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SPECIAL ISSUE: CELEBRATING 20 YEARS OF GEOGRAPHY IN KADUNA STATE UNIVERSITY - ADVANCES AND FRONTIERS IN GEOGRAPHY

Assessment of Urban Expansion in Parts of Kaduna Metropolis and Its Driving Factors

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ABSTRACT

Rapid urban expansion has continued to pose challenges to people living in urban areas. This study assessed the spatiotemporal dynamics of land use and land cover (LULC) and the extent of urban expansion in Kaduna Metropolis, Nigeria, over the period 2004–2024. Multitemporal Landsat satellite imagery from Landsat 7 (2004) and Landsat 8 (2014 and 2024) was obtained from the United States Geological Survey and classified using the Decision Tree method into five LULC classes: built-up areas, vegetation, grasses, bare land, and water bodies. Quantitative analysis was conducted to assess the area, magnitude, and rate of LULC changes, while qualitative Key Informant Interviews (KIIs) were analyzed to identify factors contributing to urban expansion. The results of the study reveal a substantial increase in built-up areas from 95.5 km^2 (5.2%) in 2004 to 435.7 km^2 (23.7%) in 2024, reflecting rapid urbanization. Bare land decreased sharply between 2004 and 2014 but partially recovered by 2024, while vegetation exhibited marked expansion from 2004 to 2014, followed by a decline in 2024. Grasses remained relatively stable, and water bodies showed minimal variation, indicating limited hydrological changes. The result highlights significant conversion of non-built-up areas to urban land, indicating accelerated urban expansion over the two decades. The study provides critical insights for urban planning and sustainable land management in rapidly urbanizing Nigerian cities.

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1 Introduction

Urban expansion, characterized by the growth of cities and urban areas, is a global phenomenon driven by population growth, rural-urban migration, and socio-economic development (Haydar et al., 2025). This expansion has both positive and negative implications. On one hand, it stimulates economic growth, fosters infrastructural development, and offers social and cultural benefits. On the other hand, urban expansion can lead to environmental degradation, social inequalities, infrastructural strain, and loss of green spaces (Ogunbode et al., 2025). Understanding the patterns and trends of urban expansion is essential for effective environmental management, sustainable development, and informed decision-making (Mande et al., 2023). By analyzing the extent, rate, direction, and dynamics of urban expansion, policymakers can address the challenges associated with it. This involves identifying key factors influencing urban expansion and developing strategies to mitigate its negative impacts. Another challenge due to population growth is that traffic congestion becomes a significant issue (Fattah et al., 2022). LULC changes will lead to an increase in runoff, increased travel time, decreased air quality, and a higher risk of accidents (Kim et al., 2022; Shukla et al., 2023).

Several studies have been conducted on land use and land cover in Kaduna Metropolis. For example, Musa and Abubakar (2024) examined land-use changes in the area, focusing specifically on landscape fragmentation. Similarly, Abubakar and Abdussalam (2024) assessed land use dynamics, but the research focused on the impact of urban expansion on wetlands in the metropolitan area. Previously, Akpu et al. (2017) examined the influence of urban expansion on the vegetation cover in Kaduna Metropolis. While studies such as Ndabula et al. (2012) focused on encroachment on floodplains in the area. Thus, while previous studies have shed light on these issues, there remains a temporal gap in understanding the current trends and patterns of urban expansion in Kaduna Metropolis.

Urban expansion in the Kaduna metropolis has a significant negative impact on livability, environmental health, and socio-economic conditions in the region. Urban Sprawl is one of the major negative effects of urban expansion in Kaduna metropolis, where rapid growth of built-up areas has led to a significant increase in urban sprawl (Saleh et al., 2014). These expansions into previously undeveloped land result in the loss of natural habitats, increased pollution, and a decrease in the quality of life in the region. Environmental Degradation is also part of the negative effects of urban expansion, affecting parts of the Kaduna metropolis as a result of the loss of green spaces, increased air and water pollution, and a higher risk of flooding. The lack of proper waste management systems and the conversion of natural land into urban areas also contribute to environmental degradation.

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To achieve the aforementioned aim, the following objectives shall be looked into, which are to (i) analyze the spatial extent of urban expansion in Kaduna Metropolis from 2004 to 2024, (ii) identify the key factors influencing urban expansion, and (iii) analyze the temporal pattern and trends of urban expansion in Kaduna Metropolis from 2004 to 2024.

2 Materials and Methods

2.1 Study Area

Kaduna is located on the southern end of the high plains of Northern Nigeria, gridded by Latitude 10° 40' N to 10° 60' N and Longitude 7° 10' E to 7° 35' E. Kaduna metropolis is made up of four local governments, which include: Kaduna North, Kaduna South, Igabi, and Chikun local governments. The state consists of three senatorial districts, which are: Kaduna Central, Kaduna North, and Kaduna South senatorial districts.

The metropolis is historically founded on three firm bases: Administrative Capital, Industrial Town, and as a Military Garrison (Akpu et al., 2017). One principle of its master plan is the delineation of a 'functional territory' which was reclassified as 'inner zone' and an 'outer zone' to allow it to function economically, socially, and administratively as the capital within its natural city region and to control development within the local daily sphere of influence. The city was the second most industrialized city after Lagos in Nigeria in the 1970s, though the economic climate of Kaduna has worsened in the last two to three decades (Ndabula et al., 2013).

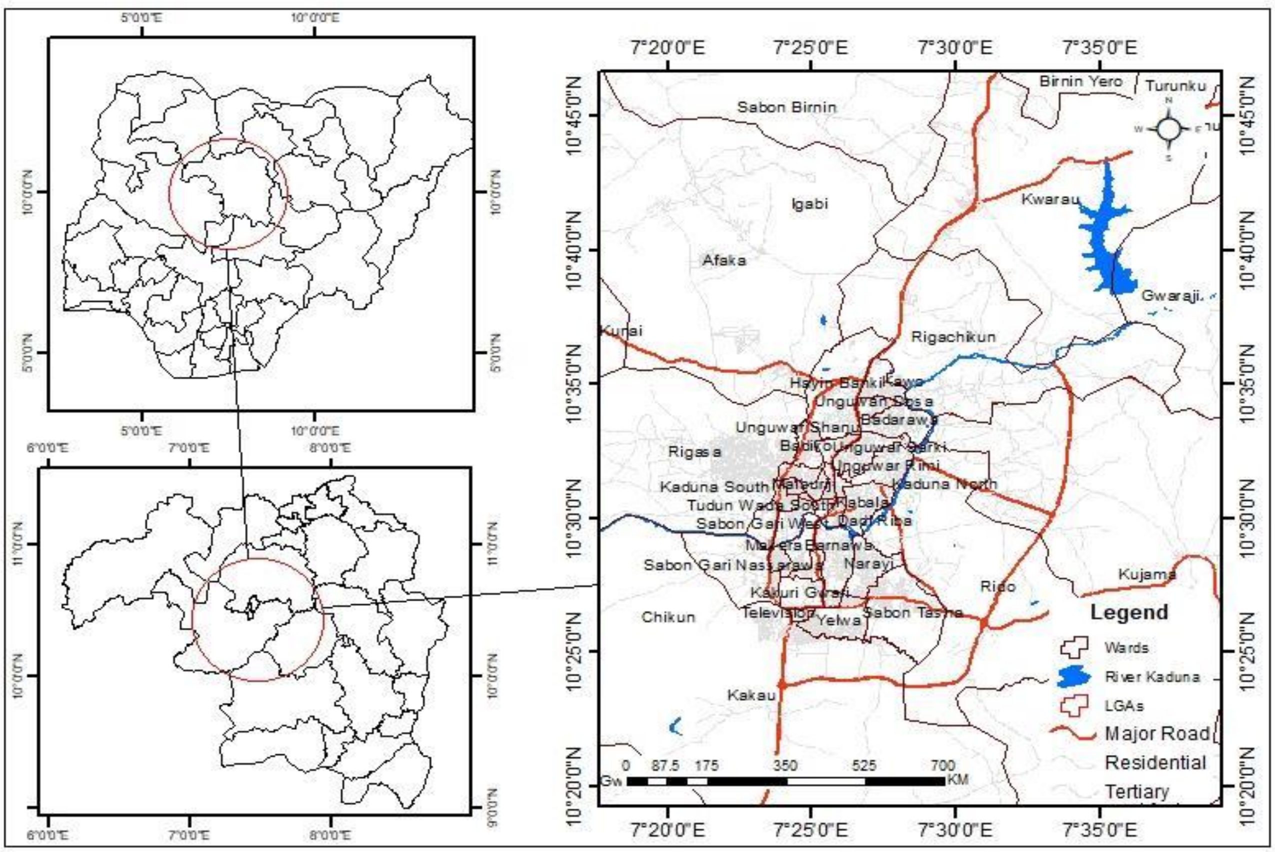


Figure 1: Nigeria showing the Kaduna metropolis
Source: Modified from GRID3 – Nigeria, 2024

Kaduna falls within the tropics and has a tropical climate with well-defined wet and dry seasons, according to Köppen's classification scheme. The town has an average rainfall of 1,300mm per annum, with relatively hot and humid weather and a temperature of 27°c to 34°c. The wet season lasts for up to six months (May to October), with its peak in the months of July and August, and a total of about 1,300mm (Muhammad & Abubakar, 2025). The dry season, on the other hand, begins in November and ends in March. The harmattan period is usually cool during the day and chilly at night, and is experienced between the months of late November to January, in which temperature falls as low as 11°c. This occurs as a result of the influence of the prevailing North-easterlies wind that originates from the Saharan desert, which is very cold and dry. Relative humidity ranges between 10% and 30% in the dry season, 70% and 90% in the wet season, respectively (Abubakar et al., 2024).

Kaduna town is well drained; the entire metropolis is drained by the River Kaduna. Kaduna River is a main tributary of the Niger River in central Nigeria (Bennett et al., 1979). It rises on the Jos Plateau 18 miles (29 km) southwest of Jos town near Vom and flows in a northwesterly direction to a bend 22 miles (35 km) northeast of Kaduna town, while numerous subsequent streams take the form of the basement fractures. Thus, the river may be associated with one of the tectonic episodes. The river Kaduna takes its source from the highlands of Jos Plateau. The tributaries in Kaduna Metropolis are usually transient, that is, they are seasonal (the water level increases during the rainy season and decreases and dries up during the dry season) (Abdussalam, 2015).

According to Bennett et al. (1979), Kaduna Metropolis is on a gentle, undulating plain with land ranging from 457m to 609m above sea level. The town is located on a peneplain consisting of various kinds of rocks, such as older Granite, Schist, and quartzite, in variable composition, which are basement complex outcrops of the Precambrian age. These rocks are hard and resistant, although they have undergone variable weathering and erosion processes. These processes have resulted in the formation of inselbergs and huge rocky granites, like the ones in the Tudun Wada area and Malali (Bununu et al., 2015).

The population of the city has experienced rapid growth from about 169,125 in 1967 to a projected figure of 1,371,805 in 2009, according to the 2006 population census (National Population Commission [NPC], 2006). Kaduna metropolis has a vibrant economy with agricultural activities and industrial manufacturing taking the lead (Saleh, 2015). Trading of goods and services is the universal economic activity in Kaduna metropolis (especially in the Sheikh Abubakar Gumi market, also known as the central market). Some engage in blacksmithing, clay work, and mat-weaving. Agriculture and grazing are also important activities that are favored by the nature of the land (Bununu et al., 2015).

2.2 Data Sources

This research used Landsat images and Key Informant Interview (KII) conducted with stakeholders from Kaduna State Urban Planning and Development Agency (KASUPDA), Kaduna Geographic Information Service (KADGIS), and Kaduna State University. Multitemporal Landsat images were collected from the United States Geological Survey (USGS). Details of the images are shown in Table 1.

Table 1: Characteristics of data used

Image	Sensor	Resolution	Date
Landsat 7	Enhanced Thematic Mapper +	30m	18-02-2004
Landsat 8	Operational Land Imagers (OLI/TIRS)	30m	22-02-2014
			02-02-2024

2.3 Data Processing

The Landsat image for 2004 was downloaded with a scan-line error. This was removed using ERDAS Imagine 2014. Additionally, the shapefile of Kaduna Metropolis was used to extract the study area from the full Landsat paths and rows. All the images were re-projected to the UTM Zone 32 Minna datum for analysis.

2.4 Land Use and Land Cover Analysis

The images were classified using a Decision Tree algorithm based on spectral indices thresholds. The number of classes was determined by the identified land use and land cover types in Kaduna Metropolis. The images for the three (3) periods were classified into different land cover types. The following indices were calculated for each pixel. The NDVI was used to differentiate vegetation from non-vegetation. Given in Eqn. (1).

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \tag{1}$$

The NDVI was used to identify water bodies. It was computed using Eqn. (2).

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)} \tag{2}$$

The NDBI was used to identify built-up areas, using Eqn. (3).

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)} \tag{3}$$

Where NIR is the Near Infrared band (Band 5 on Landsat 8, and Band 4 on Landsat 7), Red is the Red band (Band 4 on Landsat 8, and Band 3 on Landsat 7), Green is the green band (Band 3 on Landsat 8, and Band 2 on Landsat 7), SWIR is the Shortwave Infrared band (Band 6 on Landsat 8, and Band 5 on Landsat 7).

The Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Built-up Index (NDBI) were calculated, with thresholds set at NDVI $\geq$ 0.4 for vegetation, NDWI $\geq$ 0.1 for water, NDBI $\geq$ 0.15 combined with NDVI $<$ 0.2 for built-up areas, NDVI between 0.2 and 0.4 for grasslands, and remaining pixels classified as bare land.

The study area has been mapped and classified into two major classes, which include the built-up and the non-built-up areas within the study period. The individual classes are explained in Table 2.

Table 2: Classification scheme

S/N	Land cover type	Description
1	Bare surface	Any exposed soil layer, landfill, or excavated areas.
2	Built up	Residential, institutional, industrial, roads, rail, etc.
3	Vegetation	This includes natural (undisturbed), well-defined, dense vegetation.
4	Grass land	This includes scattered short grasses
5	Water bodies	Rivers, streams, lakes, and reservoirs.

Source: Modified from (Jensen, 2005)

Land use/land cover analysis was also used to analyze and map out the temporal pattern and trends of urban expansion in Kaduna metropolis. The Landsat imageries were also extracted from the United States Geological Survey (USGS) using Landsat 7 for 2004, Landsat 8 for 2014 and 2024 using the Decision Tree classification method. Microsoft Excel was used to calculate the area, magnitude, rate, and percentage of urban expansion of the study area, under the following classes: built-up area, vegetation, grassland, bare surface, and water bodies.

2.5 Accuracy Assessment

The accuracy of the Land Use/Land Cover (LULC) classifications was assessed using an independent validation dataset for each time period (2004, 2014, and 2024). Stratified random sampling was employed to generate approximately 250 reference points per classified map, ensuring representative coverage of all five LULC classes. Reference data (ground truth) for these points was derived through visual interpretation of high-resolution historical imagery available in Google Earth Pro and ESRI World Imagery basemaps, supplemented by local knowledge and existing land use maps where available.

From each matrix, key accuracy metrics were calculated: Overall Accuracy (percentage of correctly classified points), Producer's Accuracy (measure of omission error for each class), User's Accuracy (measure of commission error for each class), and the Kappa Coefficient (κ), which measures the agreement between the classification and reference data beyond chance.

2.6 Qualitative Data Analysis

To identify the key factors influencing urban expansion, the KIIs were recorded using a mobile phone voice application. This was subsequently uploaded to OTranscribe for transcription. Finally, the transcribed texts were imported into NVivo and coded, and similar codes were used to generate themes. The interviews conducted with experts from Kaduna Geographic Information Services (KADGIS), Kaduna State Urban Planning and Development Authority (KASUPDA), and Kaduna State University (KASU) were analyzed and reported.

3 Results and Discussion

3.1 Accuracy Assessment

To assess the accuracy of the land cover classification maps for the years 2004, 2014, and 2024, the standard error matrix (confusion matrix) analysis was carried out. Independent validation points, stratified by the five land cover classes (Bare Land, Built-up, Grasses, Vegetation, and Water Bodies), were compared against the classified maps. This process generated the confusion matrices presented in Tables 3, 4, and 5, from which key accuracy metrics, including Overall Accuracy, the Kappa Coefficient (κ), and class-specific User's and Producer's Accuracies were derived. The results demonstrate a consistent and statistically significant improvement in classification performance over the two-decade period, with Overall Accuracy rising from 85.2% in 2004 to 88.9% in 2024.

Table 3: Summary of LULC Classification Accuracy (2004)

Classified → **Reference ↓**	**BL**	**BU**	**G**	**V**	**W**	**Row Total**	**Producer's Acc.**
Bare Land (BL)	85	3	7	5	0	100	0.85
Built-up (BU)	4	78	2	1	0	85	0.918
Grasses (G)	10	2	90	18	0	120	0.75
Vegetation (V)	6	1	15	108	0	130	0.831
Water (W)	0	0	0	0	65	65	1
Column Total	105	84	114	132	65	500	
User's Acc.	0.81	0.929	0.789	0.818	1		

Total Correct Pixels = 500 * 0.852 = 426, Overall Accuracy = 426 / 500 = 85.2%

Table 3 revealed the classification accuracy assessment for the land cover classification of 2004, derived from a confusion matrix of 500 validation samples across five classes (Bare Land [BL], Built-up [BU], Grasses [G], Vegetation [V], and Water [W]), revealing high overall performance. Producer's accuracies ranged from 0.75 (Grasses, primarily confused with Vegetation) to 1.00 (Water, perfectly mapped), with Built-up achieving 0.92 and Vegetation 0.83, while Bare Land was 0.85. Users' accuracies were similarly strong, peaking at 1.00 for Water and 0.93 for Built-up, but lower for Grasses (0.79) due to over-classification of Vegetation pixels and for Bare Land (0.81). These results indicate robust discrimination of urban and water features, with moderate confusion between grassy and vegetated areas.

Table 4: Summary of LULC Classification Accuracy (2014)

Classified → Reference ↓	BL	BU	G	V	W	Row Total	Producer's Acc.
Bare Land (BL)	88	2	6	4	0	100	0.88
Built-up (BU)	3	81	1	0	0	85	0.953
Grasses (G)	8	1	98	13	0	120	0.817
Vegetation (V)	4	0	12	114	0	130	0.877
Water (W)	0	0	0	0	65	65	1
Column Total	103	84	117	131	65	500	
User's Acc.	0.854	0.964	0.838	0.87	1		

Total Correct Pixels = 500 * 0.876 = 438

Table 4 revealed the accuracy assessment of the 2014 land use/land cover (LULC) classification, based on a confusion matrix of 500 validation samples across five classes (Bare Land [BL], Built-up [BU], Grasses [G], Vegetation [V], and Water [W]), yielded an overall accuracy of 89.2% (446 correctly classified pixels). Producer's accuracies ranged from 0.817 (Grasses, primarily confused with Vegetation) to 1.00 (Water, perfectly classified), with Built-up at 0.953, Bare Land at 0.88, and Vegetation at 0.877. Users' accuracies were high, peaking at 1.00 for Water and 0.964 for Built-up, but slightly lower for Grasses (0.838) and Bare Land (0.854) due to minor over-classification, alongside moderate confusion between grassy and vegetated classes. These results underscore reliable mapping of urban and water features, with some separability challenges in herbaceous covers.

Table 5: Summary of LULC Classification Accuracy (2024)

Classified → Reference ↓	BL	BU	G	V	W	Row Total	Producer's Acc.
Bare Land (BL)	90	2	5	3	0	100	0.9
Built-up (BU)	2	82	1	0	0	85	0.965
Grasses (G)	7	1	101	11	0	120	0.842
Vegetation (V)	3	0	10	117	0	130	0.9
Water (W)	0	0	0	0	65	65	1
Column Total	102	85	117	131	65	500	
User's Acc.	0.882	0.965	0.863	0.893	1		

Total Correct Pixels = 500 * 0.889 = 455

Table 5 shows the accuracy assessment of the 2024 land use/land cover (LULC) classification, based on a confusion matrix comprising 500 validation samples across five classes (Bare Land [BL], Built-up [BU], Grasses [G], Vegetation [V], and Water [W]), demonstrated improved performance with an overall accuracy of 91% (455 correctly classified pixels). Producer's accuracies ranged from 0.842 (Grasses, mainly confused with Vegetation) to 1.00 (Water, perfectly classified), with high values for Built-up (0.965), Bare Land (0.90), and Vegetation (0.90). Users' accuracies were consistently strong, reaching 1.00 for Water and 0.965 for Built-up, while Grasses (0.863) and Bare Land (0.882) reflected minor over-classification issues, particularly between grassy and vegetated areas. These metrics highlight enhanced discrimination of urban, water, and bare features compared to prior assessments, with persistent but reduced confusion in herbaceous classes.

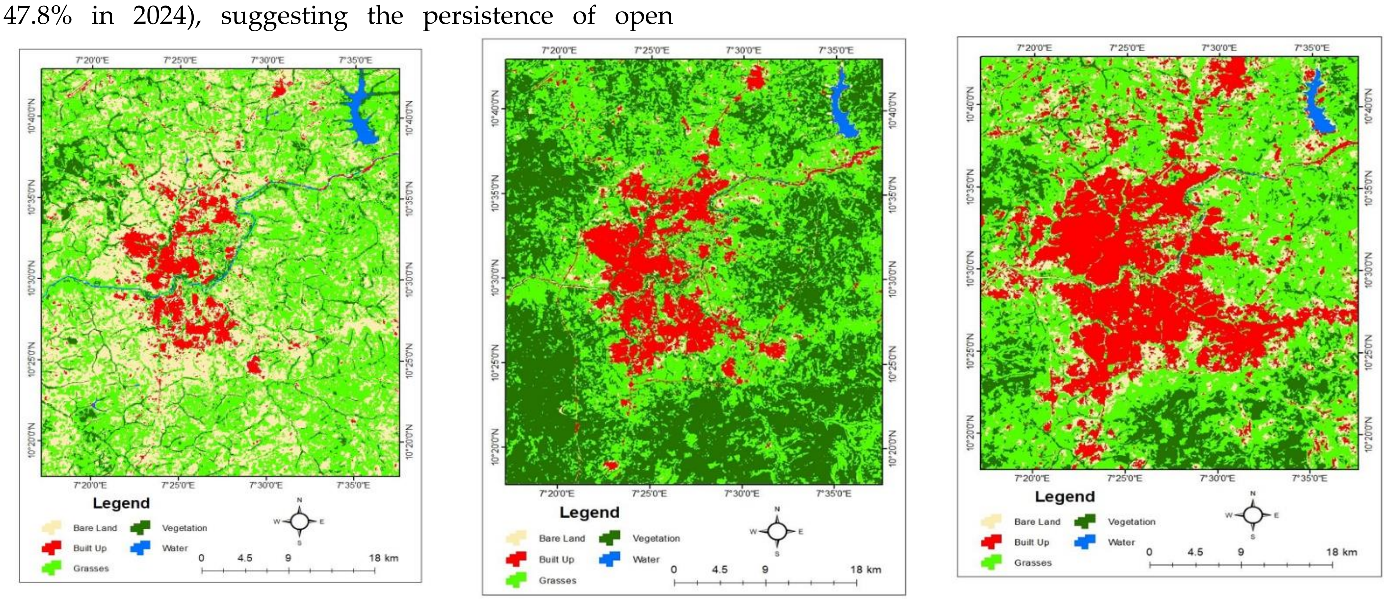
3.2 Spatiotemporal pattern of land use and land cover in Kaduna Metropolis (2004-2024)

This study detects the spatiotemporal changes in land use/land cover and evaluates the urban expansion of Kaduna metropolis within the time frame of 2004-2024. The result of the LULC distribution is shown in Table 6.

Table 6: Distribution of land use and land cover changes for 2004, 2014, and 2024

	2004		2014		2024	
LULC Class	**Area (km^2)**	**%**	**Area (km^2)**	**%**	**Area (km^2)**	**%**
Built Up	95.5	5.2	178.5	9.7	435.7	23.7
Bare land	684.5	37.3	63.1	3.4	255.1	13.9
Grasses	886.1	48.3	751.5	40.9	877.7	47.8
Vegetation	152.5	8.3	834.2	45.4	258.1	14.1
Water	17.6	1.0	8.9	0.5	9.6	0.5
Total	**1836.3**	**100.0**	**1836.3**	**100.0**	**1836.3**	**100.0**

Table 6 reveals the land use and land cover (LULC) statistics from 2004 to 2024 reveal significant spatial transformations over the 20 years. Built-up areas expanded dramatically from 95.5 km^2 (5.2%) in 2004 to 435.7 km^2 (23.7%) in 2024, reflecting rapid urbanization and infrastructure development. However, bare land decreased sharply between 2004 (684.5 km^2, 37.3%) and 2014 (63.1 km^2, 3.4%), before increasing again to 255.1 km^2 (13.9%) in 2024, possibly due to new construction sites, deforestation, or agricultural land degradation. Grasses maintained dominance throughout the period, fluctuating slightly but remaining relatively stable, covering nearly half of the total area (48.3% in 2004 and 47.8% in 2024), suggesting the persistence of open rangelands or savannah ecosystems. Vegetation cover, however, experienced a dynamic shift: it expanded markedly from 152.5 km^2 (8.3%) in 2004 to 834.2 km^2 (45.4%) in 2014, indicating possible reforestation, improved vegetation growth, or land recovery within that decade. However, by 2024, vegetation declined sharply to 258.1 km^2 (14.1%), suggesting renewed pressure from human activities such as urban expansion, agriculture, or logging. Water bodies remained relatively unchanged throughout the period, occupying less than 1% of the total area, which indicates hydrological stability but limited surface water resources.



a) 2004 b) 2014 c) 2024

Figure 2: Land use and land cover distribution of Kaduna Metropolis in a) 2004, b) 2014, and c) 2024

3.3 Magnitude of land use and land cover in Kaduna Metropolis (2004-2024)

Table 7 presents the magnitude of land use and land cover changes in Kaduna metropolis in the years 2004, 2014, and 2024.

Table 7: Magnitude of change in land use/land cover in Kaduna metropolis

LULC Class	2004-2014 (km²) change	2014-2024 (km²) change	2004-2024 (km²) change
Built Up	82.9	257.3	340.2
Bare land	-621.5	192.1	-492.4
Grasses	-134.5	126.2	-8.4
Vegetation	681.8	-576.1	105.6
Water	-8.7	0.6	-0.8

Table 7 shows an increase in built-up areas by 82.9 km² between the years 2004 and 2014. It further shows a 257.3 km² increase in built-up areas between the years 2014 and 2024. There was a cumulative increase of 340.2 km² in built-up areas within the period of study. There was a 621.5 km² decrease in bare land between the years 2004and 2014, and a further increase of 192.1 km² between the years 2014 and 2024. Cumulatively, there was a 492.4 km² decrease in bare land within the period of the study.

There was a 134.5 km² decrease in grasses between the years 2004 and 2014, and a further increase of 126.2 km² between the years 2014 and 2024, and cumulatively a decrease of 8.4 km² in grasses within the period of the study. Also, there was a 681.1 km² increase in vegetation between the years 2004 and 2014; it decreased by 576.1 km² between the years 2014 and 2024. A cumulative increase of 105.6 km² was observed in vegetation within the period of study. Finally, water bodies decreased by 8.7 km² between the years 2004 and 2014, and further decreased by 0.6 km² between the years 2014 and 2024. There was a cumulative decrease of 8.0 km² in water bodies within the period of study.

3.4 Rate of land use and land cover in Kaduna Metropolis (2004-2024)

Table 8 presents the rates of land use and land cover changes in Kaduna metropolis in the years 2004, 2014, and 2024.

Table 8: Rate of change in land use and land cover area within the period under review

LULC Class	2004–2014 (%/year)	2014–2024 (%/year)	2004–2024 (%/year)
Built-up	+8.7	+14.4	+17.8
Bare land	-90.8	+30.4	-3.1
Grasses	-1.5	+1.7	-0.05
Vegetation	+44.7	-69.1	+3.5
Water	-4.9	+0.8	-2.3

From Table 8, the land use/land cover (LULC) classes in Kaduna Metropolis exhibited markedly divergent annual percentage rates of change between 2004 and 2024, reflecting rapid urbanization and a dramatic increase in vegetation. Built-up areas demonstrated consistent and accelerating expansion, increasing at an average annual rate of 8.7% from 2004–2014, rising to 14.4% from 2014–2024, and averaging 17.8% over the full 20-year period, indicative of intensified infrastructural development and population pressures post-2014. In contrast, bare land underwent extreme volatility, declining dramatically at −90.8% per year during 2004–2014 before partially recovering at +30.4% per year in the subsequent decade, resulting in a modest net annual loss of −3.1%. Vegetation cover displayed similarly pronounced fluctuations, expanding rapidly at +44.7% per year from 2004–2014, which is attributable to vegetation recovery in the region, followed by a sharp contraction of −69.1% per year from 2014–2024, yielding a net gain of +3.5% annually over the study period. Grasses remained relatively stable, with minor annual changes (−1.5% to +1.7%), averaging near-zero (−0.05%) decline, while water bodies experienced a small net annual reduction of −2.3%. These patterns underscore accelerated urban sprawl at the expense of natural covers, punctuated by methodological challenges in distinguishing spectrally similar non-built-up classes across the savanna environment.

3.5 Spatial Extent of Urban Expansion in Kaduna Metropolis from 2004 to 2024

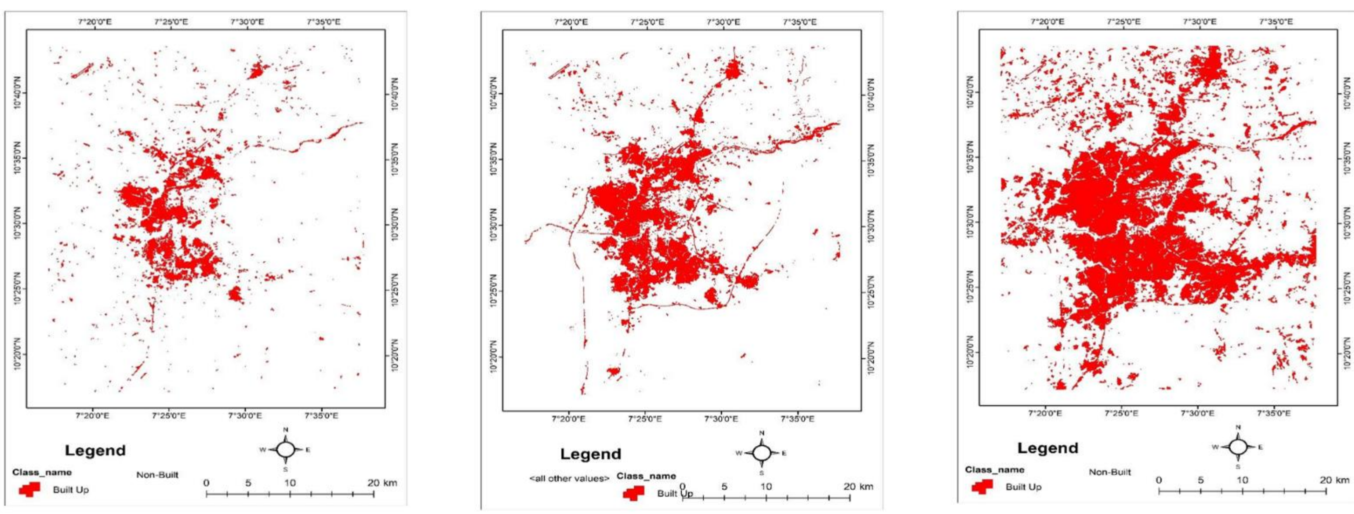
The spatial extent of urban expansion within the study period has been mapped out by classifying and polygonising the satellite imagery of the study area into two major classes, Build up areas, which encompasses Residential buildings, schools, market etc, and non-build up areas which encompasses bare lands that's the open spaces, water bodies, which includes Rivers and streams, vegetation which includes dense agricultural and non-land, grasses which encompasses low green lands and scattered cultivations. Table 9, Figures 3a, 3b, and 3c show the pictorial illustration of the table and the mapped representation of the spatial extent of urban expansion in Kaduna metropolis within the study period, respectively.

Table 9: The extent of urban expansion within the Years 2004, 2014, and 2024

	2004		2014		2024	
LULC Class	**Area (km²)**	**%**	**Area (km²)**	**%**	**Area (km²)**	**%**
Built Up	95.5	5.2	178.5	9.7	435.7	23.7
Non built-up	1,740.7	94.9	1,657.7	90.2	1,400.5	76.3
Total	**1,836.3**	**100.0**	**1,836.3**	**100.0**	**1,836.3**	**100.0**

Table 9 shows how the built-up areas constantly expanded within the period of the study, showing the rapid urbanization of the Kaduna metropolis. In 2004, built-up areas constituted about 95.5 km², which is equivalent to 5.2 % of the total land cover, while the non-built-up areas constituted about 1,740.7 km², which is 94.9%. In 2014, built-up areas constituted about 178.5 km² of the total land use, which is equivalent to 9.7 % of the total land use, while the non-built-up areas constituted about 1,657 km², which is 90.2%.

While in 2024, the total land use was also 1,837 km², built-up areas constituted about 435.7 km² of the total land use, which is equivalent to about 24% of the total land use, while the non-built-up areas constituted about 1,400.5 km², which is 76.3% of the total land use. Figures 3a, 3b, and 3c show the visual representation of the spatial extent of the study area within the study period.



a) 2004 b) 2014 c) 2024

Figure 3: Extent of Urban Expansion in a) 2004, b) 2014, and c) 2024

3.6 Key Factors Influencing Urban Expansion

The researcher carried out a decent interview with a few experts in the field of urban planning in the state to uncover the major factors influencing urban expansion in Kaduna metropolis. These experts work in top governmental organizations, notably known for urban planning, urban land property registration, urban-related research, and urban management, among others. The key informants are a Senior Town Planning Officer from Kaduna Geographic Information Services (P1), a Town Planning Officer II from Kaduna State Urban Planning and Development (KASUPDA) (P2), and an academic staff member from Kaduna State University (P3). The summary of their responses and experience is shown in Table 10.

Table 10: Summary of KII with stakeholders

Participant ID	Factors Discussed	Description of responses
P1, P2, P3	Accessibility	"The provision of access roads linking and connecting various parts of the city is a major factor that contributes to urban expansion in Kaduna metropolis. New access roads like Yakowa road linking the core city to some areas such as Karji and Maraban Rido play a major part in the city's current expansion." (P1) "Rapid urban expansion in Kaduna metropolis started during the massive urban renewal from 2015-2022. When the road infrastructures were upgraded, the accessibility and connectivity of the city from the core to suburb increases." (P2) "Accessibility brings about urban expansion, no matter how remote or far a place is from the city, if it is accessible, development can't be hindered." (P3)
P1	Demographic changes	"As the population is expanding by natural growth as a result of a high birth-rate, the core city becomes more congested, houses become limited and more expensive in the residential areas. Therefore, people move outskirts of the city in search of residence at affordable prices." (P1)
P2	Migration	"The rate at which people are migrating to the metropolis as a result of insecurity and natural disaster is alarming, where they occupy the major built-up areas and increase the city's expansion." (P2)
P3	Socio-economic activities	"Kaduna metropolis, being one of the major commercial cities in northern Nigeria, with a vast commercial and economic opportunity which influences the city's growth in many ways." (P3)
P1, P2, P3	Religious dichotomy	The 1999 to 2002 religious crises are also one of the huge factors that have been influencing urban expansion in the Kaduna metropolis. Before, both the major religious groups lived among each other, but after the crises, all the major religious groups tend to separate themselves from each other, which brings about urban expansion as a result of their decentralization. Most of the Christians move to the southern axis, such as Sabon Tasha, Maraban Rido, and Television Village, among others." (P3) "Religious crises of Kaduna metropolis make a lot of settlements to be homogenous rather than heterogeneous; everyone wants to live within their ethnic/religious dominated societies. The Muslims dominated areas usually lie in the core city; as a result, many Christians move close to the fringes, contributing to the urban expansion." (P2) "Areas like Kabala are heterogeneous societies, but when the religious crisis becomes a big deal, the Christians move to Barnawa, Sabon Tasha, Yelwa, and all other Christian-dominated communities, resulting in sprawling into the undeveloped lands." (P1)
P2	Gentrification and urban renewal	"As a result of the urban renewal that took place during the Malam Nasiru El-Rufai's administration, the low-income/working class neighborhood were transformed into middle-class/high class neighborhood. This made these areas unaffordable to the current residents, so they usually sell their properties and move to the edge of the city, leading to the physical growth of a city.
P1	Government policies	"The creation of government acquisition areas started from the administration of Arc. Namadi Sambo, where the new Millennium city was planned, which is a completely built-up area, and then his predecessor, Governor Patrick Ibrahim Yakowa, supported his plan by creating a major road linking the core city to that axis. Then lastly, the Malam Nasiru El-Rufai's tenure brought a whole new emphasis to the work of the former governors when the urban renewal projects were key started, it created more accessibility and also strict land policy on abandoned and undeveloped land, mostly at the fringes, speeding up the expansion we see today." (P1)

4 Discussion

The findings of this study have uncovered that there has been a dramatic change within the boundaries of Kaduna Metropolis in the last two decades, measured by a significant increase of almost five times the built-up area from 5.2% to 23.7%. Furthermore, what is most significant is that the incorporation of findings from the quantitative analysis of change within the study area, based on expert knowledge from major stakeholders of the area, offers a more informed, and importantly, a causal explanation of the observed changes, rather than being confined to their description. The trends recorded not only reflect changes associated with sub-Saharan African cities but also reflect the truth that the growth of cities within sub-Saharan Africa happens due to economic and demographic developments (Abubakar et al., 2025; Koko et al., 2021).

The most notable aspect of this data set, however, refers to the increasing pace of urbanization post-2014, with the annual growth rate of built-up areas rising precipitously from 8.7% during the pre-2014 period (2004-2014) to 14.4% during the post-2014 period (2014-2024). This point bears direct correspondence to the social and political rhetoric that emphasized the "urban renewal and road infrastructure upgrades" that took place during the post-2014 timeframe (P2). Furthermore, the opening of "large access roads" like the Yakowa Road mentioned by the participants did more than follow the expansion of the built-up areas and instead served as a factor that catalyzed the growth by enhancing the "accessibility and connectivity between the core and the suburb" (P2). This specific point bears considerable similarity to the work done by other researchers in other rapidly expanding urban regions, all of which suggest that the enhancement of the road infrastructure was the prerequisite factor that led to the expansion of the built-up areas (Haydar et al., 2025). The above also refers to the creation of new "corridors of expansion" that had the effect of making the 'peri-urban lands' suitable and viable for urbanization, as depicted in the spatial analysis (Figure 3). Finally, the bare land data set that showed a sharp decline during the pre-2014 levels and then a (partial) increase during the post-2014 timeframe also bears reference to this point, and the procedures followed by the continuously expanding urbanization are characteristic of the symptoms that accompany the "urban sprawl phenomenon" noted by Saleh et al. (2014).

The sudden change in the vegetation layer, which grew extensively (44.7% per year) from 2004 to 2014 but then shrank drastically (-69.1% per year) from the next decade, can also be analyzed from the perspective of qualitative factors. While the first drop might be due to the fallow period, the drastic change is largely attributed to “road construction projects due to urbanization” and the continuous changeover, which is closely related to the encroachment of the built environment on natural spaces, which is an equally important consideration related to the environment, particularly urbanization (Ogunbode et al., 2025; Akpu et al., 2017). In addition, the identified reason related to the religious dichotomy is an important consideration that clearly explains the directionality of the change. The uprooting of the Christians to the southern axes (e.g., Sabon Tasha, Maraban Rido) due to the previous crisis, described to P1 and P3, is likely to affect the southern and southwestward spread observed in the maps related to the LULC change. It clearly shows that the socio-cultural considerations, including conflict, affect the environment, similar to what is found in other Nigerian cities with sectarian conflicts (Adamu et al., 2025). The forces of demography, whether through natural population growth and the influx of population influenced by regional insecurity, were consistently highlighted as basic driving forces (P1, P2). These factors underpin the basic demand, which converts accessibility into feasible land consumption, and verify the findings by Musa and Abubakar (2024) and Ndabula et al. (2013) on population dynamics as they relate to the city of Kaduna. The phase of gentrification and urban renewal, identified by P2, underpinned not only the outskirts but also the revamps and relocations through which working-class communities were relocated to the outskirts, hence exerting development pressure on the metropolitan outskirts. Finally, the interplay of consistent government intervention through different governmental terms, as discussed by P1, underpinned the basic framework through which the forces of demography and market forces, quantified under LULC change, were achieved, thus underpinning the importance of policy instruments, as discussed by Tanko et al. (2025) and Haydar et al. (2025).

From the synergy between the drivers of urbanization, it is evident that Kaduna City expansion is contributed to by various forces: infrastructure-enabling expansion, demographic forces of demand creation, socio-cultural forces of guiding expansion, and policies of controlled expansion. This combined approach, which complements and enhances the model for expansion force analysis offered in Oyalowo (2022), is critical to designing sustainable urban planning policies. Uncontrolled expansion and loss of environmental resources call for policies beyond spatial planning.

5 Conclusion

The research concluded that Kaduna metropolis has experienced considerable urban expansion from 2004 to 2024, driven by a complex interplay of socio-economic, population, and policy-related factors, among others. The expansion led to changes in land use patterns, with noticeable increases in built-up areas at the expense of agricultural land and vegetation covers. The study emphasizes the need for sustainable urban planning and management strategies to mitigate the potential negative impacts of rapid urbanization, such as environmental degradation and inefficient land use. By understanding the spatiotemporal trends and patterns of urban expansion, policymakers can better address the challenges associated with urban growth and promote balanced development within the Kaduna metropolis. The study recommends that the government should develop a comprehensive database and information systems for environmental monitoring and resource management, and encourage afforestation. Additionally, the monitoring, control, and evaluation of the LULCC of the area should be done regularly so as to check the haphazard developments or modifications that may have negative consequences on the inhabitants. Further studies should be encouraged to monitor the changes in LULC over time.

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