TIMBOU-AFRICA PUBLICATION INTERNATIONAL JOURNAL FEBRUARY, 2025 EDITIONS.

INTERNATIONAL JOURNAL OF BUILT ENVIRONMENT AND EARTH SCIENCE
VOL. 7 NO. 4 E-ISSN 3027-1606 P-ISSN 3027-0049

TEMPORAL LANDUSE CHANGE ALONG TWO ROAD INFRASTRUCTURE: A COMPARATIVE ANALYSIS OF YAKOWA AND YAR'ADUA WAYS, KADUNA METROPOLIS, NIGERIA

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DOI: https://doi.org/10.70382/tijbees.v07i4.034

ABSTRACT

This study uses remote sensing and GIS to compare land use changes along Patrick Yakowa Way and Umaru Musa Yar'adua Way, Kaduna Metropolis, Nigeria, using Landsat imagery from 2005, 2015 and 2025. The research focuses on understanding how urban expansion impacts these areas, with results showing significant growth of built-up land and a decline in

Introduction

Urbanization is a transformative force reshaping global landscapes, impacting land use and land cover (LULC) patterns, particularly in rapidly developing regions. The construction of new roads catalyzes urban expansion, promoting economic growth and

vegetation and water bodies. Specifically, Patrick Yakowa Way experienced a surge in built-up areas from 21.93% in 2005 to 50.88% in 2025, indicating an annual growth rate of 0.485km2 over the twenty years from 2005 to 2025, while Umaru Musa Yar'adua Way saw an increase from 10.98% to 28.76% during the same period showing an annual growth rate of 0.340km2 over the twenty years from 2005 to 2025. Conversely, vegetation cover decreased at an annual rate of -0.394km2 on Patrick Yakowa Way (61.65% to 38.14%), and Umaru Musa Yar'adua Way also reduced at an annual rate of -0.340km^2 (64.00% to 49.38%). Similarly, water bodies diminished in both areas. This study compares growth patterns along the two road corridors, investigates the causes of urban expansion, and assesses current planning strategies. The comparative analysis provides valuable insights for urban planning, sustainable growth, and resource allocation in Kaduna, emphasizing the necessity of integrated urban development to minimize negative impacts on natural resources and promote sustainable urbanization.

Keywords: Land Use Land Cover (LULC), Road Infrastructure, Comparative Analysis, Yakowa and Yar'adua Ways.

improving access to previously undeveloped areas (Arimah, 2017); Tian & Li, (2019). However, this infrastructure development can also lead to challenges such as urban sprawl and the loss of green spaces (Gavrilidis, *et al.,* 2019). Numerous studies have documented the relationship between road construction and land use change, showing that new transportation routes often attract residential, commercial, and industrial developments (Mokhtari et al., 2020; Faiyetole, & Adewumi, 2024). This phenomenon is particularly evident in urban areas where demand for space escalates due to population growth and economic activities. The influx of people and businesses into newly accessible regions can result in urban sprawl, loss of agricultural land, and environmental degradation (Colsaet, 2018; UN-Habitat, 2016). Understanding these patterns is critical for effective urban planning and policy-making.

Urbanization in Nigeria has led to significant changes in LULC, particularly along newly constructed roads. Research indicates that studies in Jalingo, Taraba State, documented substantial land use changes linked to new roads, with conversion of agricultural and open lands to residential, commercial, and industrial uses and increased property values (Oruonye, 2014; Bakoji *et al*., 2020). Similarly, research in Akure and Lagos highlights how road networks drive land use conversions, often causing urban sprawl and traffic congestion (Faiyetole & Adewumi, 2024).

The development of infrastructure such as Patrick Yakowa Way and Umaru Musa Yaradua Road in Kaduna State serves as a catalyst for urban expansion, driving shifts from agricultural land to residential and commercial uses (Akpan & Eyo, 2020). It has transformed the urban landscape of Kaduna State by attracting residential, commercial, and industrial developments. While these roads have improved mobility, they also increase pressure on existing infrastructure and contribute to various challenges associated with rapid urbanization (Ogunbode *et al.,* 2017).

Yakowa Way connects suburban areas to major commercial hubs, while Musa Yaradua Road links commercial and industrial zones to emerging residential neighborhoods. These differing socio-economic contexts are anticipated to affect the nature and extent of LULC changes along each road. Specifically, Yakowa Way's proximity to commercial centers is likely to result in a higher concentration of business developments. In contrast, Yaradua Road may see more residential growth due to its connection with industrial areas.

Satellite remote sensing and GIS are increasingly used to monitor and analyze urban growth by identifying changes in land cover patterns (Mosammam, *et al.,* 2017; Shaw and Das, 2018; Toure et al. 2018; Keshtkar *et al.* 2017). Remote sensing techniques are widely used in various studies to monitor and analyze growth, providing timely, high, and medium-resolution images for visual and quantitative assessment (An *et al*., 2018). This study used post-classification comparison for change detection to analyze urban

growth and land cover change along Yakowa and Yaradua ways from 2005 to 2025, using multi-temporal Landsat imagery and GIS.

This study focuses on analyzing temporal changes in urban land use along two newly constructed roads in Kaduna State, Nigeria: Yakowa Way and Musa Yaradua Road. By examining the dynamics of LULC changes along these corridors, the research aims to provide insights into the effects of road infrastructure development on urban growth, environment and sustainability.

Study Area

The study areas lie within Kaduna North and Chikun Local Government Areas of Kaduna State and the two roads in the study areas are buffered by 1.5km on both sides. Patrick Yakowa way was constructed through an agricultural land with very few village settlements to link the commercial metropolis of Kaduna and the Kaduna Refining and Petrochemical company (KRPC).

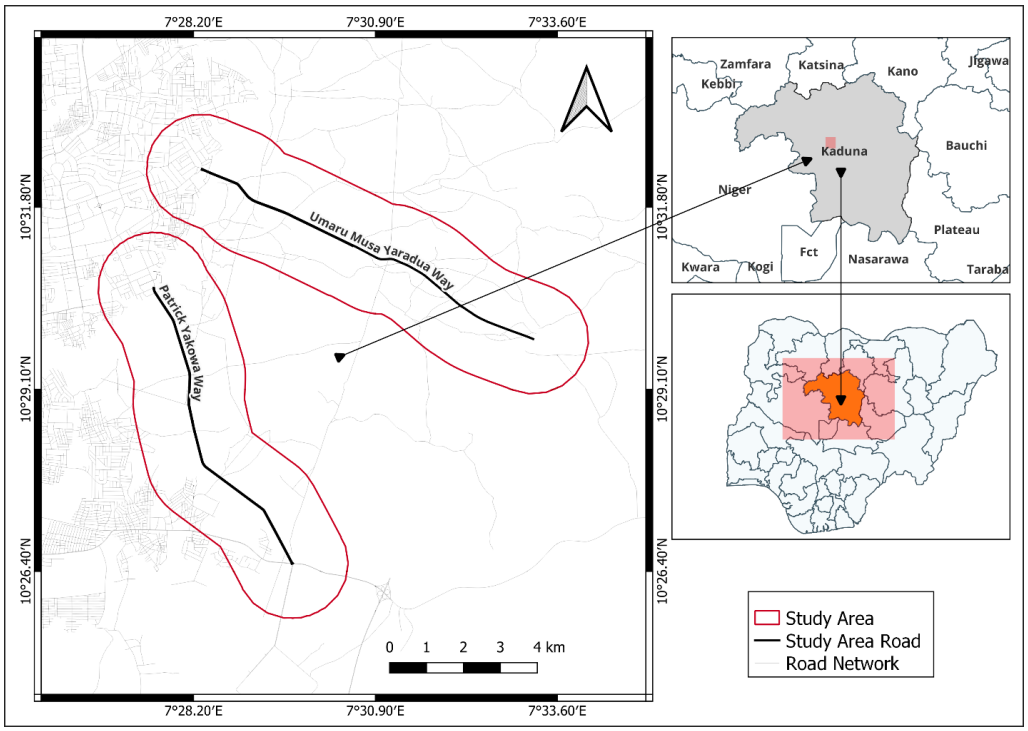

Figure 1: Study area map

Source: Adapted and modified administrative map of Nigeria and Kaduna (2023)

Patrick Yakowa Way is located approximately 10°30'38" N latitude, 7°27'34" E longitude and 10°26'31" N latitude, 7°29'40" E longitude. With the buffer of 1.5km on both sides of the road, it covers an area of 33.51km2. Named after the late Governor Patrick Ibrahim Yakowa, who served from 2010 to 2012, this road was developed to enhance connectivity and promote regional economic growth. It links suburban areas to major commercial hubs and industrial zones, facilitating access to urban centers. The development of Yakowa Way has led to significant land use changes, transforming agricultural lands into residential, commercial, and industrial areas. Umaru Musa Yar'adua Way is also situated within a geographical coordinate of approximately 10°32'22" N latitude, 7°28'19" E longitude and 10°29'50" N latitude, 7°33'13" E longitude and covers an area of 37.69 km2. Constructed as part of the Kaduna Urban Renewal Project, this road enhances connectivity between a major Eastern by-pass road, through small village agricultural/residential neighborhoods and significant commercial zones of the metropolis. It plays a crucial role in facilitating trade and access to services. The corridors have undergone significant development, transforming agricultural lands into urban uses, making it a vital area for studying land use and land cover (LULC) changes in response to infrastructure expansion.

METHODOLOGY

Data Types and Sources

Satellite image data for LULC classification were obtained from the USGS Earth Explorer website (*https://earthexplorer.usgs.gov/*) as Landsat 8 OLI-TIRS datasets. Image selection depended on quality, particularly minimal cloud cover. Each Landsat image was georeferenced The Landsat data, in seven spectral bands (1-7) with a 30m spatial resolution, are freely available through USGS Earth Explorer.

Table 1: The spectral properties of the Landsat data

S/N	Types Of Data	Spatial Resolution	Acquisition Date	Source	Path Row	Purpose
1	Landsat 7 ETM+	30 Meters	04-Jan-2005	USGS	189 And 53	LULC
2	Landsat 8 OLI and TIRS	30 Meters	24-Jan-2015	USGS	189 And 53	LULC
3	Landsat 8 OLI and TIRS	30 Meters	03-Jan-2025	USGS	189 And 53	LULC
4	Literature materials, Journal papers, Thesis, seminar papers, conference papers, textbooks and other related sources.					

Data Processing

The Satellite imageries were imported into the QGIS environment. A subset covering the areas of interest extracted from the larger scene of Landsat ETM+ and Landsat 8 OLI and TIRS. The image bands layers were stacked to produce a color composite and data were ortho-rectified and geo-referenced to enable the definition of the existence of these data sets in the physical space as well as to establish their location in the real world. Supervised classification technique was then performed using the maximum likelihood algorithm to classify the images into various classes (themes).

Data Analysis

Spatial Distribution of Land Use and Land Cover (LULC)

The LULC classes were calculated using QGIS's field calculator, providing measurements in square kilometers to determine the aerial extent of each LULC class. The aerial extents were converted to percentages by first calculating the total study area and then dividing each class's area by this total and multiplying by 100. The field calculator was again used to create a new attribute field for these percentage calculations.

Temporal Changes in Land Use and Land Cover (LULC) Patterns

The magnitude of change (C) in LULC between two specific years was calculated by subtracting the LULC value of the earlier year (A) from the LULC value of the later year (B), i.e., The mathematical formula for calculating the change (C) is:

$$C = B - A$$

Where: *C* represents the magnitude of change, *B* is Base year, *A* is reference year.

The mathematical formula for calculating the percentage of change (*E*) is:

$$E = (C / base\ year) * 100$$

Where: *E* represents the percentage of change *C* denotes the magnitude of change Base year refers to the value of the base year being used for comparison.

Annual Growth Rate of Urban Development and Land Use Changes

The magnitude of change was determined by dividing number of years between the two periods to show annual rate of change. The mathematical formula for calculating the annual rate of change (R) is:

$$R = C / T$$

Where: R represents the annual rate of change, C denotes the magnitude of change, T refers to the number of years over which the change occurred.

RESULTS AND DISCUSSION

Spatial Distribution of LULC of Patrick Yakowa and Umaru Musa Yar'adua Ways

This analysis utilized remote sensing data to create detailed maps that visually depict the various land use and land cover categories within the designated study areas of Patrick Yakowa and Umaru Musa Yaradua Way.

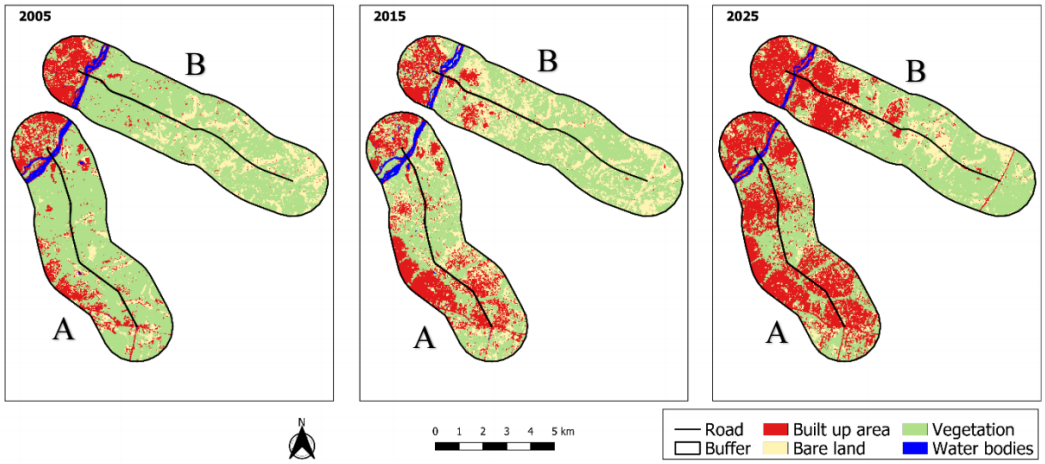

Figure 2. Land use land cover of (A)Patrick Yakowa and (B) Umaru Musa Yar'adua way

Source: Author's analysis (2025)

The LULC maps of the study areas for 2005 to 2025 were classified into four different land use classes, namely (i) build-up area, (ii) bare land, (iii) vegetation, and (iv) water bodies. The LULC changes were observed over three decades, ranging from 2005 to 2015 and 2015 to 2025. Vegetation was found to be the major land use type in the study areas in 2005 as shown in Figure 2. However, in Table 2 and Figure 2, the development of Patrick Yakowa Way has driven rapid land use and land cover (LULC) changes from 2005 to 2025. Initially, in 2005, vegetation dominated the area, covering 20.66 km² (61.65%), followed by built-up areas at 6.22 km² (18.57%), bare land at 4.69 km² (14.00%), and water bodies at 0.81 km² (2.42%). By 2015, built-up areas had expanded to 11.82 km² (35.27%), bare land increased to 6.85 km² (20.44%), while vegetation decreased to 14.07 km² (41.99%), and water bodies slightly decreased to 0.77 km² (2.53%).

Table 2: Land use land cover distribution of Patrick Yakowa Way

LULC category	2005 Area (km^2)	%	2015 Area (km^2)	%	2025 Area (km^2)	%
Built up Area	7.35	21.93%	11.82	35.27%	17.05	50.88%
Bare land	4.69	14.00%	6.85	20.44%	3.20	9.55%
Vegetation	20.66	61.65%	14.07	41.99%	12.78	38.14%
Water bodies	0.81	2.42%	0.77	2.30%	0.48	1.43%
TOTAL	33.51	100%	33.51	100%	33.51	100%

Source: Author's analysis (2025)

The trend continued into 2025, with built-up areas becoming the most prominent land use, covering 17.05 km^2 (50.88%), while vegetation decreased to 12.78 km^2 (38.14%), bare land reduced to 3.20 km^2 (9.55%), and water bodies declined to 0.48 km^2 (1.44%). Over this period, the area along Patrick Yakowa Way experienced a significant surge in built-up areas, coupled with declines in vegetation and water bodies.

Table 3: LULC distribution of Umaru Musa Yar'adua Way

LULC category	2005 Area (km^2)	%	2015 Area (km^2)	%	2025 Area (km^2)	%
Built up area	4.14	10.98%	5.72	15.18%	10.84	28.76%
Bare land	8.81	23.37%	11.08	29.40%	7.84	20.80%
Vegetation	24.12	64.00%	20.30	53.86%	18.61	49.38%
Water bodies	0.62	1.64%	0.59	1.57%	0.40	1.06%
TOTAL	37.69	100	37.69	100	37.69	100

Source: Author's analysis (2025)

Table 3 illustrates the land use and land cover (LULC) distributions along Umaru Musa Yar'adua Way for 2005, 2015, and 2025, with spatial

distribution patterns shown in Figure 2. In 2005, vegetal cover was most prominent, spanning 24.12 km² (64.00%), followed by bare land at 8.81 km² (23.37%), built-up areas at 4.14 km² (10.98%), and water bodies at 0.62 km² (1.64%). By 2015, built-up areas increased to 5.72 km² (15.18%), bare land expanded to 11.08 km² (29.40%), while vegetal cover decreased to 20.30 km² (53.86%), and water bodies slightly decreased to 0.59 km² (1.57%). Continuing into 2025, built-up areas significantly increased to 10.84 km² (28.76%), bare land decreased to 7.84 km² (20.80%), vegetal cover reduced to 18.61 km² (49.38%), and water bodies declined to 0.40 km² (1.06%). Over the study period, Umaru Musa Yar'adua Way experienced positive growth in built-up areas but negative changes in vegetal cover.

The Temporal Changes in LULC Patterns

The comparison of remotely sensed data across the study period for the changes in LULC along Patrick Yakowa and Umaru Musa Yaradua Ways were assessed in Table 4.

Table 4: LULC changes for Patrick Yakowa Way over different time intervals

LULC category	2005 - 2015 Area (km2)	%	2015 - 2025 Area (km2)	%	2005 - 2025 Area (km2)	%
Built up Area	4.47	60.82%	5.23	44.25%	9.7	131.97%
Bare land	2.16	46.06%	-3.65	-53.28%	-1.49	-31.77%
Vegetation	-6.59	-31.90%	-1.29	-9.17%	-7.88	-38.14%
Water bodies	-0.04	-4.94%	-0.29	-37.66%	-0.33	-40.74%

Source: Author's analysis (2025)

Table 4 highlights the land use and land cover (LULC) changes along Patrick Yakowa Way, reflecting the transformations observed during the study

period. The built-up area experienced significant growth, increasing by 4.47 km² (66.82%) between 2005 and 2015 and further expanding by 5.23 km² (44.25%) from 2015 to 2025. Cumulatively, the built-up area grew by 9.7 km² (139.97%) over the two decades, indicating rapid urbanization.

In contrast, bare land initially increased by 2.16 km² (46.06%) from 2005 to 2015 but decreased by 3.65 km² (-5.28%) between 2015 and 2025, resulting in a net reduction of 1.49 km² (-31.77%) over the entire study period. Similarly, vegetation cover showed a consistent decline, decreasing by 6.59 km² (-31.90%) from 2005 to 2015 and by an additional 1.29 km² (-9.17%) from 2015 to 2025, leading to a total loss of 7.88 km² (-38.14%). Water bodies also diminished, with a slight reduction of 0.04 km² (-4.94%) between 2005 and 2015, followed by a more substantial decrease of 0.29 km² (-37.66%) from 2015 to 2025, culminating in a cumulative loss of 0.33 km² (-40.74%). These changes underscore significant urban transformation along Patrick Yakowa Way, driven by the expansion of built-up areas at the expense of natural vegetation and water bodies, highlighting the environmental impacts of rapid urbanization in the region.

Table 5: Land use land cover changes of Umaru Musa Yar'adua Way

LULC category	2005 - 2025 Area	%	2015 - 2025 Area	%	2005 - 2025 Area	%
Built up area	0.16	3.86%	6.57	154.31%	6.73	164.13%
Bare land	4.40	57.87%	-4.17	-34.73%	0.23	3.04%
Vegetation	-4.59	-18.09%	-2.17	-10.43%	-6.76	-26.63%
Water bodies	0.03	4.56%	-0.24	-36.85%	-0.21	-33.97%

Source: Author's analysis (2025)

Table 5 presents the land use and land cover (LULC) changes along Umaru Musa Yar'adua Way across the specified time intervals. Between 2005 and 2015, the built-up area saw a modest increase of 0.16 km² (3.86%), which surged by 6.57 km² (154.31%) from 2015 to 2025, resulting in a cumulative

expansion of 6.73 km² (164.13%) over the entire study period. Bare land increased by 4.40 km² (57.87%) between 2005 and 2015 but subsequently decreased by 4.17 km² (-34.73%) from 2015 to 2025, yielding a small net increase of 0.23 km² (3.04%). Vegetation cover experienced consistent declines, decreasing by 4.59 km² (-18.09%) from 2005 to 2015 and by a further 2.17 km² (-10.43%) from 2015 to 2025, leading to a total reduction of 6.76 km² (-26.63%). Water bodies initially increased by 0.03 km² (4.56%) from 2005 to 2015, but then decreased by 0.24 km² (-36.85%) from 2015 to 2025, resulting in a net decrease of 0.21 km² (-33.97%). These results align with broader trends of LULC change, as urbanization often leads to the expansion of built-up areas at the expense of other land cover types such as vegetation and water bodies (Aliyu, et al, 2023). Studies analyzing LULC changes in Nigeria have observed similar patterns of urban land use increase and decrease in agricultural land, vegetation, and water bodies (Musa, & Adamu, 2021). This indicates that Umaru Musa Yar'adua Way has undergone an urban transformation, marked by increased built-up areas and decreased vegetation and water bodies, consistent with landscape changes in other parts of Nigeria (Aliyu, et al, 2023; Musa, & Adamu, 2021).

The Average Annual Rate of LULC change

Table 6 presents the average annual growth rates for LULC categories along Patrick Yakowa Way over three distinct periods: 2005-2015, 2015-2025, and the overall span of 2005-2025. The built-up area experienced consistent growth, increasing at an average annual rate of 0.447% from 2005 to 2015. This growth accelerated slightly to 0.523% annually between 2015 and 2025. Cumulatively, the built-up area expanded at an average annual rate of 0.485% throughout the entire study period (2005-2025). Conversely, bare land initially grew at an average annual rate of 0.216% from 2005 to 2015 and subsequently declined at a rate of -0.365% annually from 2015 to 2025, resulting in a small net decrease of -0.075% per year over the 20 years.

Table 6: Average annual growth rate of Patrick Yakowa Way

LULC category	2005 - 2015 %	2015 – 2025 %	2005 - 2025 %
Built up area	0.447	0.523	0.485
Bare land	0.216	-0.365	-0.075
Vegetation	-0.659	-0.129	-0.394
Water bodies	-0.004	-0.029	-0.017

Source: Author's analysis (2025)

Vegetation cover exhibited a decreasing trend, declining at an average annual rate of -0.659% between 2005 and 2015. The rate of decline slowed to -0.129% annually from 2015 to 2025. Cumulatively, vegetation decreased at an average annual rate of -0.394% from 2005 to 2025. Water bodies showed relative stability, with a minimal growth rate of 0.004% annually from 2005 to 2015, followed by a slight decrease of -0.029% per year between 2015 and 2025. Overall, water bodies decreased at an average annual rate of -0.017% over the study period. This is to say that, Patrick Yakowa Way experienced an average annual growth rate of 0.485% in built-up areas, while vegetation and water bodies declined at average annual rates of -0.394% and -0.017%, respectively, from 2005 to 2025, reflecting the urbanizing trends in the area.

Table 7: Average annual growth rate of Umaru Musa Yar'adua Way

LULC category	2005 – 2015 %	2015 - 2025 %	2005 - 2025 %
Built up area	0.016	0.660	0.340
Bare land	0.440	-0.420	0.010
Vegetation	-0.459	-0.220	-0.340
Water bodies	0.003	-0.020	-0.011

Source: Author's analysis (2025)

Table 7 highlights the average annual growth rates of land use and land cover (LULC) categories along Umaru Musa Yar'adua Way over three distinct periods: 2005-2015, 2015-2025, and the cumulative period from 2005 to 2025. The built-up area experienced minimal growth between 2005 and 2015, with an average annual growth rate of 0.016%. However, this rate increased significantly to 0.660% from 2015 to 2025. Over the entire study period (2005-2025), the built-up area expanded at an average annual growth rate of 0.340%, reflecting the growing urbanization along the corridor. The bare land category grew at an average annual rate of 0.440% from 2005 to 2015 but declined by -0.420% annually between 2015 and 2025. Cumulatively, over the two decades, bare land showed a slight overall increase at an average annual growth rate of just 0.010%.

Vegetal cover consistently declined throughout the study period. From 2005 to 2015, it decreased at an average annual rate of -0.459%, with a slower decline of -0.220% per year from 2015 to 2025. Cumulatively, vegetation decreased at an average annual rate of -0.340% over the two decades. The water bodies category showed minimal change, with a negligible growth rate of 0.003% per year from 2005 to 2015, followed by a slight decline of -0.020% annually from 2015 to 2025. Cumulatively, water bodies decreased at an average annual rate of -0.011% over the entire study period.

In summary, Umaru Musa Yar'adua Way experienced notable urban expansion, as reflected in the built-up area's cumulative growth rate of 0.340%. However, this urbanization came at the expense of natural land cover types, with vegetation and water bodies declining at average annual rates of -0.340% and -0.011%, respectively, between 2005 and 2025.

Findings of the Comparative Analysis

Both Patrick Yakowa Way and Umaru Musa Yar'adua Way exhibit a pronounced trend of urbanization, characterized by significant increases in built-up areas throughout the study period, which indicates substantial urban expansion and infrastructure development. A notable observation in

both regions is the decline in vegetation cover, suggesting potential environmental repercussions stemming from urban growth and changing land use patterns. This decline raises concerns regarding habitat loss and the reduction of green spaces.

While Patrick Yakowa Way demonstrated higher growth rates in built-up areas, Umaru Musa Yar'adua Way also experienced considerable urban growth, albeit at a slightly slower pace, underscoring the ongoing trend of urbanization. Additionally, Umaru Musa Yar'adua Way registered a modest increase in bare land, which may reflect land use changes driven by urbanization and infrastructure development.

A study conducted by Onanuga et al. (2022) in Ijebu land, southwestern Nigeria, reported a staggering 212.2% increase in built-up areas alongside corresponding decreases in forest and surface water areas by 74.4% and 66.3%, respectively. These findings further emphasize that urban growth and shifts in land use can have profound environmental impacts, including habitat destruction and diminished green spaces.

Both areas also experienced reductions in water bodies, indicating potential alterations in hydrological patterns and environmental conditions. The decline in water bodies was particularly pronounced along Patrick Yakowa Way. Average annual growth rates revealed similar trends of vegetation decline and water body reduction in both locations, with Patrick Yakowa Way showing a more significant decrease in vegetation cover.

These findings highlight the intricate interplay of factors such as population growth, urban planning, infrastructure development, and land use policies that contribute to the observed changes in land use and ongoing urbanization trends. The reductions in vegetation and water bodies across both areas underscore the urgent need for sustainable urban planning and land use policies that harmonize development with environmental conservation, considering the potential ecological and hydrological consequences.

CONCLUSION AND RECOMMENDATIONS

This study conducted a comparative analysis of land use and land cover (LULC) changes along Patrick Yakowa Way and Umaru Musa Yar'adua Way in Kaduna, Nigeria, using GIS and remote sensing techniques with Landsat images from 2005, 2015, and 2025. The findings indicate significant urban growth and expansion in both corridors, marked by substantial increases in built-up areas and decreases in vegetation cover. Patrick Yakowa Way exhibited higher growth rates in built-up areas compared to Umaru Musa Yar'adua Way, which also saw a slight increase in bare land. Additionally, water bodies decreased along both corridors, suggesting potential environmental impacts due to urbanization. The study provides insights into the temporal and spatial changes in LULC, highlighting the need for sustainable urban planning to mitigate these environmental effects.

This study offers the following recommendations for urban development and land use management. Urban planners, policymakers, and stakeholders are advised to use the study's findings to inform future planning strategies along road corridors. It is suggested that comparative studies be conducted to assess how different types of road infrastructure (e.g., tarred vs. untarred) affect land use patterns, both locally and in comparison, with other regions. Urban planners should leverage this research to manage land use changes effectively, integrating sustainability measures to mitigate environmental impacts and ensure balanced development. Continuous monitoring of land use changes is necessary to predict future trends and integrate road infrastructure with other urban developments like water and electricity systems. Engaging local stakeholders in planning processes is crucial for equitable development. Finally, employing advanced spatial analysis tools or machine learning models can enhance the accuracy and efficiency of land use change predictions.

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