



RESEARCH ARTICLE

Assessment of the Rate of Spatial Expansion of Minna Urban Area, Niger State, Nigeria

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Abstract

This study assesses the spatial urban expansion rate of Minna, Nigeria, over twenty years (2005 – 2025) using multi-temporal satellite imagery and GIS/RS analytical techniques. Urban expansion driven by population growth, infrastructure development, and institutional factors has significantly changed peri-urban areas, replacing vegetation and agricultural land with built-up areas. The study contributes to the existing literature by linking theoretical perspective with empirical evidence that provides clarity to the dynamics of spatial urban expansion in Nigerian cities. The Landsat datasets were processed and classified into four major Land Use/Land Cover (LULC) classes, namely built-up area, farmland, dense vegetation, and water bodies. The accuracy assessments indicated good quality reliability (overall accuracy 87.6-91.2%; Kappa coefficient 0.842-0.884). The results reveal that the built-up area of Minna increased from 2,841.78 ha (9.08%) in 2005 to 9,301.38 ha (29.72%) in 2025, a cumulative increase of 6,459.60 ha. The expansion took place in different phases: accelerated growth (2005-2010), sustained expansion (2010-2015), reaccelerated growth (2015-2020), and moderate expansion (2020-2025). Institutional drivers such as displacement from Abuja, infrastructure investment, and security challenges contributed to the observed trends that were also accompanied by notable changes in other land cover types. Based on the analysis, the study recommends that land management land and urban development regulations should be strengthened to control unplanned expansion. Furthermore, active community engagement is essential to harmonise regional land development objectives.

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1. INTRODUCTION

Urban expansion refers to the outward growth of the physical structure and built environment of a city, usually extending the boundaries, increasing development, and raising population densities (Samat, Ghazali, Hasni, & Elhadary, 2014; Bloch, Monroy, Fox, & Ojo, 2015). This process is mainly caused by population growth, due to natural increase and migration, as well as economic activities. Demographic pressure is known to stimulate socioeconomic development, which raises demand for housing, infrastructure, and services that culminate in spatial growth. As cities approach saturation, development inevitably tends to drift into peri-urban and rural lands, leading to the extension of infrastructure that transforms agricultural or undeveloped land into residential, commercial, and mixed-use developments (McGee, 2009).

In the twenty-first century, changes in the rural landscape into a built environment have become rapid and stand as one of the most significant human factors driving environmental change. At the global level, spatial urban expansion is advancing, and cities, especially in Asia and Latin America, are swiftly responding to it due to pressure from population growth and ineffective planning systems (Mosammam, Nia, Khani, Teymouri & Kazemi, 2017). The United Nations made a projection that by 2030, nearly 5 billion people will reside in urban areas globally, with urban land cover expected to increase by approximately 1.2 million km², nearly tripling the built-up area recorded in 2000 (Seto, Güneralp, & Hutyra, 2012). This magnitude of expansion poses threats to ecosystems, biodiversity, and environmental sustainability.

In Nigeria, the pace of urban growth is equally concerning. Major cities such as Lagos, Abuja, and Kano provide illustrative examples, as they witnessed uncontrolled expansion resulting in congestion, degradation of the environment, and loss of green spaces (Adeleye *et al.*, 2018). The urban population is rising with an annual growth rate of 3.92%, and over 63% of the total population resides in urban areas (United Nations Population Division, 2024). Most cities, especially the state capitals like Makurdi, Osogbo, Lafia, and Lagos, are undergoing accelerated physical expansion and high land use and land cover (LULC) change and land consumption ratios (Iorliam & Ortserga, 2019; Fatusin, Oladehinde & Ojo, 2019; Medayese *et al.*, 2023; Oyalowo, 2022). This pattern is influenced by the government's concentration of resources and economic activities within the urban centres. Consequently, this results in the intensity of land-use competition and mixed development typologies both within the urban and peri-urban areas.

In Minna, the capital of Niger State, these trends are evident. According to Idowu (2017), Minna grew by approximately 101.76% between 1996 and 2015, impacting the peri-urban development trend. Globally, similar patterns of peri-urban land conversion, accounting for over 80%, have been documented by Angel (2023), mostly raising environmental concerns such as loss of vegetation, open spaces, and agricultural land, which threaten future recreational land uses and sustainable environments (Asaju & Olukolajo, 2023). Studies conducted in Minna have focused on LULC changes (Morenikeji *et al.*, 2015; Suleiman *et al.*, 2020); others assess effects on agriculture (Dalil, Yamman & Omeiza, 2013), vegetative cover, land consumption, and the patterns of peri-urban development (Idowu *et al.*, 2020; Bako *et al.*, 2023). However, there is a timeline limitation; all the studies have their time frame ending between 2017 and 2020. Because the data relating to LULC changes are longitudinal in nature, this study aims to further document these changes by extending the timeline from 2005 to 2025. Specifically, the objectives are to discuss the underlying trends and factors responsible, and to integrate missing theoretical foundations from early literature to better validate the empirical findings.

2. THEORETICAL FOUNDATION

Urban expansion theory provides a foundational framework for the understanding of how urban growth impacts the spatial and physical transformation of landscapes within and at the edges of cities. The theory posits that as urban population increases and economic activities intensify, cities expand outward, extending their built environments into previously undeveloped, rural, or agricultural areas (Clark, 1951; Alonso, 1964). Bertaud (2018) argued that urban expansion is not merely a demographic trend, but a complex spatial and institutional process influenced by industrialisation, real estate development, infrastructure investment, and changes in land governance. Critically, while Bertaud (2018) emphasises market and institutional mechanisms, Angel (2023) places greater weight on demographic drivers, population growth and rising demand for housing as fundamental catalysts of urban expansion. The emphasis here is that urban expansion is a consequence of population growth in the sense that urban settlements consume land, as both urban densification and expansion can accommodate growth.

However, urban expansion is not completely characterised by outward growth; it also manifests as structural reduction, a phenomenon conceptualised as urban shrinkage. While traditional theories depict urban spatial processes through continuous growth, Yang *et al.* (2015) demonstrate that many contemporary cities simultaneously experience local population loss and economic disinvestment. This inconsistent coexistence of expansion and shrinkage shows clearly that spatial expansion is highly uneven. Yang, Zhu, and Zhang (2020) further refine this by illustrating that peri-urban land expansion often

continues even as the core demographic and economic structures in the urban area decline. Consequently, incorporating urban shrinkage into the spatial expansion framework challenges the assumption that land consumption is always determined by population growth, revealing a more complex and uneven reality where cities expand physically while shrinking internally.

At the centre of these LULC change dynamics due to expansion and shrinkage is the Urban Fringe Theory (UFT), which focuses on the transitional, mixed-use zone of rural-urban convergence, where rapid, often disruptive, spatial and socioeconomic changes occur (Dickinson, 1947; Pryor, 1968). It bridges the concepts of urban expansion and shrinkage by analysing the specific, social and physical changes, including urban-type development replacing traditional rural activities, at the peri-urban interface (Bryant *et al.*, 1982). To reveal a more complex and uneven reality where cities expand physically while shrinking internally, the UFT captures this non-linear reality. The theory notes that the rate of expansion into surrounding rural areas is not always a slow, steady, or predictable linear process. Rather, it suggests that urban fringe development often occurs in distinct episodes, sudden bursts, or leapfrog spatial growth (Angel *et al.*, 2022) triggered by specific macroeconomic events, changes in policy, infrastructure investments, or external institutional shocks, especially in developing countries.

3. LITERATURE REVIEW

In assessing the rate of urban expansion, an understanding of LULC change is critical, as the physical growth of cities directly influences their land surface characteristics and environmental changes. It fundamentally represents a spatial increase in built-up areas, encompassing settlements and infrastructure, and its immediate physical consequence is the continuous conversion of surrounding non-urban landscapes (Angel *et al.*, 2016; Nuisl & Siedentop, 2020). The theoretical understanding of urban expansion indicates that population growth, infrastructure development, and institutional factors determine the outward and inward spatial processes of cities (Clark, 1951; Alonso, 1964; Bertaud, 2018). Recent studies of Fenta *et al.* (2017), Afolayan and Adebayo (2023), and Adebayo *et al.* (2024) present empirical evidence clearly demonstrating that rapid urban expansion consistently takes place at the direct expense of productive agricultural land, natural vegetation, and open spaces. The continuous replacement of green vegetative covers with built-up structures changes the local ecosystem characteristics, which are closely linked to global economic and demographic change (Shao *et al.*, 2021).

Globally, studies have employed RS, GIS, and satellite imagery for monitoring and quantifying urban expansion and change patterns over time. Wu and Zhang (2012), for example, conducted an analysis of land-use dynamics, built-up land expansion patterns, and their driving forces in Hangzhou, China. The study covered 30 years (1978–2008), and the outcome revealed a substantial increase in built-up land, expanding from 319.3 km² in 1978 to 862.5 km² in 2008, representing 63%. The spatial expansion followed an axial pattern, radiating from the city centre along major roads and waterways. Similarly, the approach has been used in other areas, such as Gaborone, Botswana, by Mpofo, Darkoh, and Gwebu (2018), where expansion over 30 years (1996, 2006, and 2012) was tracked. This study identifies how much socioeconomic pressures influenced land conversion and expansion, particularly along main transportation corridors, and how agricultural land diminishes under an intense rise in economic activities.

Studies in some Asian countries, such as Indonesia, have examined urban expansion characteristics. Sari, Wartaman, and Luru (2021) assessed the expansion of peri-urban areas (PUAs) in Bekasi City; the focus was on assessing the conversion process and densification of the PUAs. The finding indicates that over half (51.79%) of the PUAs experienced rapid growth, with significant increases in density and built-up areas. Meanwhile, in Bangladesh, Arifeen *et al.* (2021) analysed LULC changes in Gazipur District over 20 years (1990 to 2020), with a specific focus on urban expansion and its drivers, documenting substantial growth in built-up areas (18 km² to 105 km²) from the earlier dominance of agricultural land use. A similar study in Faisalabad City, Pakistan, by Afzal *et al.* (2023) also shows that infrastructure development due to urbanisation accounts for 46% of built-up areas, making it dominant over agricultural land and vegetative cover over a period of 18 years (2000 to 2017). These studies have shown the significant impact of population growth and infrastructure development in fuelling urbanisation and leading to the expansion of built-up areas.

Related literature in Nigeria has emphasised the rapid nature and pattern of urban expansion. For instance, Idowu *et al.* (2020) analysed the trend in peri-urban land-use development in Minna, covering a span of 43 years (1972 to 2015), showing a 200% increase in built-up areas and revealing how urban expansion and built-up areas extend into peri-urban zones. The expansion, in most cases, is characterised by sparse or leapfrog development along transportation routes that gradually results in a decline in vegetation cover (Dalil *et al.*, 2013). Another related work by Suleiman *et al.* (2020) corroborates these findings, highlighting the exponential growth of built-up areas and the associated decline in natural vegetation over a similar period. In other Nigerian cities like Akure, Asaju, and Olukolajo (2023) further demonstrate that land cover transformation can occur within a decade, which will influence a significant increase in the built-up areas. This provides a key perspective on how rapidly these LULC changes can occur in other cities as consistent population growth and demand for land increase.

Infrastructure projects such as roads, drainage, and utilities often facilitate the outward growth of urban areas, enabling development into peri-urban zones. Socioeconomic factors, including increased income levels and real estate investment, also stimulate land consumption, usually resulting in leapfrog development. This is comprised of sparse or scattered developments across the landscape, separated by undeveloped spaces. These drivers are consistent globally, as evidenced by urban expansion studies in Gaborone (Mpofu *et al.*, 2018), Bekasi (Sari *et al.*, 2021), and Faisalabad (Afzal *et al.*, 2023). While in Lagos, Ogunbode *et al.* (2025) confirm that 69.7% of land-use changes are due to urbanisation, religious activities, available land resources, small-scale businesses, government initiatives, and educational institutions. All these drivers determine both spatial organisation and socioeconomic activities.

The literature review highlights that urban expansion is characterised by a steady increase in built-up areas, mostly at the detriment of agricultural land and natural vegetation, as observed through RS and GIS analyses globally. Studies from different parts of the world, including China, Botswana, Indonesia, Bangladesh, Pakistan, and Nigeria, indicate that urban growth is spatially distributed from the centres along transportation corridors, and is mainly influenced by socioeconomic, infrastructure, and demographic factors. This consistent axial pattern of expansion rapidly encroaches and facilitates peri-urbanisation and land use changes over time. However, given the variability in expansion rates and patterns of expansion across different regions, local assessments are required to inform targeted land use policies, sustainable development strategies, and effective management of urban growth corridors. The review emphasises how crucial it is to consider both spatial and temporal analysis in understanding urban expansion patterns and their environmental implications.

3.0 MATERIALS AND METHODS

3.1 The Study Area

Minna, the capital of Niger State, is located within the south-western region of the State. The city lies between Latitudes 9°33'00" and 9°40'00" North of the Equator and Longitudes 6°29' and 6°35' East of the Greenwich Meridian (Idowu *et al.*, 2020). The metropolis of Minna comprises two Local Government Areas: Chanchaga and Bosso and is one of the largest urban areas in the state. With the creation of Minna Emirate and the appointment of the Emir as traditional head by the colonial administrators in 1957, the political status of Minna was upgraded and later became the state capital upon the creation of Niger State in 1976. From eleven (11) administrative wards by 1990, the number increased to about 20 wards by 2017 as the city expanded and the population increased. The major tribes are the Gbagyis and Nupes; there are also Kadara, Kakanda, Hausa, and other ethnic nationalities.

The growth of Minna stems from the development of the Nigerian rail system that linked the city to the south-western, the north-western, and eastern regions of the country. This development opened the city to various socioeconomic activities, giving it a relative advantage in terms of trade over some cities within the neighbouring states and the northern region (Morenikeji *et al.*, 2015). Today, the growth pattern of Minna stretches along the major road traversing the city from Suleja through Chanchaga in the Southern part to Maikunkele in the Northern part, covering over 25 km. The road cut through the central business district, popularly known as 'Mobil,' covering Kasuwan Gwari, Limawa Wards, and the old railway station, dominated by heavy commercial activities. The Western growth pattern of the city spanned from Kpakungu – Albishiri-Gidan Mangoro along the Minna - Bida axis, while the Eastern section radiates towards Maitumbi - Gwada axis. Today, the growth pattern of Minna can best be described as a multi-nuclei model, with most

of the peri-urban areas forming their own suburban nuclei with growth in both population and socioeconomic activities. With a population of 496,000, the city occupies a landmass of about 119.3 Km² (Niger State Geographic Information System, [NIGIS], 2022). The land use pattern is predominantly residential and commercial, with limited institutional and recreational uses. Commercial activities are concentrated in the city core, while residential and other land uses increase with distance from the centre, particularly along major road corridors.

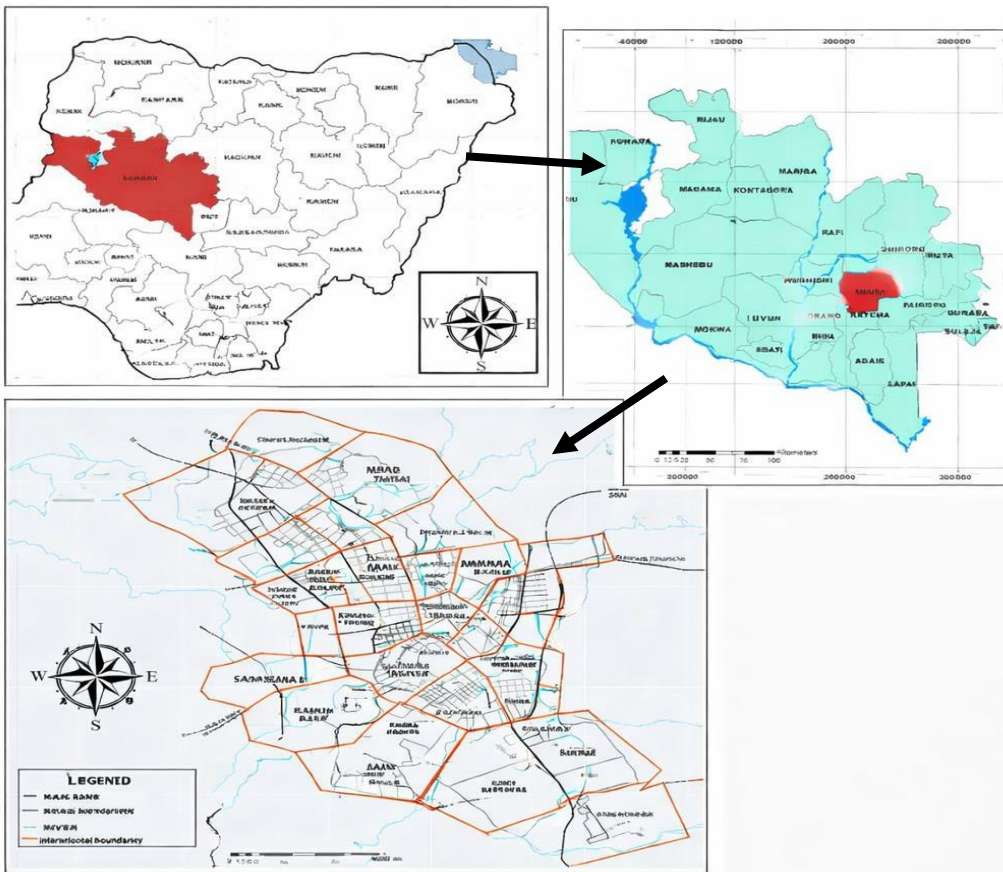


Figure 1. The study area, Nigeria, Niger State, and Minna

3.2 Data Collection and Analysis

The tools and methods of spatial data analysis were the GIS and RS software environments, analytical methods; here, the acquired images from the satellite were processed, cleaned, and interpreted. To access the rate of spatial expansion of Minna urban area, satellite imagery was acquired for a span of 20 years in five study periods (2005, 2010, 2015, 2020, and 2025) from United States Geological Survey (USGS) Earth Explorer database and the datasets were processed and analysed using the clip boundary function in ESRI's ArcGIS 10.8 and QGIS software environments to extract the extent of Minna metropolis from the acquired satellite imagery. Atmospheric and radiometric corrections were performed on both Landsat 7 ETM+ and Landsat 8 and 9 OLI/TIRS datasets to minimize atmospheric distortions and convert digital numbers into physically meaningful reflectance values suitable for analysis. In addition, Scan Line Corrector (SLC) error correction was applied to the Landsat 7 using QGIS software with Gap mask imagery to address data gaps and enhance image quality for subsequent processing.

The individual spectral bands of the satellite images were combined through layer stacking in ArcGIS, and False Colour Composite (FCC) images were generated using appropriate band combinations for each dataset. This process enhanced visual interpretation and facilitated the identification of LULC features. The composite images were subsequently used to develop training samples for classification. A Maximum Likelihood Supervised Classification (MLSC) technique was employed, consistent with comparable studies

of Arifeen et al. (2010), Asaju and Olukolajo (2023), and Shehu *et al.* (2023). The MLSC was used to classify the Landsat imagery into four (4) major LULC classes namely; built-up area, water body, dense vegetation, and less vegetation (farmland). Hence, for each class, a minimum of 30 training samples were selected based on field verification through ground truthing and Google Earth Pro high-resolution reference imagery to ensure classification reliability. LULC maps were generated for the periods of 2005, 2010, 2015, 2020, and 2025, to capture spatial variations in land cover.

Post-classification accuracy evaluate was conducted, and this was made for each of the five classification outputs using a stratified random sampling approach to generate confusion matrices. This involved the computation of Overall Accuracy and Cohen's Kappa Coefficient for each classification, consistent with standard procedures (Congalton & Green, 2009). The measures provided a quantitative assessment of the reliability and validity of the classified maps. Table 1 presents the accuracy assessment outcome.

Table 1. Assessment of Accuracy for LULC Classification

Year	Overall Accuracy (%)	Kappa Coefficient (κ)
2005	88.4	.851
2010	89.1	.863
2015	91.2	.884
2020	90.7	.877
2025	87.6	.842

Source: Field survey analysis, 2025

From the result in Table 1, the Kappa values exceed the threshold of 0.81 - 1.00, indicating a strong agreement (Landis & Koch, 1977; Wang *et al.*, 2021). To ensure high temporal precision and minimize seasonal vegetation bias, the 2025 LULC period was mapped using empirical satellite data acquired specifically between January and February 2025. This dry-season window provides near-zero cloud cover over Niger State, allowing for an accurate, non-projected baseline assessment of the landscape, which yielded an overall classification accuracy of 87.6%. This validates the reliability of the spatial data used for the analysis of the rate of expansion. Following the focus of the study on assessing the rate of spatial expansion of the Minna urban area, the post-classification change detection was used to quantify land use changes between successive intervals of the study period. Therefore, the built-up area was extracted at each time interval and differentiated to calculate the net change, percentage change, and annual expansion rates.

Four different land use/land cover (LULC) categories were successfully classified from the Landsat datasets, which are Dense vegetation, built-up area, less vegetation (farmland), and water bodies; however, the discussion of results focuses more on the built-up area class. The extent of the built-up category is justified by the fact that it is a direct reflection of the physical footprint of human settlement and artificial surfaces. The primary purpose of this research is to measure the rate of spatial urban expansion, tracking variations in the built-up class, which is the simplest proxy for urbanisation. The changes in the other three LULC classes (vegetation, farmland, and water) are mostly associated with the ecological consequences or land-conversion transitions from this expansion, rather than the urban growth process itself.

4. RESULTS AND DISCUSSION

4.1 Land Use and Land Cover (LULC) Changes 2005 - 2025

The assessment of the spatial expansion of Minna covering 2005 to 2025 is conducted to reveal the fundamental physical growth and changes of its urban area over a period of two decades. The objective here is to quantify the extent to which the urban built-up area has expanded, making use of multi-temporal satellite imagery, and the analysis has tracked the LULC transition through 20 years. This section, therefore, presents the data obtained from a longitudinal analysis, showing the rates, direction of expansion, and the spatial dimension of the urban area between 2005 and 2025.

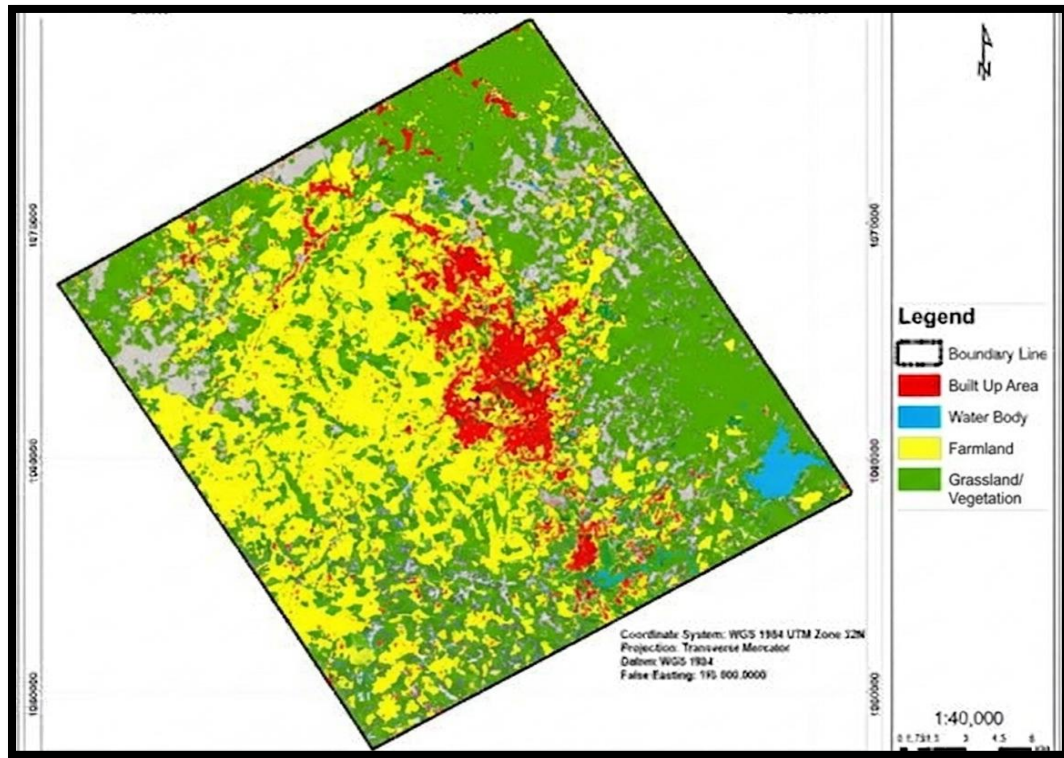


Figure 2. LULC image of Minna 2005

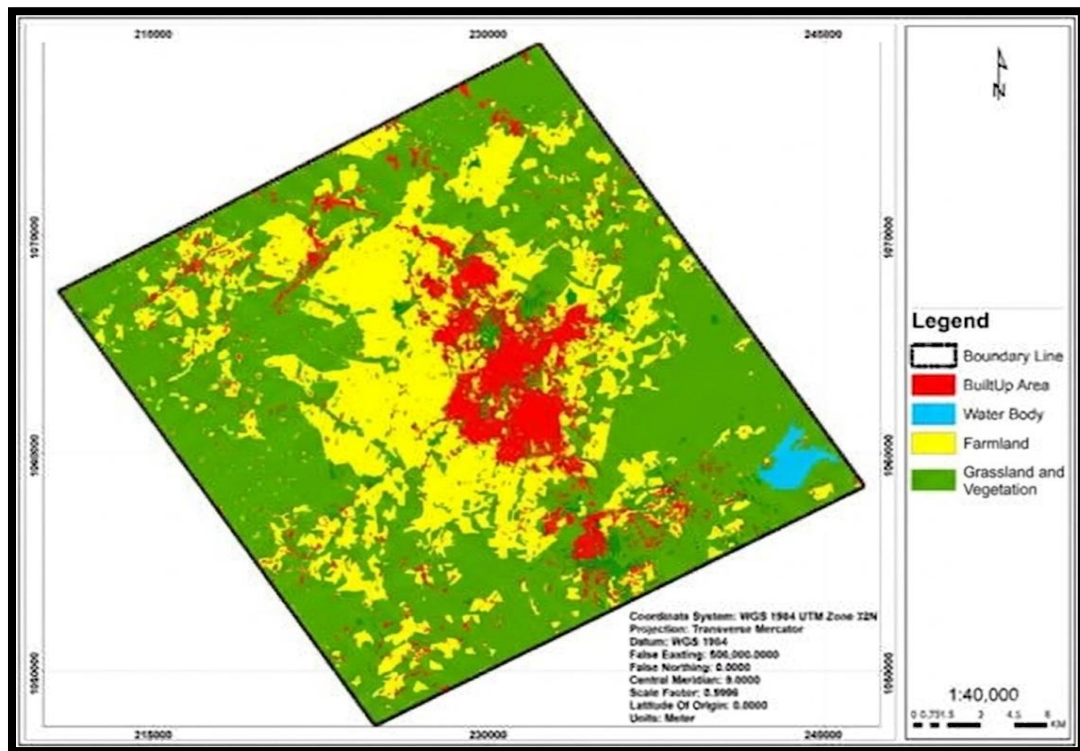


Figure 3. LULC image of Minna for 2010

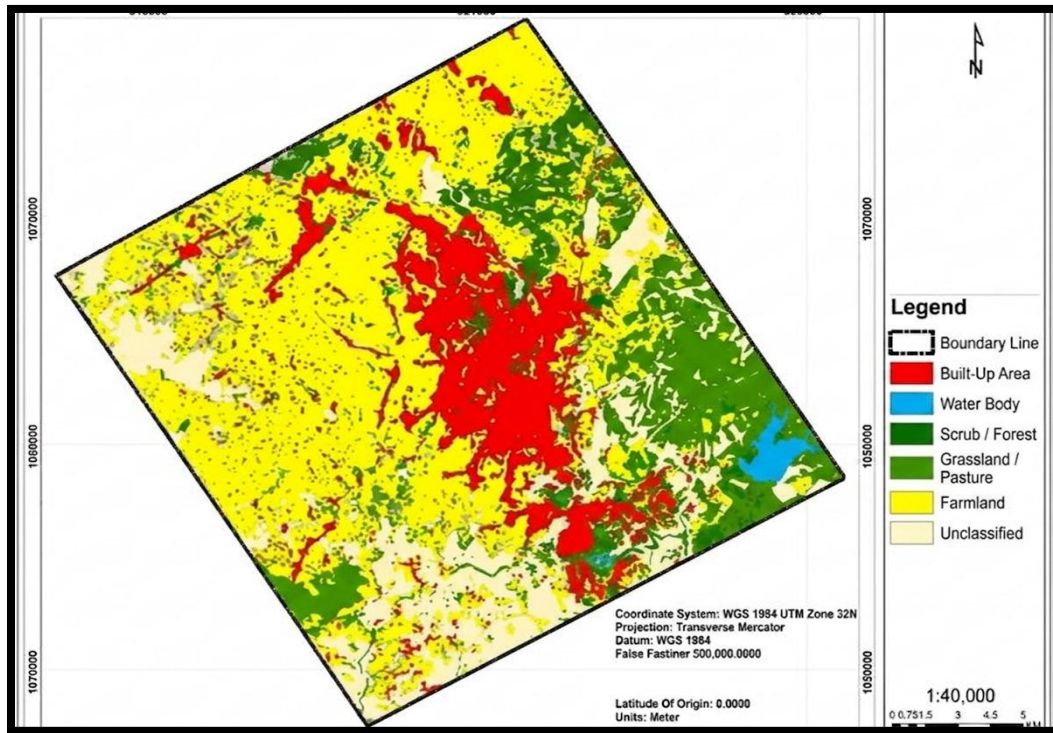


Figure 4. LULC image of Minna for 2015

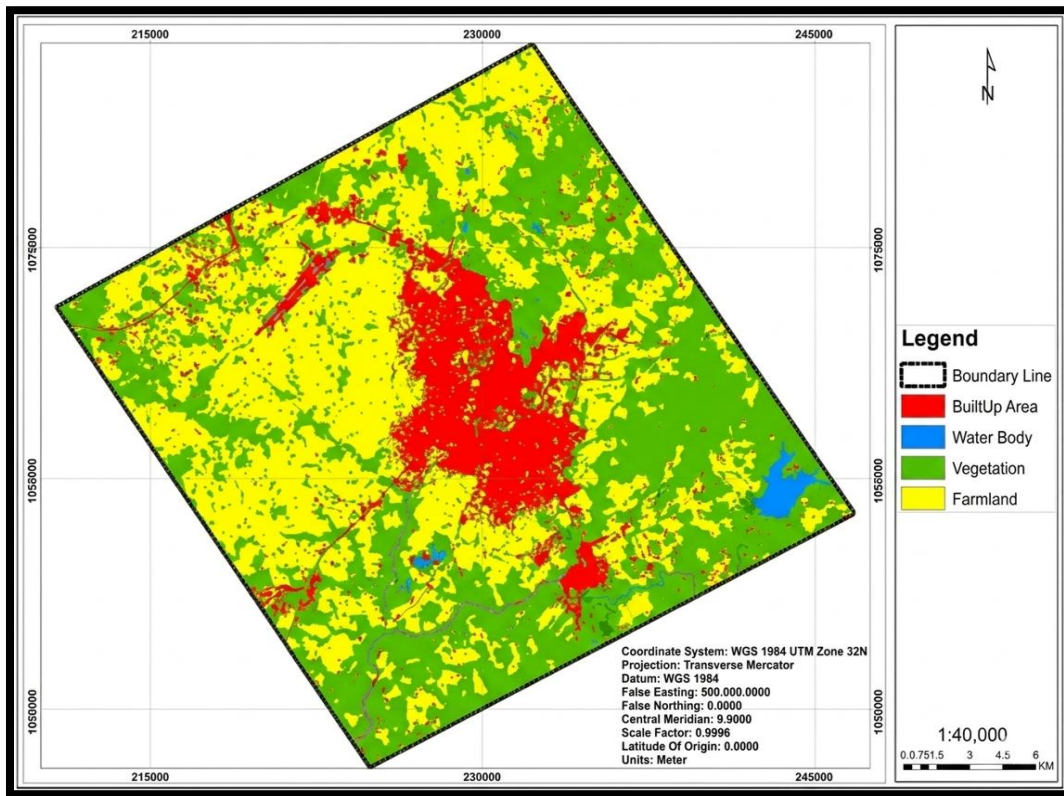


Figure 5. LULC image of Minna 2020

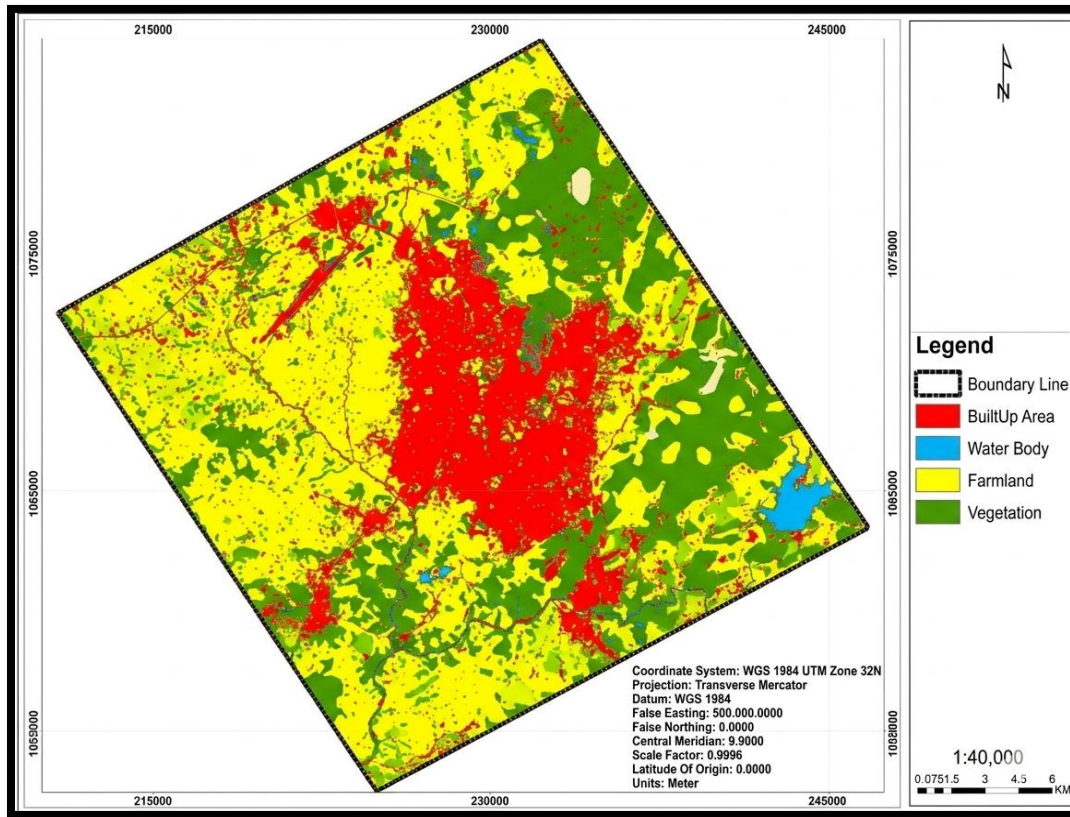


Figure 6. LULC image of Minna for 2025

Table 2. Consolidated LULC Area (Ha) for Minna 2005-2025

LULC Class	2005	2010	2015	2020	2025
Dense vegetation	20,038.14	17,216.09	8,939.65	16,326.92	17,182.46
Developed area	2,841.78	4,692.30	5,954.86	7,751.17	9,301.38
Less vegetation (farmland)	7,846.81	8,764.56	16,120.21	6,920.93	4,504.95
Water body	575.26	575.26	287.27	302.97	313.2
Total	31,301.99	31,301.99	31,301.99	31,301.99	31,301.99

From Figures 2-6 and Table 2, the Minna urban landscape underwent substantial transformations between 2005 and 2025 across a constant total area of 31,301.99 ha. The most prominent trend is the steady and continuous expansion of developed areas, which grew from 2,841.78 ha in 2005 (Figure 2) to 9,301.38 ha by 2025 (Figure 6). This urban growth changed sharply with the reduction of less vegetation (farmland), which initially peaked at 16,120.21 ha in 2015 before experiencing a steep, multi-year decline down to 4,504.95 ha in 2025. Meanwhile, dense vegetation fluctuated significantly; it dropped to a low of 8,939.65 ha in 2015 but recovered to 17,182.46 ha by 2025, remaining lower than its original 2005 extent of 20,038.14 ha. Lastly, water bodies faced an overall net loss, remaining stable at 575.26 ha until 2010, dropping sharply in 2015, and only staging a minor recovery to 313.20 ha by 2025.

However, in line with the scope of the study, which focuses on the expansion of developed areas, the results of the built-up area were extracted from the general land use classification (Table 2) for further detailed analysis and discussion of results. However, discussions on the other land use classes are also included. This was conducted at intervals of 2005-2010, 2010-2015, 2015-2020, and 2020-2025, respectively.

5.1 Period-by-Period Spatial Changes in the Built-up Area (2005 – 2025)

The extent of Minna urban expansion is observed at an interval of 5-yearly period, and analysis of the built-up area representing the rate of spatial expansion is presented in Table 3 as obtained from the spatial imagery presented in Figures 2-6. The total land area is 31,301.99 ha, and the developed area statistics as presented include: the percentage coverage of the developed area, the interval changes between periods, the percentage change from the preceding period, and the cumulative percentage change.

Table 3. Developed (Built-up) Area in Minna 2005 - 2025

Year	Developed Area (ha)	% of Dev Area	Change from Prev. Period (ha)	% Change from Prev. Year	Cumulative Change (ha)
2005	2,841.78	9.08	—	—	—
2010	4,692.30	14.99	+1,850.52	+65.12	+1,850.52
2015	5,954.86	19.02	+1,262.56	+26.91	+3,113.08
2020	7,751.17	24.76	+1,796.31	+30.17	+4,909.39
2025	9,301.38	29.72	+1,550.22	+20.00	+6,459.60

Source: Author's computation from LULC classification output, 2025

The discussion of results presented in Table 3 is hereby made according to the time interval of the analysis. These are; the 2005 baseline (established urban core), the 2005-2010 interval (accelerated initial expansion), 2010-2015 interval (sustained expansion), 2015-2020 interval (reaccelerated expansion), 2020-2025 interval (moderate expansion).

5.2 The 2005 Baseline: Established Urban Core

The 2005 (Figure 1) was used as a baseline of the study period to establish the Minna urban centre with a built-up area of 2,841.78 ha, representing 9.08% of the total land area. This baseline indicates the level of urbanisation at the onset of the current urban growth cycle. At this stage, the built-up land was predominantly concentrated in the urban centre comprising the GRA, the central business district (Mobil), and commercial precincts along the main arterial roads, as well as the older residential neighbourhoods of Sabon Gari and Tudun Wada. This baseline positions Minna as a moderately urbanised city at the beginning of the study period, with nearly 90% of its PUAs still under vegetation land cover. The configuration of Minna urban land development at this period is largely consistent with the outcome from the study of Suleiman et al. (2020) on the condition of urban expansion and the PUAs at the turn of the millennium.

Furthermore, the 2005 baseline year (Table 2) shows that the dense vegetation dominated the landscape, covering 20,038.14 ha (64.02%). Less vegetation (farmland) accounted for 7,846.81 ha (25.07%), reflecting areas of moderate vegetative stress or agricultural use, as developed areas were relatively limited (9.08%), consistent with Minna's emerging urban status at that time. Water bodies occupied the smallest fraction at 1.84%. The dominance of dense vegetation in 2005 indicates relatively intact forest and woodland cover. This baseline is critical for gauging the magnitude of subsequent changes.

5.3 The 2005 – 2010 Interval: Accelerated Initial Expansion (+65.12%)

The interval of 2005 and 2010 recorded the most significant increase of the entire study period, with the developed area expanding by 1,850.52 ha. This represents an expansion rate of 65.12%, making it approximately 370 ha per annum. By 2010, the built-up area had reached up to 4,692.30 ha, which is about 14.99% of the total land area. The significant increase within this time interval aligns with the return of the democratic dispensation; the resurgence of demolition activities by the Federal Capital Administration aimed at restoring the master plan (Ismail et al., 2024) that gave rise to migration of informal displaced households to neighbouring cities like Suleja and Minna. The provision of infrastructure like roads and urban

transportation also increases rural-urban migration in response to employment opportunities (Sulaiman & Idowu, 2020) and increases in security challenges among the neighbouring rural communities. The increased dimension of security challenges faced by the rural households among the neighbouring communities has resulted in their migration to the urban areas and PUAs, raising the demand for land and housing.

This outcome resonates with that of Buba *et al.* (2016), who reported about 110% increase in urban expansion in Suleja between 2000 and 2015, encapsulated in the current study's time frame. The resurgence of demolition activities in the FCT, which displaced informal settlers to neighbouring cities, including Minna, constitutes an institutional driver not captured in the classical Urban Expansion Theory but explained within the Institutional Theory framework. The institutional response to urban development through regulatory enforcement in the FCT resulted in a spillover effect that substantially impacted land use patterns in geographically adjacent but formally separate urban systems.

While a significant built-up area expanded, a notable decline in dense vegetation was observed by 2010, falling to 17,216.09 ha (54.99%), a net loss of approximately 2,822 ha compared to 2005. There was also a marginal increase in farmland to 8,764.56 ha (28.00%), while water bodies remained unchanged at 575.26 ha (1.84%). The 2005–2010 period reflects the early phases of urban expansion in Minna, with deforestation pressure evident from the declining dense vegetation (Dalil *et al.*, 2016). The growth of less vegetation likely indicates transitional land statuses, areas of forest clearance for farming activities.

5.4 The 2010 – 2015 Interval: Sustained Expansion (+26.91%)

This interval is defined as a period of sustained urban expansion; the continued extension of the built-up area led to an additional 1,262.56 ha, summing up to 5,954.86 ha with a proportion of 19.02% of the land area. The expansion rate is considered moderate at 26.91% relative to the 65.12% of the previous interval (2005-2010), and the absolute addition of 253 ha per annum was substantial to sustain the rate of expansion. This moderate rate of expansion could likely be attributed to a degree of saturation of the urban centre and the effect of road linkages that create access to the PUAs within urban proximity (Sulaiman & Idowu, 2020). This occurrence is often referred to as urban shrinkage, where cities momentarily experience population loss due to certain events (Yang *et al.*, 2020). However, from the Bid-rent theoretical perspective, the declining relative cost of PUA land, compared to the increasingly expensive urban centre, was redirecting investment toward the periphery, consistent with Alonso's (1964) declining bid-rent gradient for residential users. Therefore, the offer of access to affordable land with fewer development control issues encourages leapfrog property development in the PUAs as urban expansion continues along the major road corridors (Salem *et al.*, 2019).

The interval of 2010-2015 also marked a dramatic change in the vegetative cover during the study period. As shown in Table 2, Dense vegetation experienced a sharp decline to 8,939.65 ha (28.56%), a loss of more than 8,276 ha from 2010 levels and nearly 11,099 ha from the 2005 baseline. Meanwhile, a surge to 16,120.21 ha (51.50%) of farmland was observed, making it the dominant land cover class. Water bodies recorded a reduction to 287.27 ha (0.92%), likely attributable to seasonal variation or sedimentation. This period represents a critical inflection point. The transition from dense vegetation to less vegetation, rather than directly to developed land, suggests extensive agricultural encroachment, logging, or bush burning as intermediary drivers. The 2015 period signals potential ecological stress that calls for urgent land use regulatory interventions.

5.5 The 2015 – 2020 Interval: Reaccelerated Expansion (+30.17%)

The interval of 2015 – 2020 experienced a new surge in Minna urban expansion with the developed area increasing by 1,796.31 ha (+30.17%) to reach a coverage of 7,751.17 ha, representing 24.76% of the total area (Figures 4 & 5). This increase in the rate of expansion after a moderate increase observed within the 2010-2015 intervals suggests the operation of new growth catalysts, such as the resurgence of security challenges across the state's rural communities, sparking off immigration and population increase within the urban centre and the PUAs. The era also witnessed the establishment of tertiary educational institutions, improvement in road connectivity, and an increase in commercial activities (Suleiman *et al.*, 2020). This is consistent with the recognition of urban expansion theory that infrastructure investment is a catalyst for

urban growth that also precipitates increase in demand for housing and commercial spaces. This was also emphasised by Bertaud (2018) while recognising that alongside demographic trends, infrastructure investment and changes in land governance often serves as a growth catalyst leading to urban expansion.

The 2015-2020 classification reveals a partial recovery of dense vegetation, which increased to 16,326.92 ha (52.16%). This increase of approximately 7,387 ha from the 2015 trough suggests vegetation regrowth, possible afforestation, or reclassification of maturing secondary vegetation. Farmland declined to 6,920.93 ha (22.11%), corroborating the conversion of previously degraded land back to woody cover. Water bodies registered a slight recovery to 302.97 ha (0.97%). The 2020 data suggest a dual dynamic: vegetation resilience through natural regeneration or conservation efforts, coexisting with sustained urban and peri-urban development pressure.

5.6 The 2020 – 2025 Interval: Moderate Expansion (+20.00%)

This interval of 2020-2025 is tagged as an era of moderate expansion with an additional 1,550.22 ha of built-up area representing 20.00% rate of change from the 2015-2020 interval. By 2025, the physical development of the Minna urban area will have expanded to 9,301.38 ha (Table 2, Figure 6). The rate of expansion observed during this era is the lowest comparatively across the 5-year intervals; however, the absolute annual expansion of approximately 310.04 ha per annum shows that it is the second highest of the study period, indicating a continued intensity of physical expansion. The low rate of expansion under this period suggests the spatial increase in development at the PUAs, due to access to land and other peri-urban development factors.

During the 2020-2025 period, the dense vegetation maintained a relatively stable position at 17,182.46 ha (54.89%), only marginally higher than in 2020, suggesting that further vegetation gains are levelling off. Farmland declined further to 4,504.95 ha (14.39%), the lowest value across all five study periods. Water bodies remain stable at 313.20 ha (1.00%). By 2025, the study area exhibits a tri-modal landscape: a dominant dense vegetation core, a rapidly expanding built environment, and a diminishing transitional zone of less vegetation (farmland). The shrinkage of farmland relative to 2020 may partly reflect conversion into both developed land and regenerated forest cover due to increased security challenges and a reduction of farming activities.

5.7 Summary of the Rate of Spatial Urban Expansion in Minna (2005 – 2025)

The analysis of the rate of urban expansion in Minna shows a continuous and substantial increase in the developed area over the 20-year study period. A summary of the statistics of the rate of expansion that provides a comprehensive temporal overview is shown in Table 4.

Table 4. Summary of rates of change of developed area from 2005 - 2025

Period	Net Change (ha)	Percentage Change (%)	Annual Exp. Rate (ha/year)
2005 – 2010	+1,850.52	+65.12	370.10
2010 – 2015	+1,262.56	+26.91	252.51
2015 – 2020	+1,796.31	+30.17	359.26
2020 – 2025	+1,550.22	+20.00	310.04
2005 –2025 (Total)	+6,459.60	+227.31	322.98

Source: Author's Computation from LULC classification data, 2025

From the summary in Table 4, the physical development of the Minna urban area expanded from 2,841.78 ha to 9,301.38 ha, a net increase of 6,459.60 ha. The most intensive period of expansion took place during the era of 2005 – 2010, which recorded a significant 65.12% increase with the highest annual expansion rate of 370.10 ha/year. The expansion rate fluctuates in subsequent years, although maintaining a positive

increase. Cumulatively, the built-up area expanded by 227.31% since 2005, averaging an annual addition of 322.98 ha.

The theoretical interpretation takes its cue from the urban expansion and urban fringe theories. The sustained and cumulative nature of expansion within the 20 years reveals that the built-up area has expanded significantly, with varying rates across 5-year intervals. This supports the urban expansion theory that cities respond to demographic, economic, and institutional pressures by extending their boundaries beyond established limits into the adjacent rural lands. The pattern of fluctuation in the expansion rates, rather than a steady linear growth, aligns with the proposition of the urban fringe theory, which describes peri-urban expansion as episodic. The theory explains that the rate of expansion of cities into surrounding rural areas is not simply a slow, steady, or predictable linear process; rather, it suggests that urban expansion often occurs in episodes, sudden bursts of growth triggered by specific events or external shocks (Yang *et al.*, 2015; Sui & Lu, 2021). In Minna, the fluctuations are explained by institutional changes in the FCT, the security displacement of households among the rural neighbouring communities who migrate to urban areas or PUAs to be closer to government protection, and investment in infrastructure as specific events.

6.0 Environmental Implications of Urban Expansion in Minna

The unprecedented 227.31% increase in Minna's developed area between 2005 and 2025 profoundly changes the regional landscape and precipitates environmental degradation. Dense vegetation, once dominant at 20,038.14 ha in 2005, declined sharply to 8,939.65 ha by 2015 due to urban expansion and deforestation. Although secondary regeneration restored vegetative cover to 17,182.46 ha in 2025, the original ecological baseline was permanently lost. This decline undermines biodiversity, reduces natural carbon sinks, and reflects broader vegetation loss trends across peri-urban zones in Nigeria. Simultaneously, the rapid outward expansion of the built environment has accelerated the conversion of vital peri-urban agricultural land, undermining regional food systems (Dalil *et al.*, 2013). Farmland initially rose to a peak of 16,120.21 ha in 2015 due to forest clearance for agricultural activities, but as urban expansion increased to 9,301.38 ha by 2025, leapfrog development consumed most of these fields. Consequently, agricultural land was reduced to 4,504.95 ha, its lowest level historically. This drastic reduction severely compromises food security and destabilizes rural-urban economic structures, reflecting the vulnerability of peri-urban agricultural zones.

The intense LULC changes in Minna pose a serious challenge to long-term ecological sustainability. The hydrological cycle has been destabilised, with water bodies shrinking from 575.26 ha in 2005 to 313.20 ha in 2025, largely due to property development altering drainage channels and seasonal climatic changes. The replacement of natural pervious soils with impervious surfaces has reduced infiltration, heightening vulnerability to flash floods and environmental degradation. At the same time, the tripling of developed land area has intensified Urban Heat Island (UHI) effects, as concrete, asphalt, and artificial materials absorb heat while vegetation loss across 6,459.60 ha eliminates shading and cooling mechanisms. This transformation reduces evapotranspiration, modifies the surface energy balance, and drives up Land Surface Temperatures (LST), creating thermal hotspots. The altered microclimate increases risks to human comfort, energy demand, and public health, particularly for the growing urban population. Collectively, these changes emphasise how rapid urban expansion undermines ecological resilience, compromises hydrological stability, and increases climatic changes, demanding urgent attention to sustainable land management and climate-sensitive urban planning.

7.0 CONCLUSION AND RECOMMENDATIONS

The analysis clearly demonstrates that Minna has experienced significant and continuous urban expansion over the 20 years from 2005 to 2025. The built-up (developed) area has expanded remarkably, increasing by approximately 227.31%, with an average annual expansion rate of about 323 ha. The pattern of growth, however, fluctuated across different intervals that were characterised by periods of accelerated expansion, moderate growth, and reacceleration, explained by the influence of demographic, infrastructure, and institutional factors. Particularly, the rapid outward expansion during the initial years (2005 to 2010) demonstrates the impact of migration caused by security displacements in the hinterlands and land demand. The urban expansion has also been accompanied by notable changes in other land cover types: dense vegetation, which initially covered 20,038.14 ha in 2005, declined sharply to a low of 8,939.65 ha in

2015 due to expansive urban development and deforestation. Although there was some recovery by 2025, it remains below the original extent. Similarly, changes in the farmland area were also observed, which initially reached 16,120.21 ha in 2015 but have since diminished substantially, reflecting the encroachment of urban property development and infrastructure extension into peri-urban agricultural zones. Meanwhile, water bodies that covered 575.26 ha in 2005 experienced a steady decline but slightly recovered in 2025, primarily due to land conversion, construction activities, and environmental pressures. These LULC changes collectively stress the profound transformation of the Minna urban landscape, characterised by extensive urban sprawl at the expense of natural vegetation, agricultural land, and water resources, indicating the urgent need for sustainable land management strategies

To ensure sustainable urban development in Minna, the government and urban planners must adopt a comprehensive and proactive land use planning framework. This should include the development and enforcement of a detailed master plan that clearly demarcates urban growth boundaries to contain sprawl and direct expansion along designated corridors. Establishment of zoning regulations must be strengthened to control the proliferation of informal and unplanned developments, especially in peri-urban zones. In addition, integrating participatory planning processes that involve community stakeholders will foster public interest and ensure land use decisions align with local needs and environmental considerations. While investing in infrastructure projects, such as primary roads, drainage systems, and utilities, should be prioritised to support planned growth and improve connectivity. Finally, establishing a land registry system with transparent procedures and regular monitoring mechanisms will facilitate effective land management, prevent illegal land encroachments, and enable timely adjustments to urban growth policies.

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