards than the previous year.

In 2021, incidents peaked at 552, revealing a 66% increase from 2020; 128 deaths, which translates to a 23% fatality rate, as revealed in Table 5.

Table 5: Persons kidnapped and killed in 2021

Wards	Kidnapped persons in 2021	Percent	Persons killed in 2021	Percent
Afaka	170	30.8	46	35.9
Birnin Yero	32	5.8	5	3.9
Fanshanu	27	4.9	1	0.8
Gwaraji	7	1.3	0	0
Igabi	13	2.3	0	0
Kerawa	45	8.2	14	10.9
Kwarau	66	11.9	16	12.5
Rigachikun	29	5.3	4	3.1
Rigasa	32	5.8	11	8.6
Sabon Birnin	39	7.1	4	3.1
Turunku	81	14.7	22	17.2
Zangon Aya	11	2	5	3.9
Grand Total	**552**	**100**	**128**	**100**

Afaka ward retained its highest ranking with 170 cases, which is 30.8% of the total, followed by Turunku ward with 81 cases, making up 14.7%; Gwaraji had 7 cases and remained lowest, which translates to 1.3%. Figure 3c revealed a more clustered distribution pattern around Afaka and Turunku wards, and also random distribution and encroachment into other wards with fewer cases in previous years.

By 2022, incidences fell by 17%, which means 403 cases and 71 deaths, implying an 18% fatality rate. Afaka, Rigasa Turunku wards continue to be in the lead with 114, 61 and 58 cases respectively, translating to 28.3%, 15.1% and 14.4% respectively. Gwaraji remained minimal with 7 cases, which makes up only 1.7%, as shown in Table 6.

Table 6: Persons kidnapped and killed in 2022

Wards	Kidnapped persons 2022	Percent	Persons killed in 2022	Percent
Afaka	114	28.3	17	23.9
Birnin Yero	14	3.5	2	2.8
Fanshanu	14	3.5	1	1.4
Gwaraji	7	1.7	0	0
Igabi	10	2.5	0	0
Kerawa	18	4.5	7	9.8
Kwarau	40	9.9	11	15.5
Rigachikun	22	5.4	2	2.8
Rigasa	61	15.1	11	15.5
Sabon Birni	35	8.7	6	8.5
Turunku	58	14.4	8	11.3
Zangon Aya	10	2.5	6	8.5
Grand Total	**403**	**100**	**71**	**100**

Figure 3d graphically depicts these findings for visualization. Though the number of incidents is lower than in 2021, findings revealed a more even spread across the study area and even beyond, implying outliers. A clustered spatial distribution is still evident around Afaka, Rigasa, Birnin Yero, Sabon Birni, and Turunku wards, with fewer cases in Igabi, Gwaraji, and Fanshanu wards. Figure 2 employs a descriptive statistical technique (bar chart) to show the number of persons kidnapped and killed for each of the study years.

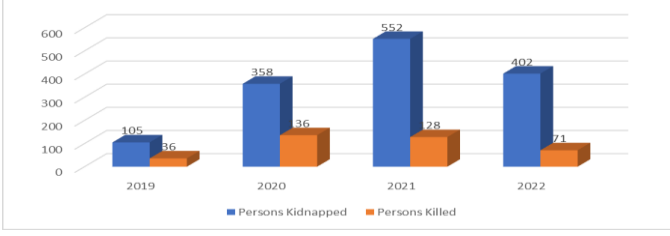
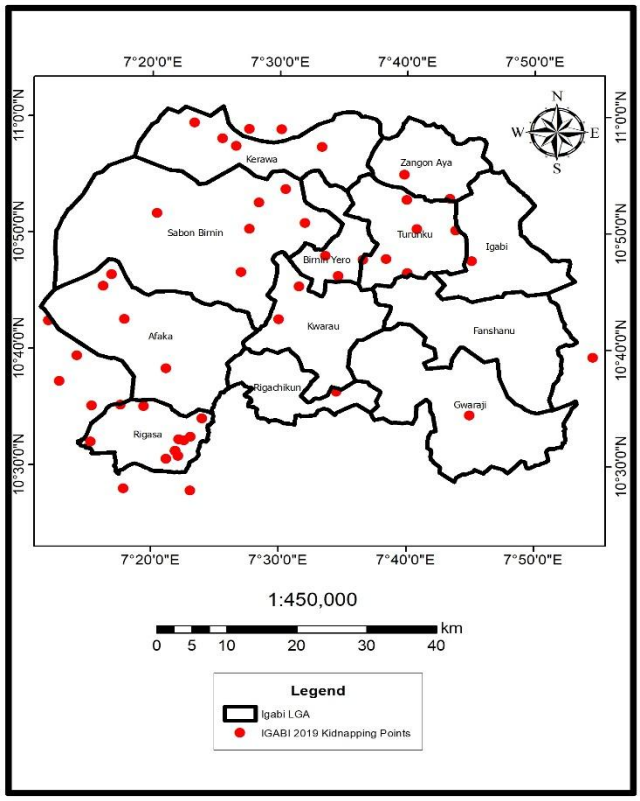


Figure 2: Persons kidnapped and killed for all years of study



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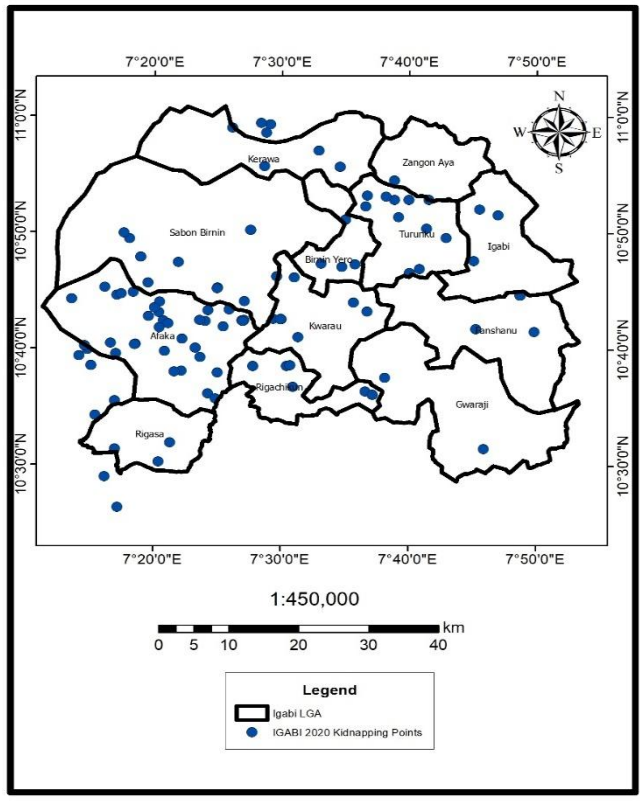

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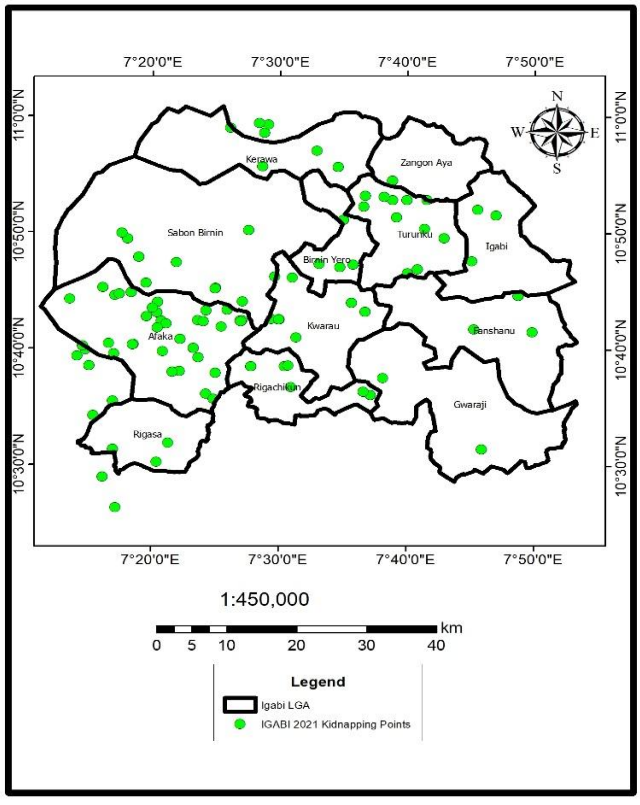

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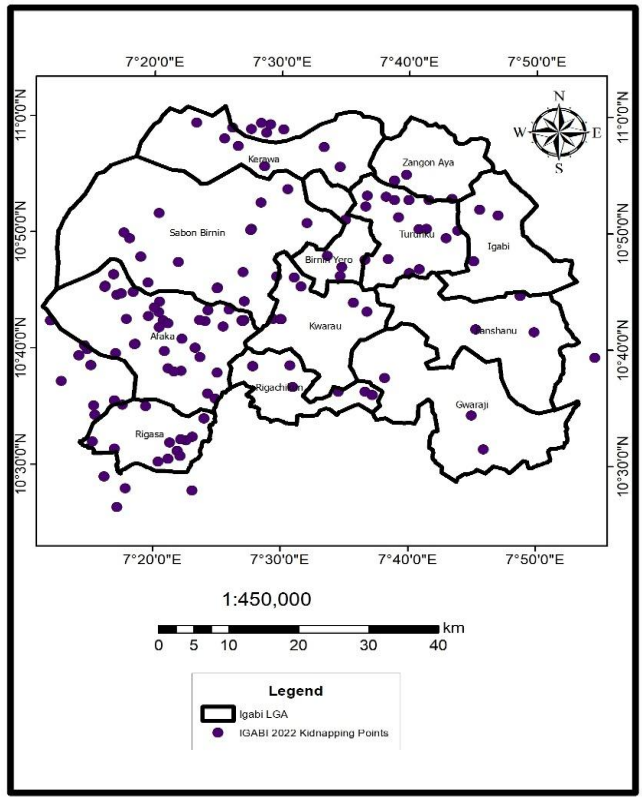

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Figure 3: Kidnapping incidents in a) 2019, b) 2020, c) 2021, and d) 2022

3.2 Spatial Relationship between Land Use/Land Cover and Kidnapping in the Study Area

Table 7 shows a breakdown of the various land use/land cover metrics of the study area over the study period as revealed by analysis.

Table 7: Igabi L.G.A. showing land use/land cover 2019, 2020, 2021 and 2022

Land Cover	2019		2020		2021		2022	
	Area (km²)	(%)	Area (km²)	(%)	Area (km²)	(%)	Area (km²)	(%)
Bare ground	2.14	0.07	2.29	0.07	2.69	0.08	3.44	0.11
Built-up area	89.12	2.77	89.18	2.77	95.80	2.97	96.26	2.99
Vegetation	3,102.38	96.31	3,102.04	96.30	3,095.50	96.10	3,096.36	96.12
Water bodies	27.47	0.85	27.59	0.86	27.09	0.84	25.03	0.78
Total	**3,221.11**	**100.00**	**3,221.11**	**100.00**	**3,221.11**	**100.00**	**3,221.11**	**100.00**

Total area of Igabi L.G.A. according to analysis is 3,221.06 km², of which the bare ground increased from 2,136 km² in 2019 to 3.442 in the year 2022; signalling an increase of 0.1068% from 0.066%. The built-up area increased from 2.766% with an area of 89.12km² in 2019 to 2.988% (96.29km²) in 2022. Findings revealed that vegetation is the predominant land cover in the study area, which makes up 96.31% of the total land area, 3102.38 km² in 2019. A slight and insignificant reduction in vegetal cover of -0.19 km2 was witnessed in the year 2022. Area covered by water bodies shrank from 27.47 km² to 25.03km² in 2022, which is 0.85% to 0.777% of the area.

Analysis shows over 80% of kidnapping victims in Igabi LGA were abducted outside built-up areas, favoring open spaces and vegetation that dominate the study area. Kidnapping incidents that occurred within built-up areas for all four years of study are 233, which makes up less than 4% of the total land cover (Table 8). The number of incidents that occurred outside built-up areas, specifically in vegetal cover, is 1,185. It should be noted that the average bare ground surface area for all four years is 2.6405 km², 92.59 km² for built-up areas, and 27.95 km² for water bodies. The average for vegetation cover over the study period is 3,099.07 km², and this amounts to 96.21% of the total. This implies that most of the kidnapping incidents occur outside built-up areas, which comprise infrastructure, transport facilities, residential, commercial, educational, recreational, industrial, and public institutional buildings in Igabi LGA (Yusuf et al., 2025).

Table 8: Persons kidnapped within and outside built-up and non-built-up areas over the study period

Year	Kidnapped within Built-up Area	Percent	Kidnapped outside Built-up Area	Percentage
2019	33	14.2	72	6.1
2020	39	16.7	319	26.9
2021	92	39.5	460	38.8
2022	69	29.6	334	28.2
Total	**233**	**100**	**1185**	**100**

In 2019, 33 of 105 persons were abducted in built-up areas, representing 31.4%. 72 cases occurred in non-urban areas, specifically vegetation cover; this represents 68.6%, as shown in Table 8. Figure 5a shows kidnapping points data overlaid on the LULC; this clearly revealed that cases occurred predominantly outside built-up areas, cartographically coded in green, while built-up areas were traditionally represented in red. It also depicts that built-up areas are dispersed as small clusters in wards such as Rigasa, which is the most urban, Riachikun, Afaka, Birnin Yero, and Turunku. In the year 2020, 39 kidnap cases were recorded out of the total of 358; this translates to 11% of the total within urban areas. 319 cases occurred in non-urban areas, amounting to 89%, as shown in Table 8. Figure 5b further illustrates that kidnapping events are distributed across the landscape, with more occurrences of kidnapping events in non-built-up areas, specifically around non-urban wards such as Afaka, Birnin Yero, and Turunku.

Findings revealed that 2021, with the highest incidents of all the study years recorded 92 cases out of 552 incidents within built-up areas; this accounts for 17% of the total. Non-built-up areas recorded 460 cases, which translates to 83%, as shown in Table 8 and depicted in Figure 5c, revealing more incidents than previous study years. The year 2022 had 69 cases out of 403, representing 17% of

occurrences in built-up areas (built-up), while 334 incidents representing 83% occurred in non-urban areas. Figure 5d shows that incidents are distributed evenly within non-built-up areas across the landscape; however, there is a reduction in incidents from the previous year, 2021. Figure 4 employs descriptive statistics, graphically describing frequencies for the built-up and non-built-up areas for all the years of study. This provides the opportunity and visual advantage for comparison across all years of study.

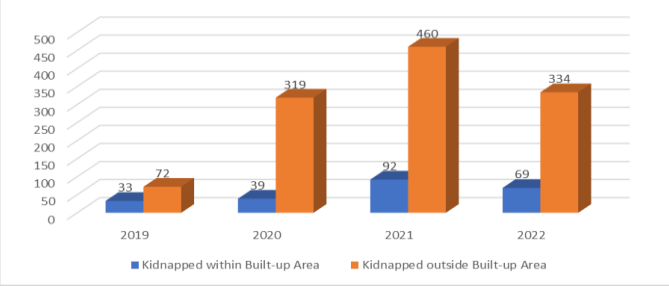
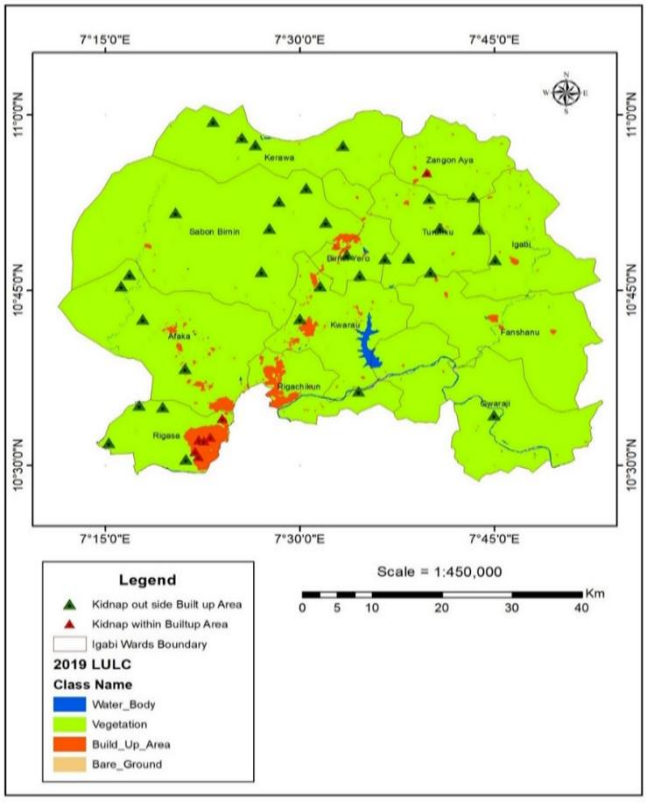


Figure 4: Kidnapping within and outside Built-up and non-built-up areas



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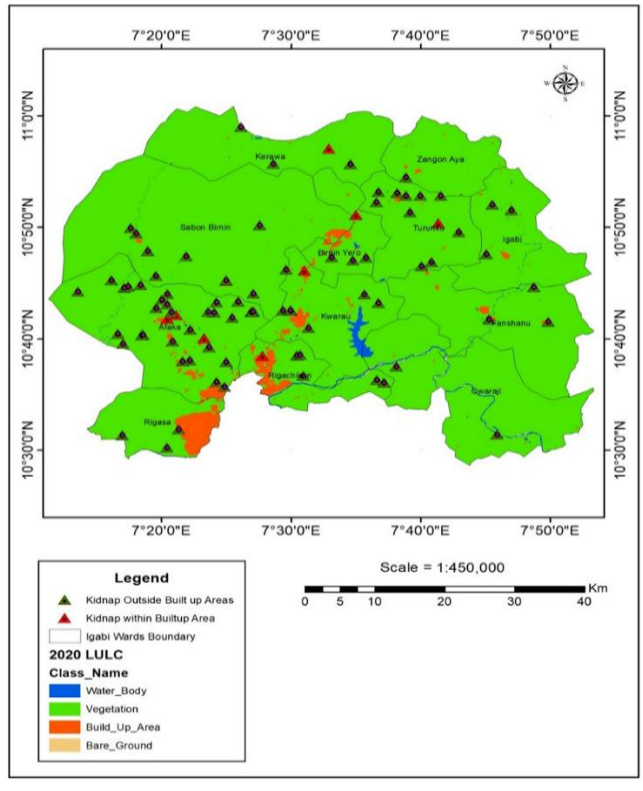

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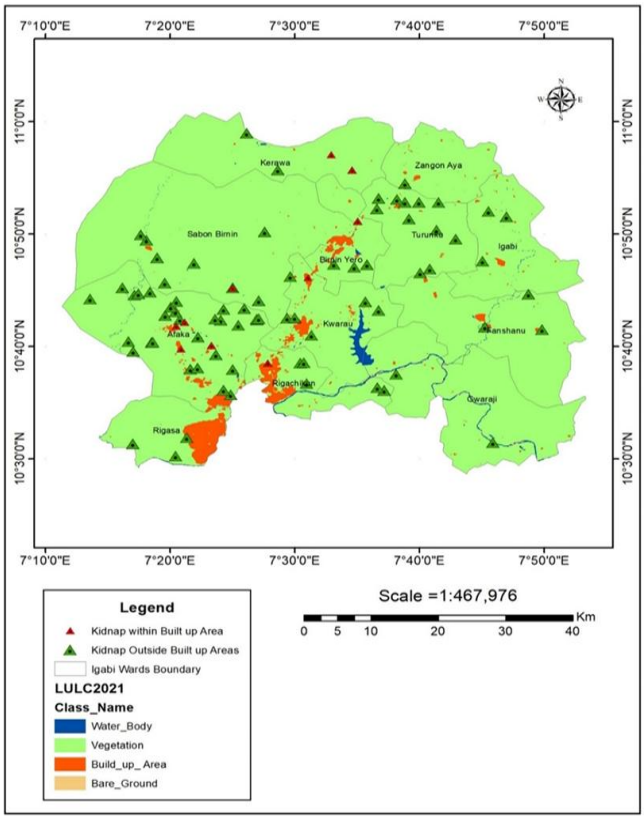

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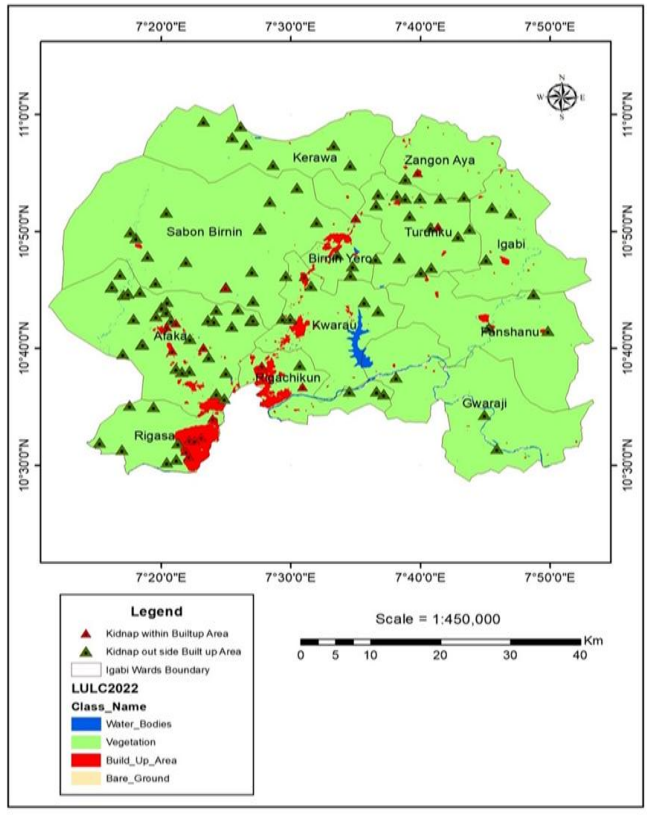

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Figure 5: LULC and Kidnapping incidents in a) 2019, b) 2020, c) 2021, and d) 2022

4 Discussion

The spatiotemporal and land-use dynamics of kidnapping in Igabi LGA, Kaduna State, North-West Nigeria, reveal a sharp escalation from 105 incidents in 2019 to a peak of 552 in 2021, followed by a modest 17% decline to 403 in 2022. This creates a volatile, high-risk environment consistent with Kaduna's "very high" incidence LGAs (Garba et al., 2024; Uzonu et al., 2024). Fatality rates dropped from 34% to 18%, signaling a shift to ransom-oriented tactics amid persistent lethality (Mach, 2024).

Kidnapping patterns evolved in 2019 from urban-ward clusters in Rigasa, Turunku, Afaka, and Zangon-Aya to multi-ward dense clusters along transport corridors by the year 2022, thus indicating diffusion rather than concentration (Garba et al., 2024; Ayuba et al., 2016; Bediroglu et al., 2023). A persistent corridor-linked belt in Afaka, Rigasa, Turunku, Zangon-Aya, Sabon Birni, and Birnin Yero wards aligns with environmental criminology, favoring peri-urban edges over city cores. Afaka dominates as the epicenter, with Rigasa and Turunku being consistently "high-risk" due to proximity to roads, markets, and settlements. Remote wards like Gwaraji, Igabi, and Fanshanu recorded minimal cases; this emphasizes connectivity, density, and activity over isolation (Uzonu et al., 2024; Ortserga & Dam, 2019; Lawanson et al., 2012).

Findings revealed over 80% of incidents occurred in vegetated, non-urban zones (68.6–89% annually), while built-up areas, which represent 2.99% of Igabi's 3,221.06 km², recorded only 11–17% of cases. This is a challenge to urban-crime norms according to studies by Yue et al. (2017) and Dangana (2021a). Vegetation being dominant in Igabi LGA, covering 96.21% of the total land area, enables ambushes, escapes, and hideouts, anchoring kidnapping as an "edge-zone" crime amid peri-urbanization (Oyebanjo & Adedeji, 2020).

Overall, the distribution of kidnapping patterns in the study area confirms peri-urban insecurity tied to weak governance, land-use conflicts, and infrastructural porosity. Strategies must prioritize LULC-integrated forecasting, vegetation patrols, and corridor security to curb bandit diffusion (Garba et al., 2024).

5 Conclusion

A total of 1,418 abductions occurred, resulting in 371 deaths over the study period, implying a 26% fatality rate that peaked at 128 deaths in 2021. Spatial analysis revealed evolving concentrations in Rigasa and Turunku wards in 2019; Kwarau, Afaka, and Zangon Aya in 2020; Kwarau, Afaka, Zangon Aya, and Rigachikun in 2021; and Rigasa, Kwarau, Zangon Aya, and Rigachikun in 2022. Notably, 80% of incidents occurred outside areas, underscoring weak governance across much of the study area,

evidenced by poor or complete absence of policing within a large swathe of ungoverned space. This provides criminal elements with significant advantages for concealment and hideouts, as evidenced by the study's results and findings. Given GIS's capabilities for real-time monitoring, visualization, trend analysis, resource allocation, and hotspot detection, the study recommends establishing new police stations, enhancing surveillance in vegetation hideouts, and prioritizing hotspots through integrated geospatial technologies to combat kidnapping effectively.

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