Spatio-Temporal Analysis of Residential Expansion in Rigasa, Igabi LGA, Kaduna State, Nigeria (1995–2025)

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***Abstract*—This study quantifies the spatio-temporal dynamics of residential expansion and its impact on farmland vegetation cover in Rigasa Ward, a peri-urban area of Kaduna Metropolis, Nigeria, between 1995 and 2025. Using time-series Landsat imagery (1995, 2010, 2025), supervised classification with the Maximum Likelihood algorithm mapped land use/land cover into four classes namely Built-up, Farmland, Natural Vegetation, and Bare Land with an achieved classification accuracies exceeding 85%. Results show built-up areas increased by 132.66% (9.5% to 22.2%), primarily at the expense of farmland, which declined by 52.1% (60.1% to 28.8%).**

Natural (non-agricultural) vegetation followed a non-linear trend, recovering to 36.1% by 2025 due to abandonment of insecure farmlands rather than conservation. Annual built-up expansion accelerated from 3.4% (1995–2010) to 3.6% (2010–2025). Overlay analysis confirmed that 11.84 km² (34.95%) of total farmland loss was directly converted to residential use, establishing urbanization as the primary driver of agricultural land loss. The study concludes that unplanned residential expansion is reshaping Rigasa's landscape, with substantial implications for agricultural productivity and ecosystem functioning. The findings underscore the urgent need for enforced spatial planning and green infrastructure integration to guide sustainable peri-urban growth across rapidly urbanizing sub-Saharan Africa.

***Index Terms*—Land Use/Land Cover Change; Peri-urbanization; Remote Sensing; GIS; Residential Growth; Vegetation Loss**

I. INTRODUCTION

Urbanization represents one of the most profound forms of land transformation, fundamentally altering the relationship between human settlements and natural ecosystems (United Nations, 2024). In developing regions like Africa, this growth is often rapid and unplanned, manifesting as urban sprawl into peri-urban zones with significant environmental costs (Huang *et al.*, 2020). Nigeria exemplifies this trend, with one of the world's fastest urbanization rates and a severe housing deficit driving informal residential expansion (World Bank, 2024). This expansion disrupts ecosystems, converts vegetated and agricultural lands, and diminishes essential ecosystem services including food production, microclimate regulation, and carbon sequestration (Wu, 2010).

Kaduna Metropolis has experienced dramatic residential growth, with studies showing a strong inverse correlation between urban expansion and vegetation loss (Akpu *et al.*, 2017). However, while metropolitan-scale analysis provides valuable context, localized, spatio-temporal studies on specific rapidly expanding suburbs like Rigasa Ward in Kaduna state, Nigeria are scarce. This gap limits the ability of the local planners to devise targeted evidence-based interventions at the community level where impacts are most acute (Musa and Abubakar, 2024).

Grounded in Land Transition Theory describes the systematic shift of land from natural vegetation to agriculture and then to urban uses (Lambin and Meyfroidt, 2010). Thus, this study investigates the localized manifestation of this process in a Nigerian peri-urban context. It addresses the critical need for a detailed spatio-temporal analysis of residential growth and its impact on vegetation cover in Rigasa ward. This is with the aim of analysing the spatio-temporal trends of residential growth in Rigasa ward and also to assess its impact on vegetation cover using satellite imagery and GIS-based spatial analysis.

1.1. The Study Area

Rigasa Ward is located within Igabi Local Government Area of Kaduna State, Nigeria. It is located between Latitudes 10°28'56.98"N -

10°36'26.12"N and Longitudes 7°16'55.18"E - 7°23'59.42"E (Figure 1). It is a peri-urban settlement approximately 5.4 km from Kaduna's Central Business District, characterized by a tropical continental climate with distinct wet and dry seasons. The area has experienced rapid population growth and transformation from a predominantly agricultural landscape to a residential suburb, with an estimated population of 492,353 as at 2025.

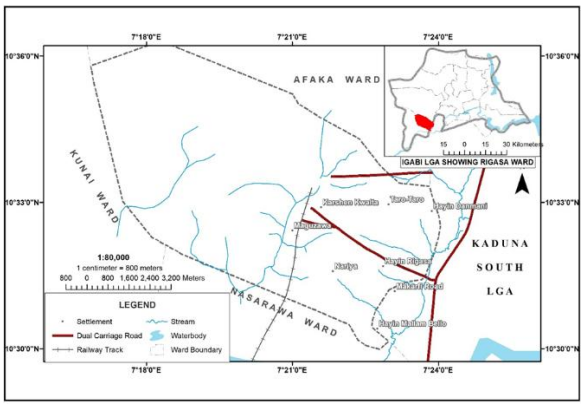

Figure 1: Study Area

II. DATA AND METHODOLOGY

Multispectral Landsat images from three epochs were acquired from the USGS Earth Explorer which includes Landsat 5 TM (November 1995), Landsat 7 ETM+ (November 2010), and Landsat 8 OLI (November 2025), all from Path 189/Row 53 with less than 10% cloud cover. The Level 1 Terrain Corrected (L1T) products were radiometrically and atmospherically corrected using the ENVI software to minimize atmospheric effects and ensure consistency across temporal datasets. False color composites (bands 5-4-3 for Landsat 8; bands 4-3-2 for Landsat 5/7) were created to enhance visual interpretation. The administrative boundary of Rigasa Ward was georeferenced in WGS 1984 UTM Zone 32N coordinate system and used as a mask to extract the study area from the larger Landsat scenes.

A supervised classification technique using the Maximum Likelihood algorithm with the aid of ENVI software was performed. Based on ground truthing and reconnaissance survey of the study area's characteristics, a classification scheme with four prominent LULC classes was adopted, namely Built-up Area, Farmland, Natural Vegetation, and Bare Land. Training samples (Regions of Interest) were selected for each class based on spectral signatures.

Accuracy assessment was conducted using a stratified random sampling method, with a minimum of 50 reference points per land cover class collected through visual interpretation of high-resolution imagery and field-based ground truthing. An error matrix (confusion matrix) was generated for each epoch to calculate Producer's Accuracy, User's Accuracy, Overall Accuracy, and Kappa coefficient (Table 1).

Post-classification comparison change detection was employed. The area statistics (in km² and percentage) for each LULC class for the three epochs were calculated using the ArcGIS 10.5 software.

The rate of change was computed using the formulas: $Percentage\ change = \frac{X-Y}{Y} \times 100$; where X is the final area and Y is the initial area.

$$Annual\ Rate\ of\ Change = \frac{Percent\ Change\ Observed}{Rate\ of\ Time\ Intervals}$$

To assess the direct impact of residential growth on vegetation, the Built-up and Farmland layers for 1995 and 2025 were overlaid in ArcGIS using spatial analyst tools to quantify farmland areas that were directly converted to built-up areas.

III. RESULTS AND DISCUSSION

3.1. LULC Distribution and Temporal Trends

The total classified area was 108.3 km² (Figure 2). Spatially, built-up expansion in 1995 was concentrated along major roads like Nnamdi Azikwe Expressway. By 2010, it expanded inward and along transport corridors like Makarfi Road. The 2025 phase showed infilling of undeveloped patches and outward sprawl into peripheral vegetated areas, creating new settlements such as Nariya and Maigingiya.

In 1995, the landscape was dominated by Farmland (65.14 km², 60.1%), followed by Natural Vegetation (27.12 km², 25.1%), Built-up (10.35 km², 9.5%), and Bare Land (5.78 km², 5.3%). By 2010, Built-up area increased to 15.62 km² (14.4%), while Farmland decreased to 60.46 km² (55.7%). Natural Vegetation slightly declined to 26.27 km² (24.2%), and Bare Land increased to 6.04 km² (5.5%). The 2025 epoch revealed a transformative shift as Built-up areas are more than doubled its 1995 extent to 24.08 km²

(22.2%). Farmland drastically reduced to 31.26 km² (28.8%). Contrary to the initial trend, Natural Vegetation increased to 39.11 km² (36.1%), becoming the dominant class, while Bare Land also rose to 13.94 km² (12.8%) (Figure 3).

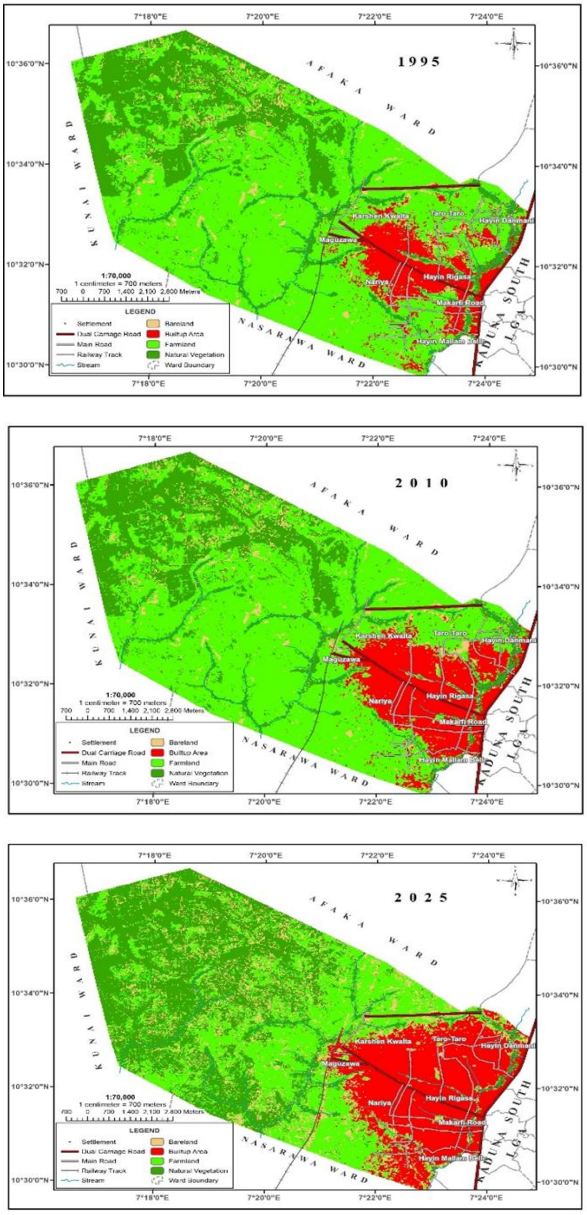

Figure 2: LULC Classifications of Rigasa Ward (1995, 2010 and 2025)

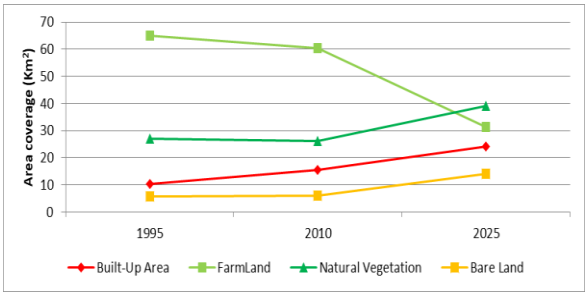

Figure 3: LULC Change of Rigasa Ward, 1995 – 2025

The unexpected resurgence of Natural Vegetation by 2025 makes it the dominant class (Figure 3). This aligns with the supplementary survey results which attributed this to the abandonment of farmlands due to insecurity on the outskirts.

It represents a non-linear transition where land is not simply moving from agriculture to urban, but is undergoing a complex de-agrarianization and potential re-wilding in specific zones, a nuance often missed in metropolitan-scale studies. Similar patterns of vegetation recovery in abandoned agricultural lands have been documented in other peri-urban and conflict-affected contexts such as Babalola et al. (2025) experiencing similar security challenges.

The overall classification accuracy was 92% for 1995, 89% for 2010, and 90% for 2025, with Kappa coefficients of 0 .89, 0.85, and 0.87 respectively. These values indicate a reliable classification suitable for change detection analysis (Table 1).

The methodological approach demonstrates the effectiveness of integrating multi-temporal remote sensing with GIS-based spatial analysis for monitoring peri-urban transformation. The accuracy levels achieved (89-92%) are consistent with similar studies in the region such as Adesola

Table 1: Producer and User Accuracy for LULC types (1995 – 2025)

PERIOD	1995		2010		2025	
Class Name	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy
Built-up	72.5%	46.03%	91.6%	68.7%	70%	41.2%
Farmland	77.85%	70.32%	70.7%	80.7%	86%	89.6%
Natural Vegetation	68.88%	74.69%	90%	84.3%	66.7%	85.1%

Bare Land	82.17%	94.97%	84.2%	89.8%	93.3%	96.6%
Overall Accuracy	77.8%		83%		84.6%	

Source: LULC Analysis, 2025.

Ogunleye and Akinbola (2024) which validates the use of maximum likelihood classification for LULC mapping in heterogeneous peri-urban landscapes.

3.2. Rate and Pattern of LULC Change

The change analysis from 1995-2025 showed that Built-up areas increased by +132.66% at an annual rate of +4.4% (0.45 km²/yr). Farmland experienced the largest decline of -52.01% at -1.7% annually (-1.13 km²/yr), natural vegetation increased by +44.21% (+1.5% annually) and bare land increased by +141.18% (+4.7% annually).

The annual change rates varied across periods (Figure 4). Built-up areas showed increasing rates from +3.4% (1995-2010) to +3.6% (2010-2025). Farmland declined at -0.5% annually (1995-2010) then sharply at -3.2% (2010-2025). Natural Vegetation declined slightly at -0.2% (1995-2010) then increased at +3.3% (2010-2025).

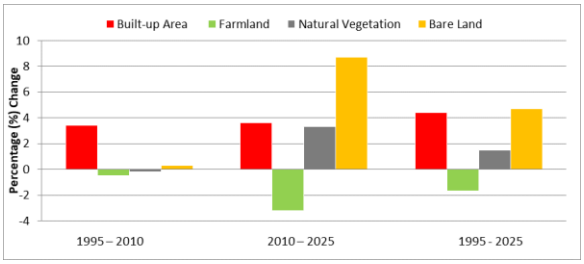

Figure 4: LULC Change Detection Comparison Trend

The findings depict a classic, accelerated Land Transition in a peri-urban African context, consistent with Lambin and Meyfroidt's (2010) characterization of compressed transition timescales in rapidly developing regions.

The rapid conversion of Farmland to Built-up area (+132.66%) aligns with studies from Akpu *et al.* (2017) in Kaduna, confirming residential expansion as a primary agent of landscape change. The accelerated annual growth rate of built-up area from 3.4% to 3.6% suggests intensifying pressure, likely driven by rural-urban migration and the search for affordable housing, consistent with Nigeria's rapid urbanization trends (World Bank, 2024).

3.3. Impact of Residential Growth on Vegetation

Overlay analysis confirmed a direct conversion of 11.84 km² of farmland (from the 1995 baseline) to built-up areas by 2025. This represents 34.95% of the total vegetation (farmland) loss of 33.88 km² recorded over the 30-year period. The remaining vegetation loss was attributed to conversion to bare land and natural vegetation regeneration (Figure 5).

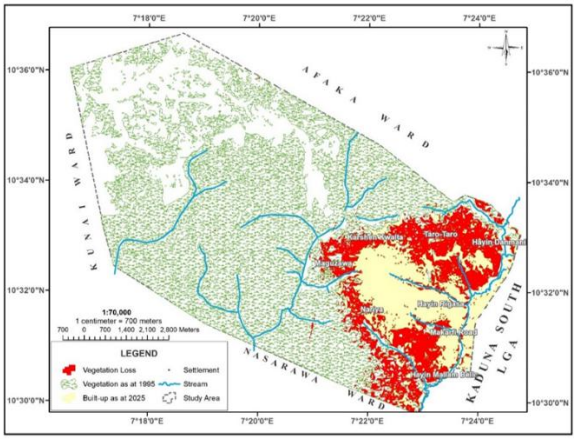

Figure 5: Vegetation (Farmland) Loss caused by Residential Growth

The direct conversion of 11.84 km² of farmland to built-up areas quantifies the tangible environmental trade-off. The loss of 52.01% of farmland over 30 years threatens local food security and livelihoods dependent on peri-urban agriculture, as observed by Okeleye *et al.* (2023). The increase in Bare Land (+141.18%) points to either speculative land clearance, temporary construction sites, or soil degradation following vegetation removal, creating additional environmental vulnerabilities like increased erosion and dust generation.

The pattern of vegetation loss closely mirrored the pattern of residential expansion, indicating a strong causal relationship (Figure 6). The most severe vegetation loss occurred in settlements like Hayin Danmani, Hayin Mallam Bello, and Nariya, where previously continuous vegetated landscapes were fragmented into isolated patches.

Spatially, the expansion pattern evolved from linear along roads to a more contiguous and infilling pattern, indicative of progressing urbanization.

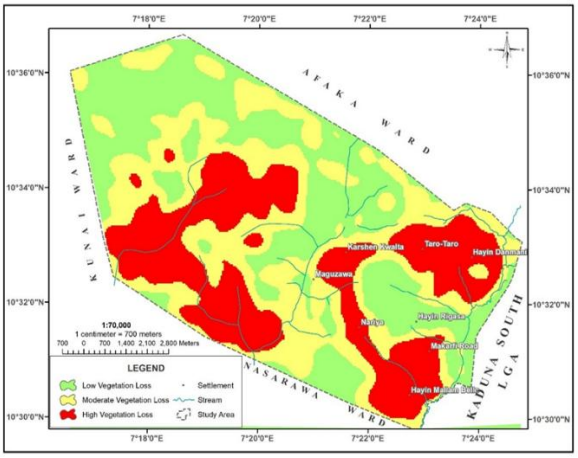

Figure 6: Spatial Distribution of Vegetation Loss in Rigasa (1995-2025)

This pattern follows the sector model of urban growth, with development extending along transportation corridors, but also exhibits characteristics of multiple nuclei development as new settlements emerge independently before connecting to the main urban fabric.

IV. CONCLUSION

This study has successfully quantified the spatio-temporal dynamics of LULC change in Rigasa Ward between 1995 and 2025, establishing that residential growth is the dominant driver of landscape transformation in this locality. The accelerated loss of farmland and its direct conversion to built-up areas pose significant socio-economic and environmental risks, including threats to food security, ecosystem service provision, and climate resilience.

The findings necessitate urgent, evidence-based spatial planning interventions such as the Development and Enforcement of an Integrated Urban Master Plan; Strategic Protection of Agricultural Land for maintaining local food security and preserving the area's agrarian heritage and ensuring future development mandating green space allocation, tree planting campaigns, and the creation of ecological corridors, especially along riparian zones, to mitigate environmental impacts, enhance biodiversity, and improve community resilience to climate change.

This study also provides a replicable model for analyzing peri-urban transformation, offering a template for local governments across rapidly urbanizing regions to develop targeted, sustainable land management strategies. Future research should integrate socio-economic data with spatial analysis to better understand the drivers and impacts of land use decisions at household and community levels.

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