ASSESSMENT OF VEGETATION COVER CHANGE FOR SECURITY MANAGEMENT IN KADUNA SOUTH SENATORIAL DISTRICT, KADUNA STATE, NIGERIA

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Abstract
Vegetation dynamics pose critical security challenges, as forested and bushy landscapes provide concealment for armed groups, bandits, and kidnappers, thereby undermining law enforcement and surveillance efforts. This study examines vegetation cover change in Kaduna South Senatorial District, Nigeria, between 2014 and 2024, with implications on security management as it relates to kidnapping incidences. The study pursued four objectives: to identify the spatial distribution of vegetation cover changes, analyze their temporal trends and assess the relationship between environmental dynamics and kidnapping incidences. The research integrated geospatial data and techniques-including Landsat (ETM and OLI) imagery, GIS analysis, and Normalized Difference Vegetation Index (NDVI) - with field surveys, police kidnapping data, and community questionnaires across eight Local Government Areas (LGAs) which constitutes the Senatorial District. Results reveal notable vegetation transitions: Kidnapping Incidence analysis identified Zangon Kataf LGA (20%) and Kagarko LGA (20%) as high-risk LGAs, with kidnapping clusters occurring near roads, water bodies, and critical infrastructures. The decade-long vegetation cover analysis shows a major ecological decline with security implications. Moderate vegetation, once dominant in 2014 (53.75%), decreased by 2024 (52.92 %), while dense vegetation also decreased (-5.52%) due to ongoing degradation. Sparse vegetation briefly increased (14.85%) before declining (6.13%), indicating fragmentation of denser areas, and very sparse vegetation remained low and stable, reflecting persistently degraded landscapes. Vegetation degradation exacerbates security risks by exposing infrastructure and diminishing natural surveillance. Eco-security framework combining environmental management and proactive policing to strengthen resilience and reduce security threats in Kaduna South Senatorial District are recommended.

Keywords*: Kidnapping; Security Management; Incidences; Landsat imagery; Vegetation cover*

INTRODUCTION

Globally, the assessment of vegetation cover change has emerged as a central pillar in environmental monitoring, disaster management, climate change mitigation, and sustainable development (Li *et al.,* 2023). This prominence reflects the increasing recognition of vegetation as both an ecological and socio-economic resource, as well as a critical security factor. Technological advancements in remote sensing and geospatial analysis have significantly enhanced the monitoring and management of vegetation, offering new opportunities to address challenges associated with global environmental change (Ma *et al.,* 2022).

Vegetation cover plays a dual role in environmental and human systems. Ecologically, it regulates biodiversity, climate, and soil health; socio-economically, it underpins agriculture and livelihoods; and in the security domain, it shapes human vulnerability and resilience. However, vegetation dynamics are increasingly altered by human activity and natural processes (Tanveer *et al.,* 2024). Deforestation, driven by logging, agriculture, and infrastructure expansion, remains acute in regions such as the Amazon, the Congo Basin, and Southeast Asia. The Amazon alone has lost an estimated 17% of its forest cover in the past five decades, with adverse impacts on global carbon cycles and biodiversity (Hansen *et al.,* 2013). In Africa, vegetation studies highlight the continent's vulnerability to degradation and the implications for environmental sustainability, livelihoods, and security. Research in the Sahel emphasizes the significance of vegetation monitoring in tracking land degradation and supporting adaptation strategies (Dardel *et al.,* 2014). The integration of satellite-based data with ground observations has become indispensable for vegetation assessments, climate resilience, and disaster risk reduction. Mamman (2017) identifies population growth, agricultural expansion, and infrastructure development as primary pressures on vegetation resources, underscoring the need for systematic monitoring to inform land management policies. Similarly, Shuaibu et al., (2018) stress the adoption of advanced remote sensing platforms, including MODIS and Sentinel-2, to improve monitoring capabilities across Africa. These studies converge on the argument that regional environmental and security challenges require technology-driven, context-specific interventions.

Kaduna South Senatorial District, located in southern Kaduna State, Nigeria, exemplifies the complex interactions between vegetation dynamics, livelihoods, and security. Characterized by rich biodiversity and agricultural potential, the district is socio-ecologically sensitive and heavily dependent on vegetation resources. The vegetation supports farming activities, provides habitats for wildlife, and acts as a proxy indicator of areas vulnerable to conflict (Jibril et al., 2021; Gowda et al., 2021). However, dense vegetation poses critical security concerns. Forested and bushy landscapes often serve as hideouts for armed groups, bandits, and kidnappers, thereby undermining surveillance and law enforcement efforts. The dense canopy and undergrowth obstruct visibility, complicating the detection and monitoring of criminal activities. Law enforcement agencies face mobility challenges in such terrains, which delay responses during emergencies. These conditions also enable illicit activities such as smuggling, illegal logging, and, in some cases, drug cultivation, further entrenching insecurity and instability.

Addressing these challenges requires an integrated geospatial framework that combines satellite imagery with GIS-based analytical tools. Such a framework enhances the capacity for environmental monitoring, improves early warning systems, and supports evidence-based security strategies. By linking vegetation dynamics to security outcomes, it becomes possible to identify hotspots of vulnerability, anticipate risks, and implement targeted interventions. This approach not only strengthens environmental governance but also enhances resilience against threats exacerbated by vegetation degradation. Through the integration of geospatial technologies and field-based data, the study provides insights into how vegetation dynamics influence kidnapping incidents and other security challenges. The findings are expected to support policy development, guide resource allocation, and promote eco-security approaches in solving the security challenges facing Southern Kaduna Senatorial District.

MATERIALS AND METHOD

Kaduna South Senatorial District- is located between Latitudes 09º 00′N and 10º 57′North of the Equator and Longitudes 06º 51′E and 8º 51′East of Greenwich Meridian. The area has a landmass of about 26, 000km^2 on an average elevation above sea level of 1, 993 feet (6577m) (Salleh, 2014). It shares common borders with Kajuru and Igabi LGAs to the North, Bauchi and Plateau States to the East, Birnin Gwari and Niger State to the West, Nasarawa State to the South and Abuja, Federal Capital Territory (FCT) also to the South as shown in Fig 1. Reconnaissance survey was carried out to enable the examination of the research area, focusing on the characteristics of vegetation cover. Complementary oral interviews with community members provided contextual insights into the physical extent of vegetation, local livelihoods, and the environmental and security challenges confronting the area.

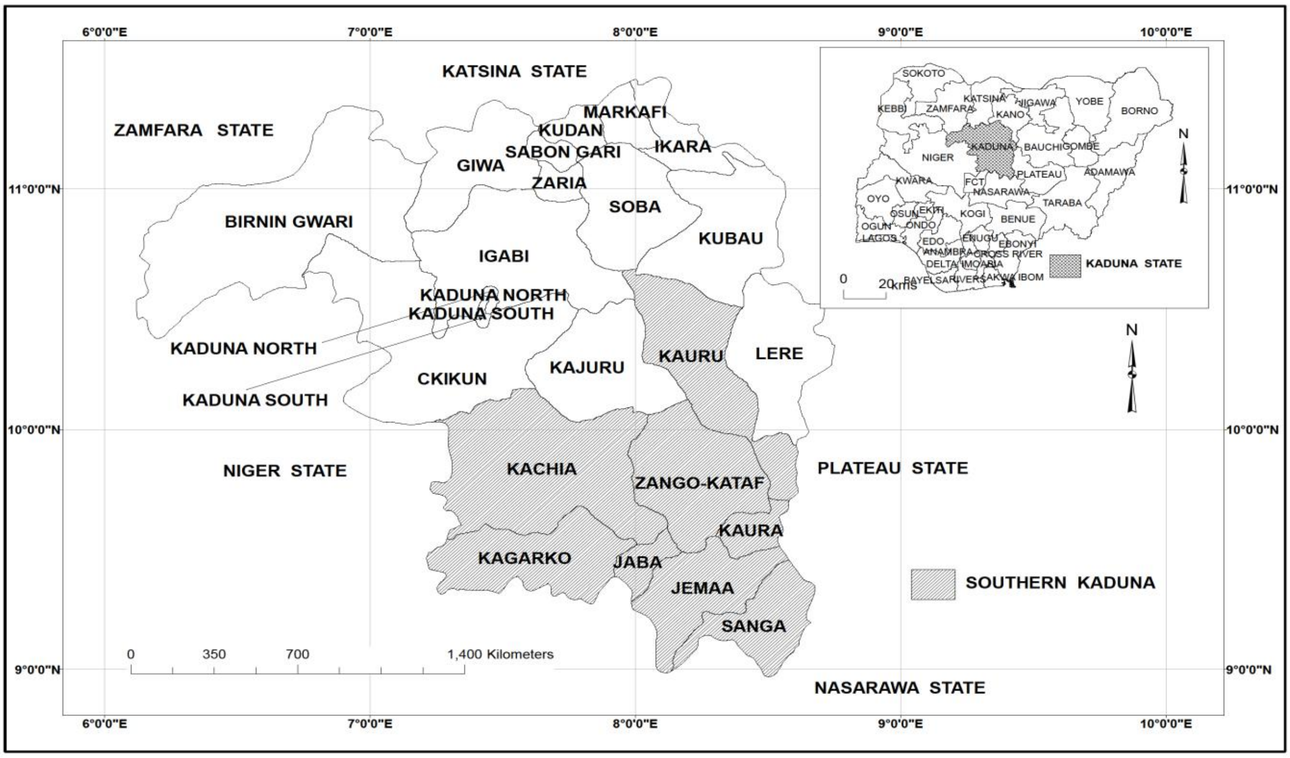


Figure 1. Kaduna South Senatorial District
Source: Department of Geography NDA, Kaduna (2024)

The data type used for this study includes both primary and secondary data sources.
Field surveys: This include ground trothing, GPS data collection and vegetation cover surveys (conducting surveys to gather information about vegetation cover changes, dense forests, shrub lands, and open grasslands amongst others).

Table 1 Instrument and Field Data Sources

S/No	Instrument for Data Collection	Date Acquired	Resolution Scale	Source	Purpose
1	Questionnaire	2024	Variance	Field Survey	Demographic Data
2	GPS	2024	± 5m	Field Survey	XY Coordinates
3	Oral Interview	2024	Not Application	Field Survey	Field based data
4	Field Observations	2024	Not Application	Field Survey	Field based data
5	Interview	2023	Not Application	Field Survey	Field based data

Source: Researcher's Work (2025).

The secondary data for this study include remote sensing data (Landsat imagery of the study area from 2014-2024. The satellite imageries was sourced from the United States Geological survey), maps, existing literature from journals, text books, seminar papers, thesis, reports and web references. Table 1 presents the characteristics of the satellite images.

Table 2: The characteristics of the satellite imageries and their Sources

S/N	Data Type	Date Acquired	Scale	Source	Purpose	Data Type	LS Product Identifier	Path/Row	Cell size reflectance	Cloud Cover (%)	SR (m)	Bands	Date Acquired
1	Landsat 7 (ETM)	2014 -	30 m	USGS	NDVI	Landsat 7 (TM)	188052_20091214_TI	0618/051	30.00	< 10	30	(B3,4,5)	1/3/2013
2	Landsat 7 (ETM)	2019	30 m	USGS	NDVI	Landsat 7 (TM)	188053_20041214_TI	188/052	30.00	< 10	30	(B3,4,5)	1/ 3/ 2018
3.	Landsat 8 (OLI)	2024	30 m	USGS	NDVI	Landsat 8 (OLI)	188053_20191205_TI	188/055	30.00	<10	30	(B3,4,5)	1/3/2023
4	STRM	2015	30 m	USGS	Relief	DEM	14218, 11465		2015		30	-	2015

Source: United State Geological Service (USGS) Database, (2025)

The kidnapping incidence data which contained the locations (coordinates) of kidnapping incidences was downloaded in excel (.csv) file format. The file was converted to a database (.dbf) file format (compatible to ArcMap) and converted to a shape file by projecting into the projected coordinate system as points. A subset of kidnapping incidences was created using spatial queries which was clipped (mask) to the boundary of the environment of the study area to obtain only the kidnapping incidences within the boundary of the areal output. This thus allowed kidnapping rates to be investigated within the spatial unit. The rationale behind this subset was to be able to generate results which are more representative of the study area. Landsat satellite image (Operational Land Imager (OLI) that are geometrically corrected were acquired in collection level 2 step 2 from the United States Geological Survey (USGS). All images were acquired in the month of March in order to discern the different kinds of vegetation in their stable stage and to properly compare the NDVI differences. In addition, the time gap between the satellite images was more than 18 days, due to cloud cover or technically damaged scenes. Image fusion techniques were used to integrate the information provided by individual sensors. Fusion of images with different spatial resolutions is an important aspect of image pre-processing. However, due to technological limitations, remote sensors cannot provide images with both spectral and high spatial-resolution (HR) characteristics. The method for the analysis of the LULC Change is the Post-Classification Comparison Method (PCM) as adopted by Ejaro and Abdullahi (2013). Post classification comparison analysis reveals the change between two epochs. Change data was generated from the analysis and from the change statistics, the rate of change (percentage) was computed. The spatial and temporal changes were then examined. Classification Accuracy Assessment average score of 96% was achieved using the error matrices method.

Descriptive and inferential statistics was used to interpret the vegetation indices and spatial distribution. Descriptive statistics percentages summarized vegetation cover characteristics, while inferential statistics (correlation analysis) evaluated relationships between vegetation cover and some specific geographical or anthropogenic factors that may influence security challenges. The analysis of vegetation cover change was approached through two primary dimensions: spatial coverage and temporal vegetation cover changes observed within the study area between 2014 and 2024. Spatial analysis was employed to investigate the trends in vegetation distribution, utilizing the Annual Rate of Change formula, expressed as:

$$\text{Annual Rate of Change} = \frac{(\%\ \text{Change})}{100} \times \text{Number of study years.}$$

This method facilitated the quantification of vegetation dynamics over the study period. A change detection analysis was performed using satellite imagery from different years to examine temporal variations. Techniques such as image differencing and post-classification comparison were applied to identify significant changes, including vegetation gain or loss. The findings provided insights into spatial patterns of vegetation expansion or depletion, emphasizing areas where changes in vegetation cover may influence environmental security activities. Hotspot analysis was applied to detect clusters of high kidnapping rate, which may represent areas of concern for security management. Buffer zones was created around critical areas (roads, settlements, critical infrastructure, water bodies) to assess the proximity of dense vegetation to these locations, which may hinder visibility and accessibility. Overlay analysis was employed to combine vegetation cover data and other spatial layers, such as topography, critical infrastructure, and settlements, to provide a comprehensive view of areas where vegetation cover impacts surveillance needs.

RESULTS AND DISCUSSION

The findings examines the spatial distribution, temporal trends of vegetation cover changes and the relationship between these changes and kidnapping incidences, within the framework of security management in Kaduna South Senatorial District.

The Relationship between Vegetation Cover change and some Environmental Parameters

This sub-section explores the relationship between vegetation cover change and some environmental parameters in relation to kidnapping rates. It examines key parameters such as critical infrastructures, road networks and water bodies.

Changes in Vegetation Cover and Kidnapping Incidences around Critical Infrastructures

The relationship between vegetation cover changes and Kidnapping Incidences around critical infrastructure is presented in Figure 4.7

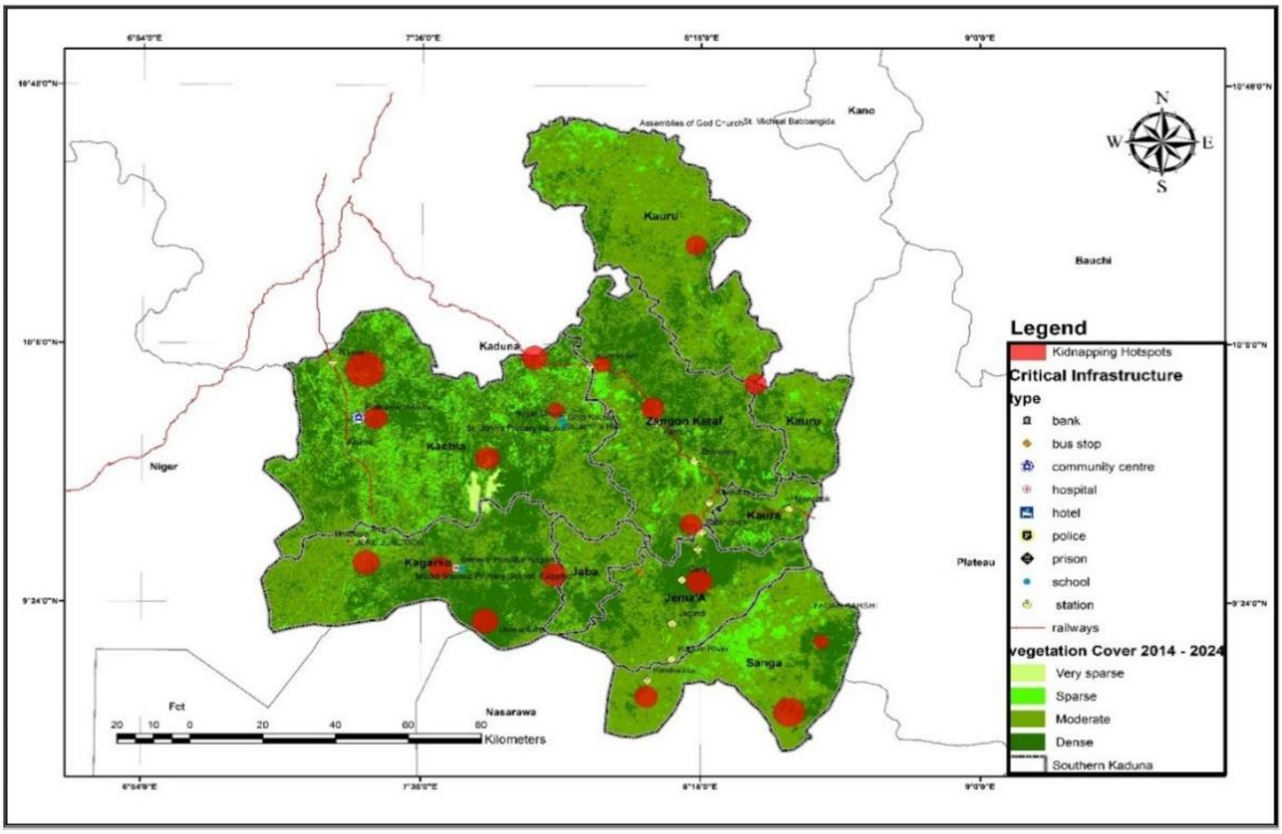


Fig 2: The Relationship between changes in Vegetation Cover and Kidnapping Incidences around critical Infrastructures in the study area

Researcher's Analysis, (2024**)**

Result from Figure 4.7 show the security landscape across the study area particularly within the Local Government Areas (LGAs) of Sanga, Jaba, Jemaa, Kachia, Zangon Kataf, Kauru, Kagarko, and Kaura, has undergone significant transformation over the past decade. Central to this transformation is the alarming rise in kidnapping incidents, particularly around critical infrastructure such as roads, telecommunications installations, and educational institutions. A growing body of scholarship suggests that these security challenges are deeply intertwined with patterns of environmental changes, notably alterations in vegetation cover. This environmental transition bears direct implications for the patterns and tactics of kidnapping. With the reduction of dense forest cover, criminals have adapted by utilizing the fragmented vegetative patches and bush corridors that remain, exploiting them for concealment and operational mobility.

Moreover, the proximity of kidnapping incidents to critical infrastructure suggests a calculated operational logic. In many parts of Sanga and Kachia, for instance, communication towers located amidst unmanaged regrowth have become focal points for abduction events, underscoring the vulnerabilities associated with environmental neglect around strategic assets. The nexus between environmental degradation and insecurity is well-documented. Scholars such as Benjaminsen *et al.*,

(2012) argue that land cover changes, especially deforestation and vegetation fragmentation, often create ecological conditions that facilitate criminal activities.

Change in Vegetation Cover and Kidnapping Incidences along Road Network

The relationship between vegetation cover changes and Kidnapping Hotspots along road network is presented in Figure 3

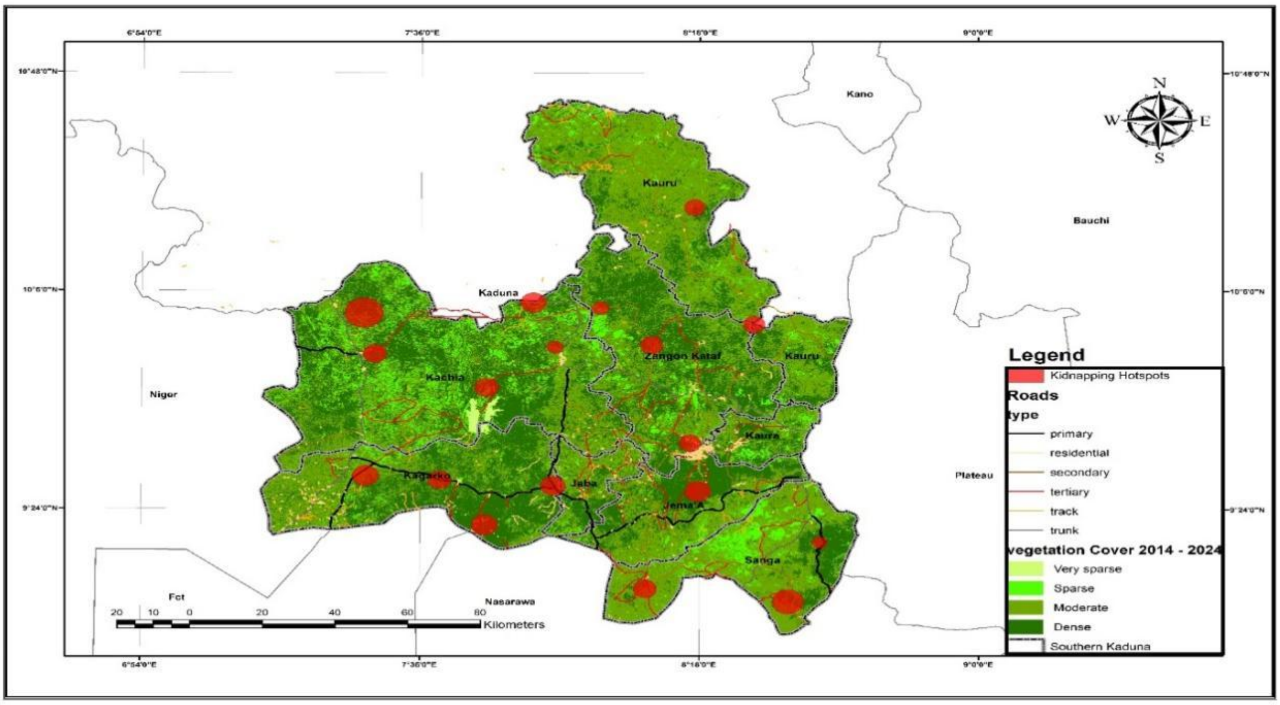


Figure 3: The relationship between vegetation cover and Kidnapping Hotspots along Road Network

Researcher's Analysis, (2024)

Result from Figure 4.8 showed that Southern Kaduna have witnessed a disturbing rise in incidents of kidnapping, particularly along major and minor road corridors. A closer examination of this pattern suggests that environmental transformations, particularly changes in vegetation cover, play a critical - if often understated - role in shaping the operational dynamics of these security threats. Vegetation cover has traditionally functioned as both a protective environmental buffer and a natural surveillance barrier across much of Kaduna South Senatorial District's landscapes. As criminals adapt to the changing landscape, they increasingly exploit the patchy and often unmanaged vegetative regrowth along roadsides to conceal their movements. Jibril *et al.*, (2021) emphasize that such fragmented vegetation creates intermittent "cover zones" that enable swift attacks on travelers, particularly in isolated stretches between towns like Kafanchan in Jemaa and nearby villages in Kauru. The deterioration of environmental conditions around road corridors is compounded by inadequate security patrols, the absence of road maintenance, and weak rural policing. In many parts of Kachia and Zangon Kataf, the combination of fragmented vegetation and governance gaps has rendered key transportation routes dangerous, inhibiting not only safe mobility but also economic activities. In synthesizing these insights, it becomes evident that vegetation cover change - specifically along road corridors - directly contributes to the patterns of kidnapping observed in the LGAs under study. Fragmented, unmanaged vegetation facilitates criminal ambushes, while infrastructural neglect exacerbates travelers' vulnerability. This dynamic affirms the assertion by Hegazy and Kaloop (2015) that tackling rural insecurity requires an integrated strategy that links environmental management with proactive security interventions.

Change in Vegetation Cover and Kidnapping Incidences around Water Bodies

The relationship between dense vegetation cover and water bodies is presented in Figure 4

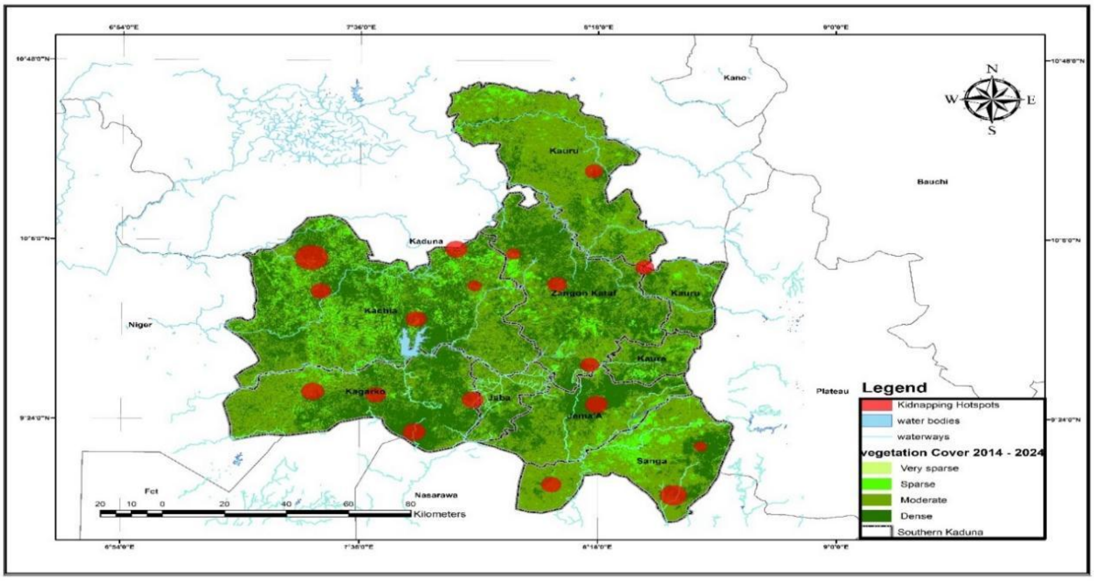


Figure 4: The relationship between vegetation cover changes and Kidnapping Hotspots around water bodies
Researcher's Analysis, (2024)

Result from Figure 4 show that the security situation in the Local Government Areas (LGAs) of Sanga, Jaba, Jemaa, Kachia, Zangon Kataf, Kauru, Kagarko, and Kaura has, in recent years, been increasingly defined by the rising incidence of kidnapping, particularly in proximity to natural features such as rivers, streams, and other water bodies. While much attention has been paid to socio-political drivers of insecurity, emerging research suggests that environmental changes - particularly shifts in vegetation cover around water bodies - have played a subtle but significant role in shaping patterns of criminal activities, including kidnappings. The fragmentation and sporadic regrowth of vegetation along rivers and streams provide concealment for criminals, facilitating ambushes, the establishment of temporary camps, and escape routes after kidnapping operations. Balcan, Tuncer and Yildirim (2020) found that fragmented riparian zones offer both tactical advantages - through natural cover - and strategic benefits - such as access to water and relative remoteness from security patrols. In Southern Kaduna, areas along the Gurara River (impacting parts of Kagarko and Kachia), the Amere River near Jemaa, and numerous smaller tributaries in Zangon Kataf and Kaura have become notable hotspots where such dynamics are evident. This finding agrees with the theoretical and empirical works of Oloukoi *et al.* (2014), who established that ecological features like water bodies often serve as both strategic resources and tactical enablers for criminal groups.

Composite map of Vegetation Cover changes and Kidnapping Incidences around some Environmental Parameters

Change in Vegetation Cover and Kidnapping Hotspots around Environmental Parameters is presented in Figure 5

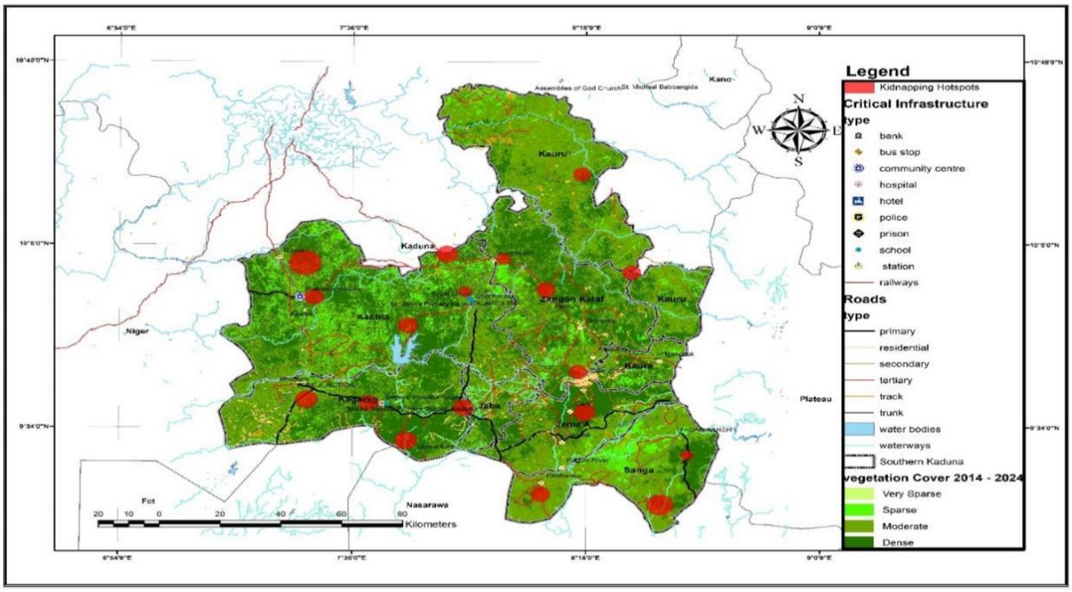


Figure 5: Change in Vegetation Cover and Kidnapping Incidences around environmental Parameters

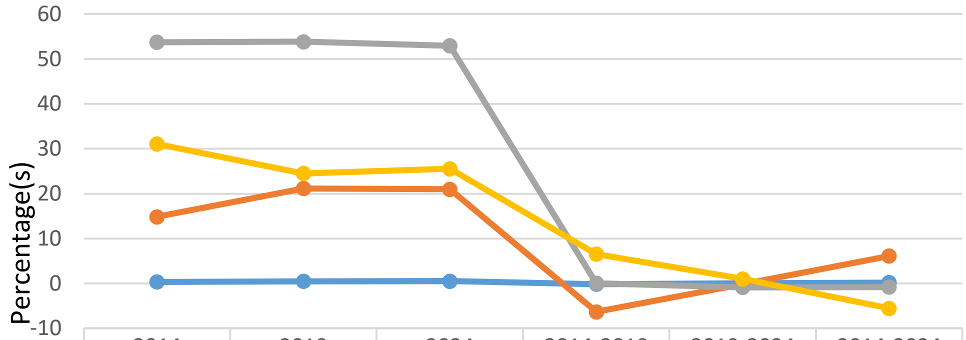
The analysis in Figure 5 revealed that the Local Government Areas (LGAs) of Sanga, Jaba, Jemaa, Kachia, Zangon Kataf, Kauru, Kagarko, and Kaura in Southern Kaduna have experienced a dramatic increase in the incidence of kidnapping, which is closely intertwined with changes in vegetation cover and proximity to critical infrastructures and other geographic features. The gradual loss of dense forests has exposed critical infrastructure such as roads, telecommunications towers, and rural schools, which become prime targets for kidnappers. For example, roads like those connecting Kagarko to Jere, often surrounded by thinly vegetated areas, have experienced an upsurge in abduction incidents, primarily because the exposed nature of these roads provides fewer barriers for criminals, making them easier to target. According to Brown and Wilson (2018) during the rainy season, regrowth along roadsides and around infrastructure corridors provides ideal concealment for criminals. This seasonal cycle of regrowth and thinning plays into the hands of abductors, allowing them to exploit the tactical advantages of an ever-changing landscape. In contrast, the dry season, while offering greater visibility along roads, does not eliminate risks entirely, as pockets of resilient vegetation remain along some rural stretches, particularly in areas around Kauru and Zangon Kataf. Kidnappers adapt to these variations, taking advantage of both the tactical benefits during the rainy season and the relative openness in the dry season.

Areas such as Kauru, where poverty and insufficient law enforcement presence overlap with degraded landscapes, have seen up to a 6% rise in kidnapping cases over the last five years. This interaction between environmental changes and socio-political factors creates a context where criminal groups find fertile ground for executing abductions with little resistance or deterrence. The presence of critical infrastructure, such as telecommunication towers, roads, and schools, exacerbates these vulnerabilities. As Balcan, Tuncer and Yildirim (2020) note, infrastructure located in areas of environmental neglect or degradation tends to be more exposed to criminal activities. In Kaduna south Senatorial District, telecommunications infrastructure located in regions with unmanaged regrowth or abandoned farmland has seen an increase in abduction incidents, as these facilities provide essential logistical advantages for kidnappers, such as communication channels and routes for rapid escape. Similarly, schools located on the peripheries of degraded vegetation zones, particularly in areas like Jemaa and Zangon Kataf, have been frequent targets for kidnappers seeking to exploit educational institutions for financial gain.

To quantify the impact of vegetation cover changes on kidnapping rates in these LGAs, an analysis of kidnapping frequency shows that areas with significant environmental degradation, such as Kachia and Sanga, report up to a 20 % higher rate of abduction incidents compared to regions with relatively intact vegetation, like parts of Kaura 8 % and Kagarko 20% . These findings align with the work of (Okeke and Oji, 2014) who emphasize that the fragmentation of natural landscapes offers better ambush sites and escape routes for criminal groups. The relationship between environmental change and kidnapping is not merely coincidental but is rooted in the practical advantages that fragmented and degraded landscapes offer to criminals.

The Nature and Trend of Vegetation Cover Change Matrix from 2014 to 2024

The nature and trend of Vegetation Cover changes Matrix from 2014 to 2024 is presented in Figure 6



	2014	2019	2024	2014-2019	2019-2024	2014-2024
Very Sparse	0.34	0.49	0.53	-0.15	0.04	0.19
Sparse	14.85	21.18	20.98	-6.33	-0.2	6.13
Moderate	53.75	53.83	52.95	0.08	-0.88	-0.8
Dense	31.06	24.5	25.54	6.56	1.04	-5.52

Very Sparse Sparse Moderate Dense

Figure 6: Trend of Vegetation Cover Change Matrix from 2014 to 2024

Source: Author's Analysis (2024)

The ten-year analysis of vegetation cover change in Figure 6 reveals a profound ecological shift with far-reaching implications for security management. The most striking feature of the trend is the complete disappearance of moderate vegetation by 2024 (-0.8%), a category that once accounted for more than half of the district's land area in 2014 (53.75%). This loss signals a dramatic transformation of the landscape, suggesting that formerly balanced, semi-intact vegetation zones have either degraded into sparser forms or been converted to bare or built-up land, most likely through deforestation, agricultural expansion, or urban development. Dense vegetation, which initially covered about 31.06% of the area, also experienced a steady decline over the decade -5.52%, indicating progressive degradation of the few remaining forested or thickly vegetated patches. At the same time, sparse vegetation showed an initial rise between 2014 and 2019 (6.13%) - evidence of denser areas breaking down into more open cover - before registering a net decline by 2024. Very sparse vegetation remained consistently low, reflecting the relative stability of already degraded zones.

Conclusion

From a security management standpoint, the vegetation changes present both advantages and risks. The decline of moderate and dense vegetation reduces natural concealment for criminals, improving visibility and surveillance efficiency. However, this benefit is countered by new challenges arising from land degradation and conversion, which heighten competition over resources and fuel farmer–herder conflicts, communal violence, and banditry. Thus, vegetation loss shifts insecurity from forest-based threats to resource-driven conflicts. This pattern aligns with findings by Ibrahim *et al.* (2022), who observed similar dynamics in Kaduna and Zamfara States, where deforestation initially disrupted criminal hideouts but later intensified socio-economic and security pressures.

These findings demonstrate a strong link between vegetation cover changes and rising security threats, especially kidnappings. The loss of vegetation has heightened the exposure of key infrastructure and removed natural deterrents to crime. The study confirms that vegetation cover significantly influences the spatial patterns of insecurity. It emphasizes the need to integrate environmental surveillance into security strategies and to promote sustainable land use, reforestation, and natural cover preservation. These measures are vital for effective policy formulation, land-use planning, and strengthening community resilience in Kaduna South Senatorial District.

Recommendations

The recommendations call for integrating environmental management with security planning through geospatial monitoring and sustainable land use. Key actions include using satellite and GIS tools to identify risk zones, implementing targeted reforestation, strategically siting infrastructure, and promoting collaboration among security and environmental agencies. Policymakers are urged to embed vegetation-security linkages into development plans and provide funding for restoration, monitoring, and rural security programs. Security agencies should incorporate environmental changes and monitoring into security management, planning and surveillance. Stakeholders should create awareness of the dynamics between vegetation cover changes and insecurity to the general populace.

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